Evaluation of wash colour strength of a printed garment with flexible filaments on 3D printers

DOI: 10.35530/IT.075.05.2023100

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ABSTRACT – REZUMAT

Evaluation of wash colour strength of a printed garment with flexible filaments on 3D printers

The research aims to evaluate the solidity of the washing colour of a garment printed with flexible filaments on 3D printers. Three groups of factors have been selected: Anet A8 and M3D Crane Quad printer, temperature (49° and 71°C) and flexible filaments TPE (thermoplastic elastomer) and TPU (polyurethane thermoplastic), framed in the factorial design, type applied of 10 units per combination of factors in a total of 80 sampling units, using Girowah equipment according to the technical standard AATCC TM61-2020. The results show that the printer factors Anet A8 and M3D Crane Quad with the CIELab and CMC (2:1) discolouration system exceed 50% in both the tolerances of the value 1. About the temperature factor (49° and 71°C), which exhibits a discolouration of 1.06 in CIE94 and 1.36 in CMC, it is determined that the combination with better resistance to discolouration of solidity at washing (CIE94 - 49°C) compared to CMC (2:1) better establishes the visual and technical concordance of the solidity of colour. As regards flexible filament types: TPE and TPU, the results show us that the colour tolerance assessments (CIELab CIE94) and (CMC (2,1)) prove that the TPE filament has greater resistance to the discoloration of the 3D-printed garment at different temperatures. In conclusion, the solidity of colour washing in a printed garment with flexible filaments in a 3D printer causes discolouration by the minimum, be it the factors of printer type, filament, and temperature. There is a need for analysis with other values and it remains open to other research.

Keywords: *TPU and TPE filament, CIE94, CMC (2:1), Snowflake pattern, standard AATCC TM61-2020*

Evaluarea rezistenței culorii la spălare a unui articol de îmbrăcăminte imprimat cu filamente flexibile pe imprimante 3D

Studiul își propune să evalueze rezistenţa culorii de spălare a unui articol de îmbrăcăminte imprimat cu filamente flexibile pe imprimante 3D. Au fost selectate trei grupuri de factori: imprimanta Anet A8 și M3D Crane Quad, temperatura (49° și 71°C) și filamentele flexibile TPE (elastomer termoplastic) și TPU (poliuretan termoplastic), încadrate în proiectarea factorială, tip aplicat de 10 unități pe combinație de factori într-un total de 80 unități de prelevare, folosind echipamente Girowah conform standardului tehnic AATCC TM61-2020. Rezultatele au arătat că factorii de imprimantă Anet A8 și M3D Crane Quad cu sistemul de decolorare CIELab și CMC (2:1) depășesc 50% în ambele toleranțe ale valorii 1. În ceea ce privește factorul de temperatură (49° și 71°C), care prezintă o decolorare de 1,06 în CIE94 și 1,36 în CMC, rezultatele au arătat că în combinație cu o rezistență mai bună a decolorării la spălare (CIE94 - 49°C) față de CMC (2:1) stabilește mai bine concordanţa vizuală şi tehnică a rezistenţei culorii. În ceea ce priveşte tipurile de filamente flexibile: TPE și TPU, rezultatele au arătat că evaluările toleranței de culoare (CIELab CIE94) și (CMC (2,1)) au demonstrat că filamentul TPE are o rezistență mai mare la decolorarea îmbrăcămintei imprimate 3D la diferite temperaturi. În concluzie, rezistenţa culorii la spălare a unui articol de îmbrăcăminte imprimat cu filamente flexibile pe o imprimantă 3D provoacă o decolorare la un nivel minim, fie că este vorba de factorii tipului de imprimantă, ai filamentului sau ai temperaturii. De asemenea, ar putea fi necesară o analiză cu alte valori, precum și studii suplimentare.

Cuvinte-cheie: *filament TPU și TPE, CIE94, CMC (2:1), model Snowflake, standard AATCC TM61-2020*

INTRODUCTION

Numerous industrial sectors, including the textile sector, are being affected by the rapid advancement of technology. Stereolithography (SL), which is based on the concept of printing 3D digital data on real objects, is a clear example of this concept [1]. When a user engages in 3D object modelling, he is digitizing a representation of a physical object.

CAM (Computer Aided Manufacturing), CAD, and CAE are just some of the new terminologies that have been developed due to the advent of the digital manufacturing process. Consequently, the merger of control technology and computer science has transformed several industries, including the textile, aerospace, naval, and other sectors [2].

With digital manufacturing and 3D printing concepts, new production techniques have been developed, such as clothing, footwear, and other products. Danit Peleg is known as one of the pioneers who successfully produced clothing with 3D printers using flexible filament materials [3].

The use of 3D printing to create clothing not only led to a new production method but also presented new challenges, including the need for product customization. As a result, innovative concepts such as Industry 4.0 have been created, allowing customers to order things to be printed in FabLab's facilities [4].

