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Bacterial fabric: introductory studies on the application of biomimetics in the bacterial fermentation process

Abstract

Thinking about innovations that reduce environmental impact and offer quality consumer goods is a way of proposing a future scenario governed by eco-efficiency values. Through an exploratory bibliographic and documentary research, which qualitatively analyses Kombucha authors and fermenters, this article seeks to identify the relationship between biomimetics and bacterial fabric production as an eco-efficient product in the fashion market chain. The general objective of this case study is to explain the fermentation process to encourage the search for raw materials inserted in the sustainability proposal.

Keywords: bacterial fabric, biomimetics, textiles innovations, kombucha, sustainability, eco-efficiency

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Introduction

The ephemerality of fashion compels designers to develop products or concepts for future use only. Fashion courses, in general, teach students from the beginning to always think ahead, studying society in small and large scale, and to be able to suppose and predict possible trends to be followed.

Companies specializing in trend research, such as WGSN and the Brazilian Box 1824, have research teams that analyse society's actions and changes in detail, from political, social, environmental, geographical, or climate issues around the world, identifying constructive aspects that may prove some ideals to be consumed in the future.

Over the past decade, researchers and scientists have emphatically pointed out that one of society's macro-trends is consumer awareness, assuming that, for a future to exist, sustainability must exist. As stated by Carvalhal,[1] millennials (people born from the 1980s onward) have greater awareness and concern about social and environmental issues, because they were born in an accelerated world and value the slowdown.

Dealing with current losses and avoiding future problems is on the agenda of feature documentaries such as The True Cost,[2] Home[3] and Cowspiracy,[4] which spell out issues such as biodiversity loss, compromising of natural resources, and harms and diseases emerging in society. And, being inserted in this environment, the new generations also carry these thoughts, values, and ways of consumption.

As a result, many brands and companies, which emerged and are, being developed in this contemporary time, propose innovations focused on sustainability, seeking solutions in all links of the fashion value chain, including raw materials, production, retail, and post consumption.

Thinking about the most basic link of fashion, which is the raw material for developing the product, new input options arise, such as recycling, production of organic fibres with natural improvements, construction of eco-friendly materials, reuse of materials, biodegradable plastics, etc. Most of them are alternatives that have differentials and benefit the system at some point, besides alerting the consumer to rethink their purchase. However, they still carry negative aspects in their production, such as waste of water, light, toxin release (even if in small quantities), and so on.

An efficient instrument to use in the breeding process within sustainable activity is biomimetics, doing nature analysis, and applying these studies to our production system. This instrument, according to Fletcher and Grose,[5] is a system of practices that imitates the patterns of nature to guide the design of products, processes, and policies, drawing inspiration from living organisms.

An example of the use of applied biomimetics in its entirety, using nature as a model and mentor, is the study of the fermentation process of non-pathogenic bacteria that has resulted in an opportunity for innovation for the textile industry. "The planet is 90% composed of cellulose" (Lee, 2014) and thinking about creating a fashion product with this material from fermentation is completely innovative and consistent with the moment we are living in.

The bacterial fabric is a possible disruptive innovation that, according to Christensen's concept, gives rise to new markets and business models, presenting more efficient solutions than the already existing ones.

Fashion and the environment

Environmental concerns have generated much debate on the future of humanity and the need to shape actions that stabilize and modify the planet's landscape.

We live a process of self-destruction that can only be stopped by a deep awakening of consciousness. Clothing and other consumer goods will no longer be mere objects and will become a subject to build a more emotional relationship with people.[1,6]

Aesthetic and consumption values have been changed because of the growing concern with the sustainability of our planet. As Box182, a consumer, behaviour, and innovation trend research agency that helps design future scenarios and anticipate behavioural movements through strategic projects, creator Rony Rodrigues mentions in the

passage above, as time goes by, we continue to cause greater damage to the environment in which we live in and, to change this situation, it is necessary to redefine our ways of consumption.

The textile industry produces, in addition to the accumulation of excess waste, various toxic substances that are released into the environment infecting various life forms and endangering the health of many people, whether or not they have had direct contact with the product.

At Eco-92, United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, when several heads of state met in Rio de Janeiro to discuss the environment, there was a consensus that past lifestyle and consumption actions were aggravating to irreversibly damage the planet, even determining a deadline for the end of natural resources. As Maciel[7] presents to us in his Exame magazine article, if we continued to consume in this way, by 2030 we would need two planets to meet our demands.

Therefore, the term eco-efficiency was introduced in the convention as the provision of goods and services at competitive prices that meet human needs and bring quality of life,[8] as a way of reducing environmental impact and simultaneously stimulating profitability, using raw materials and energy more efficiently. Quoting Paul Hawken.

