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DEVELOPMENT AND ASSEMBLING OF TEXTILE PRODUCTS

Prospects of using bio-based alternative leather for shoe manufacturing

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ABSTRACT

The linear business model of the light industry has undergone a positive transformation with the emergence of innovative alternative materials that are in a confident progress towards solving the problem of environmental pollution by including the principles to circular production and contributing to the development of consciousness towards the use of eco-friendly raw materials in nowadays realities. The uniqueness of modern developments in this area is in using raw materials that at first glance seem incompatible with light industry. The processing of secondary agricultural waste into alternative plant-based leather provides the powerful start in exploring this area and hope for the future free from many harmful factors that accompany the manufacture of everyday products. The study results: 1) the scientific and technical analysis of plant-based materials for footwear is offered as an alternative to genuine leather; 2) a comparative analysis of the mechanical properties of alternative plant-based leather Pinatex® and genuine leather is conducted; 3) the impact of the trend on society, its competitiveness compared to genuine leather and further prospects in the manufacture of footwear is defined.

Keywords
fashion Industry,
sustainability,
alternative leather,
plant-based leather,
bio-based materials,
eco-friendly fabrics,
circular economy,
pinatex

1. Introduction

Unfortunately, the environmental pollution, namely wastes in various spheres of life, still remain one of the most discussed topics nowadays. In 2010, the number of generated wastes was 3.5 million tonnes per day, 1.3 billion tonnes per 12 months; the forecast for 2100 is 4 billion tonnes per day. Organization for Economic Cooperation and Development (OECD) countries, where waste levels are the highest today at around 1.75 million tonnes per day but populations aren't growing as quickly and waste reduction efforts are underway, are likely to see their trash levels peak by 2050 and then start to decline, the authors write. Asia-Pacific countries won't peak until 2075. How soon Sub-Saharan Africa's waste increase peaks will determine how soon the world's trash problem begins to decline. (Hoornweg & Bhada-Tata, 2013). In general, the light industries play a significant role in it. The large volumes of clothes and footwear production stimulate rapid resource consumption and waste generation, thereby resulting in significant negative impacts on the society, economy and the environment. To reduce the consequences of this catastrophe, it is time to introduce circular business models (Fig. 1) into our lives, which can address most of the issues that are the most vital in the agenda [1].

