Bio-Based Leather Market

Market Scenario and Competitive Landscape

A CURA DI

Francesca Furlan

Ufficio Valorizzazione della Ricerca

Data 08/04/2024

TABLE OF CONTENTS

Disclaimer

Context

This report provides in **Chapter 1** an overview of the **bio-based leather market**, with particular reference to the main trends, dynamics, segmentations by end use industry, source, region and competitive landscape.

Chapter 2 reports an insight about the **technology scenario** related to **alternative leathers**, with information about the main technologies, players and latest news in the field.

The sources consulted for the two Chapters are different. Chapter 1 reports a market-oriented vision about bio – based leather, whereas Chapter 2 provides a more technological overview and commented insights from experts for the alternative leather field. These differences could lead to a slightly different interpretation of the future evolution and development of this particular sector.

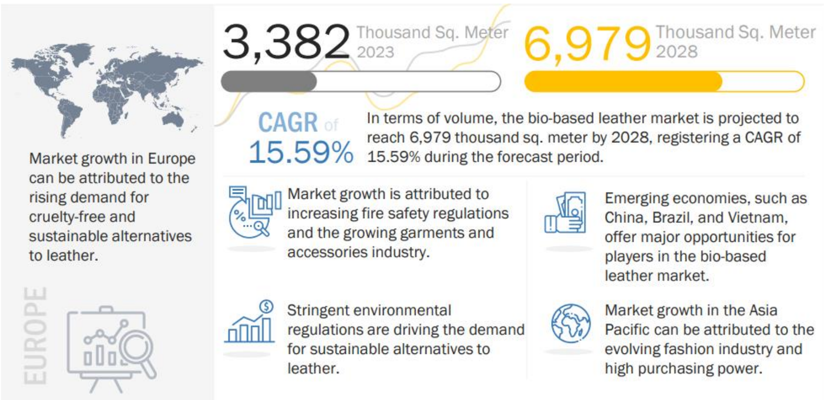
1 Bio – Based Leather Market

Bio-based leather is a sustainable alternative to real leather. The different sources of bio-based leather include **mushrooms**, pineapples, apples, grapes, cactus, tree bark, leftover fruits, and others. Bio-based leather is used in various industries such as furniture, automotive, footwear, garments and accessories. It requires **less chemicals and time** for processing than real leather. Extensive research has been conducted to find plant sources to produce good-quality bio-based leather. Bio-based leather is preferred for its **sustainability, durability, non-smelling, water resistance, flexibility, strength, and cruelty-free characteristics**. Many companies and startups are using different innovative technologies for manufacturing bio-based leather.

1.1 Global Market and Market Dynamics

The **global bio-based leather market** is projected to grow from USD 107,194 thousand in 2023 to USD 215,675 thousand by 2028, at a Compound Annual Growth Rate (CAGR) of 15.01% between 2023 and 2028. The global market in Thousand Sq. Meters in the period 2023 – 2028 is reported in the following Figure.

Figure 1. Global Bio – Based Leather Market in the Period 2023 – 2028 (Thousand Sq. Meter)



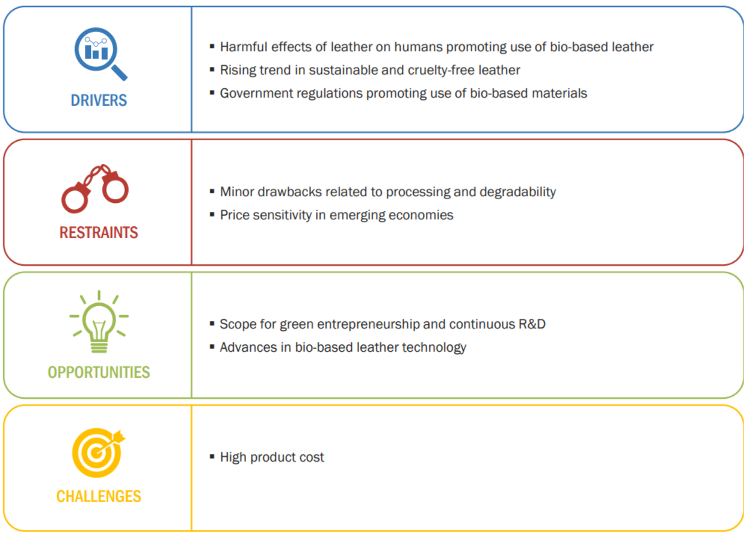
Huge amounts of fossil fuels are consumed in livestock production, and natural leather has almost three times the negative environmental impact as its synthetic counterparts, including polyurethane (PU) leather. Moreover, PU leather and PVC synthetic leather have some harmful effects on the surrounding environment. These factors are supporting the **growing** demand for bio-based leather (Figure 2).

Bio-based leather or vegan leather has been proven better than real leather and significantly improved than plastic-based leather. However, it requires chemical processing for a leather-like feel and durability.

Another **restraint** is the high price of bio-based leather (many vegan shoes are handmade in small artisanal workshops instead of large, automated factories).

The market also has a few major **challenges**, such as scalability and awareness issues. Targeting emerging economies is expected to provide significant growth opportunities to market players, as there is a good demand for bio-based leather in emerging countries due to the rising awareness about cruelty toward animals and environmental pollution.

Figure 2. Drivers, Restraints, Opportunities and Challenges in Bio-Based Leather Market



Drivers

Conventional methods of pre-tanning and tanning leather discharges account for nearly 90% of the total **pollution** from a leather tannery. Raising animals for manufacturing leather requires vast quantities of water and pastureland cleared of trees, and the deforestation causes habitat loss for millions of species, eliminates the Earth's tree canopy, and drives climate change. Tannery chemicals such as arsenic cause lung cancer in workers exposed to chemicals regularly.

Moreover, huge quantities of **fossil fuels** are consumed in the production of livestock, and real leather has almost three times the **negative environmental impact** as its synthetic counterparts, including polyurethane (PU) leather. PU and PVC, the major raw materials used to manufacture synthetic leather, have harmful effects on human and animal health and the surrounding environment. PU is an isocyanate, which potentially harms the lungs as it causes asthma attacks and lung irritation. It irritates the skin and causes difficulty in breathing due to lung infections. PVC contains various harmful carcinogens, such as vinyl chloride monomer (VCM), phthalates, and dioxin.

The **manufacturing process of bio-based leather** does not have any harmful traits, and government and environmental regulations regarding harmful toxic chemicals in various countries in the European Union and North America are the major promoters of bio-based leather. Manufacturers are focusing on producing bio-based leather with the use of **natural fibers** such as flax or fibers of cotton mixed with palm, soybean, corn, and other plants.

Various cell-based, **mycelium-based**, by-product-based sources can be used to manufacture bio-based leather, such as collagen-based on yeast fermentation, **mushrooms**, by-products from food industries, and cacti. According to experts, a new product in the bio-based leather market called **Pinatex** is made from waste pineapple leaf fiber that has the strength and flexibility needed for the manufacturing process. Pineapple leaves are considered a waste product and their use upscales them and adds value without using any additional resources. Shoes, handbags, and other accessories made of pineapple fibers have already been introduced in the marketplace.

