Scientific Research Publishing

Journal of Textile Science and Technology, 2022, 8, 187-202
https://www.scirp.org/journal/jtst
ISSN Online: 2379-1551
ISSN Print: 2379-1543

The Effect of Consumption on the Appearance of Closers Implemented by 3D Printer Technology (FDM)

Sanaa Abdullah Alsiyami[1,2], Shadia Salah Salem[1]

[1]Department of Fashion and Textiles, Faculty of Human Sciences and Designs, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia
[2]Department of Fashion Design, College of Designs and Arts, Umm Al-Qura University, Mecca, Kingdom of Saudi Arabia
Email: sasiyami@uqu.edu.sa, sssalem@kau.edu.sa

How to cite this paper: Alsiyami, S.A. and Salem, S.S. (2022) The Effect of Consumption on the Appearance of Closers Implemented by 3D Printer Technology (FDM). *Journal of Textile Science and Technology*, **8**, 187-202.
https://doi.org/10.4236/jtst.2022.84014

Received: August 29, 2022
Accepted: September 13, 2022
Published: September 16, 2022

Abstract

The shift towards sustainability in the fashion industry has become an urgent necessity and a national duty, where the life cycle of garments poses a negative impact on the environment, which increases strongly with the huge increase in the daily consumption of garments and fast fashion. One of the most prominent solutions that have been proposed is to change the manufacturing system in a way that would help reduce costs, reduce supply and provide products that are more closely related to the individual customer need. Accessories such as (closers) are an important part of the fashion industry, and therefore, this study aimed to produce closers using (FDM) technology, which is one of the least expensive and most widespread 3D printing technologies. These closers are then tested in the laboratory according to AATCC standard specifications for garments and closers to ensure the applicability of this technology in the implementation of closers for designers and manufacturers in medium and small facilities. This study relied on the experimental exploratory approach, and the results proved the success of the proposed closers, as the implemented models passed the standard tests with distinction.

Keywords

3D Printer, FDM Technology, Fashion Manufacturing, Closers, AATCC, Additive Manufacturing, Sustainable Fashion

1. Introduction and the Research Problem

The development of technology in all areas of life and the shift towards the fourth industrial revolution had positively leveraged the countries' economies. But unfortunately, some of these technologies had a negative impact on the environment and thus prompted the emergence of green institutions, the dissemination of a culture of sustainability for a secure future, and a call for preserving the earth and its natural resources.

Balconi *et al.* [1] and Jiang *et al.* [2] have confirmed that the garment industry is the second largest polluting industry for the environment, starting from the manufacturing cycle to the consumption and disposal of garments. Therefore, many fashion institutions, such as the Dutch C & A[1], took the initiative to use bio-cotton in the manufacturing of their products. It has also launched a program to collect old garments and recycle them. In 2017, C & A received the C2CTM[2] certificate, and now it has more than 4 million certified pieces of garments. Meanwhile, New Balance USA for Sporting Goods[3] started to take great strides toward the preservation of the environment by recycling polyester, which subsequently resulted in lower carbon emissions and energy consumption. Swedish H & M[4] is one of the first brands to embrace sustainability, creating a digital tool and guide that any brand, designer or production team can use for recyclable design and called it "Circulator". It also launched an initiative that provided a guarantee to buy back recycled materials; because demand for it is key to unleashing the recycling potential within the fashion industry.

In 2019, the Ministry of Culture in the Kingdom of Saudi Arabia launched the future of fashion event, which was the turning point in the fashion industry at the local level. The initiative resulted in the creation of the Fashion Authority and increased interest in the fashion sector with the emergence of many designers and fashion houses. Yet, the fashion industry itself is still in its initial stages compared to leading garment manufacturers such as China, Indonesia and Bangladesh.

Saudi Arabia seeks to develop the national industry and logistics services in all sectors, within a program that seeks to achieve Vision 2030. This program targets the manufacturing industries which include the fashion and textile sector, with a focus on the aspect of sustainability, raising local production and applying the fourth industrial revolution such as artificial intelligence, the Internet of things and the 3D printer.

