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SOFW Journal 1+2/2026 p. 8-11 | Volume 152 | Thannhausen, Germany, January 04, 2026

Polyesterase: a New Dimension in Fabric Care

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abstract

Polyester fibers have overtaken cotton in the textile industry during the past decade, especially in apparel. Polyester has an advantage over traditional fabrics such as cotton. It does not absorb moisture and is wrinkle-resistant. However, polyester garments are also known to be susceptible to abrasion when exposed to multiple wash and wear cycles. This results in the formation of fuzz and pills on the fabric surface. When garments look worn, old and faded, it prompts consumers to dispose of them before their actual end-of-life. Polyesterase, a novel enzyme developed through protein engineering, offers innovative fabric care by reducing fuzz and pills on polyester and polycotton blends during the laundry process. It works synergistically with cellulase to extend garment life without compromising fabric strength. Polyesterase addresses the growing demand for polyester fiber in textiles and the consumer need for garment preservation.

Introduction

For many consumers of laundry detergents, fabric care and cleaning performance are equally important. A good example of fabric care is the need to protect colored garments. Most consumers separate colored and delicate garments from whites, use specific color safe detergents, or select a milder wash condition. Another aspect of fabric care is the occurrence of fuzz and pills on garments due to the consecutive wash and wear process. When garments look worn, old and faded, it prompts consumers to dispose of them before their actual end-of-life. This contributes to textile waste and landfills, and makes consumers purchase more clothes. Therefore, there is a need for solutions that enable consumers to keep their garments last longer and look better.

For cotton garments, there is already an enzymatic solution available. Cellulase is a well-known enzyme functionality in the detergent industry and can provide several fabric care benefits for cotton and cotton-polyester blends. By including a low level of cellulase, the detergent can prevent or delay the occurrence of fuzz and pills through a multicycle wash process [1]. Another benefit of cellulase is its anti-greying property that enables whites to stay white for longer. The textile industry, however, is increasingly relying on synthetic fibers, especially polyester.

The Growing Importance of Polyester Fibers

Polyester fibers have overtaken cotton in the textile industry during the past decade, especially in apparel. The demand for polyester fiber is projected to triple the size of cotton by 2030. This is mainly driven by the lower price of polyester relative to cotton [2].

Polyester has an advantage over traditional fabrics such as cotton. It does not absorb moisture which makes polyester suitable for the application of water- and soil-resistant finishes, for example in sports- and outdoor wear. Polyester is wrinkle-resistant and does not shrink, reducing the need for ironing and making it easier to maintain. However, polyester garments are also known to be susceptible to abrasion when exposed to multiple wash and wear cycles. This is illustrated in **Figure 1** by means of a Scanning Electron Microscope (SEM) picture of a polyester fabric swatch that has been submitted for multiple cycles to the washing process in a front-loading automatic washing machine. The picture shows a woven polyester swatch with its typical interlacing of warp and weft yarns. At its surface, loose fibril is formed that appears as fuzz.

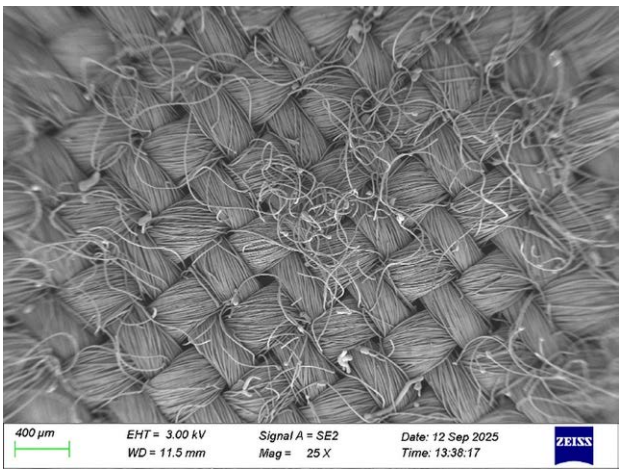


Fig. 1 SEM picture of polyester fabric (WFK30A) after multicycle treatment in a washing machine. The image was taken with a Zeiss-Sigma 360 High-Performance Field Emission Scanning Electron Microscope at 25X magnification.

Polyester, or polyethylene terephthalate (PET), is a synthetic polymer formed through the esterification of terephthalic acid and ethylene glycol. Its high molecular weight and crystallinity make polyester non-biodegradable, but its ester bond is susceptible to hydrolysis, and even enzymatic degradation. This offers an opportunity for developing a novel enzyme class in laundry detergents.