Leather has the greatest impact on **eutrophication**, a serious ecological problem in which runoff waste creates an overgrowth of plant life in water systems, which suffocates **animals** by depleting oxygen levels in water and is the leading cause of hypoxic zones, also known as dead zones. The EPA has confirmed that factory farms account for 70% of the water pollution in the US. Many tannery effluents are generated in the Asia Pacific region, as most leather manufacturers are established in countries such as China, India, and Bangladesh. Significant quantities of fossil fuels are also consumed in the production of livestock, and cow-derived leather has almost three times the negative environmental impact as its alternative counterparts. There are a high number of **sustainable bio-based leather options** that mimic the properties of real leather without cruelty to animals or environmental devastation. These are the major factors that drive the bio-based leather market.

Governments around the world are increasingly promoting the use of bio-based materials. This is due to several factors, including the **environmental benefits** of bio-based materials, the growing demand for sustainable products, and the potential economic benefits of the bioeconomy. Governments set standards for the production and labeling of bio-based materials. This can help ensure that consumers have access to reliable information about the environmental and sustainability benefits of bio-based products. Governments provide financial incentives, such as tax breaks or grants, to companies that develop and use bio-based materials. This can help lower the costs of bio-based products and make them more competitive with traditional materials. Governments mandate the use of bio-based materials in certain products. This can help drive demand for bio-based materials and increase innovation in the bio-based leather market.

Restraints

Although bio-based leather or vegan leather has been proven to be better than real leather and plastic-based fake leather, it still relies on **chemical processing** to provide a leather-like feel and durability, presenting environmental problems of its own. For instance, Pinatex is just one type of vegan leather preferred in the fashion industry, especially by sustainable sneaker brands such as Po-Zu, EcoAlf, and No Saints, but unfortunately, it is coated with a petroleum-based material for greater durability, making it non-biodegradable. Apple leather is made with 50% apple waste mixed with 50% polyurethane coated onto a cotton/polyester canvas. This polyurethane can have a harmful effect on the environment during the degradation process. Bio-based leather shoes are niche products and involve an **expensive production procedure**. North America and Europe produce bio-based leather, where regulations are stricter, and the minimum wage is higher than in emerging countries. Regions such as Asia Pacific, Africa, and South America are price-sensitive markets. Many vegan shoes are handmade in small artisanal workshops instead of large, automated factories. Handmade shoes are superior quality, and each pair costs more to craft. These factors are restraining the bio-based leather market in most countries in the Asia Pacific.

Opportunities

Increasing **awareness** about cruelty toward farmed animals and widespread environmental degradation has caught the interest of consumers and of many entrepreneurs: many startups are being set up with bio-based leathers made from various raw materials such as cork, coconut, mycelium, leftover fruits, cacti, and hemp. Some examples are provided by Ananas Anam Ltd., a vegan leather company, makes a leather-like material from the fibers of pineapple leaves and by **MycoWorks Inc**. which has developed an eco-friendly leather alternative that is strong, water-resistant, and completely biodegradable using **mushroom mycelium**.

As the market is at a nascent stage, there is significant scope for new entrants. There is also scope for developing better versions of bio-based leather with 100% biodegradable properties. Thus, the scope for **green entrepreneurship** and continuous R&D creates opportunities for manufacturers of bio-based leather.

Challenges

The bio-based leather market is still in its **early stages of development**, and there are several **scalability issues** that need to be addressed before it can reach its full potential. These issues include lack of availability of raw materials, **high cost** of production, and lack of consumer awareness. The availability of raw materials is a major challenge for the bio-based leather market. Many of the plant-based materials that are used to make bio-based leather are not yet widely available, and this can make it difficult to produce bio-based leather on a large scale. The cost of producing bio-based leather is still relatively high, which makes it difficult to compete with traditional leather. **As the technology for producing bio-based leather continues to develop, the cost of production is expected to reduce, but this will take time**. Many consumers are **not yet aware** of bio-based leather, and this can make it difficult to market and sell biobased leather products. As more consumers become aware of the benefits of bio-based leather, the demand for bio-based leather products is expected to increase. But, until then, the nascent market with **scalability issues** is a **major challenge** to the bio-based leather market.

1.2 Technology Scenario

In recent years, there has been a growing interest in the use of plant-based materials for bio-based leather. The bio-based leather **technologies** described in the following are just a few of the advances that have been made in recent years. As these technologies continue to develop, bio-based leather is expected to become a more viable alternative to traditional leather.

Microbial Fermentation Technology

Microbial fermentation is a process that uses microorganisms to convert organic materials into biopolymers, that can then be used to create bio-based leather. Microbial fermentation is a promising technology for bio-based leather production, as it can be used to produce leather-like materials that are both sustainable and affordable. There are several **advantages** to using microbial fermentation for bio-based leather production. First, microbial fermentation is a relatively simple process that can be easily scaled up to produce large quantities of bio-based leather. Second, microbial fermentation can use a variety of organic materials as feedstock, including agricultural waste, food waste, and even wastewater. This makes microbial fermentation a sustainable and environmentally friendly process. Third, microbial fermentation can produce bio-based leather that has similar properties to traditional leather, including durability, water resistance, and flexibility. There are also a few **challenges** associated with using microbial fermentation for bio-based leather production. One challenge is that the process can be slow, as it can take several days or even weeks for microorganisms to break down organic materials and create biopolymers. Another challenge is that the process can be sensitive to environmental conditions, such as temperature and pH. This can make it difficult to control the quality of the bio-based leather that is produced.

Mycelium Technology

The **mycelium technology** is a process that uses the roots of mushrooms, called mycelium, to create a leather-like material. Mycelium is a natural, renewable resource that can be grown on a variety of substrates, including agricultural waste, food waste, and even sawdust. This makes the mycelium technology a sustainable and environmentally friendly process for producing bio-based leather.

To produce mycelium leather, mycelium is first grown in a nutrient-rich substrate. As the mycelium grows, it forms a network of interconnected fibers, which are then harvested and processed to create a leather-like material. The material can then be dyed and treated to achieve the desired properties and appearance.

Mycelium leather has several **advantages** over traditional leather. It is vegan, cruelty-free, and environmentally friendly. It is also lightweight, durable, and water-resistant. Mycelium leather can be used to make a variety of products, including shoes, bags, wallets, and clothing.

There are a few **challenges** associated with mycelium leather production. One challenge is that the process can be slow, as it can take several days or even weeks for mycelium to grow. Another challenge is that the material can be delicate and difficult to work with. However, as technology continues to develop, these challenges are likely to be overcome.

