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Industrial *Cannabis sativa* (Fiber or Hemp): Hemp made Leather

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Abstract

Industrial *Cannabis sativa* (hemp or fiber type) is mainly used to produce leather, paper, ropes, food, medicines, cosmetics, hempcrete, leather, bioplastic, biochar, 3D printing housing and textiles. This wide range of applications makes hemp a unique plant that can have positive impacts in many industries including leather production. Hemp-based leather substitutes are an emerging class of ethically and environmentally responsible natural fabrics that are increasingly exceeding consumer aesthetic and functional expectations as an alternative to bovine and synthetic leathers. While traditional leather and its alternatives are sourced from animals and synthetic polymers. Plant-driven, fungal-origin, bacterial-driven, bio-leathers are the current innovative research advances. These renewable and sustainable leather substitutes are gained from bacterial cellulose, mycelium, plant cellulose, and animal cells using tissue engineering and other eco-friendly techniques. However, tanning leather also adversely impacts the environment and human health. Chromium agents have the potential to be very toxic and detrimental to the environment, with the degree of harm dependent on their present condition. Chrome tanning harms the environment, and the final product frequently releases noxious chemical scents. An essential concern in the leather industry is the management of chromium waste, which arises when the treatment procedure results in the creation of sludge contaminated with chromium. Recently, there are more natural, environmentally friendly, and cruelty-free alternatives have experienced a shift rise in popularity within the various industries especially leather production. Today, consumers increasingly demanding eco-friendly options, and seeking brands that prioritize sustainable and ethical practices. With the growing demand in the market, these alternatives are becoming more accessible to consumers particularly hemp-based leather.

Keywords: Animal Leather; Bio-Leather; Banafi; Chromium; Cactus; Desserto; Plant Leather; Malai; Vegan Leather

1. Introduction

The wild noxious weed *Cannabis sativa* L. belongs to the family *Cannabaceae* is a dioecious plant, producing male and female flowers on separate unisexual individuals, a trait regulated by an XY chromosome sex determination system [108-148]. *Cannabis sativa* and *Cannabis indica* are the native of Indian origin found as wild noxious weed in the foothills

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of Indian Himalayan Region and other parts of India, China, Nepal, Bhutan, Sri Lanka, Pakistan, Afghanistan, Persian, Iran, and Morocco and plains of Pamir (a high mountain range centered in eastern Tajikistan with extensions into Afghanistan, the Republic of China and Kyrgyzstan) [108-148]. Now days *Cannabis sativa* is a globally domesticated, cultivated and introduced species occurring in North and South America, Europe, Africa, Australia, Asia and other parts of world [108-148]. These cannabis species are hybrid varieties and known for very high levels of THC (0.3 to 38%) as compared to wild noxious weed found in all the parts of India [108-148].

Cannabis sativa L., is classified into two types as Industrial *Cannabis sativa* (hemp or fibre) and Medical *Cannabis sativa* L.(drug or marijuana) based on its Λ9-tetrahydrocannabinol (THC) content [108-148]. Medical *Cannabis sativa* (drug or marijuana) contains very high levels of THC (above 0.3 to 38% of dry weight) and grown inside the greenhouse-controlled conditions for the production of unfertilized female flowers and used as a medicine for many health disorders [1-21, 58]. On the other hand, Industrial *Cannabis sativa* (hemp or fibre) contains very low levels of Λ9-tetrahydrocannabinol (THC) (0 to 0.3% of dry weight) grown outside in a large agriculture farm for the production of fibre, seeds, oil, medicine, bioleather, bioenergy, hempcrete, and biochar [1-21, 58,108-148]. The ability to utilize the entire plant for multiple purposes creates opportunity for the market to value hemp products [108-148]. Hemp production technology varies depending on the type of hemp cultivated (grain, fibre, or Cannabinoids), soil characteristics, and environmental factors [1-21, 58, 108-148]. Industrial *Cannabis sativa* (hemp or fibre) has the potential to be a very sustainable and ecologically benign crop. Industrial *Cannabis sativa* (hemp or fibre) is a herbaceous annual plant (family *Cannabaceae*) that has a 4- to 5-month life cycle, is naturally dioecious, reproduces via seed propagation grown for the production of fibre, seeds and oil [108-148]. Industrial *Cannabis sativa* (hemp or fibre) roots have a significant potential for absorbing and storing heavy metals such as lead, nickel, cadmium, and other harmful substances [108-148]. In addition, hemp has been proven to be an excellent carbon trap and biofuel crop [108-148]. Hemp has the ability to successfully suppress weeds, and it is generally regarded a pesticide-free crop [1-21, 58, 108-148].