The Professional School of Textile Engineering and Confections of the National University of Juliaca (UNAJ) is an academic centre that supports research and seeks to advance knowledge through its studies, framed in its research lines as “Productive processes, design, safety, and quality in the textile and confectionery industry” [5]. As a result, it aims to experiment and investigate techniques of 3D printing and digital manufacturing, with some factors that derive directly from these techniques being price, time, quality, comfort, durability, flexibility, etc.

In the work of Gavancho et al. [6], the design incorporates three natural designs: a snow cup, bee panel, and flower of life, with line variants and a 12% filling percentage, using flexible TPU and TPE filaments as material. The printing process is carried out with the Anet A8 and M3D Crane Quad printers. The design tests are for traction and elongation. The results obtained determined that the design pattern “Snowball with Line” showed superior performance in the elongation test compared to the traction test, which is why it was chosen for 3D printing of the garment with a total of 29 pieces, previously modelled off the 3D in the Rhinoceros 6 software. The modelling was done with CLOE 3D to generate the G-CODE files using Voxelizer. A 3D pen was used to assemble and join the parts, giving a total of 4 garments in material and TPE and TPU filaments with the printers Anet A8 and M3D Crane Quad. Women of different clothing sizes participated in the examination, intending to test the garments' comfort. The article does not show colour solidity tests for wash tests, which is one of the recommendations for future work studies.

The AATC (American Association of Textile Chemists and Colorists) is a professional organization with over 3,000 members focused on technical and scientific disciplines. Established in 1921, AATCC has more than 200 test techniques and evaluation processes to measure and evaluate the performance characteristics of chemically treated fibres and tissues [7]. The AATC 61 test standard evaluates tissue colour resistance to repeated washing by evaluating the impact of the detergent solution and abrasive action on colour loss and surface changes. However, the 45-minute test cannot accurately predict stains resulting from standard hand washing or at home. Commercial washing techniques have evolved, and a single accelerated laboratory operation cannot replicate these processes. In 2005, commercial washing was excluded due to uncertainty about the accuracy of these techniques in replicating contemporary commercial practices [8].

The CIELab colour differential system (also known as Delta E, ΔE) uses the proposed formulas (with their variants) to measure the colour variation in the ICELab space. The term LAB comes from measuring: dL* = Luminosity, da* = red-green colour space (axis a), and db* = yellow-blue colour variance (axis b); these three components are measured using coordinates of the CIELAB space, but the main disadvantage is that not always the colour calculated is the colour perceived. The formula CIE94 is used for the textile industry, making variants of dL*, da*, and db* by components L, C, and H, described in CMC [9].

The CMC colour difference system (Colour Measurement Committee) is established by measuring the components SL = Luminosity, SC = Chrome, SH = Saturation (called components); this formula allows you to see dark and achromatic colours. The component l:c values for textile applications are 2:1 [9].

No antecedents of colour solidity tests were found in washed 3D printing filaments and less in garments made from these materials (TPU and TPE); however, research using the colour tolerance system (ΔE) found.

Palacios-Ochoa et al. [10] evaluated the colour resistance of fabric fabrics made of wool and alpaca fibres using natural pigments from plants and animals native to Azuay, Ecuador. The dyes were extracted from native plants and animals, and the accumulated colour variation (ΔE) was calculated. The results showed that the tone of the tissues painted with these plants remained stable through most of the tested factors, indicating an optimal rating for the colour resistance of these tissues.

In Bou-Belda et al. work [11], CIELAB colour values (L, a, b) were used to examine the antimicrobial and cleaning properties of chitosan on traditional cotton breeches from the Maramures region of Romania. The study aimed to assess the viability of a non-intrusive substitute for conventional cleaning chemicals for textiles. The results showed that chitosan treatment did not induce any colour changes, as the CIELAB colour values (L, a, b) were used to determine the colour changes. This suggests that chitosan has potent antimicrobial properties.

METHODS AND MATERIALS

Research samples

Evaluation of washing solidity colour in textile garments is based on the technical standard AATCC TM61-2020, NTP 231.008:2015, or ISO 105-C01, taking into account the printers Anet A8 and M3D Crane Quad, temperature, and type of filament used. Therefore, we performed the colour solidity analysis when washing flexible filament garments to determine the discolouration of the 3D-printed garment.

From the research work of Gavancho et al. [6], ten samples were generated for each combination of TPE and TPU flexible filaments, printers Anet A8 and M3D Crane Quad, with temperatures of 49° and 71°, giving a total of 80 samples. From the standard AATCC Test Method 61-2020, the tests 2A and 3A (49° and 71°) were taken, being those of the highest temperatures and without the presence of chlorine; it is worth mentioning that if the temperatures had any other effect on the washing process as possible, deformation of the samples and the tests 4A and 5A would remain as future work.