Biomimetic Technology

Biomimetic technology is a process of using the design and function of biological systems to create new materials and products. Biomimetic technology can be used to create collagen-like proteins from plant-based sources, such as soybeans or corn. These collagen-like proteins can then be used to create a material that has the same properties as natural leather but is made from a sustainable source. The benefits of using the biomimetic technology to produce bio-based leather are that it is more sustainable than traditional leather production, as it does not require the use of animal products. It can create materials that have the same properties as natural leather, such as strength, durability, and water resistance. It can be used to create a variety of different textures and finishes, which can be customized to meet the specific needs of different applications. The biomimetic technology is still in its early stages of development but has the potential to revolutionize the leather industry.

Takumi Technology

The **Takumi technology** process of bio-based leather mimics the natural tanning process of animal skin. The process starts with the extraction of cellulose fibers from plant sources. These fibers are then combined with plant-based oils and resins to create a material that has the same properties as natural leather. The Takumi technology process is relatively new but has the potential to revolutionize the leather industry. It is a more sustainable and ethical alternative to traditional leather, and has several advantages in terms of durability, water-resistance and UV-resistance.

1.3 Market Segmentation by end–use industry

The main end-use industries for bio-based leather are **garments & accessories, footwear and others** (including furniture and automotive) (Figure 3).

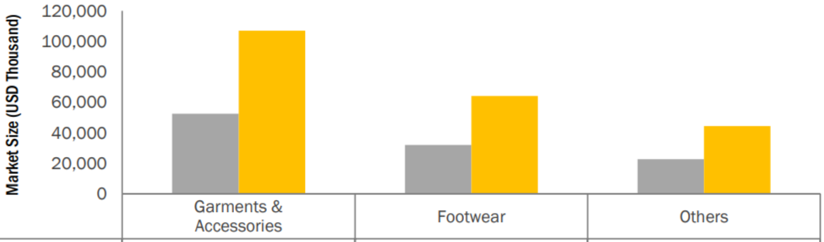
Leather made from leftover fruits, cacti, **mushrooms**, and pineapples is trending in the current **fashion** scenario: labels such as Jill Milan, Matt & Nat, Stella McCartney, Jord, and Versace are using different plant sources for making clutches, bags, watch bands, wallets, purses, belts, jackets, and various other outfits. As bio-based leather is a niche market, the products are high-priced. Demand for bio-based leather is expected to increase during the forecast period, which is expected to lead to a reduction in prices due to economies of scale.

The **garments & accessories segment** accounted for the largest share of the global bio-based leather market in 2023. This segment is projected to grow at the highest CAGR of 15.29%, in terms of value, between 2023 and 2028. This is due to the stringent environmental regulations and demand for lightweight, cruelty-free, and durable clothing. Moreover, consumerism is another reason for the growth of the garments & accessories industry across the globe. The market for **garments & accessories** has always been driven by North America, Europe, and Asia Pacific. Most fashion brands such as Gucci, Versace, and Giorgio Armani S. p. A. opting for vegan leather are located in North America and Europe.

The market in the **footwear industry** is projected to witness a CAGR of 14.95%, in terms of value, during the forecast period. The growth of the market in the footwear segment is attributed to the rising trends in sustainable, cruelty-free, lightweight, and comfortable shoes in the fashion industry in North America and Europe.

The **other end-use industries** segment accounted for a share of 21.2% of the global market, in terms of value, in 2022, majorly due to the demand for vegan leather in vehicle interiors and furniture.

Figure 3. Bio – Based Leather Market, by End Use Industry, in the Period 2023 - 2028



	Garments & Accessories	Footwear	Others
2023	52,556	31,985	22,653
2028	107,056	64,183	44,436
CAGR (2023–2028)	15.29%	14.95%	14.43%

1.4 Market Segmentation by source

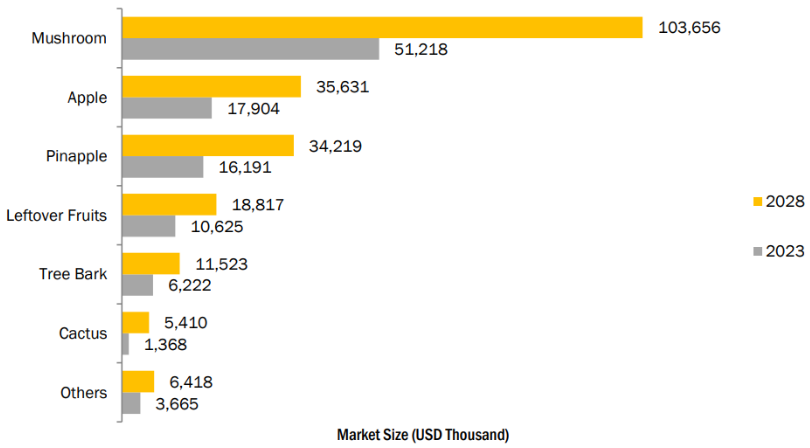
The bio-based leather market is broadly segmented based on source into **mushroom, pineapple, apple, cactus, tree bark, leftover fruits, and others** (coconut husk, palm, corn, and cork) (Figure 4).

The **mushroom** segment accounted for the largest share of the bio-based leather market in 2023. Mushroom-based leather, also known as mycelium leather or mushroom leather, is an innovative and sustainable alternative to traditional animal-based leather. It is made from mycelium, the root structure of mushrooms, which is grown and processed into a leather-like material. Mushroom-based leather can be produced in various thicknesses and textures, making it suitable for a wide range of applications, including fashion, accessories, and upholstery. The cost of fine mycelium is higher than that of traditional leather but is expected to reduce in the near future as production volumes increase.

Apple is projected to be the second-largest source segment, with the market size projected to reach USD 35,631 thousand by 2028, at a CAGR of 14.76% between 2023 and 2028. The market size for the **pineapple** source is projected to reach USD 34,219 thousand by 2028, at a CAGR of 16.14% between 2023 and 2028.

Fungus-based leather technologies were first patented by the US companies **MycoWorks** and **Ecovative Design**. These technologies use mycelium, the root-like structure of mushroom. Instead of acres of land and tons of grain to raise cattle, mushroom-based leather manufacturers cultivate giant mats or vats of fungus feeding off beet sugar, molasses, or other industrial by-products such as sawdust. When grown on a flat surface, the mature fungus can be sliced off and dehydrated before chemicals and physical treatments make it look and feel like leather. Mycelium is generally grown in trays which can be infinitely scaled for making mushroom bio-based leather.

Figure 4. Bio – Based Leather Market, by Source, in the Period 2023 - 2028



Europe was the largest market for mushroom-based leather in 2023 in terms of value (Table 1). The continuous focus is on sustainable and scalable mushroom bio-based leather that is leading the market in Europe. Currently, **the cost of fine mycelium is higher than that of traditional leather but is expected to reduce in the near future as production volumes increase**.

