Future Fashion II: sustainable alternatives to animal-derived materials

Introduction

In the previous instalment of the Future Fashion article series, we provided an overview of the environmental impacts of some of the most widely used textiles in the fashion industry – natural and synthetic. We provided an overview of the existing sustainable and biobased alternatives to those and showed that they could allow the fashion industry to transition towards a circular sustainable economy. This second article focuses on sustainable biobased alternatives to animal-derived materials, namely leather, silk and (faux-) fur.

Opinions on the use of those materials are often very polarised due to their inherent animal-derived nature. As numerous activist organisations such as PETA raise awareness on the often cruel treatment inflicted on animals[1,2] to source the raw materials, some businesses argue that as leather, silk and fur are manufactured from biobased raw materials, they are more environmentally friendly than man-made alternatives which often contain petroleum-derived polymers, like polyester[3,4,5]. In addition, providers of 100% animal-derived materials also argue that their activity plays a crucial role in helping protect the environment by optimising ecosystem services and making use of waste from other industries (i.e. meat and dairy for leather). This everlasting debate perfectly illustrates the complex nature of the transition that the fashion industry is attempting to undertake, especially when dealing with animal-derived products.

In 2017, the Fashion Global Agenda released its "Pulse of the Fashion Industry" report assessing the overall environmental impact of the fashion industry and identifying the areas where it could improve. As part of the report, a "cradle-to-grave" environmental impact analysis of some of the main textiles and materials used in the industry was presented, showing their effects on global warming, eutrophication, water scarcity, abiotic resource depletion and "chemistry", which relates to toxicity. Cow leather and silk ranked first and second respectively, showing that aside from the moral aspect of using animal by-products to manufacture fabrics, the consequences of this type of trade can be very detrimental to the environment and the climatic situation we currently find ourselves in. Therefore, it appears that neither natural animal-derived materials, nor most of their synthetic alternatives provide a suitable solution to the moral and environmental issues being posed. There are however a few biobased and sustainable alternatives being discovered, or re-discovered, which could potentially solve those issues.

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Leather

Conventional leather

One of the oldest fabrics in the world, the market value of the leather industry was more than $260 billion globally in 2020 and is expected to reach $630 billion by 2050 (according to Grand View Research Inc).

Leather is manufactured from animal hides obtained as a result of the meat and dairy industries. Although it is therefore a biobased material, its sustainability is highly debated. Being a by-product of other industries, it is sometimes argued that there is no direct "production" of animal hides, therefore making the material's environmental impact low. However, with animal skin being the most expensive part of the animal, it can also be regarded as one of the main incentives for farmers to rear cattle. As a result, the environmental impacts of leather are also often assimilated to the environmental impacts of cattle farming, which include greenhouse gas emissions, global warming, deforestation, eutrophication and soil degradation. The Sustainable Apparel Coalition (SAC) is the fashion industry's leading partnership for the promotion of sustainable production. With more than 250 members, the coalition includes brands, retailers and manufacturers, including leading brands such as Levi's, Benetton and Patagonia, to name only a few. As part of their work towards the development of a sustainable fashion industry, the SAC has created the Higg Index which allows members to calculate the annual environmental impact of their activities. In 2020, the SAC updated its Higg Index calculation methods which led to complaints from the leather industry. Leather producers and manufacturers argued that the data and methods used by the Index were outdated and inaccurate, and therefore painted an unfair picture of the leather industry as a whole. There were disagreements on cattle lifespan, resource depletion and the lack of varied geographical data. Another point of debate was also the "cradle-to-factory" approach used by the Index, which according to the leather industry does not reflect the durability of the material. The two alliances are now working together to develop a more accurate Higg Index for leather, however, this shows that leather production remains a controversial topic even within the fashion industry itself.

The chemical impact of leather production is well known and has one of the worst environmental track records in the fashion industry. Tanning is the process through which the structure of animal hides is modified to prevent decomposition and degradation of the material. It is designed to make the fabric durable and allows it to be coloured. In essence, it is through tanning that animal skin becomes leather as we know it. This step of the leather production process has large environmental impacts due to the chemical substances used, which lead to river pollution and the release of toxic compounds which can lead to biodiversity loss, soil degradation and serious health conditions in humans. All the solid waste removed from the hides – such as hair, fat, mould, faeces and meat – is also often discarded through the water system, which only worsens wastewater pollution originating from leather treatment. Typically, one short ton of hide results in 20 to 80m^3 of wastewater containing dangerous levels of chromium, lead, arsenic and sulfide. In Kanpur, which is India's leading exporter of leather, 50 million litres of highly toxic tannery water is generated every day. As much as 80% of this water remains untreated and is discarded into water streams such as the Ganges. A range of diseases such as skin discolouration, asthma, tuberculosis and cancer have been reported as resulting from the high levels of toxicity contained in the water, both in India and other countries such as the US.