Closers are an essential component of a garment and have preserved their function and shape. The only change is the material used in its production as they are now being made of plastic. Costa & Broega [3] proposed the development of biodegradable closers based on the foundations of circular economy and design thinking methodology for product development. While the current study relied on changing the closers manufacturing system to become more related to the customer's need and on-demand production and then re-manufacturing it again at the end of the life cycle of a garment using the 3D printer technology

[1]Bio Cotton—game changer for a sustainable fashion industry (c-and-a.com).
[2]Home—Cradle to Cradle Products Innovation Institute (c2ccertified.org).
[3]Sites-NBUK-Site—New Balance.
[4]Sustainability Reporting—H&M Group (hmgroup.com).

FDM.

Thus, the researcher decided to make use of the 3D printer technology in the fashion industry sector at the medium and small enterprises level to achieve the objectives of the National Industry Development Program, starting with the production of garment closers according to the needs of designers and local fashion houses, and ensure their quality and suitability for use as closers for ready-made garments, while adhering to sustainability and maintaining the principles of circular economy in the fashion industry sector in the Kingdom. From this, we arrive at the following research question:

What is the effect of temperature, washing frequency and detergents on the FDM-made Closers in terms of (shape, colour, texture, hardness)?

Objectives

- To use the 3D printer FDM technology in the field of plastic closers production.
- To measure the impact of Standard Laboratory Tests (AATCC 150: 2018/ AATCC 135: 2018 - AATCC 150: 2018/AATCC 135: 2018/AATCC EP1: 2012 - AATCC 61 - AATCC 132 - AATCC 133 - ASTM D 5171) on the implemented models in terms of (shape, color, texture, hardness).

2. Research Significance

- The application of the 3D printing FDM technology in the fashion industry sector within the National Industrial Development and Logistics Program, would leverage the domestic product and thus achieve the Kingdom's Vision 2030.
- Benefiting from the studies of specialized academic bodies, ready-made garment factories, and fashion houses in the Kingdom of Saudi Arabia.

3. Terminology

3D Printer (3D Printing)

A 3D printer is defined as the manufacture of objects by depositing materials using a head, nozzle, rays, light, or other printer technology until the desired shape is completed. It is often used synonymously with additive manufacturing and is associated with devices with low prices or comprehensive capability [4].

Fused Deposition Modeling (FDM)

Procedural definition: It is one of the three-dimensional printing technologies known as fused deposition modeling (FDM) and provides unparalleled design freedom and speed of implementation using strong thermoplastics. Functional prototypes with distinct thermal and chemical resistance and excellent strength ratios can be produced and can be increased according to the materials used.

Closers

A small, usually circular object is used to fasten something, for example, a shirt or coat. They are usually a dislike piece of solid material having holes or a shank through which it is sewed to one side of an article of clothing and used to fasten or close the garment by passing through a loop or hole in the other side. They are used by ready-made garment producers [5].

American Association of Textile Designers and Chemists (AATCC: Chemists & Colorists).

Procedural definition of laboratory tests carried out on the implemented models:

(AATCC 150: 2018/AATCC 135: 2018): Dimensional stability test of garment fabrics in the case of normal household washing at 40˚C after repeating the wash once, five times and ten times. An accurate dimension scale in the micron unit was used to measure the dimensions of the implemented models before and after washing times.

(AATCC 150: 2018/AATCC 135: 2018/AATCC EP1: 2012): Color fastness test of garment fabrics in the case of normal domestic washing at 40˚C after repeating the wash once, five and ten times. The gray scale under daylight standard No. D65 was used to measure the color fastness of the implemented models before and after washing times.

(AATCC 61): Color fastness test of clothing fabrics in the case of normal household washing at a temperature of 71˚C after repeating the wash three and five times. The gray scale under standard daylight No. D65 was used to measure the color fastness of the models executed before and after washing times.

(AATCC 132): Color fastness test of garment fabrics in the case of commercial dry washing at 65˚C. After repeating the wash three and five times. The gray scale under standard daylight No. D65 was used to measure the color fastness of the implemented models before and after washing times.

(AATCC 133): Color fastness test of garment fabrics when ironed at 150˚ for 15 seconds with a pressure of 50 g/m^2 after repeating the wash three times and five times. The gray scale under standard daylight No. D65 was used to measure the color fastness of the patterns. It is performed before and after ironing times.

(ASTM D 5171): A test to determine the ability of a plastic sewing button to resist breaking under the influence of impact, where a mass equivalent to 84 kg is dropped vertically from different heights (according to the formula: height = button size ÷ 0.651) on the button fixed at the base of the device. Then it is checked with a telephoto lens up to 5X. If any cut or break is observed on the closers, it will mean that the button failed the test and is not fit for use.