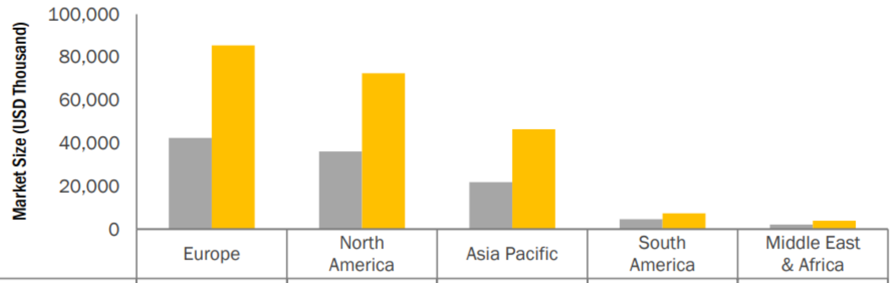
Table 1. Mushroom: Bio-Based Leather Market, by Region, 2022–2028 (USD Thousand)

Region	2022	2023	2024	2025	2026	2027	2028	CAGR (2023–2028)
Asia Pacific	9,322	10,584	12,125	14,018	16,347	19,228	22,818	16.61%
North America	15,331	17,162	19,388	22,098	25,409	29,471	34,490	14.98%
Europe	18,056	20,228	22,876	26,102	30,045	34,887	40,874	15.11%
Middle East & Africa	959	1,056	1,172	1,312	1,481	1,685	1,934	12.87%
South America	2,014	2,187	2,380	2,601	2,864	3,173	3,540	10.11%
Total	**45,681**	**51,218**	**57,941**	**66,131**	**76,146**	**88,444**	**103,656**	**15.14%**

1.5 Market Segmentation by region

In the following, the bio-based leather market is segmented into five regions: **Asia Pacific, Europe, North America, Middle East & Africa and South America** (Figure 5). **Europe** accounted for the largest share of the global bio-based leather market, in terms of value, in 2023. **North America** is projected to be the second-largest bio-based leather market due to the adoption of sustainable alternatives to leather by footwear and clothing brands. The market in the Asia Pacific is projected to grow at the highest CAGR, in terms of value, during the forecast period. The rising awareness regarding cruelty toward animals and environmental pollution play key roles in the growth of the bio-based leather market in the region. Besides being a sustainable option for leather, it also provides an extra source of income for local farmers and raw material suppliers.

Figure 5. Bio – Based Leather Market, by Region, in the Period 2023 - 2028



	Europe	North America	Asia Pacific	South America	Middle East & Africa
2023	42,440	36,159	21,881	4,560	2,154
2028	85,492	72,459	46,473	7,360	3,891
CAGR (2023–2028)	15.04%	14.91%	16.26%	10.05%	12.56%

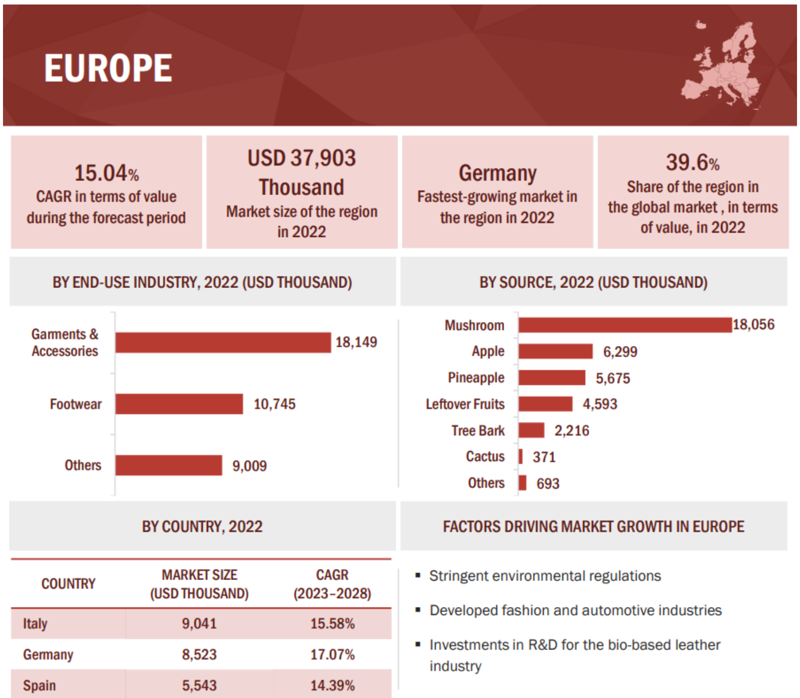
1.5.1 Focus on Europe

The bio-based leather market in **Europe** is highly regulated with Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) closely monitoring and issuing guidelines to ensure a high level of protection for the environment and human health from the risks that chemicals can pose. Due to the implementation of stringent environmental regulations in the EU and rising demand for footwear, garments and accessories made of bio-based leather in the region, the market is expected to grow moderately during the forecast period.

The **mushroom-based segment** dominated the European bio-based leather market in 2022 (Figure 6). Demand for scalable bio-based leather is expected to drive the mushroom-based leather market during the forecast period. The **garment and accessory segment** was the first-largest segment, in terms of value, of the European bio-based leather market in 2022. There are major fashion brands in this region that prefer bio-leather over conventional leather to reduce the carbon footprint.

Italy led the bio-based leather market in Europe in 2022. This dominance is attributed to the increased demand from various industries such as footwear, furnishing, automotive, and garments. Italy is the leading footwear manufacturer in Europe. Companies such as Marzeri MilanoBio, BLANLAC, and Verdura shoes are a few brands offering vegan shoes in the country. The improving regional and economic conditions followed by the increase in investor confidence in the country also act as drivers for the bio-based leather market in the country. Footwear was the second-largest end-use industry of the Italian bio-based leather market. According to World Footwear Yearbook 2021, Italy is the leading shoe manufacturing country in the European Union and holds the eighth place among worldwide footwear manufacturing countries in terms of volume.

Figure 6. Europe: Bio-Based Leather Market Snapshot



1.6 Competitive Landscape

The global **key players** in the bio-based leather market are: Natural Fiber Welding, Inc. (US), Ananas Anam Ltd. (UK), MycoWorks Inc. (US), Bolt Threads Inc. (US), Modern Meadow (US), Adriano di Marti (Mexico), Ultrafabrics Holdings Co., Ltd. (US), Beyond Leather Materials (Denmark), Fruitleather Rotterdam (Netherlands), and VEGEA (Italy).

In Table 2 are reported and described the main **European players** active in the market.