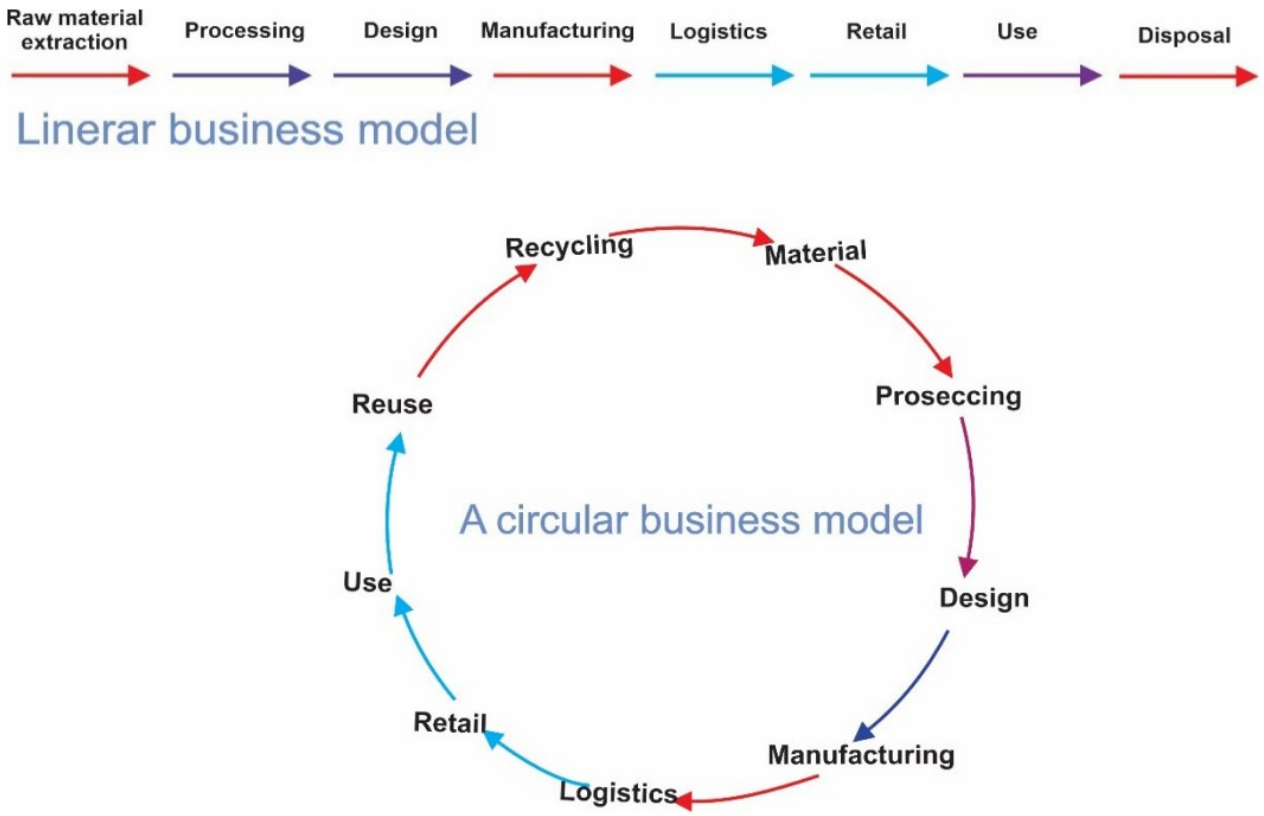

Fig. 1 Linear or «Creadle to grave «business model» and Cyrcular or «Creadle to creadle» business model

Therefore, one of the tasks for the producers is to create a new infrastructure based on the conscious consumption and the use of environmentally friendly materials, based on the implementation of the circular economy basic principles (reduce, reuse, repair, renovate, recycle, recover, redesign), which will be beneficial to both sides, as for a company is concerned, reducing the amount of wastes means reducing the costs of the product due to the lower raw material consumption, as far a consumer is concerned, it means a lower price for the finished product [2].

Guided by this concept, being at the stage of model creation, it is necessary to take into account the materials from which the item is made in order to reduce the negative impact on the environment in the future, when recycling/utilizing this product. The projects that offer innovative and environmentally friendly solutions for the creation of biodegradable and more easily recyclable raw materials, reintegrating waste, mainly from agriculture, as a resource into a new product cycle, help to achieve this goal [3]. Fig. 2 shows the types of textile materials from food waste: a) Cellulose extracted from plants

and used directly (seed or stem fibre) or in regeneration process; b) naturally occurring chemicals (e.g., sugar) extracted from a plant source and used in a polymer synthesis process; c) protein extracted from a plant or animal source and used in a regeneration process.

Projects, using biogenic raw materials in fashion products include, for example, Palmleather leather made from the leaves of the Areca betel nut that is a type of palm tree. These leaves are an incredible material resource, they are underutilised because they become very dry and brittle being raw. However, Dutch designer Tjeerd Veenhoven has developed a biological solution by adding a mixture of glycerine, water and other substances to the leaves to give the palm leaves plasticity, pressing them and fixing them to a fabric base. Fig. 3 shows Palmleather for the development of fully biodegradable fashion products [4].