4. Methodology

The research followed the experimental method by applying standard tests to printed forms, discovering their impact, and recording the results.

5. The Research Limits

They were confined to FDM printed closers from two materials:

(PTEG) is a tough plastic that is resistant to acids, salts, and alkalis with high durability, low shrinkage, multiple color options that can be multi-prototyped, food safe and recyclable.

(PLA) 100% biodegradable plastic in industrial compost, safe to use, ideal for models, gives aesthetic details and multiple color options, and can be mixed with iron, wood or any other different materials.

6. Research Community and Sample

Research community: 3D-printed closers implemented by an FDM 3D printer, using the PLA/ PTEG materials. The closers' sizes are 12/15/16 according to the number required for each standard test.

7. Research Tools:

Standard Tests including: (AATCC 150: 2018/AATCC 135: 2018), (AATCC 150: 2018/AATCC 135: 2018/AATCC EP1: 2012), (AATCC 61), (AATCC 132), (AATCC 133), (ASTM D 5171).

8. Applied Study

The closers were modeled using the open-source Blender program in sizes 12 mm, 15 mm and 16 mm, with two holes. They were printed using an FDM printer, with a device from Tronxy-X3SA, using 1.75 mm threads. The following eight different materials were used: PLA NATUR BRONZ/PLA WHITE/PLA BLACK/PLA NATUR WOOD/PLA NATUR ALUMINUM/PLA TRANSPARENT/PETG SOLED RED/PETG SOLED YELLOW.

First: A dimensional stability test (AATCC150:2018/AATCC135:2018) was conducted after normal washing at 40˚, and after one, five and ten times. A micron micrometer was used.

No dimensional change occurred for all eight implemented models. This means the success of the materials used in the implementation of the models and therefore can be used in the production of closers (Table 1).

Second: The color fastness test after normal washing at 40˚ (AATCC 150: 2018/AATCC 135: 2018/AATCC EP1: 2012) was conducted after one, five- and ten-times washings. CIE standard illuminant D65 was used to confirm the degree of discoloration.

There was no color change in all the five implemented models except for the white and bronze color, with a slight change at 4 degrees, and the woody color with a significant change at 2 degrees. The change occurred after repeating the washing process for the tenth time only. This means that the materials used in the implementation of the models are efficient and can therefore be used in the production of closers (Table 2).

Third: Color fastness test after normal washing according to (AATCC 61-A3) at a temperature of 71˚ after 3 and 5 times. CIE standard illuminant D65 was used to check the degree of color change.

There was no color change in all the five implemented models except for the

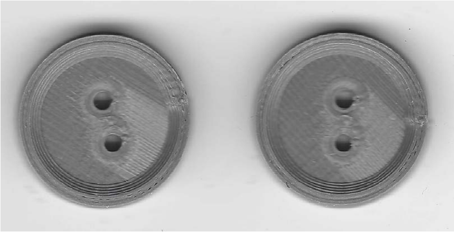
Table 1. Results of the dimensional stability test after washing.

Type and color	Once	Five Times	Ten Times
PLA WHITE	No change has occurred Diameter: 16.15 Thickness: 2.90	No change has occurred Diameter: 16.15 Thickness: 2.90	No change has occurred Diameter: 16.15 Thickness: 2.90
PLA BLACK	No change has occurred Diameter: 16.09 Thickness: 2.94	No change has occurred Diameter: 16.09 Thickness: 2.94	No change has occurred Diameter: 16.09 Thickness: 2.94
PLA NATUR BRONZ	No change has occurred Diameter: 16.5 Thickness: 2.87	No change has occurred Diameter: 16.5 Thickness: 2.87	No change has occurred Diameter: 16.5 Thickness: 2.87
PLA NATUR WOOD	No change has occurred Diameter: 16.14 Thickness: 2.98	No change has occurred Diameter: 16.14 Thickness: 2.98	No change has occurred Diameter: 16.14 Thickness: 2.98
PLA TRANSPARENT	No change has occurred Diameter: 16.3 Thickness: 2.92	No change has occurred Diameter: 16.3 Thickness: 2.92	No change has occurred Diameter: 16.3 Thickness: 2.92
PLA NATUR ALUMINUM	No change has occurred Diameter: 16.12 Thickness: 2.87	No change has occurred Diameter: 16.12 Thickness: 2.87	No change has occurred Diameter: 16.12 Thickness: 2.87
PETG SOLED YELLOW	No change has occurred Diameter: 16.12 Thickness: 2.87	No change has occurred Diameter: 16.10 Thickness: 3.05	No change has occurred Diameter: 16.10 Thickness: 3.05
PETG SOLED RED	No change has occurred Diameter: 16.10 Thickness: 3.05	No change has occurred Diameter: 16.10 Thickness: 3.05	No change has occurred Diameter: 16 Thickness: 3.06

Table 2. Results of color fastness test after normal washing.