Table 2. European Players in the Bio – Based Leather Market

Company	Location	Description	Website
Ananas Anam Ltd.	UK	The company manufactures products such as bio-based leather and bio-based yarn. Ananas Anam Ltd. developed Pinatex, a natural leather made from pineapple leaf fiber. It is used in several applications such as bags, shoes, wallets, watch bands, and automotive seat covers	https://www.ananas-anam.com/
Beyond Leather Materials	Denmark	Danish company that produces a sustainable leather alternative made from apple waste. Beyond Leather Materials' product, Leap, is made from the leftover apple pulp from the juice and cider industry. The pulp is processed into a leather-like material that is water-resistant, durable, and vegan. The company's products are used in a variety of industries, including fashion, furniture, and automotive	https://www.explore-leap.com/
Biophilica	UK	Develops green waste into a leather-like material called Treekind. Treekind is a plastic-free and PU-free leather substitute that is recyclable and compostable. It is made using non-edible agricultural feedstock and lignocellulosic feedstock from urban parks and gardens. Treekind is used in a variety of industries, such as fashion, furniture, automotive, and others	https://www.biophilica.co.uk/
Fruitleather Rotterdam	The Netherlands	Biotechnology company established with the main goal of finding new uses for large quantities of fruit waste. Mango leather is the bio-based leather developed by the company, which is made from mango waste. It can be used in footwear, fashion accessories, furniture, and interiors	https://fruitleather.nl/
MABEL SRL	Italy	Leader in the development of sustainable and innovative materials. In 2010, the company launched AppleSkin, a vegan leather alternative made from apple waste. AppleSkin is a sustainable and environmentally friendly material that has a lower environmental impact than traditional leather. company's products are used in a variety of industries, including fashion, furniture and automotive	https://www.mabelsrl.it/en/default
Nat-2	Germany	Unique and innovative footwear company that combines sustainability, craftsmanship, and creativity. The company manufactures different lines of shoes, such as wooden lines, fruit lines, algae, and fungi. It offers bio-based leather in all the shoe lines	https://nat-2.eu/
Nova Milan	UK	Nova Milan's product, plant-based vegan leather, is made from the fibers of pineapple leaves that are a by-product of the pineapple industry. The fibers are extracted from the leaves and then felted together to create a nonwoven fabric. The company's products are used in a variety of industries, including furniture, medical, nautical, and automotive	https://www.novamilan.com/
Pangaia Grado Zero Group	Italy	Global collective focused on high-tech naturalism, combining the fields of bio-design, nanotechnology, and material science. The company offers bio-based products through its subsidiary company, Life Materials. The company offers bio-based leather from different sources such as tree bark, mushroom, and fruit peel. Its products are used in a variety of industries, including fashion, furniture, and automotive	https://www.pangaiagradozero.com/

Company	Location	Description	Website
Revoltech	Germany	Revoltech develops an alternative leather made from hemp residues, which it calls LOVR. Its plastic-free and plant-based leather is fully recycled and biodegradable. LOVR is moldable and nonabrasive and can have a variety of textures and appeals	https://www.revoltech.com/#top
Spinnova	Finland	Spinnova's mechanical fiber-spinning process enables the conversion of cellulosic biomass like wood pulp and waste streams like textiles and leathers into man-made cellulosic fibers for textile production. The company produces SPINNOVA fibers and mainly sells to the textile and fashion industry.	https://spinnova.com/
Studio Tjeerd Veenhoven	The Netherlands	Product design studio. Studio Tjeerd Veenhoven aims to create products that are not only esthetically pleasing but also environmentally friendly and socially responsible. This holistic approach allows them to address sustainability challenges and create innovative solutions that have a positive impact on the environment and society	https://www.tjeerdveenhoven.com/
VEGEA	Italy	Manufactures biomaterials for the fashion, furniture, packaging, and automotive industries. The company develops plant-based alternatives to synthetic oil-based materials by incorporating the use of renewable resources. VEGEA grape leather is the bio-based leather developed by VEGEA as a substitute for animal-based leather	https://www.vegeacompany.com/

2 Focus on: Technology Scenario

This chapter reports the **technology insights** about **alternative leathers** developed by **Lux Research**, a leading European information provider, including the comments expressed by its team of experts on this field (“**Lux Take”**, chapter 2.3).

2.1 Overview

Why It Matters: Alternative leathers are analogs or replacements to animal leathers or petrochemical-based synthetic leathers. While a historical practice, animal leathers are criticized for industrial animal husbandry and tanning practices. Consumers are also avoiding synthetic leathers to avoid plastic consumption and because of safety concerns.

How It Works: Alternative leathers are positioned as low-carbon, low-impact, and humane substitutions to synthetic and animal leathers. Developers are using alternative inputs like agricultural byproducts, leather waste, and mycelium. Others are exploring more complex production technologies like fermentation and tissue engineering.

Key Players: Small to midsize companies dominate the landscape. Companies like Ananas Anam and Revoltech are producing alternatives using biomass. Others like Polybion are taking more advanced biological approaches. Large synthetic leather corporations (Kuraray, Toray, and Trinseo) are taking small steps toward alternative leathers via biobased synthetics.

Challenges To Overcome: Few alternatives check all the boxes concerning environmental benefits, performance, and cost. Alternatives made from **mycelium**, bacterial cellulose, and collagen that have the promise of performance are highly complex and struggle to scale. Furthermore, alternatives are sensitive to consumer demands, which are often fickle and hard to predict.

The performance and scalability of alternative leathers have failed to match up to the enormous hype of late. Despite record investments and consumer interest in the solution, the majority of alternative leathers on the market, made from biopolymers, agricultural waste, and leather waste, have little disruptive potential as they are prone to water damage, often peel and flake, and have poor durability. **Mycelium leathers**, once hailed as a promising replacement for both synthetic and animal leather, haven't been able to be produced consistently at scale with the durability of incumbents. Other developers have turned to complex and costly synthetic biology approaches like bacterial cellulose, fermentation-derived collagen, and cell culture techniques in hopes these technologies can mimic the strong bonds and structure of animal leather. These solutions are only now graduating out of lab stages and may be moonshot innovations as they greatly need advancements in strain engineering and biomanufacturing to progress.

In the near term, expect developers to trickle in and fail fast. There is seemingly a new entrant every six months in alternative leathers, many of which never progress past low-volume limited collections. Only solutions that can match and exceed the performance of synthetic leathers will find long-term success, but there is not yet a worthy replacement that matches the strength and elasticity, abrasion resistance, durability, and longevity of animal leathers.

The most relevant news related to **mycelium technology** in recent years are reported below.

- **Sqim**, formerly Mogu, will use EUR 11 million in investor funding to further develop its **mycelium technology** and build a demonstration production plant. The company previously focused on mycelium-based architectural sound insulation. In 2022, Sqim introduced Ephea, its mycelium-based leather, in partnership with Balenciaga at Paris Fashion Week. Sqim's mycelium technologies are undifferentiated from those of Ecovative Design and MycoWorks, but the developer has been able to build ties with the European fashion industry as seen by its partnership with Kering. Sqim is also one of the only developers to continuously offer mycelium-based building products, such as its acoustic wall panels, by selling them as niche specialty items (January 2024);
- With USD 4.5 million in hand from investors like SOSV, Brooklyn-based **Tômtex** aims to grow its team and focus on forming manufacturing partnerships to get its alternative leathers to market. Tômtex is developing two types of alternative leathers: a material based on shrimp shells called Series WS and a **mycelium material** called Series M. The company claims that its approach is more straightforward and less costly than other methods like cell- and collagen-based leathers. While true, Tômtex will face issues with performance and consumer acceptance (December 2023);
- Ten years after its inception, **MycoWorks** has opened its first commercial mycelium production plant in South Carolina, U.S., made possible by its USD 125 million Series C funding in 2022, which allowed MycoWorks to implement advanced manufacturing approaches such as automated guided robotics, digital analytics, and AI for **mycelium production**. MycoWorks states with the technology, 80% of the production is automated, including cultivation, tray handling, and processing. It is ramping up its capacity to produce and deliver thousands of metric tons of mycelium and Reishi leather annually. While the announcement is a milestone for MycoWorks, the company will need to demonstrate that it can deliver on product launches marked for 2024 (September 2023).