Leather is a strong, flexible and durable material obtained from the tanning, or chemical treatment of animal skins and hides to prevent decay [1-85, 146]. In the commercial market, there are 3 types of leather are available, one is synthetic, natural animal and plant based leather [1-85, 146]. In contrast, the production of plant-based leather does not require the killing or mistreatment of animals [1-85, 146]. By choosing plant-based leather, consumers can support a more compassionate and ethical industry [1-85, 146]. In addition to its environmental and durability benefits, plant-based leather is also a more humane option than animal leather. Plant-based leather available in the market can be made using a variety of plants and plant materials for example, cactus- (Desserto; Mexican), sugarcane bagasse, pineapple (Piñatex; Thailand), mushroom (Mylo), corn leather - Veja (Italian), coconut water (Malai) (Kerala, India), Industrial *Cannabis sativa* (Fiber): Hemp leather, mango, tomato (Bioleather), dried waist flowers, oak tree bark and leaf, apple, teak leaf, banana leaf (Banafi), grape, orange peel waste, cork oak trees (Portugal), jute fibre, brittle leaves of the Areca betel nut tree (palm leather) and coffee husk [146]. Plant-based leathers do not involve the exploitation of animals, unlike animal leathers. The production of animal leather often involves cruel practices, such as dehorning and branding, which are not necessary for the production of plant-based leathers[146]. The production of animal leather is a highly polluting industry, with toxic chemicals such as chromium and formaldehyde commonly used in the tanning process[1-85, 146]. These chemicals can contaminate soil and water, leading to negative impacts on the environment and human health. Tanneries are among the polluting industries mainly causing chromium pollution, and its effect is highly pronounced on regions where high concentrations of tanneries are located [1-74-86-93, 95, 99, 146]. For instance, it has been reported that more than 2500 tanneries were operating in India by 2009, of which 80% of them were engaged in the chrome tanning process [1-74-86-93, 95, 99-101, 146]. Hexavalent chromium (Cr^{6+}) and other toxic compounds are discharged via industrial wastewater to the environment [1-74-86, 95, 99, 146]. This hexavalent chrome is soluble, toxic, mutagenic, tetragenic, and known to have a number of negative effects on human health as a result of its high oxidizing potential [1-74-86-93-101, 146]. The toxicity occurs in humans because of environmental pollution through soil and water contamination or due to occupational and non-occupational exposure to heavy metals[1-74-86-93]. Chromium is toxic and mutagenic to microorganisms at concentrations between 10 and 12 mgl^{-1} which are inhibitory to the majority of soil bacteria in liquid media [1-74-86-93, 99-101, 146]. Therefore, bio-based leather is gaining popularity in the fashion industry due to its ability to replace traditional leather materials in footwear, garments, and accessories. The Indian vegan leather industry, also known as plant-based leather, has experienced remarkable growth in recent years[1-74-86-93, 146]. In 2023, it was valued at USD 73.38 billion, and projections indicated that by 2030, it will soar to USD 139.02 billion, boasting an impressive compound annual growth rate (CAGR) of 9.58%1[1-74-86-93, 146]. This eco-conscious sector provides cruelty-free alternatives to traditional animal-derived leather, catering to consumers who prioritize ethics and sustainability [1-74-86-93, 146]. Currently, there are the few Indian vegan industries involved in the plant-based leather production companies for example, Banofi, Vortex Flex Private Limited, Bioleather, Winner Nippon Leatherette Private Limited, Malai Eco, Responsive Industries Limited, Response Fabrics, Aulive, Zaibunco