Table 1

RESEARCH SAMPLES			
Temperature	**Printer 3D**	**Filament**	**Total**
49°	Anet A8	TPU	10
		TPE	10
	M3D Crane Quad	TPU	10
		TPE	10
71°	Anet A8	TPU	10
		TPE	10
	M3D Crane Quad	TPU	10
		TPE	10

Gavancho et al. [6] worked on the fractal geometry of nature and on hexagonal patterns such as the snow cup on which they developed the garment, the TPU (white) and TPE (black) filaments as well as the colour and dimensions of the pattern (13.2 cm × 10.8 cm × 0.15 cm) were replicated and the research intends to evaluate the proposed pattern in the garments.

Surface characteristics of TPU and TPE polymer materials

Thermoplastic polyurethane (TPU) is a polymer that combines the characteristics of polyurethanes and thermoplasts. Its physical and geometric properties include moderate density, low porosity, and surface roughness. TPUs can be manufactured in various shapes and sizes, with a density range of 1.1 to 1.25 g/cm^3. They can also have shore hardness ranging from 60A to 75D. TPUs have a traction resistance ranging from 20 to 70 MPa, an elongation to rupture of 400% to 700%, and a tracing resistance of 50 to 150 N/mm. Commercial thermoplastic elastomers (TPE) have similar properties, with densities ranging from 0.9 g/cm^3 to 1.25 g/cm^3. TPEs are denser materials with low porosity, and surface roughness can vary depending on the manufacturing process and application. For accurate information, it is recommended to consult the technical data sheets provided by the manufacturer, which often include details about the density, mechanical properties, chemical resistance, and other important characteristics of the material [12].

Equipment

The following equipment was used (figure 1); the technical specifications can be found in the respective quotations:

- Anet A8 3D printer; specifications in [13].
- 3D printer M3D Crane Quad; specifications in [14].
- SUNLU SL-300 3D Pen; specifications in [15].
- CM-700d Spectrophotometer; specifications in [16].
- 815/8 GiroWash; specifications in [17].

Software

The following software was used:

- Rhinoceros 6: for the creation of the snow cup pattern in stl format.
- Ultimaker Cure 5.2.1: for GCODE generation.
- SpectraMagix NX CM-S100w 3.4: colour data software, to measure colour tolerance.

Procedure for the development of the test pattern

From the garment created in Gavancho et al. work [6], using the Rhinoceros 6 software, we proceeded to print three repetitions of the base pattern (snowflake), ordered in 1 row by three columns, matching the hexagonal shape of the patterns (which is called the piece; see figure 2, *b*); file exporting was made in stl format, to subsequently work in the Cura software and generate the new gcode file, which would be printed on the filaments and printers described above using USB memory.

After completing the printing phase, each of the two pieces was joined by the 3D pen (parts joining, which is called sample; see figures 2, *f* and *g*), generating 80 samples. The washing test was carried out under the Girowash machine with temperatures at 49° and

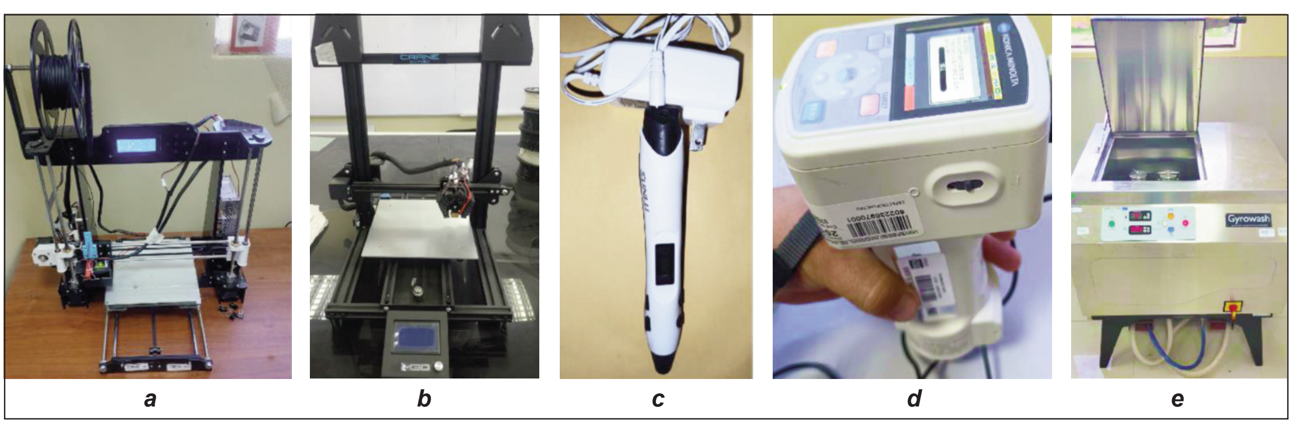


Fig. 1. Equipment: *a* – Anet A8 3D Printer; *b* – M3D Crane Quad 3D printer; *c* – SUNLU 3D Pen; *d* – CM-700d Spectrophotometer; *e* – 815/8 Girowash

