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Proceeding Paper

Sustainable Textiles from Unconventional Biomaterials—Cactus-Based †

Cornelia Wjunow [1], Kim-Laura Moselewski [1], Zoe Huhnen [1], Selina Sultanova [2] and Lilia Sabantina [3,*]

[1] Faculty of Textile and Clothing Technology, Niederrhein University of Applied Sciences, 41065 Moenchengladbach, Germany; cornelia.wjunow@stud.hn.de (C.W.); kim-laura.moselewski@stud.hn.de (K.-L.M.); zoe.huhnen@stud.hn.de (Z.H.)
[2] Faculty of Linguistics, Higher School of Foreign Languages and Translation Studies, Kazan (Volga Region) Federal University (KPFU), Kazan 420008, Russia; selinasultanova@icloud.com;
[3] Berlin School of Culture + Design, Berlin University of Applied Sciences—HTW Berlin, 10963 Berlin, Germany; lilia.sabantina@htw-berlin.de
* Correspondence: lilia.sabantina@htw-berlin.de
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Abstract: Petroleum-based resources are used in the manufacture of products and the recycling of products at the end of their life cycle is not environmentally friendly. Various studies have shown that vegan leather alternatives are particularly suitable because they mimic the properties of real leather, and the quality of the bio-based material combined with textile substrates is relatively close to real leather. In addition, cactus plants require less water and can completely replace real leather. The use of cactus as a source of sustainable textiles and leather offers numerous environmental benefits. This is due to the fact that harvesting the cactus does not harm the plant or its roots, allowing it to keep growing and sequestering carbon dioxide. This paper discusses sustainable materials based on cactus species that can replace leather products, for example, and explores the development of bio-based textiles in the near future.

Keywords: cactus leather; eco-friendly textiles; vegan leather; sustainable textiles; unconventional biomaterials

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1. Introduction

In light of the present environmental condition of our planet, human beings have come to realize the importance of exercising moderation in their actions [1,2]. The production of goods and luxury products through the utilization of petroleum-derived resources is an unsustainable and environmentally unfriendly practice that is restricted by limited resources [3,4]. Consequently, some emerging companies are opting to use bio-based materials in the manufacture of various products in the textile and apparel, accessories and automotive industries such as car interiors [5,6]. Being vegan or wearing vegan products and clothing has become something of a fashion trend. Vegan alternatives to leather were sought as many wanted to stop using animal leather altogether [7]. Strengthening and using a sense of responsibility for the future can be an effective tool to promote environmental awareness and intergenerational environmental behaviour.

This paper discusses sustainable materials based on cactus species that can replace leather products, for example, and explores the development of bio-based textiles in the near future.

2. Cactaceae Family

The cactaceae, a broad group of plants, are primarily found in regions characterized by arid and semi-arid climates [8,9]. There are more than 5000 cactus species, most of which are found on the American continent. In addition, they are widespread in the arid regions of Mexico (e.g., Chihuahuan Desert), Brazil (e.g., Caatinga region) and Argentina (e.g., Jujuy province). Cacti inhabit tropical forests, grasslands, semi-deserts and deserts [10,11]. Argentina is a country with a great diversity of cactus species, with some 200 to 300 native species [12]. Typically, cacti thrive in dry regions where their lifestyle is dictated by the limited availability of water. They must gradually and consistently accumulate biomass to survive, relying on water to absorb nutrients. During the winter, like many other plants, cacti require a period of rest [13]. For example, inside the *Opuntia* cladodes, a fiber net serves as a reinforcing and cushioning skeleton. The fibers can be obtained through different techniques such as water retting [14], burying [15], or using dried cladodes that only have the fiber net remaining [16,17]. Cutting back cactus plants to control growth or processing the fruit produces large amounts of waste, but this can be a sustainable resource as it can be used to produce fibres. These fibres can be used as reinforcements in a variety of applications, including the manufacture of protective clothing, shoes and accessories, as well as for technical purposes such as water purification or the filtration of heavy metals from waste water in the textile industry [18–24].

3. Recent Research Findings

The interest in cactus bio-based materials is growing, which is reflected in the number of publications. Belay et al. studied cactus species, *Opuntia ficus-indica*, used for biogas production [25]. The use of cactus and banana peels as a natural coagulant for drinking water treatment was investigated in the study by Kalibbala et al. [26]. Cactus mucilage for use in food and medical applications was the subject of discussion in the de Andrade Vieira and Tribuzy de Magalhães Cordeiro work [27]. The results of Al-Nageb's study have shown that the extraction of oils from the seeds of the cactus *Opuntia ficus-indica* (OFI) *and Opuntia dillenii* (OD) for use in food products is promising [28]. The use of *Opuntia ficus-indica* as a biosorbent for the removal of chromium from wastewater in the leather industry was investigated in the study by Figueirôa et al. [29]. Some studies discussed the use of cactus fibres or cactus components as reinforcements for polymer composites and reported good mechanical properties, such as in energy absorption and tensile tests [30–32]. Araújo Júnior et al. conducted a study on the growth patterns and accumulation of forage mass in feeder cactus clones, investigating how they are affected by meteorological variables and water regime. The research found that the *Nopalea* genus cactus clones are more sensitive to semiarid climatic conditions compared to the *Miúda* (MIU), *Orelha de Elefante Mexicana* (OEM), and *IPA Sertânia* (IPA) clones [9]. In the study by Vadivela and Govindasamy, the cellulose-rich fibers of *Acacia Arabica* tree's bark and *Euphorbia Tirucalli* plant's stems were examined for their potential use in polymer matrix composites. These hybrid composites, which combine biobased fibers and polymer matrix, exhibit promising properties such as lightweight, excellent strength, and biodegradability, making them suitable for industrial applications [33].