Industries Private Limited, and Giriraj Coated Fab Private Limited. Plant-driven, fungal-origin, bacterial-driven, and animal-origin bio-leathers are the current innovative research advances addressed in this literature [146].

2. Hemp made Leather

Hemp is a natural fiber that can be grown with minimal environmental impact compared to cotton. The plant requires little to no irrigation and uses less fertilizer than other crops. In addition, hemp improves the soil and does not require artificial fertilizers during its approximately four-month growth cycle. It supplies the topsoil with important nutrients, prevents erosion and helps to keep the air clean [102-105, 146]. The miracle plant is booming - because hemp is extremely helpful in the fight against the climate crisis [102-105, 146]. It is not without reason that it is one of the oldest cultivated plants in the world, but was forgotten for many years due to the triumph of synthetic fibers. Now it is experiencing a revival [102-105]. No wonder, because the super fiber is not only ideal for textiles, but also serves as a composite material, for example in skateboards or skis, and athletes swear by the healing powers of hemp [102-105, 146]. This refers to products made from industrial hemp (also known as industrial hemp in Germany), which have no intoxicating effect. The industrial hemp plant is a variety with a low THC content (0-0.3 percent), without intoxicating effects, and is used in the textile, automotive and construction industries, among others. Due to its higher CBD content, it is also used to make medicinal products [102-105-148]. In contrast, there is the cannabis plant. It has a high THC content and an intoxicating effect - it is grown for medicinal or recreational purposes. The CBD content can also be higher, especially when cultivated for medicinal purposes [102-105, 146-148].

The hemp industry is rapidly evolving, and product categories and specifications are fluid. **Volkswagen** is working with German startup Revoltech on a hemp-based substitute for leather upholstery to help further lower the environmental impact of its vehicles [102-105, 146]. The new material could see use in VW models **by 2028**, the automaker said. VW claims the hemp-based material can be produced at existing factories, and can be recycled or composted at the end of its useful life[102-105, 146].

The material is made from residue of hemp cultivated for the food industry that would otherwise have no practical use, according to VW, which also claims the material is vegan and oil-free, unlike the synthetic leather upholstery some automakers put forth as a vegan alternative to animal hides. In one of the recent study by Basak et al., (2024) [37] hemp fibre was extracted from hemp plant, normally available in the Uttarakhand region of Northern India[37]. Extracted fibers were degummed, bleached and physico-mechanical properties of the extracted fibres was examined [37]. Bleached fibre was used to prepare non-woven based fibrous structure and used as reinforcement material for making vegan leather [37-44, 48, 50, 51, 146-148]. Natural rubber-based formulation was used as matrix for making flexible composite like material. For developing such unique product, primarily, hemp fibre was extracted from the *Canabinus sativa* L., i.e., industrial hemp plant [37-44, 48, 50, 51, 146]. The structure and physico-mechanical properties of extracted hemp fibre used for making leather alternative were thoroughly studied [37-44, 48, 50, 51, 146]. Characterization analysis has underscored that the fibre has crystallinity of around 78 % and composed of mainly cellulose, hemicellulose and lignin[37-44, 48, 50, 51, 146]. Physical properties of fibre denote that hemp is longer, finer, stronger, higher elongation%, than widely available ligno-cellulosic jute fibre [37]. Natural rubber (latex) biomolecule-based formulation was used as matrices, allowing the hemp fibre content in the flexible composite approximately 38–40 %[37, 146]. Developed flexible composite was then hot-pressed and coloured for mimicking with natural leather [37]. Natural fibre-reinforced-leather with areal density of 250–550 g/m^2 were fabricated and were characterized in detail in terms of physical, structural, mechanical, and chemical properties [37, 146]. Tensile and tear strength of the developed leather material lies in between 8 and 9 N/mm^2 and 90–110 N, respectively [37]. Moreover, different integral parts of natural rubber based engineered leather were examined by Fourier-Transform-Infrared-Spectroscopy (FTIR), X-ray diffraction (XRD), surface roughness, chemical composition analysis and scanning-electron-microscopy (SEM) techniques to understand the mechanical of interaction among the different component were studied[37]. This study suggested the possible chemical reaction among the different macro-molecules, responsible towards good stability of the natural fibre-reinforced-leather structure [37, 146].