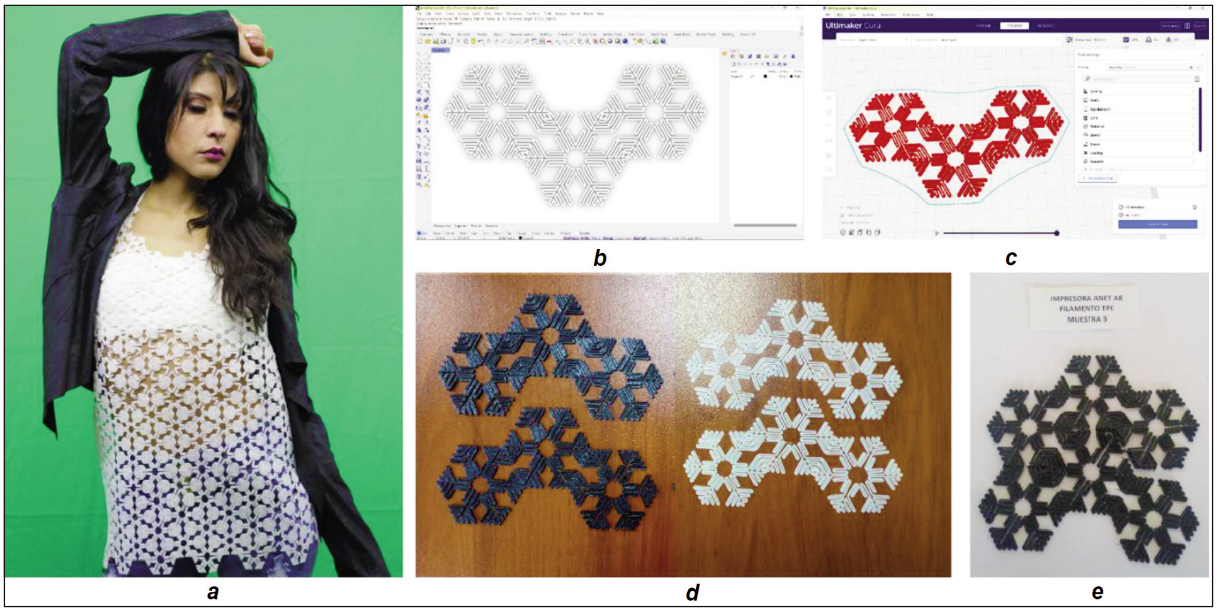


Fig. 2. Photos of: *a* – 3D printed TPU filament garment; *b* – Snowflake pattern with 3 repetitions and simulated in Rhinoceros 6; *c* – GCODE file creation piece in Ultimarker Cura software; *d* – parts for bonding with TPE filaments and TPU; *e* – sample for strength test at washing in TPE Filament

71° Celsius under the AATCC Test Method 61-2020, which standard allowed to evaluate of the solidity of the colour when washed.

Preparation, conditions, and procedure for the tests

The laundry firmness test was carried out with the Girowash team. It is suitable for the climatic conditions of any part of the world since the process is in a closed circuit, which does not affect the results when applying to the technical standard AATCC TM61-2020, NTP 231.008:2015, or ISO 105-C01, in the research specifically the city of Juliaca that is located at 3824 msnm and 0.5 atmosphere (atm), in addition to the low temperatures outside the equipment.

The technical conditions are based on the AATCC TM61-2020 standard, which indicates the following procedure for Girowash accelerated washing:

Girowash washing equipment for rotating closed containers in a thermostat-controlled water bath at 40 ± 2 rpm has Type 2 stainless steel lever locking cubes of 90 × 200 mm (3.5 × 8.0 in.) for tests No. 1B, 2A, 3A, 4A, and 5A. For our specific case, the 2A and 3A tests also have adapter plates to fasten the containers on the washing machine axis, 6 mm (0.25 in) diameter stainless steel balls, 9–10 mm (3/8 in) white synthetic rubber (SBR) balls, Teflon fluorocarbon joints, and a preheater and storage module.

