BIOMATERIAL EXPERIMENTAL DESIGN PRACTICES AS AN STRATEGY FOR SUSTAINABLE FASHION

PRÁTICAS DE EXPERIMENTAÇÃO EM DESIGN DE BIOMATERIAIS COMO UMA ESTRATÉGIA PARA A MODA SUSTENTÁVEL

DEBORA BARAUNA, PhD. | Universidade do Vale do Rio dos Sinos (UNISINOS), Brasil

GIOVANNA EGGERS RENCK| Universidade do Vale do Rio dos Sinos (UNISINOS), Brasil

PEDRO MAROSTEGA SANTOS | Universidade Federal do Rio Grande do Sul (UFRGS), Brasil

VITÓRIA PARCHEN DREON TOMÉ | Accademia Costume & Moda (ACM), Itália

ABSTRACT

This paper inquires about the subject of textile manufacturing. It proposes considering the possibility of innovation and sustainability in Fashion through Textile Biomaterial Design instead of the excessive use of synthetic fibers, such as polyester. This paper addresses experimental practices in Strategic Design for achieving such purposes. It portrays the production of materials based on gelatin, sodium alginate, and corn starch bases. Twelve experiments were performed based on bibliographic and documental research. Several variables in terms of production, shaping modes and drying times are discussed in relation to the behavior of the biomaterials subjected to various tests and final analyses, such as machine sewing, water absorption, appearance, tactile characteristics and malleability during the process (and established in the results obtained). These variables were not pre-defined but perceived and learned through experimentation. It was possible to observe that each sample presented strong and weak features from the analyses and applied tests. The sodium alginate sample, for instance, proved to be water-resistant. However, it ruptured when sewing and removing the yarns. This study explores creativity and fosters new sustainable conceptions in Fashion as it is one of the most polluting industries in the world.

KEYWORDS: Sustainability; Innovation; Experimentation in Design; Textile Manufacturing; Biomaterials.

RESUMO

Este artigo questiona a manufatura têxtil e propõe uma reflexão sobre a possibilidade de inovação e sustentabilidade na moda pelo design de biomateriais têxteis em alternativa ao uso excessivo de fibras sintéticas, como o poliéster. Para isto, realizaram-se práticas de experimentação em design estratégico com a produção de materiais à base de gelatina, alginato de sódio e amido de milho, fundamentadas em pesquisas bibliográficas e documentais. Ao todo doze experimentos foram criados. Durante a realização destes experimentos, foi possível discutir diversas variáveis de produção, considerando desde modos de conformação e tempos de secagem até o comportamento dos biomateriais à diversos testes e análises finais, tais como: costura em máquina; absorção de água; aparência; características ao toque e maleabilidade. Estas não foram variáveis pré-definidas, mas sim percebidas e aprendidas com a experimentação. A partir das análises e dos testes realizados, foi possível observar que cada amostra apresentou pontos fortes e fracos. A amostra de alginato de sódio, por exemplo, demonstrou ser resistente à água, o que é relevante para um material têxtil. Entretanto, ao abrir as costuras feitas nesta amostra, os fios romperam-se. Por fim, considera-se que a atividade de experimentação explora a criatividade e instiga novas concepções estratégicas e sustentáveis na moda.

PALAVRAS CHAVE: *Sustentabilidade; Inovação; Experimentação em Design; Manufatura Têxtil; Biomateriais*

1. INTRODUCTION

The fashion industry is the second-most-polluting industry worldwide, only exceeded by the petroleum industry (FRIEDMAN, 2018). It consumes around 98 million tons of non-renewable natural resources globally yearly (MORLET *et al.*, 2017). Most of these resources are targeted for manufacturing polyester textile fibers. It is a polymeric material originating from a petroleum source that requires intense energy usage for its production and takes an average of 400 years to degrade and return to the environment. For example, which makes it a potential polluter of marine ecosystems due to the microplastics released into rivers and oceans (CREAGH et al., 2019; FASHION REVOLUTION FOUNDATION 2020). According to the 'Preferred Fiber and Materials Market Report' from the Textile Exchange, prepared by Opperskalski *et al.* (2020), polyester was the most manufactured synthetic textile fiber in the world in 2019, corresponding to 58 million tons of manufactured raw materials, equivalent to 52% of the total textile fiber produced in the world that year.

Such intensive use of polyester in the fashion industry occurs due to the optimal performance of its physical-chemical, mechanical, thermal, and morphological properties (HATCH, 1993; COSTA, 2014). An alternative to decrease the utilization of polyester in the fashion industry is to foster the use of biodegradable polymeric materials, for example, biofilm textiles.

Three main components are generally employed in biofilms' composition: polysaccharides, proteins, and lipids (CAGRI *et al.*, 2004). According to the previously mentioned authors, starches are some examples of polysaccharides derived from diverse sources as corn, rice, and potato, sodium alginate, pectins, and cellulose derivatives; since the most frequently used proteins are collagen, zein, and casein; and finally, the most common lipids are glycerides, waxes, and some fatty acids. There has been a certain degree of socioenvironmental progress using these materials in the fashion industry: reducing energy and water usage in the textile manufacturing processes and avoiding using chemicals harmful to human health in the production process (VARTAN, 2017).

This study explores the development of textile biofilms from biodegradable polymeric materials and their production variables. The objective of the article is to question textile manufacturing, in the face of experimentation in strategic design, learning and creatively discussing the possibility of innovation and sustainability in fashion through the design of textile biofilms. In Bell's perspective (2011), in a highly technological century and advanced conceptions in materials, biomaterials are a strong trend, playing an increasing role on the market as an alternative to materials considered as non-sustainable. Barauna and Razeza (2018), in an investigation regarding the directions of RD&I – research, development, and innovation on advanced engineering textile materials, reaffirms the purpose proposed by Bell. The authors mention the advanced material design, based on the conception of biomaterials, as a pathway towards sustainability and innovation in the XXI century in diverse, productive sectors. In this context, experimentation in strategic design is a type of research on design, capable of investigating varied situations, such as the unsustainability of textile manufacturing, and resulting in, aside from learning, creative and innovative solutions, as the creation of new materials and processes in fashion. Thus, throughout this article, experiments of textile biomaterials in films produced by experimentation in strategic design and inspired by food engineering knowledge are presented and discussed. Food engineering is an area that involves studies of food production and when worked with a particular approach to the properties of food, it is very similar to what is sought for the creation of textile biomaterials.