Animal leather industries consume a larger quantity of toxic chemicals, acid, alkali, salt, heavy metal, etc [37, 146]. It generates large quantum of liquid effluent that pollutes surrounding atmosphere [37]. Indeed, chemicals used in leather processing have detrimental effect on skin of work-force and cause of associated hazardous risk [1-37-86, 146]. Moreover, most of the artificial leather products, available in the market, are also not eco-friendly due to usage of polyurethane, poly vinyl chloride like petroleum products in their manufacturing formulations [1-37-86, 146]. Most of the cases, synthetic leather available in the market, are manufactured using polyester, nylon, etc., as reinforcement fibre matrix [1-37-86, 146]. They are neither biodegradable not their physical properties are similar to the natural leather in term of tensile, weight, thickness and performance [1-37-86]. As the world R & D is moving towards sustainable direction, therefore nowadays development of fibre-based leather or natural-fibre-reinforced-leather (NFRL) is truly a promising area of research and product development [1-37-86, 146]. Very few research findings have been registered in the literature on the domain of leather alternative engineered using on ligno-cellulosic plant fibres like pineapple, flax, wool and ramie, and biopolymer [1-37-86, 146].

Another work reported by YORGANCIOGLU et al., (2019) [38] in Turkey evaluated the potential applications of fiber-type industrial hemp for leather industry [38]. According to this study of YORGANCIOGLU et al., (2019) [38], the root, stem and fiber parts of the hemp plant were investigated in terms of tannin content as the residues of the hemp [38]. The results of this study by YORGANCIOGLU et al., (2019) [38] showed that root and stem parts have low phenolic content, but fibers of the plant have a great potential in the use of leather production and can be evaluated in different processing steps such as tanning and retanning [38, 146]. Besides, the antimicrobial activity of the hemp fabrics was determined with five different microorganisms due to the demonstration of potential antimicrobial effect of the hemp extracts that will be used in the leather production [38]. Additionally, fabrics of hemp can be also used in leather products as auxiliary material by means of the promising properties in literature and clothing hygiene and will be evaluated in the manufacturing of lining materials for footwear [38, 146].

Fatliquors are very important in the manufacture of leather [40, 146]. Leather treated with fatliquor become more flexible and softer by the separation of leather fibers in the wet state so that they do not stick too much during drying, also the physical properties, such as tensile strength, softness, tear strength and stability of the leather become influenced simultaneously [40]. The step of fatliquoring is carried out during leather processing operation after tanning [40]. Variety of fatliquors is synthesized so far from various vegetable oils [40, 146]. In one of the studies reported by Mahboob et al., (2022) [40] for the first time, fat-liquor, named as, “Hempfat” is synthesized from oil extracted from hemp seeds [40]. As hemp oil consists of high amount of omega-6, omega-3 fatty acids possessing antioxidant activities, so accepted as beneficial to health for public, also possess high kinetic stability and increased protective effect during increase or decrease of temperature. On high temperatures, trans-fatty acids are not formed [40]. So, the developed fatliquor, “Hempfat” and the leather developed from it were evaluated on physical and chemical grounds, both found to possess the excellent properties of a fatliquor as leather fatliquoring agent in making good quality finished natural leather [40, 146]. “Hempfat”, it is claimed that for the first time, fat-liquor is synthesized from the oil extracted from hemp seeds, which possesses the excellent properties of a fatliquor as leather fatliquoring agent in making good quality finished natural leather carrying better properties of tensile strength, tear strength, stability and softness of the leather [40].