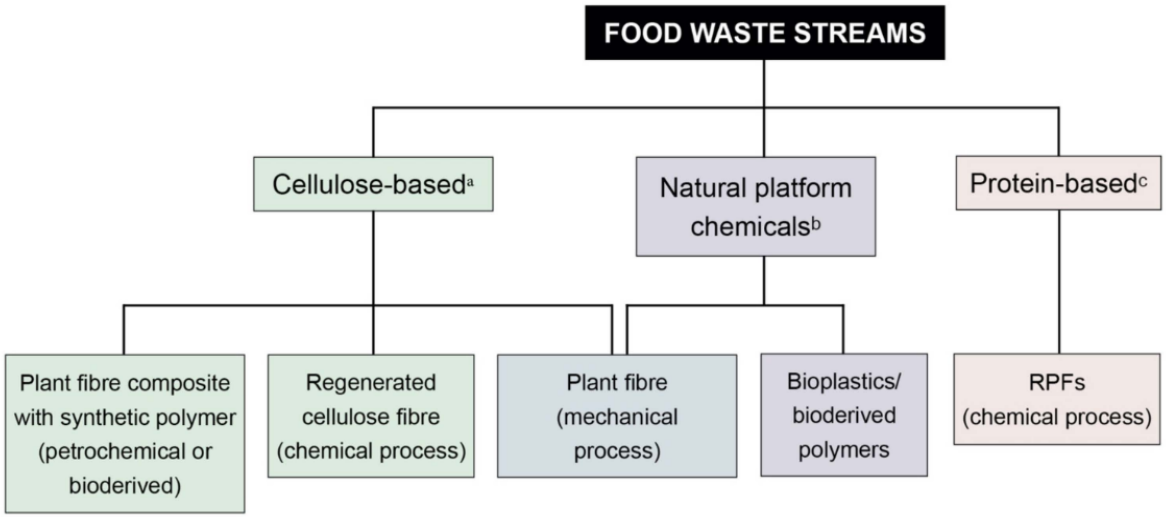

Fig. 2. Types of textiles materials from food waste.

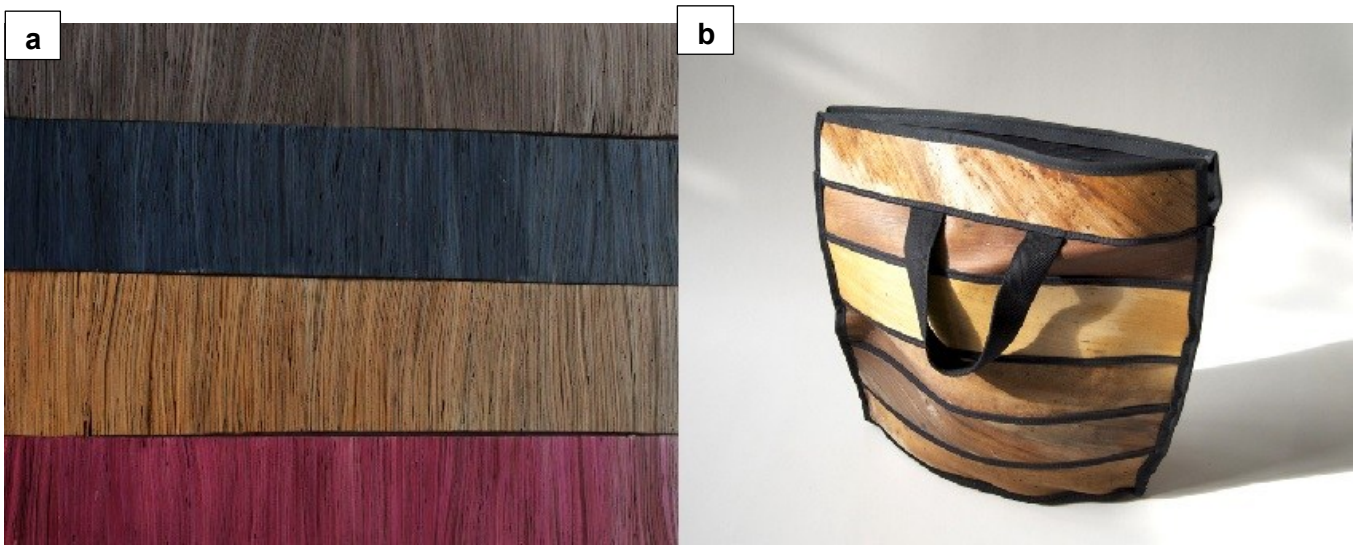

Fig. 3 (a) The palm leather rug; (b) A palm leather bag by Tjeerd Veenhoven

Orange Fiber and the Lenzing Group, the world's leading producer of special wood-based fibers, combined forces to create the first ever Lyocell fiber under the TENCEL™ brand from orange and eucalyptus wood pulp [5]. Lyocell is widely used in textiles and knitwear and is taking its first steps towards footwear [6].