Following this article, the characteristics of the main base components used in the polymeric biofilm experiments are specified. Then, the materials, processes and variables of the experimental practices are detailed, as well as the research sources used. Finally, the results are presented and discussed.

2. CHARACTERISTICS OF BIOFILMS

Three types of biopolymers are generally used as a base for creating biofilms: gelatin, sodium alginate, and starch. Chart 1 summarizes the formations of biofilms made from these polymeric bases.

Gelatin is a compound obtained from collagen denaturation, a protein extracted from the connective tissue of cattle or swine livestock (UFRGS, [2021?a]). It is composed predominately of the aminoacids glycine, proline and alanine; the main characteristic of gelatin is its ability to form stable gels at a temperature under 40°C, but the thermal reversibility hinders its usage in temperatures above 35°C; as the film can end up melting (UFRGS, [2021?b]).

Since sodium alginate, according to Damodaran and Parkin (2019), is a material extracted from algae and technically, it is a copolymer composed of units (monomers) from β-D-mannopyranosyluronic acid and α-L-gulopyranosiluronic acid, which can be in homogeneous regions (the same repeated unit) or mixed blocks. Furthermore, the authors advise that segments only composed by D-mannuronopyranosyl units be named M blocks and the segments composed by L-guluronopyranosyl units are G blocks. The different percentages of the amount of G and M blocks modify the alginate properties, and a larger amount of G blocks produce a stronger film. Damodaran and Parkin pointed out an interesting property of alginate calcium salts and their insolubility in water due to the interaction of calcium ions with G blocks.

Chart 1: Biofilm formation from gelatin, alginate and starch. Source: Prepared by the authors, based on Cagri *et al.*, 2004.

Biopolymer	Biofilm formation
Gelatin	Aqueous and glycerol solution
Sodium alginate	Aqueous solution, calcium ions, glycerol, and heated under alkaline conditions
Starch	Aqueous solution, glycerol, and heated

And finally, the starch, a polysaccharide present in substantial amounts in vegetables, displays some characteristics that have been focused on in research studies on the creation of biomaterials, such as their partially crystalline structure and thermoplasticity, which when processed in the presence of heat jointly with some plasticizer (water) forms a biofilm (MAIA, 2016). Most starches are composed of two main polymers – a linear polysaccharide (amylose) and another highly ramified (amylopectin). The organization of both these polysaccharides in starch granules creates crystalline and non-crystalline regions (amorphous shapes) in alternate layers (DAMODARAN; PARKIN, 2019). The starch must go through a gelatinization process to form a thermoplastic film. It is an irreversible process in which it`s granules are in an aqueous medium. In the presence of heat, they swell until they rupture and release amylose molecules that solubilize in water, creating a viscous elastic paste. The product obtained after cooling becomes a stiff and dense gel (DAMODARAN; PARKIN; 2019). To increase the malleability of the films, it is necessary to add plasticizers, substances that modify the properties of the polymeric materials. The most common are glycerol and polyols such as sorbitol (FOLLMANN, 2009).

3. BIOMATERIALS THROUGH EXPERIMENTATION IN DESIGN

Experimentation in design is a type of design research that is not strictly analytical and does not impose scientific rigor, has no rules or linearity, and is a heterogeneous process. (MAINSAH; MORRISON, 2013; MINEIRO, 2016). For Steffen (2014), it is the juncture of scientific and artistic experimentation. Yet, for Mineiro (2016), it can be constituted by the overlapping of characteristics of scientific, artistic and technical experimentation, and the use of these different perspectives is not pre-established but felt in the face of the situation in which it is being worked on. Experimentation in design is still based on three main activities: knowledge creation, different investigation methods, and methodological innovation (MAINSAH; MORRISON, 2013). And it is in this perspective that an approach to strategic design is sought - a type of design that is concerned with investigating and creating processes. In addition, experimentation in design is a method used to develop new hypotheses, create new design strategies and contribute to knowledge, being strongly dependent on the interaction and dialogue between disciplines. (MAINSAH; MORRISON, 2013; STEFFEN, 2014). Thus, this type of design research also addresses the transdisciplinary way of thinking and operating strategic design, focused on the conception of creative, dialogic and social learning processes, which problematize the ecosystemic complexity of the world, guide strategic directions of innovation and sustainability and result in new systems, processes, products and/or services.

Thus, based on such a methodologic approach and perspective, a bibliographic and documentary research was carried out in order to find elements capable of guiding and inspiring. The primary research works that guided the preparation of the experiments were from the following reports' Research Book Bioplastic' by Juliette Pépin (2014),' Recipes for Material Activism' by Mariam Ribul (2014), and' Bioplastic Cookbook' by Margaret Dunne (2018), as well as the materials provided by the Fabricademy course, which is focused on the transdisciplinary development of new technologies for the textile industry.

The 'Research Book Bioplastic' report reviews diverse usage of plastic in society, as the production of packaging and synthetic fabrics (polyester and synthetic leather), and their environmental consequences. It is necessary to cite the extremely long decomposition period in nature as one of them. After that review, there is an explanation of what biopolymers are, and as they are prepared from a base recipe, they present diverse formulations for modifying their characteristics (PEPIN, 2014). The experiments were sorted by materials based on a starch, gelatin or agar-agar-based materials, milk-based materials, and starch-based materials with added fibers. Figure 1 exemplifies those formulations prepared with a starch-based recipe. The addition of pigments, changes in the basic proportions of the recipes, and drying methods were some tested modifications. Besides that, the tested formulations were also added to the bases, for example, mixing gelatin and corn starch to the same basic recipe.