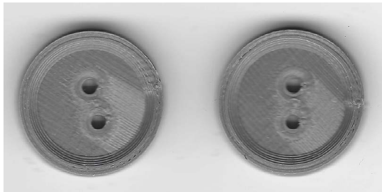
Type and color	Once	Five times	Ten times	Before and after washing
PLA WHITE	5	5	4	
PLA BLACK	5	5	5	

Continued

PLA NATUR BRONZ	5	5	4	
PLA NATUR WOOD	5	5	2	
PLA TRANSPARENT	5	5	5	
PLA NATUR ALUMINUM	5	5	5	
PETG SOLED YELLOW	5	5	5	
PETG SOLED RED	5	5	5	

woody and transparent color, which saw a slight change after the third wash, and the red which saw a slight change after the fifth wash. This means that the materials used in the implementation of the models are efficient and can therefore be used in the production of closers (Table 3).

Table 3. Color fastness test results after normal washing.

Type and color	Once	Five times	Ten times	Before and after washing
PLA WHITE	5	5	4	
PLA BLACK	5	5	5	
PLA NATUR BRONZ	5	5	4	
PLA NATUR WOOD	5	5	2	
PLA TRANSPARENT	5	5	5	
PLA NATUR ALUMINUM	5	5	5	
PETG SOLED YELLOW	5	5	5	
PETG SOLED RED	5	5	5	

Fourth: Color fastness test after dry washing Commercial use as per AATCC 132 at 65˚ After 3 and 5 times. CIE standard illuminant D65 was used to confirm the degree of discoloration.

There was no color change for the black and white and lead models, while the other colors were affected by only half a degree and all the changes were very slight. This means that the materials used in the implementation of the models are efficient and can therefore be used in the production of closers (**Table 4**).

Fifth: Color stability test after dry ironing according to (AATCC 133) at a temperature of 150˚/15 seconds and a pressure of 50 g/m^2, after 3 and 5 times washing. CIE standard illuminant D65 was used to confirm the degree of discoloration.

There was no color change in some of the executed models, and all changes were very slight for yellow, red, woody and transparent. This means that the materials used in the implementation of the models are efficient and can therefore be used in the production of closers (**Table 5**).

Sixth: The test of fracture resistance and shock endurance according to (ASTM D 5171) was carried out on two sizes of closers, diameter 15 mm and diameter 12 mm respectively.

This means that the materials used in the implementation of the models are efficient and can therefore be used in the production of closers (**Table 6**).

To ensure that the test results were not biased, the samples were photographed using an electron microscope SEM: Scanning Electronic Microscope in SABIC Company, and the enlarged images showed that the models were free of any signs of fractures (**Table 7**).

9. Results

By comparing the effects, we find the following:

From Figure 1 below we can deduce the following:

- The two materials PLA BLACK and PL NATUR ALUMINUM were colour-fast in all tests and after all repetitions, due to the stability of the black color and the quality of the thread workmanship.
- The PLA WHIT material was color-fast in all tests and after all repetitions except for the tenth time in normal washing, it recorded 4 degrees.
- The PLA TRANSOART material was color-fast at 40˚ and below after all repetitions, while it scored 4.5 in CIE standard illuminant D65 test at 65˚ and above after all repetitions. Therefore, it is advised to take care of clothing at lower temperatures. Of course, transparent plastic utensils lose their purity with frequent use and cleaning.
- The two PETG SOLD YELLOW And PETG SOLD RED materials were color-fast at a temperature of 40˚ and less after all repetitions, while it scored 4.5 in the dry wash after 3/5 repetitions, the yellow color scored 4.5 in the ironing test after 5 repetitions, while the red color scored 4.5 in the ironing test after 3/5 repetitions and normal washing at 71˚ after 5 repetitions. Therefore,

Table 4. Results of color fastness test after dry washing.