For the time being, national and industrial regulations are the only solution for the mitigation of the environmental impacts of conventional leather tanning. For example, the EU has long been regulating the use of chemicals in tanneries and has set clear health and safety measures that "modern tanneries" must comply with in order to continue their activity in the Union. Initiatives such as the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) standards is leading to the removal of

harmful chemicals and increased protection for workers. Further EU regulations also call for increased transparency from tanneries, which has led to continuous progress towards modernising the practice across Europe. However, most of the leather is produced in developing countries where such regulations are rare or nonexistent, and where the price of the finished products is low due to low labour costs. Leather produced in regulated modern tanneries in Italy or Japan is often linked to luxury products which only a minority of consumers can afford.

Sustainable leather

Leather remains a very popular material that is regarded as being durable and elegant. As such, controversy and environmental issues are leading the industry to look at transitioning towards sustainable practices and sustainable alternatives to animal hides.

As mentioned above, the sustainable nature of animal hides is still widely debated and remains a controversial topic. This section will solely focus on sustainable alternatives to animal hides and will steer away from animal-derived products altogether. Artificial leather has been around for a long time, with the first leather substitute *Presstoff* synthesised in the 19th century from paper pulp. Since then, a variety of materials have been developed, mainly from fossil-derived compounds like polyester, polyurethane and PVC. The production of PVC in particular requires petroleum and large amounts of energy, calling into question its sustainability. In addition, toxic by-products resulting from the synthesis and the degradation of PVC in landfill can remain in the environment for a long time.

In the past few years, a wide array of plant and waste-based leathers have been developed to provide an answer to the issues posed by both animal-derived and fossil-based synthetic leathers. One of the first plant-based alternatives arrived on the market in 2013. Produced by the company Ananas Anam, Piñatex is a leather alternative made from pineapple tree leaves. The leaves are sourced from a plantation in the Philippines where they would otherwise be incinerated or left to rot. The fibres obtained from those leaves are then mixed with polylactic acid (PLA), a biobased plastic which was covered in the first Future Fashion article, and transformed into a non-woven material. Piñatex has been very successful and has notably been used by brands such as Hugo Boss. Another similar plant-based material was developed by designer Tjeerd Veenhoven who successfully synthesised leather-like fabric from the leaves of the areca palm. In this case, the raw material is submerged in a solution containing only water and other non-toxic ingredients which are deemed fit for human consumption.

Perhaps one of the best-known leather-alternative so far, Mylo by Bolt Threads shot to fame in 2017 when it was featured as part of Stella McCartney's collections. In this case, the material is synthesised from mycelial biomass extracted from fungi. Growing those organisms requires little energy, therefore contributing to the product's low environmental impact. Mylo also contains other biobased elements such as sawdust. Just like most alternative leathers out there, Mylo remains an expensive commodity that only leading brands can afford. The price is reflected down the value chain to the finished product that only a minority of consumers can afford. To turn this trend around, a consortium composed of Stella McCartney, Adidas, Gucci and Lululemon has pledged substantial annual financial contributions to Bolt Threads to boost the company's production capacity, lower the costs of the finished product and allow smaller brands to incorporate Mylo into their designs.

Due to their vegetal and fungal nature, the artificial leathers presented above are often dubbed "vegan leathers". There are however other alternatives that incorporate animal-derived compounds. Tômtex for instance, developed by Vietnamese designer Uyen Tran, is manufactured from coffee grounds and seashell waste. This particular material is 100% biobased and does not contain any fossil-derived or biobased plastics. In addition, Tômtex does not require any tanning and is 100% recyclable.

The chemical treatment of leather (both conventional and alternative) is a major environmental issue which the industry is attempting to address. A lot of progress has been made to improve the sustainability of the tanning process by introducing a vegetable tanning alternative which does away with toxic compounds such as chromium. Ironically, vegetable tanning has existed for centuries, much longer than chrome-based tanning, however, only 10% of all leather produced nowadays is treated through this biobased method. In essence, it involves using compounds found in bark, leaves, fruits and roots which are akin to the phenol compounds require for tanning hides. The dyes used at the end of the process are also non-toxic vegetable oil-based solutions. The waste produced at the end of the tanning process is also recovered, reused and recycled. Although vegetable tanning takes much longer than conventional tanning, which could be regarded as a downside, it is not harmful to workers and does not release any toxic compounds into the environment. However, its sustainability has been questioned as a number of activist organisations and scientists believe that harvesting the raw materials needed for the tanning reagents (mainly bark) could lead to major deforestation events if kept unchecked[6]. These claims have sparked anger from the leather industry who fiercely refutes the validity of the allegations put forward, arguing that the raw materials are harvested sustainably and that forests are closely managed to promote regeneration[7]. So far, there are no other tanning alternatives.