Figure 1. Modifying the basic recipe by adding corn starch. Source: Bioplastic Research Book (2014)

The book 'Recipes for material activism' presents experiments utilizing conventual equipment and ingredients to foster the creative exploration of new manners of viewing commonplace materials. In contrast to the "Research Book of Bioplastic", this book presents just five recipes, all of them being starch based (potato starch, corn starch or cassava starch, but it explores non-conventual uses for each one of them, producing thin plaques, yarns, and sculptures. The book also introduces the possibility of allying bioplastics with 3D printing, suggesting an emulated textile by 3D printing, creating a layered result that does not require any sown seams as illustrated by the blouse in Figure 2.

On the other hand, the 'Bioplastic cookbook' presents a theoretical base on biopolymers and their main ingredients, explaining how each raw material contributes to result. It also addresses the characteristics of biopolymers and how to use some additives, such as wax or glycerin, to improve the final properties of the materials. Besides the conventional base recipes using gelatin, agar-agar and starch (Figure 03 - A) it also presents recipes using non-conventional materials such spirulina (acting as a pigment). Clay (acting as a pigment and a structural material) (Figure 03 – B) and tow (acting as a structuring element).

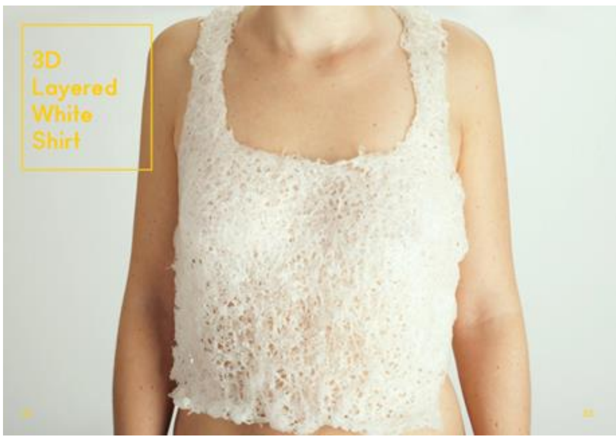

Figure 2. A white blouse made by 3D printing. Source: Recipes for material activism (2014).

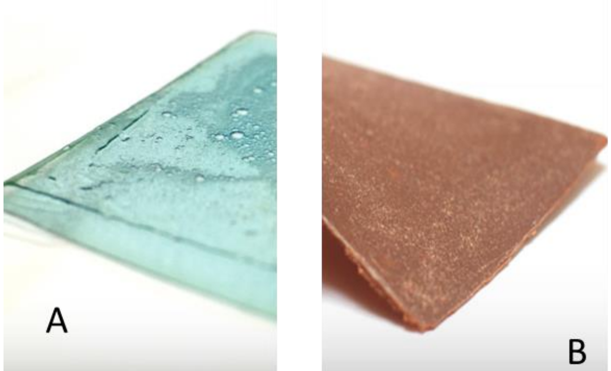

Figure 3. A) A sample of a biomaterial made from gelatin and spirulina; (B) A sample of a biomaterial made from gelatin and red clay. Source: Bioplastic Book (2018)

4. METHODOLOGICAL PROCEDURES

The choice of materials used in the study contains the various polymeric groups mentioned above - polysaccharides, proteins and lipids. Five base recipes were selected initially based on base components involving the following polymers: gelatin, sodium alginate, starch, chitosan, and agar-agar. Although, these recipes were previously tensioned regarding some variables, such as economic feasibility, facility to obtain the polymer, possibility to formulate at home, and preparation method. That caused the selection of only three recipes: gelatin, sodium alginate, and starch. In this case, corn starch was used. The chitosan recipe was discarded due to the prohibitive cost, and as agar-agar provides similar characteristics as gelatin, but it is not easy to obtain in its pure form.

Regarding the study on employing dyeing practices as well, so they abide by a sustainable spectrum, was opted for working with natural dyeing, as the ingredients are biodegradable and cause decreased toxicity. Thus, to propel such a technique, information was sought from bibliographic sources, whereby the main one was Trinca (2017). Natural pigments are sorted into two categories, one from organic sources, as animals (originating from mollusks, insects, and sea snails) and vegetables (plants, stems, leaves, rhizomes, and roots), and inorganic, from mineral sources (for example coal, hematite, and malachite) (TRINCA, 2017). According to the author, a mordent or dye fixative is necessary for the dyeing process to allow the dye to penetrate the fiber no matter what its classification may be. They make it possible for the dyeing to remain fixed or permanent after washing. An observational study was also performed in the respective kitchens of the group members, besides of the theorical research.

Some foodstuffs provide optimal natural pigmentation properties, which generated insights into experimenting on new residues and foods that can be used for experimentation.

The selected base recipes were strictly followed for performing the experimental practices from October to November 2020. All the experiments were homemade, using equipment such as a stove, blender, pots, silicon mats, glassware, and a 0.1-gram precision scale. After the team acquired further knowledge, 3 standard recipes were defined, other ingredients and shaping modes were proposed for the recipes, and 12 samples and experimental practices were determined (Figure 4).

Figure 4. Biomaterial experimentation design for the mode. Source: Prepared by the authors (2020)

The samples discussed in the article, as displayed in Figure 04, are 1 (gelatin), 3 (sodium alginate), and 4 (corn starch). The rest of the other samples (2, 5, 6, 7, 8, 9, 10, 11, and 12) are variations of the same bases with the addition of mango fibers, of natural pigments extracted from the water of red cabbage sauce and using different quantities of ingredients. In sample 3, it was also possible to change the shaping mode to create yarns.

The obtained biomaterials were interpreted related to their tactile characteristics (dry, damp, with or without texture); they underwent qualitative analysis or perceptible malleability (bad, good, excellent); also, final appearance was analyzed; the drying time was identified; the examination of the ease or difficulty of removal from the shapes used was made, and water absorption tests were performed, as they were dipped in running water for 24 hours. The biomaterials even underwent sewing machine tests, performed with TEX 29 thickness lines (the number of grams for every 1000 meters of yarn). It is also important to point out that the ratio of straight and distant sewing stitches is considered a stitch width of 2.5 millimeters.

The following are descriptions of the research results and discussion on the composition of recipes, process variables, qualitative analyses, and performed tests on the obtained biomaterials.