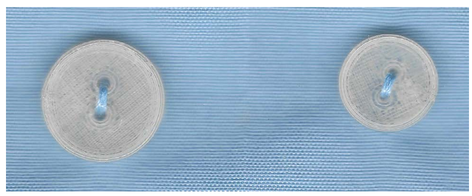
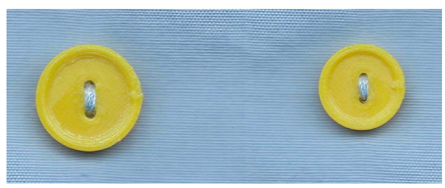
Type and color	Three times	Five times	15 mm\12mm
PLA WHITE	5	5	
PLA BLACK	5	5	
PLA NATUR BRONZ	4.5	4.5	
PLA NATUR WOOD	5	4.5	
PLA TRANSPARENT	4.5	4.5	
PLA NATUR ALUMINUM	5	5	
PETG SOLED YELLOW	4.5	4.5	
PETG SOLED RED	4.5	4.5	

Table 5. Results of color fastness test after ironing.

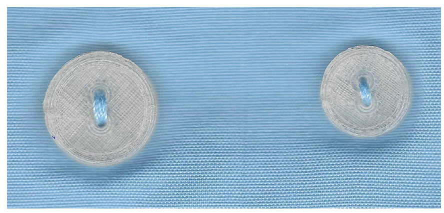
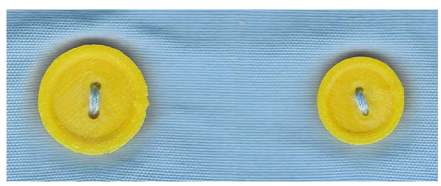
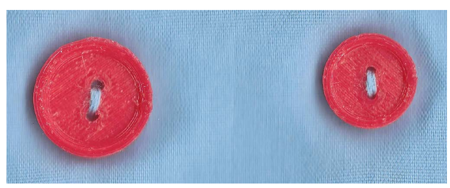
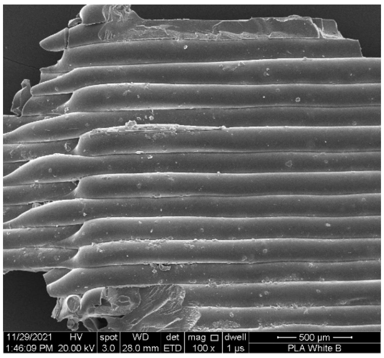
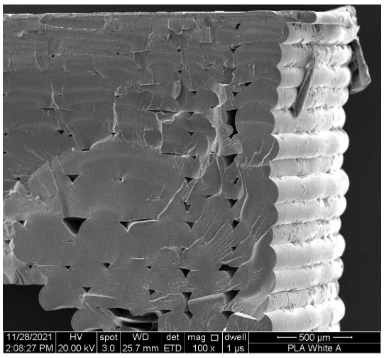
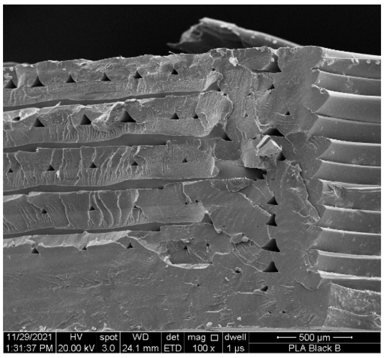
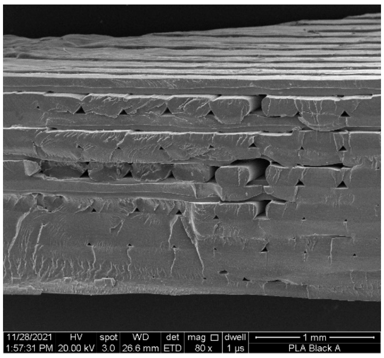
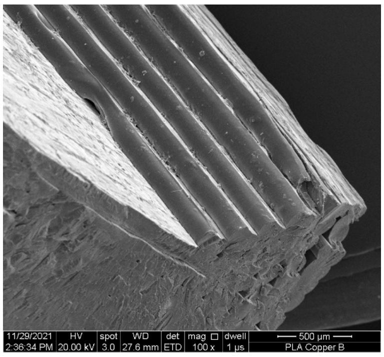
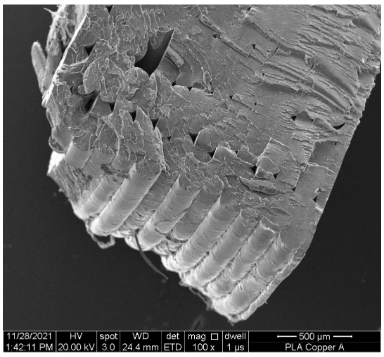
Type and color	Three times	Five times	15 mm\12mm
PLA WHITE	5	5	
PLA BLACK	5	5	
PLA NATUR BRONZ	5	5	
PLA NATUR WOOD	4.5	4.5	
PLA TRANSPARENT	4.5	4.5	
PLA NATUR ALUMINUM	5	5	
PETG SOLED YELLOW	5	4.5	
PETG SOLED RED	4.5	4.5	