Testing procedure

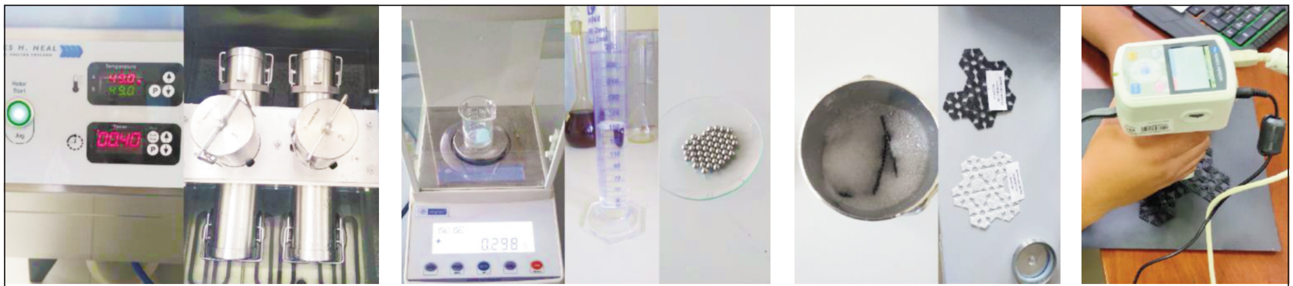
1. The containers were placed in the preheater module at the prescribed test temperature. They should stay in the module for at least 2 minutes. Insert a well-ridden test sample into each container; in this case, the sample pattern.
2. Place 150 ml of distilled water and 0.15% detergent (1993 Standard Reference Detergent WOB (Without Optical Brightener)) about the total volume.
3. Place the amount of steel balls according to our case test numbers 50 and 100, respectively, for the test types (2A and 3A).
4. After turning on the rotor and running for at least 2 minutes preheat the containers.
5. The wash was performed at 40±2 rpm for 45 minutes.
6. Rinse, extraction and drying procedures are the same for all tests. The machine was stopped, the containers were removed, and the contents were left empty in precipitated vases, keeping each test sample in a separate precipitate vase. Each of the test patterns was rinsed three times, in precipitated vases, in distilled or deionized water at 40 ± 3 °C (105 ± 5°F) for 1 minute, with periods of occasional agitation or hand-stressing. Drying was done in the air without exposure to sunlight and at a temperature of 18.5°C.
7. Additionally, samples may be conditioned at 65±5% relative humidity and 21±2°C (70±4°F) for 1 hour prior to evaluation. In the case of this study, it is not necessary to wait or perform the drying operation, as this does not require it because of the type of flexible filament material.

In Moya [18], the parameters for the wash test were taken.

Table 2

PARAMETERS FOR THE LAWING TEST

Parameter	Temperature	
	49°	**71°**
Detergent gr/lt.	2	2
The volume of solution ml.	150	50
Number of steel balls	50	100
Time	45 min.	45 min.



a *b* *c* *d*

Fig. 3. Photos of: *a* – configuration of time, temperature, and location of containers; *b* – measurement of detergent, solution and steel spheres; *c* – samples inside the container; *d* – colour solidity measurement median to the spectrophotometer

The spectrophotometer equipment was used to measure the colour difference tolerance according to CMC (2:1) and CIELab 1994 standards for the colour solidity test. (figure 3, *d*).

RESULTS

ISO 105 is a method used to calculate the colour difference between two samples of the same material under the same conditions. The resulting numerical value, ΔE*CMC(l:c), measures the total colour difference between samples. This method allows a maximum tolerance based on the degree of approximation required to mimic the colour for the intended application of a specific textile. It also helps to determine the correlations between the brightness/chrome difference and the lightness/shadow difference. The CIELAB formula (ΔE*) was the first formula historically used to determine colour differences in textiles. In 1989, the American Association of Textile Chemists and Colorists (AATCC) adopted ΔE*CC (l:c), a variant of the ΔE*CMC formula for textiles [19]. The International Commission on Illumination (IEC) granted in 1994 the approval of a variant of the CIE94 formula known as ΔE*94 (textile) for textiles. Currently, both ΔE94 and ΔE*CMC (l:c) are universally recognized in the field of textile colour difference analysis.

The results obtained are shown in table 3. For the colour difference system using the CIELab system [20], the formula of CIE94 was used (equation 1), and for the colour differential system using the CMC system [21], the formula with the adjustment of the brightness and chromium factors (l:c)(2:1) (equation 2) was used. In both cases, unacceptable colour or value variation is also considered for textile applications when the value is equal to or greater than 1.

$$\Delta E^*_{CIE94} = \sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2 + \left(\frac{\Delta C}{K_C S_C}\right)^2 + \left(\frac{\Delta H}{K_H S_H}\right)^2} \quad (1)$$

Where $\Delta L = L_1 - L_2$ (*Difference in brightness*), $\Delta C = C_1 - C_2$ (*Difference in Chroma or Saturation*), ΔH (*The difference in the matrix of –a green or +a red and –b blue or +b yellow expressed in degrees*), K_L = 1 : *Default*; 2 : *Textile Applications.*

For a better understanding of the formula, see the complete formula description in Lindbloom work [20].

$$\Delta E_{CMC(2:1)} = \sqrt{\left(\frac{\Delta L}{l S_L}\right)^2 + \left(\frac{\Delta C}{c S_c}\right)^2 + \left(\frac{\Delta H}{S_h}\right)^2} \quad (2)$$