5. RESULTS AND DISCUSSION

The recipe of sample 1 (Figure 05) is mainly made with the gelatin biopolymer. It was used 240 ml of water, 48 g of powdered gelatin, and 12 g of vegetal glycerin. The process begging stirring the water and gelatin on medium heat while continually stirring the solution until it became homogeneous, and then the glycerin was added. The mixture was heated on the stove for over 20 minutes, making a portion of the water evaporate and thus reducing the final volume. Then the product was poured on a glass surface for drying in a well-ventilated space, at a room temperature of 24°C degrees and without any sunlight shining on it. That drying process took an average of 5 days. The biofilm removal from the glass shape was quite tricky, as the sample was sticking to the surface, making it seem like it would rupture. But, despite the initial difficulty, there was great success when removing the biofilm. It resulted in a shiny surface sample with good malleability properties – easily foldable, with a dry touch, and with a light textured caused by the surface where it was placed. For an easy removal is recommended drying the material in a silicon or acrylic base.

Figure 5. Sample 1 gelation base. Source: Prepared by the authors (2020)

In Sample 3 (Figure 6) sodium alginate is the main ingredient. It was used in the recipe 12 g of sodium alginate, 20 g of glycerin, 400 ml of water, and 10 g of sunflower oil. The ingredients were mixed in a blender, and the resultant paste was set aside for 24 hours so that the air bubbles could rise and pop. The mixture was then poured on a glass surface, and a 100 g/l calcium chloride solution was sprayed on the surface. After 10 minutes, the material was washed under running water and left at room temperature for 7 days to dry and cure. This sample has a dry and smooth to touch, opaque appearance, excellent malleability, and easily foldable. It is important emphasize that the recipes made from sodium alginate were not exposed to any flame as there is the possibility of causing resultant warpage, as shown in samples 5 and 10 showing a variation in the shape of the yarn. in samples 5 and 10, showing a variation in the shape of the yarn.

Figure 6. Sample 3 sodium alginate base. Source: Prepared by the authors (2020)

The same previously described biofilm components were used for making the alginate yarns (Figure 7); however, the technique was modified. Thus, for the biopolymer to acquire the shape of a yarn, the previously mixed components were placed using a plastic syringe in a container with a calcium chloride solution. It is important to emphasize that the pressure applied in the syringe directly affects the thickness and the length of the yarns; thus, as it is a manual process, changes can occur in the thickness along the length of the yarns. After pouring, the yarns are immersed for fifteen minutes in the solution before being removed so that they can begin the drying process. After 7 days, the yarns are completely dried and cured. In this state, the yarns are stiffer and become transparent and darker, so their thicknesses are considerably decreased.

In Figure 7 the change in thickness of the alginate yarn is noticeable. Image A in Figure 7 shows the yarn a few minutes after the production process, but image B in Figure 7 shows the yarn already cured 7 days after its production. The yarn, when produced, acquires a spiral shape, and soon afterward, it becomes a smooth yarn. It is necessary to smooth it and stretch it gently so that it does not rupture during the drying process. An alternative was created in the experimentation process to smooth the yarns by rolling them carefully on a spherical bottle, like a spool, and then they go through the drying step. It is ideal to do this in this process immediately after being produced. Right after that, the yarns are removed from the sodium chloride solution to begin the drying process and then acquire the desired shape. It is possible to make plaques and yarns when making biomaterials, generating a wide range of opportunities for sustainable creations. In image C in Figure 7, for example, the yarns were respectively intertwined, creating an esthetic appearance that can be incorporated diverse ways in the Fashion industry.

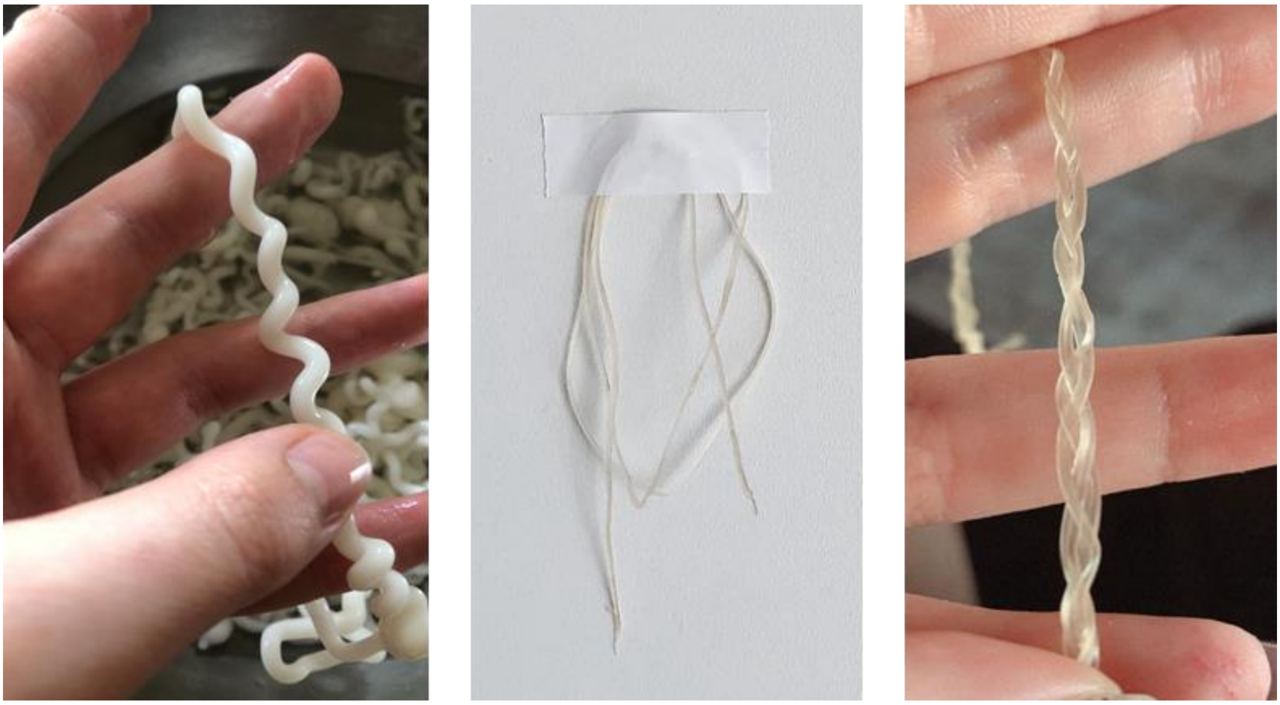

Figure 7. (A) Samples of recently produced alginate yarns. (B) Samples of dried and cured alginate yarns, (C) Samples of intertwined alginate yarns. Source: Prepared by the authors (2020)

The same production technique was also employed in an experiment making yarns but applied differently: the pressure was modified in the syringe, and thus small spheres were created.