Silk

Conventional silk

It is said that silk was first woven into fabric in China around 2700 BC. Legend has it that empress Xi Lingshi discovered it when a silkworm cocoon fell from a tree into her cup of tea and started to unravel. However, there is evidence that silk was first discovered and used as a material during the Neolithic period (10,000 BC to 4,500 BC). From then on, silk became a very lucrative commodity for China as exemplified by the famous Silk Road which remained an economic lifeline from around 130 BC to 1453 AD. The merchant route also allowed the knowledge of silk production to expand outside of China for the first time. Nowadays, silk remains an expensive fabric assimilated with elegance and luxury.

Raw silk comes from the inner part of a silkworm cocoon. In essence, silk is produced from the worm's saliva which builds a cocoon to protect itself until it transforms into a moth through the process of metamorphosis. About 90% of global stocks of raw silk is harvested from the mulberry silkworm. Each silkworm only produces one cocoon which is often harvested before the worm has a chance to go through metamorphosis. The cocoon is then boiled to kill the worm inside. Each cocoon contains approximately 1,000 yards of silk filament, and about 2,500 cocoons are needed to produce one pound of raw silk. In addition, one hectare of mulberry trees (on which silkworms thrive) is needed to produce only 40kg of raw silk.

Although silk is made from natural protein fibres (i.e. fibroin and sericin), it is the textile with the worst environmental impact mainly due to the energy consumption needed for silk farming (called sericulture). For the worms to thrive and produce cocoons, silk farms must maintain very specific temperature and moisture conditions all year round, which is where the energy use comes in. Steam and hot air are also used to dry the cocoons after harvesting, mostly thanks to the burning of mulberry wood or through municipal energy often produced by coal-fired plants. As a result, silk farming actively participates in climate change and greenhouse gas emissions. As with all fabrics, chemical treatment is often applied to silk. In particular, worms are sometimes given hormones to grow bigger and produce more raw silk. In addition, the worms are also sometimes "weighted" which is a process through which the worms are given metallic salts to become heavier and appear more lustrous. This process leads to

increased toxicity in wastewater. As with most other fabrics, dyes applied to silk can also contain toxic chemicals which eventually find their way into surface water and the environment.

Sustainable silk

There are several aspects to consider here. First, on the subject of energy use, a lot of progress is being made towards decarbonising grids in Europe notably, with European and national policies leading to the increased uptake of bioenergy to produce power, heat and fuels. However, as most of the world's silk is produced in China and India, whose energy production still heavily relies on fossil resources such as coal and oil, sustainable energy for use in silk farms remains extremely rare.

Secondly, as with any animal-derived material, there is controversy surrounding the industrial use and the killing of living organisms. After centuries of selective breeding, the mulberry worm has become completely dependent on humans for survival as it has lost the ability to fly, see, camouflage and fear predators. As a result, it is now fully extinct in the wild. The debate remains polarized, however, as a large proportion of the public question the harm in killing insects which "do not feel plain". As the scientific community attempts to answer the everlasting mystery of pain perception among living organisms, some members of the fashion industry are taking steps to remove silk from their production and supply chains altogether. Recently, British fashion retailer ASOS decided to ban a number of products that contain animal-derived materials, including silk, as they believe it to be unethical.

A number of newly created fashion brands have also been building their designs and production lines on 100% organic silk, which is produced without any use of toxic chemicals including pesticides (often used on the mulberry trees) and dyes. Another aspect of organic silk involves letting the worms leave the cocoons before harvest and allowing them to live the rest of their natural lives. Brands such as Ziran and Roopa pride themselves on perpetuating a sustainable traditional silk production know-how which they aim to keep alive and pass on to future generations.

There are man-made alternatives to silk that do not involve the harvest of natural raw silk from cocoons. These are commonly known as viscose (or Rayon) and Tencel, and were covered in the first Future Fashion article. To summarise, those are considered semi-synthetic fabrics that are produced from cellulosic feedstock which is then extensively transformed through intense chemical processing. The production of Rayon is highly unsustainable and can lead to the release of toxic compounds in the environment as well as deforestation when not subjected to strict regulations. Tencel is an alternative to conventional viscose which is produced through the lyocell process requiring non-toxic chemicals. It is therefore possible to find artificial silk which was not produced from animal-derived products and was not treated with toxic chemicals.

Silk is often considered a circular and non-waste fabric. Worms feed on the leaves of mulberry trees, removing the need to source further resources. Any leftover foliage can also be used to feed cattle. Mulberry fruits are fit for human consumption, while the wood can be used for timber or fuel. In addition, as a certain amount of sericin is lost in the water while the cocoon is washed, effort can be made to recover the protein which can subsequently be used in cosmetics, pharmaceuticals and even food. Furthermore, raw silk or low-quality silk is not wasted and is used through the production of bedding items such as duvets and pillows. Finally, with silk being a natural fibre, it has high biodegradability rates both on land and in the ocean. Unsurprisingly, organic silk is also less likely to release potentially toxic chemicals in the environment as it biodegrades.