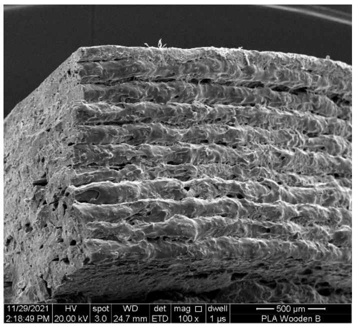
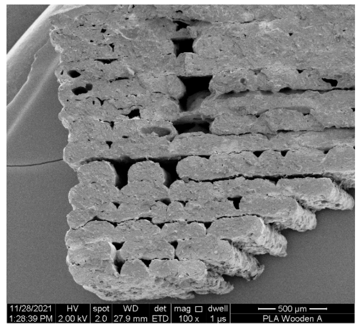
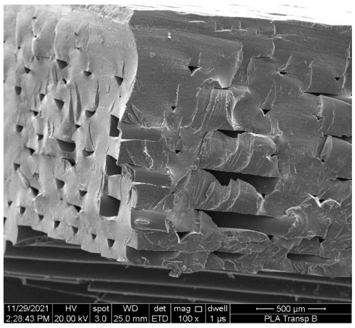
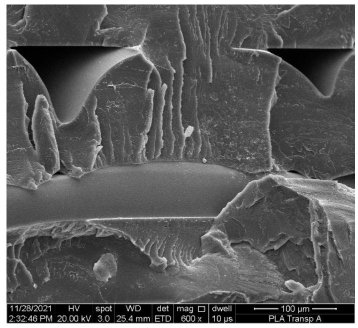
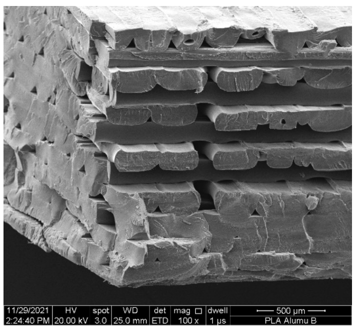
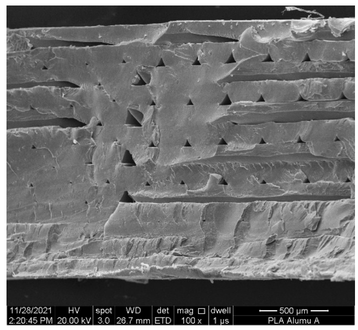
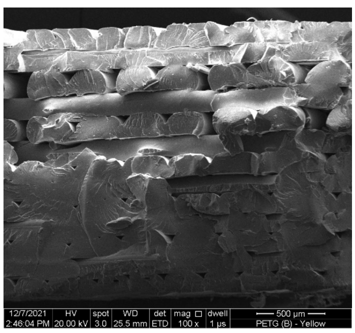
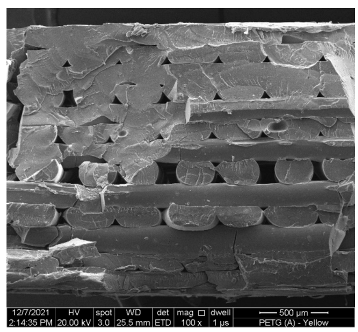
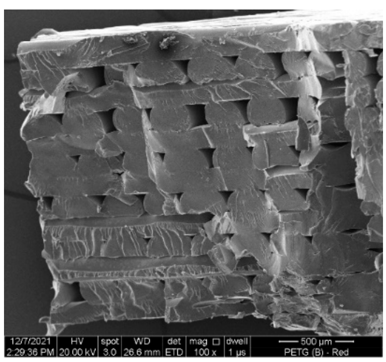
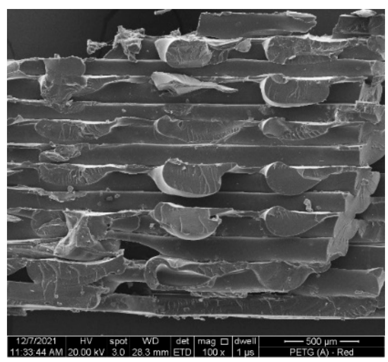
Table 6. Results of fracture resistance test