Figure 8. (A) The production process making mini alginate spheres, (B) Samples of the dried and cured alginate mini spheres. Source: Prepared by the authors (2020)

That process is illustrated in image A in Figure 8, in which the recipient on the left displays the sodium chloride solution while on the right, it shows the sodium alginate. In image B in Figure 8 it is possible to see that the small spheres have already been dried and cured. When one looks at everything in Figure 8, it is possible to notice the color change; the damp biopolymer is considerably lighter and much more whitish after being dried.

And lastly, sample 4 (Figure 9) uses corn starch as a biopolymer.

Figure 9. Sample 4 based on corn starch. Source: Prepared by the authors (2020)

For this recipe, it was used 96 g of water, 27 g of corn starch, 18 g of glycerin, and 8 g of vinegar in a pot. All the ingredients were blended until they became a homogeneous liquid, and after that, they were heated on a stove. After the mixture is in contact with heat, the liquid state becomes more viscous, the mixture is blended for 4 minutes, and after that, it is removed from the flame and spread on a glass shape. The sample was set aside to dry in the sun for 6 hours as that was how long it was possible to expose it due to the climatic conditions on the day the sample was made (dry climate and an average temperature of 26°C). The appearance of the biomaterial was silky, moisty touch, and a little gelatinous, a smooth texture, and excellent malleability, as it was easily foldable. The drying time for materials based on corn starch is variable and depends a great deal on the climatic condition, especially when the weather is humid. Although the climatic condition affected the drying time, this sample displayed good versatility, as it was possible to dry it in different temperature and moisture content surroundings. It is possible that this recipe dries at room temperature and does not require it to be outdoors, exposed to the sun. However, the drying time will be prolonged in this case.

Chart 2 provides a comparative synthesis and improved viewing of the observed variables and the tests on the three presented samples. Specifically, the water absorption and stitching tests are shown, and the 3-sample comparisons are then discussed.

	Sample 1 - Gelatin	**Sample 3 - Sodium alginate**	**Sample 4 - Corn starch**
Drying time	Five days	Seven days	Six hours
Easy to remove	Difficult to remove	Not difficult	Not difficult
Final appearance	Glossy	Opaque	Silky
Touch	Dry and textured	Dry and not textured	Damp and not textured
Malleability test	Very good, no cracks	Very good, no cracks	Very good, no cracks
Water absorption test under running water	Disintegrated	Unchanged	Disintegrated
Water absorption test – immersed in water	Became weaker	Unchanged	Became weaker
Stitching test	Good behavior in all types of stitches and when opening the seams	Good behavior in all types of stitches, but ruptured when trying to open the seams	It could not cope with tight or straight stitches, and it could cope reasonably well when opening the seams

Chart 2: Results from performing the tests. Source: Prepared by the authors (2021).

Regarding the sewing tests, the gelatin biomaterial presented a good behavior, as it can be sewn using loose, tight, straight, or distant stitches and cope with opening the seams. The sodium alginate also presented a good behavior in the sewing tests, however, it could not cope with opening the seams, as it ruptured instantly. The corn-starch-based sample could not cope with sweing with tight or very straight stitches, but it could cope with stitches that were slightly loose and separated; however, when unstitching the seam, it also ruptured when force was applied.

Regarding water absorption it was confirmed that only the sodium-alginate-base biomaterial was insoluble in the water, as it was capable of coping with running water and submersion in a container filled with water without undergoing any apparent changes in its physical characteristics. However the gelatin and corn starch biomaterials disintegrated when they were placed under running water. And when they were submerged in the water recipients, sample 1 swelled; the same situation was not observed in sample 4, but both weakened after remaining in contact with water, although they did not disintegrate.

Still, it is pertinent to mention that some ingredients that can be implemented, causing specific modification in processing when making biomaterials as well in all the previously mentioned recipes that delivered different results. Increased or decreased plasticizers can be used to modify the mechanical characteristics of the material. On the previously mentioned recipes glycerin it was used as the plasticizer. This ingredient is responsible for adjusting the malleability of the material. It is necessary to pay close attention to the quantities of the added plasticizers, as if excess is added, it will make the biofilm sticky, as occurred in the case of sample 11. On the other extreme, if too little plasticizer is added, the material may rupture after drying, creating slits along its structure. That does not mean that those variations are incorrect, just that these items are relevant for analysis. Linked to that, it is also possible to increase or decrease the thickness of the biomaterial so that the malleability is also affected.

Furthermore, it is possible to create different colorations to biomaterials. This can be performed by adding natural or synthetic pigments, however, so that the purpose is coherent with this type of material and experimentation in this study, natural pigments were used. It was verified that it is possible to use homemade ingredients for creating various pigments, such as yellow from saffron; green from yerba mate; orange from paprika; brown from coffee or cinnamon; blue from beans; green, purple, and pink from red cabbage; light yellow from onion skin; pink from beet skin or avocado pits; and purple from wine. The interesting part of this practice is that it can use ordinary food wastes. It also can be done by using supplies found in nature, for example, hibiscus, roses, purple ipê (tabebuia tree), the Clitoria ternatea flower, "urucum" (achiote), indigo, logwood, and others (TRINCA, 2017). It is essential for this application, in this technique, to dissolve the ingredients in water until it releases its color. Then when the desired color is achieved, use this colored water in the recipe of a biomaterial. One crucial point is to emphasize that in some cases, such as in red cabbage, the color changes when there is a change of the pH of the solution. It can happen spontaneously in a recipe, as took place in sample 6: initially, there was purple water, but that sample was produced from a recipe that contained vinegar, then, when that ingredient was added, it modified the pH, that changed the color to pink. Besides making the solution pH becomes acidified, it can become more alkaline by adding sodium bicarbonate, which, in the case of cabbage, will change the color to green. Another essential subject to emphasize is in the dyeing of biomaterials; when that is performed the way it was descript previously, then no mordents or dye fixatives are necessary, as when dyeing fabric requires. The study on natural dyeing is relevant by considering what is based on the World Bank Group (2014); the traditional technique, depending on the conditions that are performed, can be responsible for releasing 72 different chemical toxic products in the water. Trinca (2017) mentions lead, sulfur, and petroleum derivatives, as some supplies found in industrial pigments. When such harmful components are released, grave consequences can be generated to human health and nature, for that reason, natural pigments have been attracting the attention of researchers in traditional applications and diversifications for developing technologies for cleaner production (TRINCA, 2017).