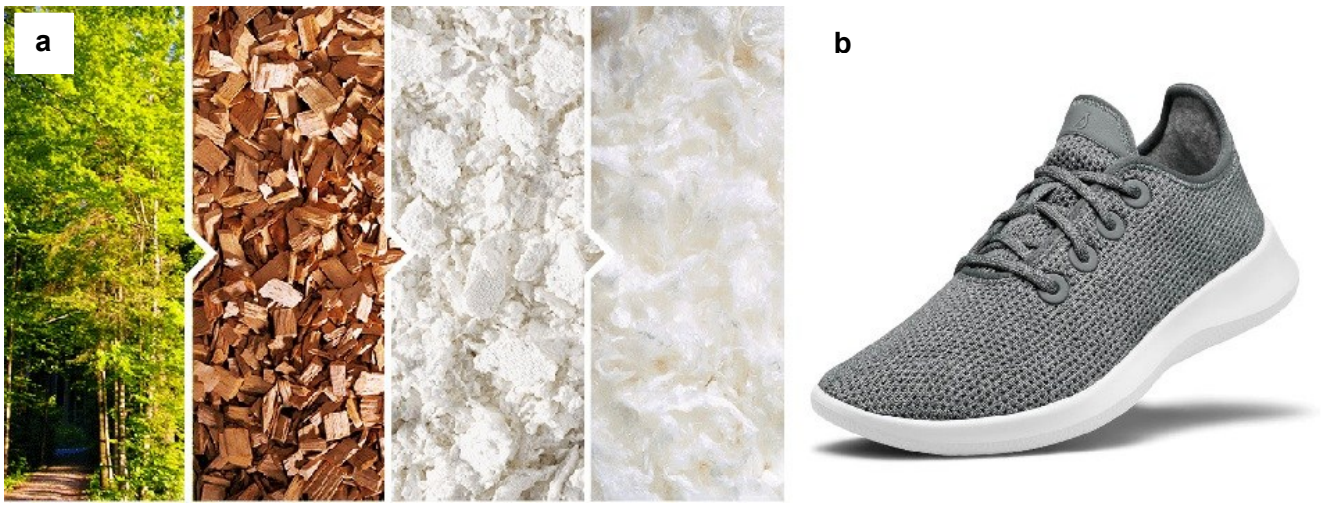

Fig. 4 (a) TENCEL Lyocell material; (b) Men's Tree Runners by Allbirds with TENCEL Lyocell

Pinafelt®, the non-woven textile material that forms the basis of Piñatex®, is made by extracting fiber from pineapple leaves. After drying, the pineapple leaf fiber is mixed with corn-based polylactic acid (PLA) and undergoes a mechanical process to create Pinafelt®, which is then dyed with pigments and treated with a resin coating to obtain more resistant properties of the top layer [7].

Fig. 5 (a) Piñatex® material; (b) Products from Piñatex® [7]

Having been combined, the indifferent attitude towards the environment and the endless use of non-renewable resources created a serious social problem, leading to the increased consumer attention to the use of sustainable raw materials in the fashion industry. Due to celebrities and fashion designers who started supporting the animal rights movement, vegetarianism gained momentum, which eventually created an alternative vegan fashion that declared its goal to solve the environmental problems of society [8].

Major global brands did not stay apart from this trend and began to create vegan product lines. Such start-ups in this direction were the industry leaders H&M and Zara, which were the first to introduce various sustainable business models for ethical consumption into their corporate strategies and values, thus, setting an example of environmental policy for the entire fashion market. Currently, more and more high-end brands, such as Stella McCartney, Jean-Paul Gaultier, Chanel, Versace, Burberry, Gucci, Giorgio Armani, Ralph Lauren, Coach, Tommy Hilfiger, Calvin Klein and many others, declare the cessation of leather and fur usage, which is the beginning of the industry's shift to sustainable fashion. Making every effort to work in accordance with the circular economy and practice sustainability at every stage of production and distribution of their products, companies encourage consumers to buy products produced within this process by conducting various campaigns involving musicians and artists, creating

a ripple effect among the public, encouraging customers to naturally participate in creating a common ecosystem for the realisation of social interests. [8]

Although the sustainability of the fashion industry is still in its infancy, a large number of brands have already started experimenting with capsule collections using sustainable materials. A striking example is Pinatex®, which is successfully used by Hugo Boss, Paul Smith, Nike, Saucony, Zara and many others for footwear production as an alternative plant-based leather, which does not have only the aesthetic appearance, but also the audience's interest in the development of this industry (Fig. 5).

Fig. 5 (a) Piñatex® shoes by Hugo Boss; (b) Piñatex® shoes by Hugo Boss ® by Saucony

Taking into account the information provided above, it can be stated that there are already many brands that offer alternative plant-based leather, as well as that one which manufacture products from this leather. However, there is still no complete information on the compliance of alternative plant-based leather with consumer requirements and regulatory indicators of genuine leather which is still number one material for footwear [9, 10, 11]. Therefore, the task was to comparatively analyse the characteristics of the most famous and discussed product on this market - Pinatex® - in order to determine the impact of this trend on society, its ability to compete with genuine leather, how environmentally friendly it is and whether it has prospects in footwear production.