The idea that sustainability augurs a smaller world is true because it calls for less waste, pollution, damage, devastation, depleted soil, poisoned workers, dying bodies of water, etc. But it does not portend a monochrome world, made of rice and brown uniforms.[5,9]

Such thinking triggered the emergence of sustainable alternatives in various fields of fashion that rethought previous production models and provided for change. Many brands have emerged from this eco-efficient bias, reusing discarded materials from industries, stimulating slow and local production, and choosing methods with reduced resource wastage, thereby enshrining the lowsumerism movement as a macro-trend worldwide. Such a concept, according to Box1824's analysis, is a tendency that has emerged to counteract the excessive capitalist system and reduce negative social and environmental impacts through conscious consumption, valuing shared economy, local production, and utilizing only what is necessary.[10]

Textiles innovation

Fashion is one of the three main daily activities that have most impact on the planet, along with food and fuel.[5,9] As a result, the fashion industry has begun to look for textile innovations, particularly in the area of material exploration, including sustainable improvements in the manufacturing process and new input options that may preferably be biodegradable, that is, decomposed by other organisms.

Advances in research related to sustainability and textile options that do not increase the damage caused to the planet have grown in recent decades. In 2003, the Soil Association (London) decreed the organic concept for fabrics that meet the criteria of being biodegradable and non-toxic to fish, possessing natural or insect-derived dyes, and not genetically modifying their fibre. Fabrics that do not harm the soil during the planting process nor intoxicate the skin with strong pesticides are being studied, as well as fibres from recycled products. However, despite the efforts to minimize damage, they still have negative impacts, even if it is the light that is consumed during production, material waste, or excess waste production.

Wool, cotton, and leather without toxic benefits are more favourable alternatives to human skin and, therefore, the incentive to produce with these elements is continuously growing. In England, as the Soil Association declared in 2009,[11] the organic textile· market grew by 50% in sales, almost double the growth of organic food (26%). Sales of 100% organic CO fabrics grew by almost 35%, resulting in nearly $2.6 billion in 2008.

However, despite expressing itself as a positive impact on the environment, reducing the rates of toxins released and of waste due to easy degradation, the process of fabrics beneficiation does not support the eco-efficiency of the product. Textile processing, cited by Fletcher and Grose[6] as dyeing, waterproofing, and other characteristics, is an essential part of converting fibres into fabrics and has a major impact on sustainability. These characteristics, despite facilitating the use of these materials in the consumer's daily life, waste numerous amounts of water and energy in their production, as well as release toxins in ecosystems and harm people's health.

Product reuse and recycling are also actions that help extend the life cycle of a product, postponing the consumption of non-renewable natural resources, since they reuse discarded raw material. This can also be applied to textiles made from food scraps, such as pineapple peel, corn, soybeans, milk starch, and plant cellulose, such as bamboo, banana leaf, and hemp. However, just like the organic fabrics mentioned above, they also use an excess of renewable energy and natural resources for the process.

Faced with so many variables that need to be considered for the development of a fashion product inserted in terms of eco-efficiency, questions arise as to how to create a fabric that does not have so much negative social and environmental impact before, during, and after the production process.

Biomimetics, according to Fletcher and Grose,[5] is the practice of using nature's standards as a model and mentor to assist in product design, processes, and policies. This method, given the environmental problems presented, can open many doors to the future of textile industry, since nature does not practice waste, recycling all the material produced. But, in agreement with Stewart Brand, if nature is wonderful and inspiring, the practical application of its lessons is a huge challenge, and it requires a lot of research and development.

Practical application of this concept can be cited as the work of the English Suzanne Lee, who created the research project Bio Couture to study and develop a new vision of fashion from nature.

Bacterial fabrics

Using nature as a model and mentor, in 2011 Suzanne Lee and her team developed several experiments with the base of Kombucha drink, aiming to build a textile element formed by bacteria. Bio Couture is a design consultancy focused on innovating in sportswear by bringing sustainable values and biological fabrics into fashion. As she tells:

We started just growing small trays, me in my bathroom and he (biologist) in his garage comparing notes about what we were doing with the temperature and the protection, but very quickly we could see that there was something there that was really promising. The process we used was incredibly simple and, in fact, I realized that it was not so difficult to produce something that was not just a fabric in sensation, but that I could normally sew, like a garment, and it simply changed my thinking about creating fashion in the future. (Lee, 2014, 0:15:01).

Bacterial tissue is limited in a set of scoby fibres produced by a colony of non-pathogenic actinobacteria on the surface of a low ph aqueous medium. Initially classified as a film, the material may also be nonwoven, which, according to NBR-13370-Standard stipulated

by the Brazilian Association of Technical Standards, "is a flat, flexible, and porous structure consisting of a directional or randomly oriented veil or blanket of fibres or filaments, mechanical (friction) and/or chemical (adhesion) and/or thermal (cohesion) processes and combinations thereof."

It is basically understood as a static process fabric, which does not require many specific interventions, such as handling, sunlight, and other variables. Once the solution has been prepared, after the time of natural growth of the bacterial culture and after it is allowed to dry, it presents characteristics of light and transparent paper or similar with vegetal leather, because of its high resistance, flexible texture, and neutral colours (Lee, 2011).