Generally, biomaterials represent significant potential for the creation and sustainability in a century, whereas humanity faces urgent environmental issues. Thus, the intersection between biomaterials and natural pigments can provide a potentially fruitful field. It has already been possible to find some options in the market for available textile biomaterials, such as Orange Fiber (Figure 10 - A), Fuitleather Rotterdam (Figure 10 - B), Piñatex (Figure 10 - C), Malai (Figure 10 - D), Mylo (Figure 10 - E), and Reishi (Figure 10 - F).

Although developing and commercializing biomaterials is not an easy task, RD&I requires time and investments, but increasingly popularization of biomaterials must be sought. One option for this can be to develop them on a smaller scale and

http://dx.doi.org/10.29183/2447-3073.MIX2021.v8.n3.95-108

Mix Sust| Florianópolis | v.8 | n.3 | p.95-108 | MAR | 2022

ISSN: 2447-0899 (IMPRESSA) | 2447-3073 (ONLINE)

thereby empowering the customization of local textile products.

After all, it was possible to explore the creativity of a variety of natural-based experimentation based on the performed experimental practices, inspiring new conceptions of biomaterials in fashion and focusing on a more sustainable perspective. Furthermore, it was possible to learn about diverse variables that can influence this process. The implementation of biomaterials in the fashion industry is a sustainable alternative to synthetic fibers utilized in this sector, such as polyester, making up over 50% of the textiles used globally and are potential environmental polluters.

Figure 10. Examples of biomaterials. SOURCE:(A) Orange Fiber ([2022?]); (B) Fruitleather ([2022?]); (C) Material District (2017); (D) Malai (c2022); (E) Bolt Threads ([2022?]); (F) Lee *et al.*, (2020

6. FINAL CONSIDERATIONS

Some homemade recipes of biomaterials were tried here in order to question the current scenario of textile manufacturing. Thus, a list of existing biopolymers, biofilm formulations and several variables relevant to the processes were explored that enabled learning and the promotion of creativity, fundamental skills for the promotion of sustainable innovation. The possibilities were even verified for generating of biomaterials to generate a transdisciplinary field of exploration in fashion: as their production integrates different bodies of knowledge and enables collaboration among productive sectors.

Evidently, it is essential to consider that the samples and processes produced are homemade and experimental, however they contribute to generating a reflection on the importance of promoting RD&I studies in biomaterials for sustainability in fashion. A positive aspect of that incentive is that using biomaterials provides fashion a wide variety of production possibilities, as were explored in the performed tests. As one can see, even though the trials took place at home, creating different esthetics, perceptions, and textures is feasible, for example. That factor manifests a more creative industry. It is also essential to pay attention to diverse types of existing materials for the composition of a biomaterial, as well as their possibilities of shaping and adjusting to the kind of garment the biomaterial will be used for, since, as one can observe in the performed experiments, depending on the biopolymer used, the final characteristics can change.

Above all, based on the tests and analyzes carried out, the samples of biomaterials produced have strengths and weaknesses. The alginate sample proved to be water-resistant; however, the threads ruptured when opening the seams. However, other types of sewing can be exploited for enhanced adaptation of this biomaterial for the fashion industry. Since the corn starch sample did not perform well in the sewing tests. The gelatin and

https://doi.org/10.29183/2447-3073.MIX2021.v8.n3.95-108

the corn starch samples disintegrated in the running water absorption test. It was difficult to remove the gelatin sample as it was produced; however, that did not affect the final result. It is pertinent to emphasize that all tested biomaterials demonstrated excellent malleability. Anyway, in an experimentation in design study, all these results are relevant, because in this type of research there is no right or wrong. In experimentation in design, what doesn't work is just as significant as what is seen as a success. It is with the mistake that you learn, it is a mistake that will be tensioned again, encouraging changes in directions and stimulating creativity. On the other hand, positive results motivate and inspire the possibility of reaching a hypothesis or performing investigations, such as the Huná project - conception of biomaterial textiles for the innovation and sustainability of the fashion industry.

Finally, the last considerations of this article were related to the three main experimentation in design activities described by Mainsah and Morrison (2013), as follows:

1. Associated with the development of new hypotheses - the study speculated that experimental practices can be considered in the Textile and Clothing Industry as a means of creativity and biomaterials design.

2. Regarding the new design strategies - the study pointed towards directions for conceiving and developing experimental biomaterials, multiple variables were perceived and examined.

3. Concerning the contribution to the knowledge creation - in this study, the learning promoted in the development of design experimental practices, in a relationship between theory and practice, had repercussions on the production of formalized knowledge, as well as provoked new theorizations and experiments that are still happening, now through the Huná project, financed by the Fundação de Amparo à Pesquisa do Rio Grande do Sul (FAPERGS).

ACKNOWLEDGEMENTS

To the “Fundação de Amparo à Pesquisa do Rio Grande do Sul” (FAPERGS) we are grateful for the financial support assigned through “Auxílio Recém Doutor” (Recent Doctoral Aid) (ARD - 2021-2023) and the “Bolsa de Iniciação Científica” (Scientific Initiation Fund) PROBIC/FAPERGS (2021-2022).

REFERENCES

BELL, B. Material intelligence: an overview of new materials for manufacturers. Canada. **PFInnovation**. 2011.