2. Method

The paper applies the method of analysis and synthesis of scientific and technical publications, innovative projects and environmental solutions dedicated to the use of biogenic raw materials in materials for fashion products as an alternative to cattle leather for footwear and accessories.

A comparative analysis of the environmental performance, mechanical and consumer properties of nonwoven textile material based on vegetable cellulose from pineapple leaves - Piñatex® and genuine cattle leather using the chrome tanning method was carried out.

3. Results

Cattle leather is now widely available due to the high consumption of meat and milk which is already an environmental problem due to the large number of cattle and CO_2 emissions, but this is not the last environmental issue that accompanies the leather industry. The most polluting stages of production are the tanning and liming processes, which are the processes of turning animal leather into a durable material, mainly using toxic chemicals. During the liming process, sodium sulphide and lime are added to the leather. At this stage, the sodium sulphide can turn into hydrogen sulphide, which is highly toxic to both humans and animals [12]. Most tanneries use chromium-based tannins because they work very well to create durable leather. Chromium is highly toxic to humans and very harmful directly to the environment if disposed of through wastewater. The chromium used in the tanning process is not recovered, and Cr(III) atoms in the waste sludge (sludge) can be converted to Cr(IV), which is

carcinogenic and mutagenic [13].

Unlike cattle leather, Pinatex® is an environmentally friendly fabric that does not involve toxic chemicals. Its production is predominantly mechanical and is a closed-loop process in which a by-product of an existing industry is used for processing, which reduces agricultural waste without requiring additional natural and environmental resources such as water or land, significantly reducing the overall environmental impact. The raw materials for Pinatex® are fibers from pineapple leaves that are discarded after harvesting the fruit and PLA (corn-based polylactic acid, a bioplastic made from corn, a renewable plant-based resource). After the Pinatex® base is created by blending fiber material with corn-based PLA, the semi-finished product is dyed using GOTS-certified pigments and finished with a REACH-compliant resin coating on the front for durability and strength. According to the manufacturer Ananas Anam, Pinatex® does not naturally decompose in a landfill environment, due to the fact that this fabric contains PLA, a bioplastic, but is biodegradable under controlled industrial conditions. In particular, PLA can be broken down into water, carbon dioxide and biomass within a few months, in an industrial composting facility. However, in the creation of Pinatex®, the carbon-intensive step is the logistics by collecting raw materials from pineapple fields throughout the Philippines and delivering them to local fibre factories where they are converted into Pinafelt® substrate and then shipped to Europe for further finishing and appearance [14].

It is known that the physical and mechanical properties of materials determine the limits of their technological suitability in footwear manufacturing. Therefore, it is possible to determine the possibility of using Pinatex® plant-based non-woven fabric as an alternative to natural cattle leather for shoe uppers by comparing the physical and mechanical characteristics of these materials. Pinatex® is the material that is intended to replace natural animal leather, but research and performance comparisons show a big difference between the two materials. Bovine leather for shoe uppers has much better mechanical properties than Pinatex® plant leather. Table 1 shows the parameters of physical and mechanical properties of materials and quality requirements for leather for shoe uppers.

Table 1. Physical properties.

Physical properties	**Thickness (mm)**	**Tensile strength (N/mm^2)**	**Tear resistant (N/mm)**	**Elongation at break (%)**	**Water vapor permeability ($mg/(cm^2 \times h)$)**
	ISO 17186-A [15]	ISO 3376 [16]	ISO 3377-1 [17]	ISO 9073 [18]	ISO 14268 [19]
Chrome tanned cattle hide upper leather	1.7	37.5	80.0	41.5	5.0
Piñatex®	1.53	12.3	31	22	5.6
Quality requirements for the shoes [20,21,22]	1.6-2.0	> 15	> 40	> 40	5.0

The tensile strength and tear strength of the alternative material are quite moderate and less than about 3 times the reference (cattle leather) and show that they do not meet the quality requirements for footwear leather. The elongation at break, which characterises the deformation strength of the sample before fracture, in Pinatex® is approximately 2 times lower than that of cattle leather for shoe uppers and does not meet the specified quality requirements. However, studies [23] show that Pinatex® is one of the plant-based leathers with high flex resistance which can provide partial strength to the product with a small amount of excessive stress and comfortable use at low loads.