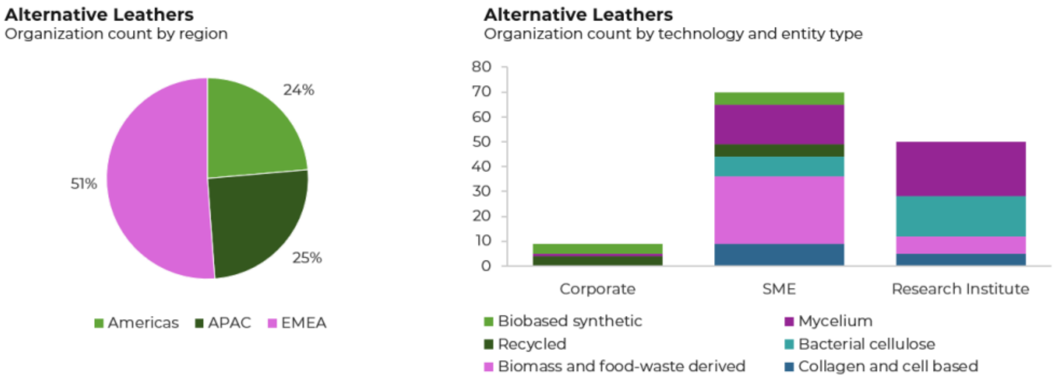
2.2 Technology Landscape

Today, the production of animal leather has run into criticism on environmental and humanitarian grounds. Faux leather has been rebranded to "vegan" leather in light of recent consumer trends. Now, consumer consciousness is yet again shifting due to environmental concerns surrounding carbon emissions and plastic waste associated with synthetic leathers. Consumers are demanding low-carbon and plastic-free options, which have opened the door for a second generation of faux leather alternatives — this time aimed at displacing both synthetic and animal leathers.

Now, **new categories of alternative leathers** are rapidly emerging as developers are exploring various inputs like agricultural byproducts, **mycelium**, and leather waste as well as more complex production techniques like bacterial fermentation and tissue engineering. In all cases, the goal is to create flexible sheets of material that look and feel like animal leather with less emissions and fewer petrochemicals.

Figure 7 reports an overview of each alternative leather, from low-complexity solutions to novel innovations: **biobased syntetic, recycled, biomass and food waste derived, mycelium, bacterial cellulose and collagen and cell based.**

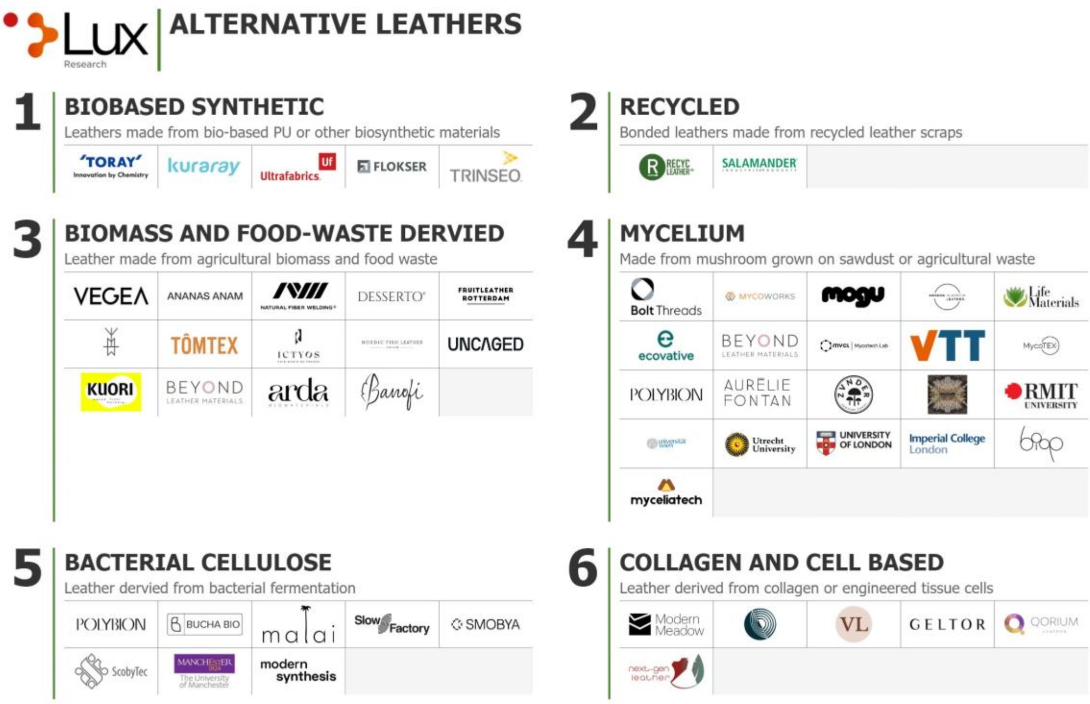
Figure 7. Alternative Leathers by Country and Entity Type



Note: The figures above are a nonexhaustive representation of the technology landscape for players with innovation activity in technologies for alternative leathers. Analysis by organization type and technology segmentation is nonexclusive, with several organizations active in more than one technology area. Organizations with minor patents and academic publications were excluded from the analysis.

Moreover, to provide a comprehensive overview of the technology landscape for alternative leathers among the different players (Figure 11. Market Map), Lux Research analyzed developers of all sizes [corporate, small to midsize enterprises (SMEs), research institutes] across different geographies (Americas, EMEA, APAC) using Lux's proprietary data tools.

Figure 8. Market Map



Biobased synthetics. Developers of conventional synthetic leathers are replacing fossil-based polymers — typically polyurethane (PU), polyvinyl chloride (PVC), or polyamide for equivalent biobased or CO-based polymers and intermediates. Leather producers like Flokser, Kuraray Co., Toray Industries, Trinseo, and Ultrafabrics have developed partially biobased synthetic leathers and suedes with increased renewable content and lower carbon emissions. Similarly, developers of PVC-based leathers like Ineos Inovyn have increasing renewable content in their offerings as seen with Biovyn, which has been used in Polestar's vehicle interior. Beyond carbon reduction, the move to biobased polyols doesn't improve performance, and given that the leathers would still be plastic, these alternatives are less disruptive but support the current market of synthetic leathers. Just a few developers are producing alternative leathers from novel biopolymers like polytrimethylene terephthalate, polyhydroxyalkanoates (PHAs), and algae. Two recent entrants, Soarce and PeelSphere, are developing leathers based on algae biopolymers. New generations of materials present the opportunity to disrupt biobased synthetic leather, beyond the stepwise improvement of incorporating renewable content.