BOLT THREADS,. [S. l.]: **Bolt Threads**, [2022?]. Available at: https://boltthreads.com/ Accessed on: June 14, 2021.

CAGRI, A. et al. Antimicrobial edible films, and coatings. [*S. l.*]: **Journal of Food Protection**, v.67, n.4, p.833-848, 2004.

COSTA, L. “***Desenvolvimento de Bioprodutos a partir da Glicerina Residual do Biodiesel:Goma Xantana em Escala de Biorreator e Filmes Flexíveis Reforçados Com Nanowhiskers***.” (Development of Bioproducts from Residual Glycerin from Biodiesel) Thesis (Chemical Engineering Doctorate)– Escola Politécnica, Universidade Federal da Bahia, Salvador, Ba, 2014. Available at: https://repositorio.ufba.br/ri/bitstream/ri/18861/1/Tese.pdf. Accessed on: June 10, 2021

CREAGH, M. *et al*. **Fixing fashion**: clothing consumption and sustainability. London. Environmental Audit Committee, House of Commons. 19 Feb. 2019. Available at: https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1952/report-summary.html. Accessed on: June 17, 2021.

DAMODARAN, S.; PARKIN, K. L. “**Química de Alimentos de Fennema” (Fennema Food Chemistry)**. 5. ed. Porto Alegre: Artmed 2019. 1112 p.

DUNNE, M. **Bioplastic cookbook**. Fab Lab Barcelona: FabTextiles, July 2018. Available at: https://issuu.com/nat_arc/docs/bioplastic_cook_book_3 . Accessed on: June 08, 2021.

FASHION REVOLUTION FOUNDATION. “**Como começam nossas roupas? Saiba como o poliéster, algodão e viscose são produzidos” (How our clothes begin? Learn how polyester, cotton, and viscose are produced)**. [*S. l.*] Fashion Revolution Foundation. 2020. Available at: https://www.fashionrevolution.org/brazil-blog/como-comecam-nossas-roupas-saiba-como-o-poliester-algodao-e-viscose-sao-produzidos/. Accessed on: June 22, 2021.

FOLLMANN, H. “**Utilização de Derivados da glicerina na Produção de Plastificantes” (Utilization of glycerin derivatives in Plasticizer Production)**. Dissertation for the post-graduate Chemistry program at Universidade Federal do Paraná, 2009. Available at: https://acervodigital.ufpr.br/bitstream/handle/1884/22384/Dissertacao_HevelineFollmann_biblioteca

.pdf?sequence=1&isAllowed=y. Accessed on: June 10, 2021

FRIEDMAN, V. The Biggest Fake News in Fashion: Untangling the origins of a myth repeated so often that no one thought to question it. **The New York Times**, New York, 18 Dec. 2018. Available at: https://www.nytimes.com/2018/12/18/fashion/fashion-second- biggest-polluter-fake-news.html. Accessed on: June 09, 2021.

FRUITLEATHER ROTTERDAM. [S. l.]: **Fruitleather Rotterdam**, [2021?a]. Available at: https://fruitleather.nl/. Accessed on: Jan. 18, 2022.

HATCH, Kathryn, L. **Textile Science**. [*S. l.*]:. West Publishing Company; 1993. ISBN 0-314-90471-9.

LEE, S. et al. **Understanding "Bio" Material Innovations: a primer for the fashion industry**. [*S. l.*]: Biofabricate e Fashion for Good. December 2020. Available at: https://www.biofabricate.co/. Accessed on: June 14, 2021

MAIA, N. "**Produção E Caracterização De Blendas Poliméricas Com Poli (3-Hidroxibutirato)) (Phb) E Amido De Milho Para Produção De Plástico Biodegradável" (Production and Characterization of Polymeric Blends with Poli (3-Hydroxibutirate)) (Phb) and Corn Starch for Producing Biodegradable Plastic)**. 2016. Dissertation (master's degree course in Food Engineering) Universidade Federal de Santa Catarina. Post-graduate program in Food Engineering. Florianópolis, SC, 2016. Available at https://repositorio.ufsc.br/handle/123456789/172365. Accessed on: June 10, 2021.

MAINSAH, H.; MORRISON, A. Towards a manifesto for methodological experimentation in design research. *In:* NORDIC DESIGN RESEARCH CONFERENCE, 2013, Copenhagen-Malmö. **Electronic Proceedings** […]. [*S. l.*]: Nordes, 2013. p. 153-167. Available at: https://www.researchgate.net/publication/281714069_TOWARDS_A_MANIFESTO_FOR_METHODOLOGICAL_EXPERIMENTATION_IN_DESIGN_RESEARCH. Accessed on: June 01, 2021.

MALAI. [S. l.]: **Malai**, c2021. Available at: https://malai.eco/about/. Accessed on: Jan. 18, 2022.

MATERIAL DISTRICT. **Pinãtex.** [S. l.]: Material District, 19 Dec. 2017. Available at: https://materialdistrict.com/material/pinatex/. Accessed on: Jan. 18, 2022.

MINEIRO, E. F. "**Experimentação em Design como Estratégia no Cenário da Autoprodução" (Experimentation in Design as an Auto-production Scenario Strategy).** Thesis (doctoral) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Artes e Design. advisor: Claudio Freitas de Magalhães. 2016.

MORLET, A. *et al*. **A new textiles economy**: redesigning fashion's future. [*S. l.*]: Ellen MacArthur Foundation: Nov. 28, 2017. Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/A-New-Textiles-Economy_Full-Report_Updated_1-12-17.pdf. Accessed on: Mar. 09, 2021.

OPPERSKALSKI, S. et al. **Preferred Fiber & Material**: Market Report 2020. [*S. l.*] Textile Exchange. Dec. 2020. Available at: https://store.textileexchange.org/product/2020-preferred-fiber-materials-report/. Accessed on: Apr. 10, 2021.

ORANGE FIBER. [S. l.]: **Orange fiber**, [2021?]. Available at: http://orangefiber.it/en/. Accessed on: Jan. 18, 2021.