4. Sustainable Textiles and Vegan Leather Alternatives

Vegan alternatives are being actively sought to replace animal leather with bio-based alternatives such as plant fibres or fungal mycelium fibres in the face of global climate change [34]. Several different vegan leather alternatives to real leather are available on the market today, including Muskin®, Desserto®, Appleskin®, Vegea®, SnapPap®, Kombucha, Teak Leaf®, Pinatex® and Noani® [35]. Diverse bio-based materials, including leaves and fibers from various sources, are utilized to create leather alternatives. For example, Teak Leaf® leather is produced from leaves, while Desserto® made from cactus fibers and Appleskin® from apple residues, and Vegea® is derived from the skins, seeds, and stems of grapes. Pinatex® leather contains fibers sourced from pineapple leaves [35,36]. SnapPap®, an interesting alternative, is composed of a mixture of cellulose and latex and can be washed, ironed, or varnished. Additionally, Noani® incorporates fibers from eucalyptus leaves [35,36]. Materials such as polyurethane foam (PUR) or textile reinforcements such as woven or non-woven textiles are commonly used in some leather alternatives [37].

5. Cactus Leather in Fashion

An environmentally conscious approach to fashion has emerged, with a focus on sustainability. Vegan fashion items such as clothing and accessories are gaining popularity as a viable option. A prominent advocate for environmentalism in fashion, Stella McCartney, who runs a fashion brand of the same name, uses a variety of eco-friendly methods. McCartney was among the influential leaders who participated in the G7 Summit in June 2021 [38]. In addition, she and other leaders pledged their support to the Terra Carta Transition Coalitions, a collaborative effort dedicated to advancing sustainability worldwide. The use of eco-friendly leather substitutes has gained widespread attention, with the term "vegan fashion" making a significant impact on society [39,40]. In 2019, Marks & Spencer, a fashion brand, introduced a line of vegan footwear [41]. Topshop, another fashion retailer, launched a Peta-approved vegan leather shoe collection that featured 12 designs made with non-animal and non-fish glue in its Spanish factory [42]. Even Dr. Martens, a major footwear retailer, offers a 100% vegan leather version of its classic 1460 leather boot [43]. H&M, a popular fashion retailer, used Piñatex, a fiber produced from discarded pineapple leaves in the Philippines, to create faux-leather for its Conscious collection in 2019 [44]. The number of animal leather alternatives continues to grow, with many more examples emerging. The use of cactus leather in fashion has become increasingly significant in recent times, with numerous companies and brands partnering with Desserto®, a prominent cactus leather producer. In March 2021, the major fashion retailer H&M released The Science Story collection, which incorporated cactus leather and castor oil thread [45]. The collection featured a pair of high-heel sandals crafted from Desserto® cactus leather. Renowned car brands like Mercedes-Benz and BMW are incorporating Desserto®'s cactus leather into their car interiors. This is because consumers are now seeking alternative options to real leather, and sustainable trends, including eco-friendly textiles and clothing, are becoming increasingly important. As a result, luxury fashion brands such as Givenchy, Karl Lagerfeld, Adidas, and Fossil are introducing collections made of Desserto®'s cactus leather to cater to this demand [5].

6. Conclusions and Future Outlook

An increased sense of responsibility for the future can be an effective way to promote environmental awareness and action among consumers. Out of this need, new companies are emerging that use bio-based materials for various products. The trend of living vegan or wearing vegan goods and clothing is currently on the rise. A vegan alternative to leather is being sought, as many people want to avoid using animal leather of any kind in the future. Vegan leather made from bio-based resources such as cacti can offer a sustainable alternative to real leather. The production of bio-based materials such as cactus leather will continue to increase and can take a significant share in the fashion and leather industry. The positive environmental aspect will gradually change the luxury goods image as it becomes more important to care for and protect the environment. Cactus leather is a promising bio-based alternative product as it can cover many of the functions of animal leather. It remains to be seen whether it can completely replace real leather, but with further research in the field of bio-based materials such as cactus leather, it may well be possible to soon do away with animal leather completely and turn to vegan alternatives.

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