Table 3

DATA OBTAINED																
Sample	***CIE94***								***CMC (l:c)(2:1)***							
	Anet A8				**M3D Crane Quad**				**Anet A8**				**M3D Crane Quad**			
	TPU		**TPE**		**TPU**		**TPE**		**TPU**		**TPE**		**TPU**		**TPE**	
	49°	**71°**	**49°**	**71°**	**49°**	**71°**	**49°**	**71°**	**49°**	**71°**	**49°**	**71°**	**49°**	**71°**	**49°**	**71°**
1	1.83	1.59	0.78	1.23	1.74	1.13	0.68	0.77	2.36	2.24	1.18	1.88	1.81	1.46	1.03	1.15
2	0.42	1.55	0.39	0.33	1.21	1.28	0.70	0.93	0.56	1.22	0.57	0.48	1.69	1.72	1.06	1.40
3	0.85	1.20	0.56	0.46	1.44	0.65	0.52	1.01	1.16	1.49	0.83	0.69	1.45	0.89	0.75	1.49
4	0.80	1.08	0.97	1.48	0.91	1.43	1.48	0.64	1.09	0.88	1.47	2.25	1.23	1.33	2.27	0.96
5	0.60	0.91	0.55	1.15	1.03	0.70	1.41	0.82	0.58	1.05	0.83	1.71	0.79	0.76	2.16	1.21
6	1.31	2.04	0.51	1.06	1.47	0.75	1.33	0.76	1.66	2.48	0.76	1.60	1.81	0.79	1.98	1.12
7	1.72	0.89	1.41	0.60	1.52	2.05	0.92	1.29	2.17	1.26	2.10	0.90	1.74	2.31	1.37	1.93
8	1.66	1.27	1.01	0.34	0.99	1.03	0.49	0.34	2.03	1.28	1.51	0.52	0.96	1.21	0.74	0.52
9	1.19	1.51	0.89	0.20	1.37	2.16	1.01	0.18	1.28	1.65	1.34	0.31	1.56	2.53	1.50	0.27
10	1.34	1.14	1.52	1.52	1.41	1.23	1.08	1.08	0.92	1.25	2.30	2.29	1.19	1.32	1.59	1.61

Where $\Delta L = L_1 - L_2$ (*Difference in brightness*), $\Delta C = C_1 - C_2$ (*Difference in Chroma or Saturation*), ΔH (*The difference in the matrix of –a green or +a red and –b blue or +b yellow expressed in degrees*), (2:1) = *Modify by doubling color intensity.*
For a better understanding of the formula, see the complete formula description in Lindbloom work [21].

CIE94

Figure 4, a and table 4 show that the colour solidity test for the CIE94 system exceeds the tolerance value by 56.25% (>=1), while 43.75% is within the permissible margin (<1). It is concluded that the CIE94 system is rigorous for discolouration in 3D-printed filament garments. Similarly, figure 4, *b* against the temperature factor of two groups of 40 sampling units each, the first with 49°C and the second with 71°C, shows a discolouration greater than the tolerance value 1. It is concluded that the garment with 3D printing at different temperatures has a discolouration greater than or equal to the tolerance value 1 allowed according to the AATCC Test Method 61-2020 standard. On the other hand, in figure 4, *c*, opposite the combination of the printer factors Anet A8 and M3D Crane Quad and the temperature of 49°C and 71°C of 20 sample units of four groups, there is a discolouration mainly greater than the value 1. It is inferred that the combination of the factors of the printer Anet A8 and the temperature of 49°C has better resistance to solidity discolouration when washed in 3D printing prey. Also, in figure 4, *d*, the colour solidity with the factor of filament type and temperature shows that there is less discolouration in the TPE filament compared to the TPU filament. The TPE filaments have greater resistance to the discolouration of the garment with 3D printing at different temperatures.

CMC (2:1)

Figure 5, *a* and table 5 show that the colour solidity test for the CMC system (2:1) exceeds the tolerance

Table 4

CIE94 DESCRIPTIVE STATISTICS									
Variance	**N**	**N***	**%**	**Mean**	**Std. Error Mean**	**Std. Deviation**	**Min.**	**Max.**	**Range**
General	80	0	100	1.06	0.05	0.45	0.18	2.16	1.98
<1	35	0	43.75	0.65	0.04	0.23	0.18	0.99	0.81
>=1	45	0	56.25	1.38	0.04	0.29	1.01	2.16	1.16