Type and color	15 mm	12 mm
PLA WHITE PLA BLACK PLA NATUR BRONZ PLA NATUR WOOD PLA TRANSPARENT PLA NATUR ALUMINUM PETG SOLED YELLOW PETG SOLED RED	Passed the fracture -resistance test according to the American Standard (ASTM D 5171), and there is no effect of fracture with the naked eye or by ten times magnification with the lens. The surface appearance was evaluated by electron microscope at magnifications of (100/600/10,000) times	Passed the fracture -resistance test according to the American Standard (ASTM D 5171), and there is no effect of fracture with the naked eye or by ten times magnification with the lens. The surface appearance was evaluated by electron microscope at magnifications of (100/600/10,000) times

Table 7. Microscopy—longitudinal section—before and after the fracture resistance test.

Type and color	Before	After
PLA WHITE		
PLA BLACK		
PLA NATUR BRONZ		

Continued

PLA NATUR WOOD		
PLA TRANSPARENT		
PLA NATUR ALUMINUM		
PETG SOLED YELLOW		
PETG SOLED RED		

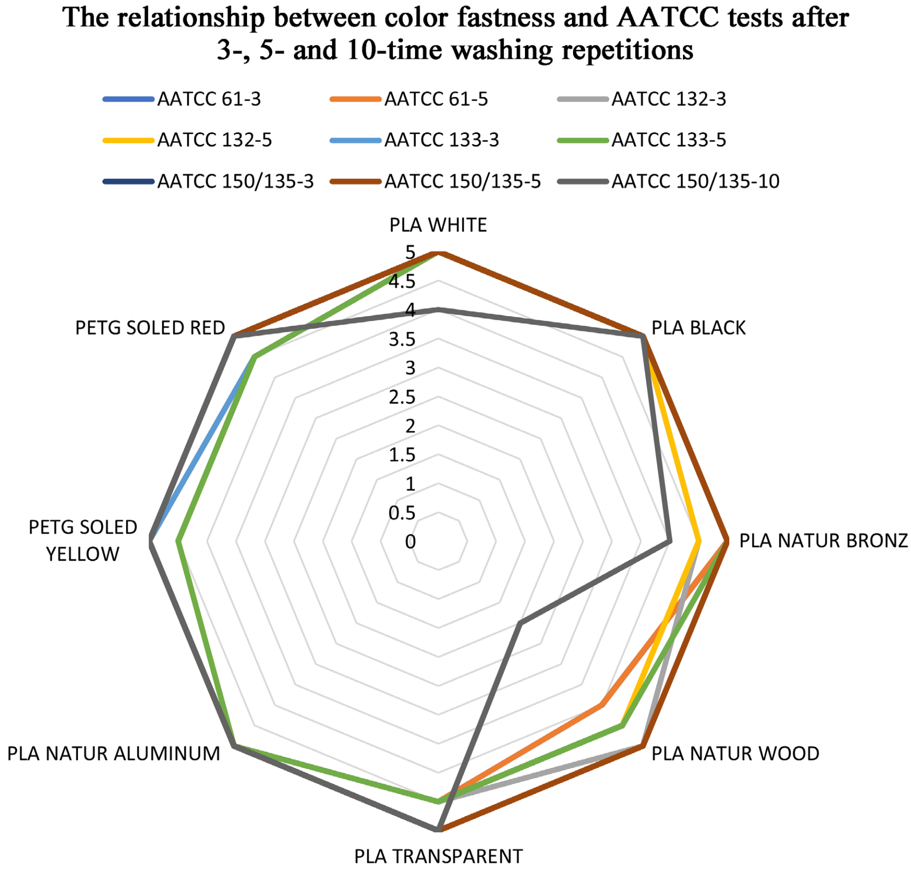


Figure 1. Shows the relationship between material color stability and AATCC tests after 3-, 5- and 10-time washing repetitions.

it is recommended to take care of clothes at lower temperatures, especially the red color. This is due to the nature of the color added to polyethylene triphthalate Glycol according to the quality of the thread manufacturer.