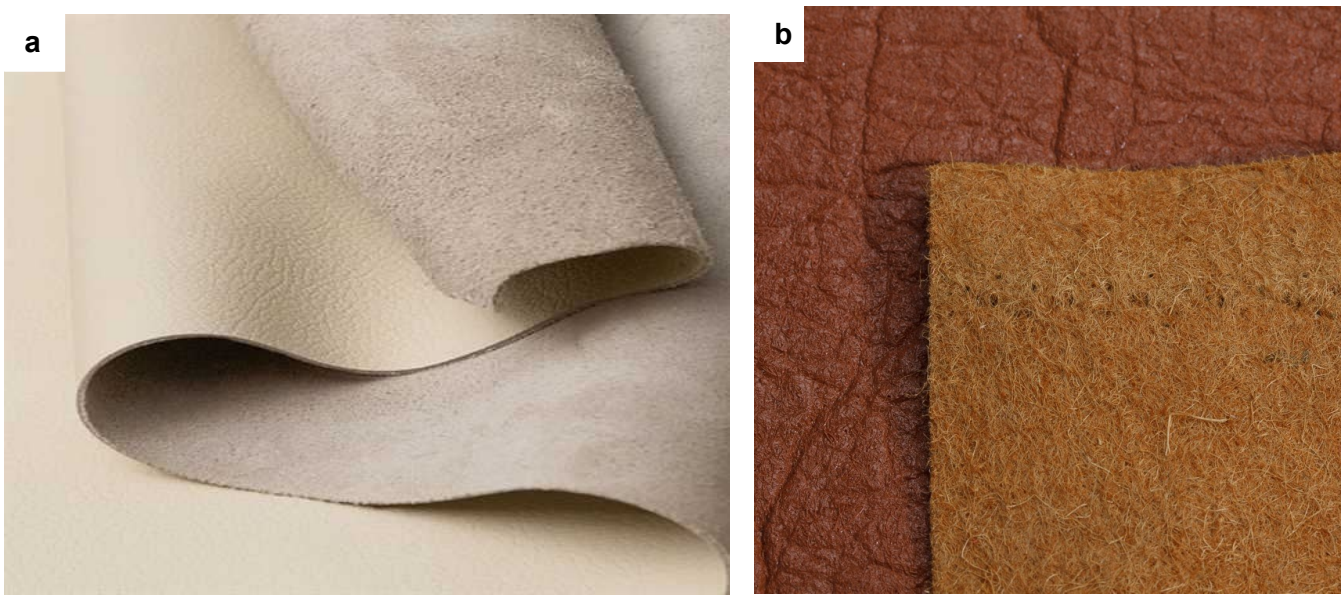

Fig. 5 (a) Chromium-tanned cattle leather; (b) Alternative vegetable/cellulose-based leather Piñatex®

Manufacturers and designers who use Pinatex® in their collections [23] note that this material is harder than leather and the coating that makes the material waterproof fades during the usage which affects the appearance of the product. All respondents confirmed the low durability of the "alternative leather" and the greater labour intensity of the Pinatex® manufacturing process compared to cattle leather. A positive aspect of using Pinatex® is the reduction of wastes due to the various configurations of cattle leather and the absence of defects and blemishes that are an integral part of this raw material. Despite all the disadvantages, experts pay more attention to plant-based leather as an alternative to cattle leather.

4. Conclusions

Despite the monopolistic advantages of the leather industry, concrete changes in the apparel industry are already underway. The launch of more environmentally friendly, innovative alternatives, such as Pinatex®, has not become unnoticed and has been warmly welcomed by the society. The properties of plant-based leathers are not yet completely identical to animal raw materials, and have significantly lower quality indicators in terms of mechanical characteristics, but manufacturers are still trying to experiment and integrate plant-based alternatives to genuine leather into the production of shoe uppers and leather goods, which is already a great achievement at the initial stage of development. The next step is to further improvement of the leather alternatives production technology which will help improve their physical and mechanical properties, make them less expensive, more environmentally friendly and lead to a competitive position with animal-based leather which producers will be motivated to create the product that is less harmful to the environment.

Plant-based leather is not just a one-day trend, but it is a conscious, evolutionary stage of humanity which has enormous potential and opportunity for the development in all areas of production, changing the way we treat the environment with creative solutions and modern technologies that will transform the fashion industry forever.

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