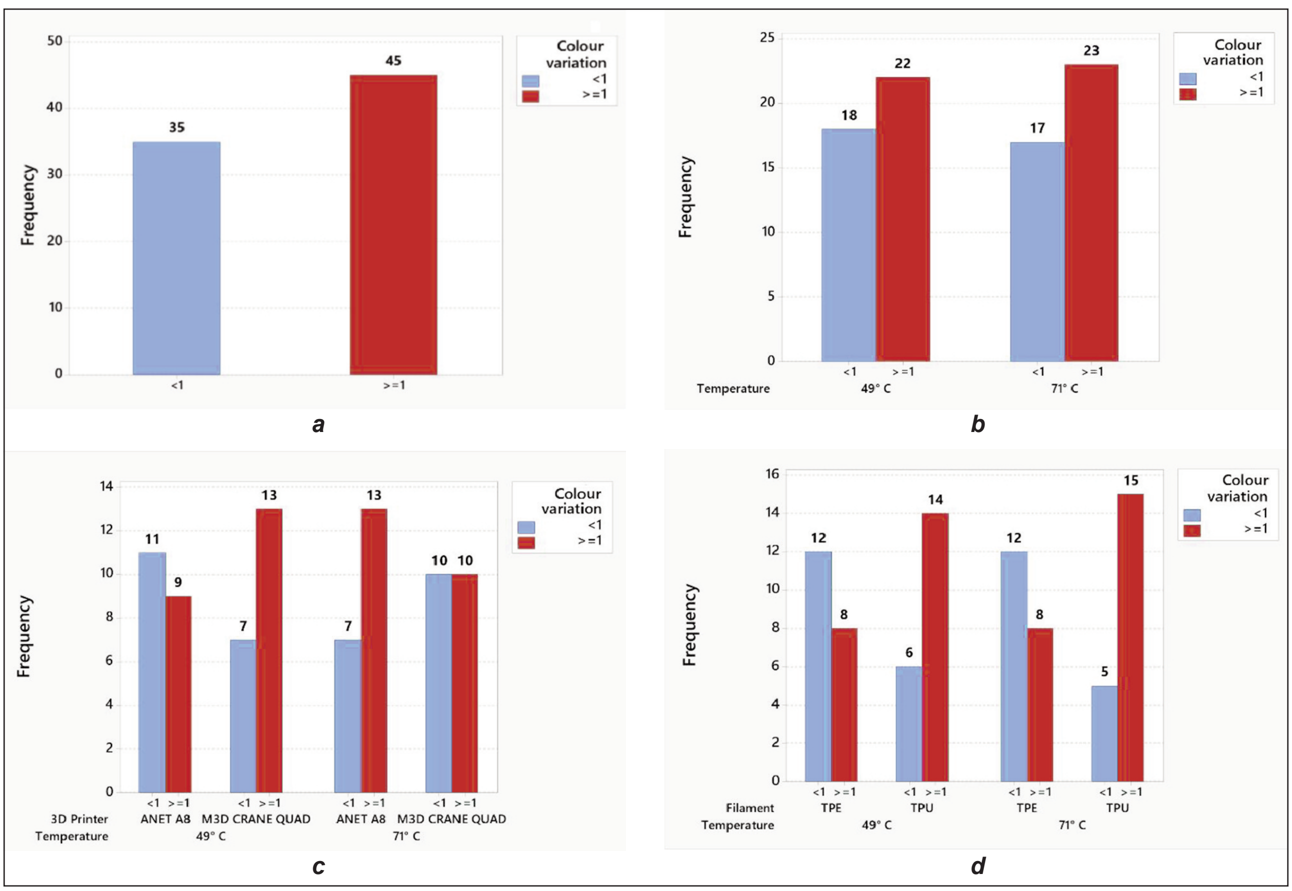


Fig. 4. Colour solidity bar graph with the formula CIE94: *a* – General; *b* – Temperature; *c* – Temperature - 3D Printer; *d* – Temperature - Filament