Volkswagen has entered into a cooperation with the German start-up Revoltech GmbH from Darmstadt [36, 39, 41, 42, 51, 146]. The aim is to research and develop sustainable materials based on industrial hemp [36, 39, 41, 42, 51]. These could be used as a sustainable surface material in Volkswagen models from 2028 [36, 39, 41, 42, 51, 146]. The material made from 100% bio-based hemp uses residues of the regional hemp industry. It can be produced on existing industrial plants and recycled or composted at the end of its service life in an automobile [36, 39, 41, 42, 51, 146]. The first presentations of the innovative material have already received a very positive response and feedback from customers [36, 39, 41, 42, 51, 146]. **100% bio-based leather** alternative from industrial hemp**:** Together with the Revoltech GmbH start-up, the predevelopment team at the Volkswagen brand is working on a material innovation as a substitute for imitation leather [36, 39, 41, 42, 51, 146]. This material made from what is known as industrial hemp cultivated for the food industry is an all-natural, 100% biological single-layer surface material called **LOVR™** (the letters stand for leather-free, oil-free, vegan and residue-based) that is being developed specifically with the automotive industry in mind [36, 39, 41, 42, 51, 146]. LOVR™, a hemp-based leather alternative, excels in environmental impact compared to other sustainable textiles. Its production involves zero plastic, uses natural pigments for dyeing, and is carbon-neutral (cradle to gate) [102-105, 146]. The hemp fibers and a fully bio-based adhesive are combined using a special technology and processed to become a surface material [36, 39, 41, 42, 43, 51, 146]. This truly circular material is sourced from regional hemp fields and is fully recyclable or compostable once it has reached the end of its service life [36, 39, 41, 42, 51, 146]. It is produced from residues of the hemp industry that have no further use[36, 39, 41, 42, 51, 146]. In addition, it can be manufactured on existing industrial plants, thus enabling swift scalability – and is therefore also suitable for use in large-scale production [36, 39, 41, 42, 51, 146].

One of the study reported by HULTKRANTZ (2018) [43] covered a preliminary life cycle assessment (LCA) on imitation leather made from hemp fiber (hemp leather) and a comparison to bovine leather [43, 146]. Further examined whether hemp leather is an environmentally sustainable alternative. The bovine leather industry is responsible for heavy chemical use and emissions, detrimental effects to the environment as well as to human health [43]. The United Nations (UN) and other organizations call for immediate action against the animal product industry sector to greatly reduce emissions and protect the environment [1-43-85, 146]. Hemp is a versatile plant that can be used for many things, including paper, composites, textiles, food and medicine, and is probably a suitable material for imitation leather [36, 39, 41, 42, 43, 51, 146]. The comparison showed that hemp leather is superior to bovine leather in all compared categories except for water consumption and hazardous waste [36, 39, 41, 42, 43, 51, 146]. Bovine leather had 99% more energy use, 78% higher acidification potential (AP), 99,9% higher eutrophication potential (EP) and 83% higher global warming potential (GWP) than hemp leather [36, 39, 41, 42, 43, 51, 146]. The large water consumption in the manufacturing phase of hemp leather is possible to be explained by over dimensioning of inputs [36, 39, 41, 42, 43, 51, 146]. This report of HULTKRANTZ (2018) [43] concludes that hemp leather would be the environmentally and ethically admirable choice between the two leathers[36, 39, 41, 42, 43, 51, 146].