Recycled. Bonded or recycled leather isn't new, but the category is getting some attention due to environmental benefits and circularity. Recycled leathers utilize leather scraps or residues from the leather production process or leather waste from goodsNew entrants within recycled leathers are looking to improve durability and strength over the older bonded leather technologies that use petrochemical binders. For example, new entrant Recyc Leather uses natural rubber as the binder. Other companies in this category include Cotexa Ecologia, Salamander Premium Solutions, and Wenzhou Ourui Trade Co., Ltd. Within academia, there also is some research to understand better methods of recycling leathers, especially in regions with large leather industries.

Biomass and food-waste derived. Biomass-based leathers are typically made from agricultural biomass or food byproducts that have been processed and molded with biobased or synthetic binders. Compared with other alternative leather categories, byproduct-based leathers have lower costs of production and more streamlined manufacturing. Companies like Natural Fiber Welding (NFW) and Revoltech use the same hemp residue to develop their alternative leathers, but NFW further stands out due to its solvent welding technology that enhances the strength and flexibility of its alternative leathers. Some emerging developers are using unconventional waste streams like pineapple (Ananas Anam), tea leaves (Wastea), coffee (TomTex), and ceremonial flowers (Fleather), claiming environmental benefits. The challenge with the emergence of this alternative leather category is the continued use of PU as the binding matrix. Some have moved to biobased binders or polymer matrices like PHA, but very few developers have formulated their own methods of processing and binding without petrochemicals while maintaining durability, flexibility, and strength. Binding and processing technologies will be key to unlocking performance and durability in this category.

Mycelium. Mycelium, the fibrous root structure of mushrooms, is a recent material input for alternative leathers that is getting attention due to its biodegradability and is grown on sawdust or agricultural waste. For fashion applications, developers cultivate mycelium via solid-state fermentation in controlled environments. Developers can tune the fungal strain, inputs, and growth conditions to create various grades of mycelium mats. The mycelium is then pressed, embossed, and tanned/treated to look and feel like conventional leather. Mycelium-based leathers have been one the fastest-growing categories in alternative leathers, but there are slowdowns ahead. Incorporated in 2007, Ecovative Design is the first prominent developer of mycelium materials, initially for building materials and packaging and now for food and fashion applications with its Forager leather and foam materials. Developers have piggybacked off Ecovative, including Bolt Threads and MycoWorks, which have been closest to scaling up mycelium-based leathers for mass and luxury markets. All three players have established well-known brand partnerships, such as MycoWorks with Hermès, Bolt Threads with Adidas, and Ecovative Design with Wolverine Worldwide. Headlines and hype have enlarged consumer understanding of mycelium as well as the number of startups in this category. For example, Sqim, the parent of Mogu, which made its start in acoustic panels and building materials, is developing Ephea, a mycelium-based leather for designer fashion. Despite the attention, **mycelium-based leathers have been difficult to scale to high volumes**. Bolt Threads has struggled to keep afloat and announced a halt to its mycelium production facility in 2023. Now, all eyes are on Ecovative and MycoWorks as they attempt to move mycelium-based leathers out of the valley of death.

Bacterial cellulose. Alternative leathers made from bacterial cellulose have emerged only in the past decade. Here, developers engineer bacterial strains and/or modify production conditions to tune the performance of the cellulose yield. The microbial fermentation yields a gelatinous culture of bacteria and yeast (i.e., **scoby**), which is further processed to sterilize and dry the material into sheets. The sheets can be tanned and processed to look and feel like animal leather. The feedstock inputs vary but are typically high in glucose and fructose. Developers commonly utilize locally available waste feedstock or byproducts of an industrial process. For example, Malai produces bacterial cellulose leathers using local coconut byproducts. Other developers like Polybion and Modern Synthesis claim their platforms are input agnostic and can use a wide range of high-glucose waste feedstocks. Other notable developers of these types of leather include Bucha Bio, Faircraft, and ScobyTec. Academic research indicates that bacterial cellulose-based leather has material properties that rival animal and mycelium-based leathers, but further development is necessary. Like mycelium leather developers, innovators in this category are challenged by the **higher complexity and scalability** of a novel production process. No player stands out yet in this category, but entities like Bucha Bio, Polybion, and Slowhide are emerging as leaders.

Cell and collagen based. Many startups are pursuing cell culture and tissue engineering techniques to produce sheets that can be processed into leather. The products from these technologies feel the most like animal leather, and the resulting material can be matured and tanned like hides. This approach is the most cost intensive of emerging alternative leathers as these are difficult to scale past lab- or pilot-scale volumes. Hide Biotech, Qorium, and VitroLabs are taking various cell-based approaches to leathers. Vitrolabs and Qorium are altering the molecular structure of the collagen/cell network to enhance properties like strength and thickness. Players have made little progress in this category, and some have abandoned or shifted efforts. Cell-based leathers will be able to scale only if there are disruptive advancements in biomanufacturing and cell engineering.

2.2.1 Key Players[1]

Developers of alternative leathers are primarily **young startups**, of which two-thirds were incorporated less than five years ago (Figure 10). Among startups, the level of maturity ranges — in large part due to the complexity of the technology to scale. Players developing biomass- and food-waste-derived leathers like Ananas Anam, Desserto, and Natural Fiber Welding (NFW) have launched several products thanks to their straightforward manufacturing processes. Other startups like Bucha Bio and VitroLabs tackle complex production processes like fermentation and cell engineering that require more lab or early-stage development. **Academic institutions** are focused on evolving these complex production processes for mycelium, bacterial cellulose, and lab-grown hides (Figure 11). **Corporate activity** is concentrated within biosynthetic leathers and includes incumbent developers of synthetic leathers like Toray Industries and Kuraray, as well as automotive OEMs (Figure 9).

Figure 9. Large Players in the Alternative Leather Market

kuraray	TORAY Innovation by Chemistry	TRINSEO

[1] This section identifies leading companies, start-ups, and research centers in alternative leathers. Companies and research centers are chosen based on the strength of their patent portfolio in this technology, with further curation and additions by our Lux Research analysts as necessary; the resulting lists are alphabetically sorted. Meanwhile, the start-ups section is based on companies Lux analysts have profiled and is sorted in order of descending Lux Take.