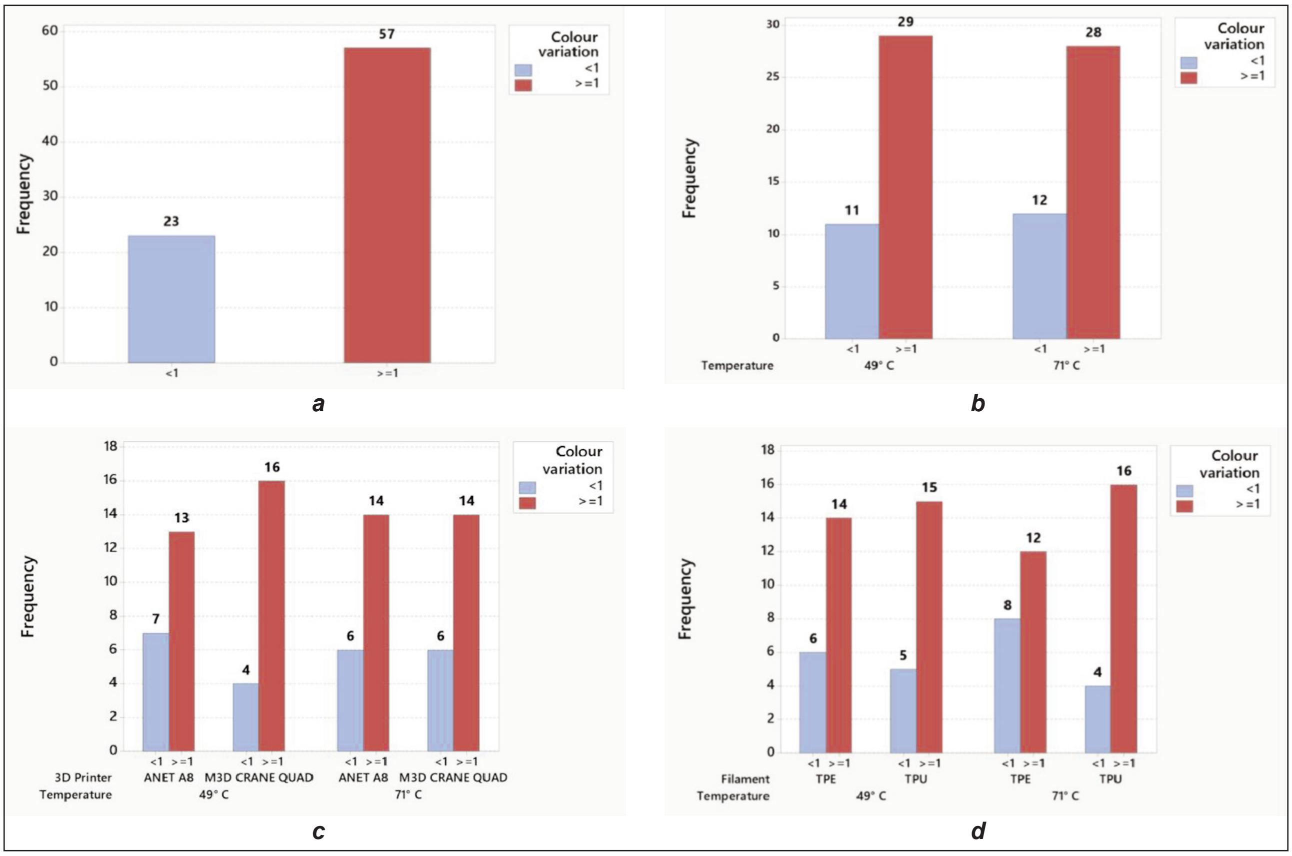


Fig. 5. Colour solidity bar chart with formula CMC(2:1): *a* – General; *b* – Temperature; *c* – Temperature - 3D printer; *d* – Temperature - Filament

Table 5

CMC(2:1) DESCRIPTIVE STATISTICS									
Variance	**N**	**N***	**%**	**Mean**	**Std. Error Mean**	**Std. Deviation**	**Min.**	**Max.**	**Range**
General	80	0	100	1.36	0.06	0.56	0.27	2.53	2.27
<1	23	0	28.75	0.71	0.04	0.20	0.27	0.96	0.69
>=1	57	0	71.25	1.62	0.06	0.42	1.03	2.53	1.51

value by 71.25%, while 28.75% is within the permissible margin. It is concluded that the CMC system (2:1) specifies more precisely the prey discolouration of filaments with 3D printing. Similarly, figure 5, *b* against the temperature factor of two groups of 40 sampling units each, the first one with 49°C and the second with 71°C, shows a discolouration greater or equal to the tolerance value of 1. It is concluded that clothing with 3D printing at different temperatures has a discolouration greater than the tolerance value 1 permitted in the CMC system performed according to the standard AATCC Test Method 61-2020. On the other hand, in figure 5, c opposite the combination of the printer factors Anet A8 and M3D Crane Quad and the temperature of 49°C and 71°C of 20 sample units of four groups, there is a discolouration mainly greater than the value 1. It is concluded that the combination of the printer factors and temperature presents a more significant discolouration at the permitted levels in the CMC system performed according to the technical standard AATCC Test Method 61-2020.

Also, in figure 5, *d* the solidity of the colour when washed with the factor of the type of filament and temperature indicates that there is discolouration in the filaments TPU and TPE greater than the permissible value. TPE and TPU filaments have more significant discolouration of garments with 3D printing at different temperatures.

CONCLUSIONS

- In the evaluation of the solidity of colour at washing, the results show us that there is discolouration in the 3 groups of factors: Printer Anet A8 and M3D Crane Quad, TPE and TPU filaments with temperatures of 49°C and 71°C, that there is a discolouration for the least (0.18 in CIE94 and 0.27 in CMC (2:1)); also, it is informed that the CMC system (2:1) more rigorously accurately predicts the discolouration, that is, it obtains values higher than the CIELab CIE94.
- On the other hand, the printer factors Anet A8 and M3D Crane Quad with the CIELab and CMC

discolouration systems (2:1) exceed 50% (56.25% for CIElab and 71.25%) in both value tolerances of 1, according to the AATCC Test Method 61-2020. It would be interesting to evaluate other standards.

- Similarly, the temperature factor (from 49°C to 71°C) of color solidity to wash in 3D-printed prey. In the tolerance assessment system (CIELab CIE94) and (CMC (2:1)) exhibit a discolouration of 1.06 in CIE94 and 1.36 in CMC (2:1), it is determined that the combination of the printer Anet A8 and CMC (2:1) at temperatures of 49° and 71°C has better resistance to the discolouration of solidity at wash (CIE94 - 49°C) compared to CMC (2:1), as it better establishes the visual and technical concordance of the solidity of colour. It remains open for evaluation at other temperatures within the proposed standard.
- Similarly, the type analysis of filaments used TPE and TPU in 3D printing garments in colour solidity to wash present according to the colour tolerance system assessment (CIELab CIE94) and (CMC (2,1)) evidence that the TPE filament has greater resistance to the discolouration of the garment with 3D printing at different temperatures.

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