Automakers have started moving away from leather for reasons of sustainability. Volvo plans to go leather-free in all of its EVs by 2030, while Kia plans to phase out leather in the future as well[102-105]. Beyond leather, Polestar has experimented with various natural and recycled materials to address the environmental impact of manufacturing, which becomes a much bigger consideration in EVs that produce zero "tailpipe" emissions [102-105, 146]. The leather industry is pushing back against claims that alternatives are more sustainable, though. In January the trade group One for Leather issued a statement claiming leather had a lower carbon footprint than the synthetic upholstery being proposed for EVs [102-105]. Its argument was that cattle are already being raised for milk and meat, so use of hides is effectively upcycling material that would otherwise be wasted [102-105, 146].

3. Cellulose Fiber

Cellulosic fiber or cellulosic biomass finds major role in the modern scientific era [106]. One of the major research areas today is to extract cellulose from natural resources abundant with us such as hemp, banana, rice husk, wheat husk, maize husk, pine needles, cotton, jute etc[106]. Cellulose can be extracted from these available sources by numerous chemicals, mechanical and green techniques [106]. Cellulose itself is bio renewable, biocompatible and nontoxic biopolymer with number of hydroxyl functionalities which provide it uses in various enrichment and separation technologies. Biomass, such as plant resources or agro waste are the major sources of cellulosic fibre [106]. Plant waste fibres like wood, rice husk, maize husk, hemp fibre, banana peel, coffee bean husk, barley husk etc. are major sources of cellulose [106]. Banana represents one of the extensively consumed fruit worldwide and finds 40% share in world fruit trait [106]. Therefore, a lot of banana peel is thrown as waste and the factories producing banana-based food products produce huge banana peel waste which result into foul smell and also cause many human diseases [106]. Factories produce a lot of banana peels, which can cause an environmental problem such as a bad smell and become a source of human disease [106]. It consists of 12.1% cellulose and rest lignin, hemicellulose, ash and moisture. In order to extract cellulose from it, banana peel at maturity stage that is yellow peel with little brown patches on it is collected and cut in to the small pieces on around 0.3 x 2.5 cm dimensions [106]. These pieces are then dried around 55^{o} C for about 10 h' time to remove moisture from it, then cool at room temperature [106]. Peel grounded into powder and kept in polythene in refrigerate at 4 ^{o}C. In maceration process around 50 g of banana peel is mixed with ethanol/ toluene (1:1) solvent for 3 days. In the process of bleaching lignin was removed by using NaOCl at 80^{o}C with constant stirring [106]. Hemicellulose was removed from the pulp by treatment with NaOH at 60 ^{o}C [106]. Extracted cellulose was washed with distilled water and ethanol. It is dried at optimum temperature until give constant weight [106]. This cellulose can be further utilized for the leather production.

Sugarcane bagasse (SCB) powder was first subjected to delignification with sodium chlorite in acidic conditions for 2 h contact time and temperature approximately 70^{o} C [106]. After this treatment, the residue was filtered and washed with distilled water properly. It is then dried in hot air oven at optimum temperature [106]. Extraction of holocellulose was carried out with alkali solution. Residue obtained after the process is cellulose rich [106]. It is filtered and washed with water to remove the chemical residues along with. Sample was dried and then weighed [106]. The crude cellulose material obtained can be purified by the treatment with nitric acid. The final sample obtained was washed with subsequent fractions of ethanol and water, dried and weighed until give a constant weight [106].