Fur and faux-fur

Fur

Fur is probably the most controversial material ever used by the fashion industry, so much so that garments made of natural fur have become a rare sight. The intensive information campaigns spearheaded by organisations like PETA have been raising awareness about the often cruel treatment of animals for the sourcing of raw fur. Nevertheless, the sustainability of wild fur versus farmed fur is still a dividing topic within the fashion industry, with a number of businesses arguing that some fur sourcing strategies are both humane and a way of maintaining healthy ecosystems. The divide between the wild-fur and farm-fur sectors is often wide and competition is fierce between the two, with each side arguing that their methods are "better". Wild-fur traders argue that their role is crucial in regulating animal populations, therefore maintaining optimal ecosystem functioning and protection cattle farms. On the other hand, fur farmers maintain that their "euthanasia" methods are more humane and that their fur is of better quality.

Aside from the moral aspect of sourcing real fur, they are clear environmental downsides to rearing animals in captivity and to treating the pelts. Due to the need for high quantities of feed for the animals, added to the fact that a lot of animals are needed to produce a small amount of fur (i.e. 11 minks for 1kg of fur), the carbon footprint of fur farming is extremely high (i.e. 110kg CO_2 or a car drive of more than 775miles for 1kg of mink fur). In addition, similarly to leather tanning, the chemical treatment of real fur is intensive and extremely toxic, involving compounds such as heavy metals, organic solvents, organochlorine pesticides, polycyclic aromatic hydrocarbons and reduced organic nitrate compounds. All of which have been shown to induce mild to extremely severe health conditions in humans.

Conventional faux-fur

Faux-fur, or pile fabric, was first introduced in 1929 when alpaca hair was used to imitate the feel and look of "real fur". However, faux-fur as we now know it (i.e. not made from any sort of animal-derived by-products) did not arrive before the mid-1950s. From then, faux-fur has been manufactured from acrylic polymers or polyester, and has not stopped improving since. Nowadays, it is hard to distinguish real fur from its imitations, both in terms of warmth and feel.

The structure of faux-fur itself represents another danger for the environment. If you read the previous Future Fashion article, you may remember that acrylic and polyester have a very negative impact on the environment, both in terms of energy consumption and pollution. The compounds used to manufacture these polymers are typically petroleum-derived. In addition, neither of these polymers are considered biodegradable. Finally, although polyester can be recycled to produce recycled polyester, acrylic is not recyclable. Despite the progress made with faux-fur there is still room for improvement.

Establishing a clear picture of the fur (and faux-fur) industry is tricky. Finding reliable information on the respective environmental impacts of both materials is hard, as stakeholders and activist organisations are likely to be biased one way or another. The heavy moral aspect of the practice makes it hard for anyone to think about it objectively, in particular when presented with a choice between the cruelty imposed on animals for the production of real fur, and the negative environmental impacts that faux fur could induce directly or indirectly as a result of climate change, plastic pollution or lack of ecosystem regulation (which could in turn lead to major biodiversity loss).

Sustainable faux-fur

Faux-fur being mainly manufactured from polyester, it is not hard to imagine that faux-fur alternatives could be developed from recycled polyester (c.f. Future Fashion I for more details). Unsurprisingly, Stella McCartney is at the forefront of this new trend with a first of its kind partially biobased fur KOBA® first showcased in summer 2020. The product is composed of recycled polyester and corn by-product (about 37% of the blend) and can be recycled again at the end of its life. The new product, created by the company ECOPEL, has received PETA's seal of approval and is also used by brands such as Calcaterra.

Other brands are also putting their own faux-fur products out there. These are usually mainly manufactured from recycled polyester but also containing biobased products such as hemp, straw and organic cotton.

Conclusion

It is important to keep in mind that there is no "sustainability silver bullet". Reaching a point at which most of the fabrics and textiles we use are not harming the environment "too much" will take a lot of effort and will require an open-minded conversation between stakeholders, scientists, consumers and environmental activists. Eco-friendly alternatives are becoming more accessible, however, as exemplified in the case of leather vegetable tanning, severe environmental risks may remain. Despite all the fantastic leaps forward presented in this article, some of the points raised bring us back to what is perhaps the main issue with today's fashion industry: overconsumption.

Our third, and last, instalment of the Future Fashion article series will focus on the chemistry of fashion, discussing the most common chemicals used for the treatment of fabrics (e.g. bleach and dyes), and reviewing the sustainable alternatives currently available to us.

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