The manufacturing process, as Lee (2014) comments, is almost more like producing beer or food than a textile product. The solution prepared initially is a green tea at room temperature, sugar, some acetic liquid like vinegar, and a starter culture, with yeast and bacteria to reproduce with each other.

Feeding on the sugar of the solution, and at an appropriate temperature (between 27 and 35 ºC) as well as acidity (below 4.5 pH units), the bacterial colony begins to reproduce and weave cellulose "nanofibers", forming a film on the surface of the container in which it is stored. From ten to twenty days this film becomes dense, almost 3cm thick, and is ready for the drying process.

Since it is a naturally produced element, its aesthetic appearance is rarely uniform, with irregularities along its surface. May contain roughness, transparencies, colour changes, thickness changes, stranded filaments, and bubbles or punctures due to fermentation gases. Speaking with Kombucha biologists and growers, it was emphasized that, in order to make the crops a little more homogeneous, the most efficient method would be to maximize the reproduction of bacteria, stabilizing the ideal pH and temperature values for their development and using products with less added chemicals, such as quality organic tea and sugar and mineral water at room temperature.

The still damp bacterial tissue is malleable, so it can mould itself into the desired shape and join in the cutouts, forming the "seams" as it evaporates. Consequently, it acquires a type of non-waste as it produces a fibre, transforms it into a material, and builds it in the desired shape (Lee, 2014), discarding the need for useless cuts and scraps of fabric. Still, even if it produces some kind of surplus, it is easily degradable and can be disposed of as fertilizer, even.

Besides allowing the reuse of solutions and bacteria used, the process uses few amounts of water and light, limiting the use to only boiling the tea. Further aggravating the concept of eco-efficiency, fabric manufacturing could also stimulate the circular economy by utilizing the waste flow of sugar and tea from the food industry. The rest of the production is done solely by the fermentation of bacteria and yeast, and as research goes deeper, imagination is the limit. According to Lee,

The future will be about designing the bacteria to create yarns that give the qualities we want. If we want them to repel water, we project into their cells. If we want them to deliver some types of nourishing quality to your skin, maybe this could be designed in the material. (Lee, 2014, 0:19:25).

Improvement opportunities

One of the obstacles in the way of trading bacterial-fermented fabric is the high water absorption that the input provides. Formed by cellulose filaments, the bacterial film has a hydrophilic nature because of its high number of hydrogen bonds, which bind to water molecules.

Consequently, cellulose fibres absorbing water become swollen and more flexible,[12] giving more weight to the fabric and possibly breaking the seams of the product. As Lee quotes in one of her lectures, the non-waterproof fabric can continue the growth process by feeding on the body's own sweat, so, to prevent this, it is necessary to benefit the garment with some waterproofing ingredient.

Another obstacle that would affect the acceptance of the textile product in the retail market would be the small range of colours it makes possible. As comment Fletcher and Grose.

Colour is one of the most important factors in the commercial appeal of apparel products and a primary focus on short-term fashion trends, as it is the fastest, cheapest and safest way to change the look, attract consumers and secure new sales.[5]

The colour of the bacterial tissue, according to Suzanne Lee,[13] is exclusively due to the pigment present in Kombucha's solution. In the case of the original solution, a brownish beige tinge is formed from the green tea, which even resembles the tone of human skin.

This colouring process prior to drying the crop, coupled with eco-efficient activities, opens the door to numerous natural dyeing experiments by adding concentrated food and plants with strong pigments to the solution.

For decades, natural dyes have generally been belittled by the mass market of the textile industry. Today, with growing interest in sustainability, technical innovations are beginning to blur the differences between industrial and artisanal goals, and between what is natural and what is synthetic.[5]

At the same time, it is still possible to change colour through iron oxidation processes, use of fruit pigments for organic patterns, and even assign specific characteristics, such as antimicrobial (Lee, 2011).[14–19]

Final considerations

With the development of a society focused on environmental concerns and the need for sustainable alternatives in the global fashion chain, it is necessary to look for and produce innovative raw materials that produce attractive commercial pieces and have the values of eco-efficiency, such as easy biodegradability, reduced use of resources and energy, high market acceptance, and promising aesthetics.

Using the biomimetic resource to analyse the deficient ecosystem in which we find ourselves, many companies began to look for alternatives to the traditional way of consumption and accelerated production, by contrasting the built patterns.

The use of bacterial tissue in the construction of commercial clothing is an interesting alternative to confront the most common textile options today, which produce several negative impacts on the environment. This textile innovation is not only a biodegradable product with an almost 100% natural production, without using many resources such as water and energy, but it also reduces the waste disposal of fabrics in the mould cutting and sewing processes, as it adapts to the desired surface by fitting into the necessary cutouts.

However, the main difficulty in inserting this product in the textile market is the irregular aesthetic quality that the fabric has, besides the permeability that impairs its use. Some studies indicate that there are several possibilities to improve a bacterial cellulose textile product in

order to make it attractive to the consumer market, but further studies will be needed to find textile processing methods to expand colour options, as well as find waterproofing methods that do not restrict comfort.

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