Hemp fibres have high strength, low density, and high sustainability; therefore, they are used as reinforcement in composite materials [107, 145, 108-146]. This usefulness of cellulose fibrils is because small fibrils have better mechanical properties than the individual macrofibres. Within their structure, small fibrils include more cellulose crystals, having a higher elastic modulus than fibres, which contribute to their increased strengths [107]. Microfibrillated cellulose (MFC) is cellulose fibril aggregates obtained through disintegration of the cell wall in cellulose fibres [107]. The diameter of MFC fibrils is usually at the range of 10–100 nm and can be up to several micrometres in length, depending on the preparation methods and material source [107]. Microfibrillated cellulose was extracted from hemp fibres using steam explosion pre-treatment and high-intensity ultrasonic treatment (HIUS) [107]. The acquired results after steam explosion treatment and water and alkali treatments are discussed and interpreted by Fourier transform infrared spectroscopy (FTIR). Scanning electron microscopy (SEM) was used to examine the microstructure of hemp fibres before and after each treatment [107]. A fibre size analyzer was used to analyze the dimensions of the untreated and treated cellulose fibrils. SEM observations show that the sizes of the different treated fibrils have a diameter range of several micrometres, but after HIUS treatment fibres are separate from microfibrils, nanofibres, and their agglomerates [107, 146].

Hemp cellulose microfibrils are individualized from bast fibres and shives using steam explosion, hydrothermal and alkali treatment and high-intensity ultrasonication [107, 146]. Results of this study have shown that SE treatment combined with following hydrothermal and 0,4 wt.% NaOH treatment allows partial removal of constituents from hemp fibres [107]. SEM observations showed that the sizes of the different treated fibrils have a diameter range of several micrometres. It can be seen that after HIUS treatment fibres are separate from microfibrils, nanofibres, and their agglomerates [107]. FTIR analysis showed differences between the spectra for the untreated, steam exploded, and ultrasound-treated hemp fibres and shives [107, 146].

4. Conclusion

Plant-based leathers can be used in a wide range of applications, from fashion to furniture. They are versatile and can be molded into a variety of shapes and sizes, making them suitable for a wide range of products. Plant-based leathers often outperform animal leathers in terms of durability, comfort, and style. They are often more flexible and breathable, and do not require the same level of care and maintenance as animal leathers [1-85]. Hence plant-based leathers are a better choice than animal leathers for those who value sustainability, ethics, and performance. Plant-based leathers are often just as durable as animal leathers. They are resistant to water, stains, and other environmental factors, and do not require the same level of care and maintenance as animal leathers. Plant-based leathers can be just as beautiful and stylish as animal leathers. They come in a wide range of colors and textures, and can be designed to mimic the appearance of animal leathers. Plant-based leathers are often more comfortable to wear than animal leathers. They are breathable, lightweight, and do not retain heat, making them ideal for use in shoes, bags, and other accessories. Even luxury cars are going vegan. For its 100-year anniversary, Bentley designed an electric car with an all-plant leather interior. It chose **grape leather**, collaborating with Italian company Vegea. Many other brands, including Tesla, Renault Twizy and Volvo, have launched vegan-friendly cars, ditching animal leather completely in favor of plant-based alternatives.

Leather is a durable and flexible material created by tanning the animal raw hide. The main used raw material is cattle hide and skin. **It is widely known that the production of animal leather is very harmful to the environment, but leather is a staple of many industries**. Secondly, the animal hide must undergo the tanning process to become leather. Tanning treats the hide with chemicals to slow its decomposition and make it tough and flexible. Chromium tanning is the most common method, but this produces wastewater with high concentrations of toxic chromium and sulphide, as well as the pesticides that are often used to protect the hide before tanning. However, the major part of synthetic leather is made from polyvinyl chloride (PVC), polyurethane (PU), and polyolefin (PO) mixed with a base material of plant and/or synthetic fibers, which are made from carbon-based materials that also need special care for recycling [17]. Therefore, replacing these materials with the bio-degradable fibrous materials can be a better choice. Natural fibres are soft, flexible material, Bio-based leathers are increasingly adopted by a range of footwear manufacturers, from luxury brands to more affordable, and mass-market producers. Plant-based leather alternatives are a growing market, with innovators turning to hemp, pineapple, olives, and coconuts to produce eco-friendly materials.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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