- Color change in PLA NATUR BRONZ material agrees with the results of Albardakhini's study [6], as the closers made of copper are affected by their interaction with the acids and alkalis found in industrial detergents only, and unlike those made of aluminum. The effect was very slight, as it scored 4.5 degrees on the gray scale in dry washing after 3 and 5 repetitions and 4 degrees on the maximum change in color after repetition for the tenth time in normal washing at a degree of 40˚. This could be due to the fact that the threads are made of copper filings mixed with polylactic acid, not pure copper.
- The PLA NATUR WOOD material recorded the lowest color fastness, where it scored 2 degrees in the normal washing test at a temperature of 40˚ after 10 repetitions, and 4 degrees in the normal washing at 71˚ after 3/5 repetitions, and recorded 4.5 degrees in the dry wash after 5 repetitions, a 4.5 degree on the ironing test after 3/5 repetitions. This is due to natural sawdust mixed with polylactic acid, which is affected by detergents and high temperatures.
- All eight materials passed the fracture resistance test according to ASTM D

5171, and the closers were free of fracture through optical inspection with a magnifying lens up to five times, and in the microscopy with SEAM technology up to 100/60/10,000 times magnification.

10. Recommendations

1) Conducting empirical studies on other materials such as ABS and comparing the results of the implemented models with the current research in terms of quality and functional efficiency.

2) Conduct exploratory studies of the use of nature-derived biopolymers such as lignocelluloses[5], starch, algae and chitosan-based biopolymers[6] [7].

3) Conducting empirical studies on different 3D printer technologies such as SLA for mass production and comparing the results of the implemented models with the current research in terms of quality and economical cost.

4) Production of other requirements in the fashion industry, such as supports, belts and laces, down to integrated clothing parts using FDM technology and testing their quality and functionality.

5) Dissemination of the results of the study to the garment factories to benefit from them after obtaining the necessary approvals.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Balconi, M., Sebastiani, R. and Angioletti, L. (2019) A Neuroscientific Approach to Explore Consumers' Intentions towards Sustainability within the Luxury Fashion Industry. *Sustainability*, **11**, Article 5105. https://doi.org/10.3390/su11185105

[2] Jiang, Q., Chen, L.C. and Zhang, J. (2019) Perception and Preference Analysis of Fashion Colors: Solid Color Shirts. *Sustainability*, **11**, Article 2405. https://doi.org/10.3390/su11082405

[3] Costa, J. and Broega, A.C. (2022) New Sustainable Materials for the Fashion Industry. The Button in the Circular Economy. In: Raposo, D., Neves, J., Silva, R., Correia Castilho, L. and Dias, R., Eds., *Advances in Design, Music and Arts II*, Springer, 342-356. https://doi.org/10.1007/978-3-031-09659-4_26

[4] Narayan, R. (2014) Rapid Prototyping of Biomaterials: Principles and Applications. Woodhead Publishing, Cambridge.

[5] Muqlan, S.M. (2012) Design and Finishing of Functionally and Aesthetically Suitable Ready-Made Clothes to those with Special Needs. Ph.D. Thesis, Umm Al-Qura University, Mecca. https://dorar.uqu.edu.sa/uquui/handle/20.500.12248/129846?locale=en

[6] Al-Bardakhini, A.J. (2019) Proposed System for the Reuse of Production Accessories to Achieve Sustainability in Ready Made Garments. *The Scientific Journal of the College of Specific Education*, **1**, 539-590.

[5] A compound of lignin and cellulose found in the cell walls of woody plants.

[6] It is made by treating chitin shells from shrimp and other crustaceans with an alkali, such as sodium hydroxide.

https://www.arablifestyle.com/16/153004

[7] Liu, J., Sun, L.S., Xu, W.Y., Wang, Q.Q., Yu, S.J. and Sun, J.Z. (2019) Current Advances and Future Perspectives of 3D Printing Natural-Derived Biopolymers. Carbohydrate Polymers, **207**, 297-316. https://doi.org/10.1016/j.carbpol.2018.11.077