PÉPIN, J. **Research Book Bioplastic:** experiments on bio-plasticity. [S. l.: s. n.] May 14, 2014. Available at: https://issuu.com/juliettepepin/docs/bookletbioplastic . Accessed on: Jun. 08, 2021.

RIBUL, M. **Recipes for Material Activism**: part 1. Embodied energy series. [S. l.: s. n.] Abril, 2014. Available at: https://issuu.com/miriamribul/docs/miriam_ribul_recipes_for_material_a. Accessed on: Jun. 08, 2021.

SERENA, K. K. R. *et al*. "Desenvolvimento de folders e banners para divulgação do curso de engenharia de alimentos" (Preparation of folders and banners for disclosure of the food engineering course). [*S. l.*]: **Anais eletrônicos** [...] SEMEX. n. 11. 2018. Available at: https://anaisonline.uems.br/index.php/semex/article/view/5452. Accessed on: Jun. 15, 2021.

STEFFEN. D. New experimentalism in design research characteristics and interferences of experiments in science, the arts, and in design research. Lucerne University of Applied Sciences and Arts, School of Art and Design, Switzerland. **Artifact Journal of Design Practice**. v. 3, p. 1.1-1.16. 2014. Available at: https://www.researchgate.net/publication/276306171_Characteristics_and_Interferences_of_Experiments_in_Science_the_Arts_and_in_Design_Research/fulltext/55d78fc508aec156b9aa1738/Characteristics-and-Interferences-of-Experiments-in-Science-the-Arts-and-in-Design-Research.pdf . Accessed on: Jun. 01, 2021.

TRINCA, F. "Tingimento natural: novos desafios e ações sutentaveis" (Natural dyeing: new challenges and sustainable actions). In: MAROTTO, Isabela (conception and coord.). + “**Suntentabilidade às marcas de moda: reflexões e indicadores**” (Sustainability for fashion brands: reflections and indicators). Rio de Janeiro: [s. n.], Dec.. 2017. p. 169-176. E-book. Available at: http://porfavormenoslixo.com.br/wp-content/uploads/2018/01/LIVROSUSTENTABILIDADE-%C3%80S-MARCAS-DE-MODA.pdf. Accessed on: Jan. 17, 2022.

UFRGS, a. “**Produção de Gelatina**” (Gelatin Production). [S. l., 2021?]. Available at: http://www.ufrgs.br/alimentus/disciplinas/tecnologia-de-alimentos-especiais/gelatina/producao-de-gelatina. Accessed on: Jun. 25, 2021.

UFRGS, b. "Gelatina" (Gelatin). [S. l., 2021?]. Available at: http://www.ufrgs.br/alimentus/disciplinas/tecnologia-de-alimentos-especiais/gelatina. Accessed on: Jun 25, 2021.

VARTAN, S. Fashion Forward: How Three Revolutionary Fabrics Are Greening the Industry.[*S. l.*]: **Jstor Daily**. Dec. 19, 2017. Available at: https://daily.jstor.org/fashion-forward-three-revolutionary-fabrics-greening-industry/ . Accessed on: Jun. 22, 2021.

WORLD BANK. **The Bangladesh Responsible Sourcing Initiative** A NEW MODEL FOR GREEN GROWTH. Washington, DC: World Bank. 2014. Available at: https://documents1.worldbank.org/curated/en/614901468768707543/pdf/922610WP0P11950DEL0FOR0GREEN0GROWTH.pdf. Accessed on: Jan. 21, 2022.

AUTHORS

ORCID: https:// 0000-0002-5841-9897

DEBORA BARAUNA (DB), Dra. | Universidade do Vale do Rio dos Sinos | Design | Porto Alegre, RS - Brasil| Correspondência para: Avenida Doutor Nilo Peçanha, 2110 Ap 308 – Boa Vista, Porto Alegre – RS, 91330002 | email: dbarauna@unisinos.br

ORCID: https://0000-0002-7744-8618

GIOVANNA EGGERS RENCK (GER) | Universidade Do Vale Do Rio Dos Sinos | Moda | Porto Alegre, RS - Brasil| Correspondência Para: Rua Barão De Santo Ângelo, 189 Ap 801 – Moinhos de Vento, Porto Alegre – RS, 90570090 | gi_renck@hotmail.com

ORCID: https: 0000-0002-1376-1277

PEDRO MAROSTEGA SANTOS (PMS) | Universidade Federal do Rio Grande do Sul | Engenharia de Alimentos | Porto Alegre, RS - Brasil| Correspondência Para: Avenida Protásio Alves, 3890 Ap 401 – Petrópolis, Porto Alegre – RS, 91310000 | pedro@pedromarostega.com

ORCID: https: 0000-0001-8941-715X

VITÓRIA PARCHEN DREON TOMÉ (VPDT) | Accaddemia Costume e Moda |Alta Moda, Fashion Design |Roma, Lazio - Itália | Correspondência Para: Rua Marquês do Herval, 468 Ap 301 - Moinhos de Vento, Porto Alegre - RS, 90570140 |vitoriapdt@gmail.com

HOW TO CITE THIS ARTICLE

BARAUNA, Débora; RENCK, Giovanna Eggers; SANTOS, Pedro Marostega; TOMÉ, Vitória Parchen Dreon. Biomaterial Experimental Design Practices as an Strategy for Sustainable Fashion. **MIX Sustentável, v. 8, n. 3, p. 95-108, mar. 2022**. ISSN-e: 24473073.Disponível em: <http://www.nexos.ufsc.br/index.php/mixsustentavel>. DOI: http://dx.doi.org/10.29183/2447-3073.MIX2022.v8.n3.95-108.

Submitted: 07/02/2022

Approved: 08/02/2022

Published: 31/03/2022

Editor: Amilton José Vieira de Arruda

CRediT (Contributor Roles Taxonomy) (http://credit.niso.org/)

FAVOR INDICAR A AUTORIA DE CADA AUTOR DE ACORDO COM O SISTEMA CREDIT

DB: Conceptualization; Data curation; Formal Analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

GER: Conceptualization; Data curation; Formal Analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

PMS: Conceptualization; Data curation; Formal Analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

VPDT: Conceptualization; Data curation; Formal Analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

Declaration of conflict: nothing has been declared.