Figure 10. Start-ups in the Alternative Leather Market

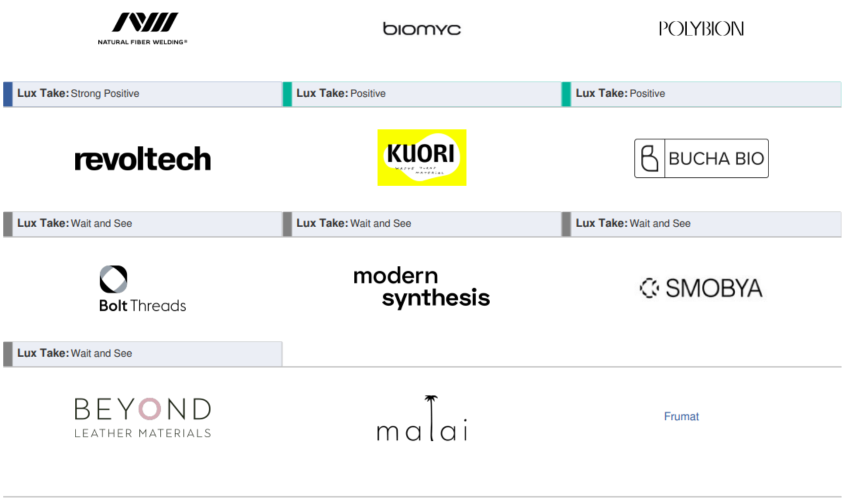
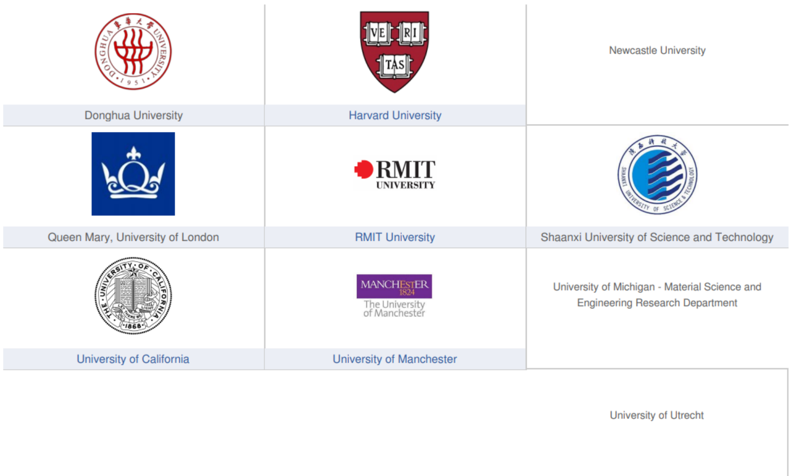


Figure 11. Research Centers in the Alternative Leather Market



Half of innovation activity occurs in Europe; **the remainder is split between the Americas and APAC**. Within Europe, innovators are distributed evenly among France, Italy, the U.K., the Netherlands, and Germany. Developers of alternative leathers are located in European regions close to the leather industry and prominent fashion industries in Paris and London. Similarly in the U.S., alternative leather developers are often located in California or New York, due to the proximity of fashion houses and design institutions. In the broader Americas and APAC, alternative leather innovation and research reside near regions with large leather industries.

The majority of alternative leather developers are young startups focused on novel material inputs and processes. New innovators are actively emerging in this market, especially within byproduct-based leather and mycelium leathers. Innovators are also young; two-thirds of the startups have been incorporated for less than five years. In other categories like biobased synthetic leather, several innovations are coming from corporates.

Academic research is still ongoing to understand new manufacturing techniques and the environmental impacts of emerging alternatives. Academics are focused on evolving the production of novel materials like mycelium, bacterial cellulose, and lab-grown hides. Some of these innovations have spun out into startups like Qorium Leather from Maastricht University and 3D Bio-Tissues from Newcastle University.

2.3 Experts Opinion ("Lux Takes")

In the long term, the alternative leather market will find it fits into niche areas, like the full-grain, genuine, exotic, bonded, and synthetic categories of incumbent leathers. Furthermore, **in reality, only some niche applications will require the same high-quality match with animal leather**.

- **Low-complexity products** like byproduct-based leathers, biobased synthetic leathers, and recycled leathers will continue to be adopted into the market due to ease of manufacturing. In the near term, these materials have clear paths to scale and a clear demand from consumers. However, as the landscape settles in the long term, these developers that are taking incremental steps such as displacing synthetic material with ground-up biomass or substituting in renewable content will have limited growth opportunities, as is the case with the existing synthetic leather market.
- **High-complexity leathers** that offer higher or more animal-leather-like performance have more developments in store, though fraught with scaling challenges. Collagen and cell-based leather solutions require complex synthetic biology and tissue engineering approaches that have major technological barriers at present. **Mycelium-based leathers** are progressing toward commercialization, but players are challenged with producing at mass-market volumes. Bacterial cellulose leather is a more promising innovation that faces fewer challenges than mycelium and collagen approaches. The processing technology is established and translated from the food and beverage industry. Furthermore, there is significant academic research on bacterial cellulose that could translate in the coming years.

To capture the largest market opportunity and secure long-term success, innovators can no longer differentiate themselves on sustainability and environmental impact alone; performance, durability, and cost are other key elements defining success. In this regard, many innovators in alternative leathers fall short, but not all. Companies like NFW and Polybion stand out for taking balanced approaches to performance, sustainability, and cost. Chemicals companies with businesses in leather and suede have an opportunity to strategically engage with innovators to collaborate on performance improvements and maintain market share.

3 Conclusions

Bio-based leather, also known as vegan leather, is a material that mimics real leather but is created from plant products instead of animal skins. It is made from innovative and sustainable materials such as pineapple leaves, **mushrooms**, corks, apple peels, and other fruit waste. Bio-based leather is a cruelty-free and eco-friendly material, unlike real leather, which is a by-product of the meat industry. Pollution, toxic products, and greenhouse gas (GHG) emissions are the main issues related to the leather industry. Due to the increasing awareness about the harmful effects of leather production, consumers are shifting toward sustainable options. Moreover, bio-based leather offers a second revenue stream for local farmers.

The **bio-based leather market is at a nascent stage** but is projected to **grow** due to the significant demand from the footwear, furniture, automotive, and apparel industries. In particular, **mushroom** segment is expected to dominated bio – based leather market in the forecasted period 2023 – 2028. Some challenges related to mycelium technology, as reported by Lux research, are related to the **scalability** of the technology. However, further research & development in the field and the clear advantages of the technology could eventually overcome these challenges.

4 Sources

MarketsandMarkets Knowledge Store - Multisectoral database that collects market research reports in various technological fields and designed to process some information interactively. More than 1,200 market reports are published each year (https://www.mnmks.com/).

The information presented are contained in the report "*Bio – Based Leather Market – Global Forecast to 2028*", published in September 2023.

Lux Research - Lux Research is a leading provider of sustainable innovation research and advisory services, helping clients drive growth through emerging technology innovation. Lux Research combines technical expertise and business insights with a proprietary intelligence platform, using advanced analytics and data science to surface true leading indicators. With quality data derived from primary research, fact-based analysis, and opinions that challenge traditional thinking, Lux empowers clients to make more informed decisions today to ensure future success (https://www.luxresearchinc.com/).

The information presented are contained in the reports:

- Lux Research "*Alternative Leathers*" published in December 2023;
- Lux Research "*Technology Landscape: Alternative leathers*" published in December 2023.