Materials and Methods

The removal of fuzz and pills on polyester and polycotton fabric is assessed by quantifying the irregularity of the fabric surface by means of a Videometer Lab4 (Videometer, Denmark). The surface irregularity is converted into a so-called fuzz index. The fuzz index has a linear correlation with a "pilling scale" which ranks from 1 to 5, where the higher score corresponds to less fuzz and pills on the fabric. The same methodology is also used for biofinishing in textile processing.

Two fabric monitors were evaluated: a 100% polyester WFK30A swatch (purchased from CFT B.V.) and a 65% polyester/35% cotton blue fleece swatch (sourced from a textile mill in China). Both new (untreated) and pre-pilled swatches were used. The pre-pilled swatches were generated in the lab by washing new swatches in a Miele WCI660 front loading automatic washing machine for six consecutive washes in a normal cycle at 40°C and water hardness of 25° French Hardness (Ca/Mg 3:2). Fuzz and pill removal were assessed for up to 18 cycles in a normal cycle at 30°C in a Miele front loader. The fabric monitors were stitched to a cotton pillowcase and 2.5KG wash load was added.

A Novel Enzyme Technology: Polyesterase

Polyesterase is a novel lipolytic enzyme that has been developed to provide fabric care benefits for polyester and polycotton garments in laundry. Its use in the textile processing industry has been explored in the past. Enzymatic surface modification results in enhanced hydrophilicity and improved dying of polyester [3]. Polyesterase acts by cleaving the polymer chain through hydrolysis of the ester bonds and releasing soluble fragments of the polymer. PET is not the natural substrate of the enzyme; however, it presumably fits into the substrate binding pocket well enough for hydrolysis to occur.

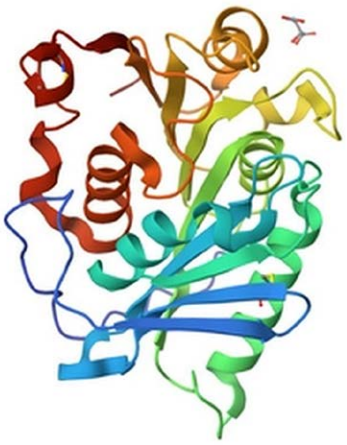
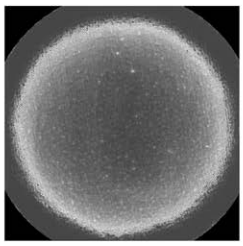
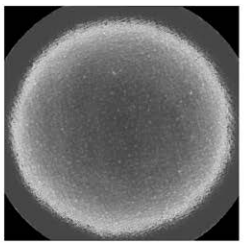
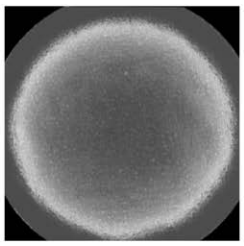
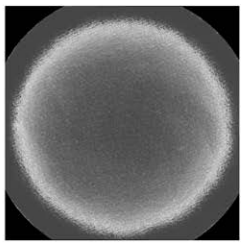
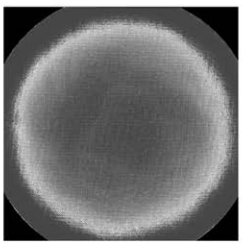


Fig. 2 Enzyme model of polyesterase developed for fuzz and pill removal on polyester fabric [reproduced from: https://www.rcsb.org/]

Polyesterase, like other enzymes, is biodegradable and acts as a biocatalyst. A structural model of the enzyme is shown in **Figure 2**. The model shows the typical alpha helix and beta sheets that can be found in enzymes. Due to the molecular dimensions of the enzyme, it is hypothesized that it cannot penetrate the bulk polymer, and the reaction probably occurs at the surface of the polymer, creating hydroxyl and carboxylate end groups [3].

Removing fuzz and pills from polyester fabric

Small differences in the occurrence of fuzz and pills on the surface of a fabric swatch can be difficult to observe by eye. A more accurate assessment is achieved by using an instrumental method, i.e. by means of a Videometer Lab4 (www.videometer.com). The surface irregularity observed under a standard light source is converted into a so-called fuzz index, which is subsequently converted into a discrete set of reference scores, or pilling scale (e.g., from 1 to 5). A visual representation and description of the pilling scale is shown in **Table 1**.

				
SCALE 1: Fabric surface is densely covered with pills, indicating significant wear.	**SCALE 2:** Moderate pilling with clusters of pills forming. Surface texture is visibly rougher.	**SCALE 3:** Noticeable surface fuzziness. Pilling is more frequent and distributed across the fabric.	**SCALE 4:** Slight texture variation and a few small pills begin to appear.	**SCALE 5:** Smooth surface with minimal irregularities or visible pilling.

Tab. 1 Visualization and description of the pilling scale for a 100% polyester fabric swatch (WFK30A). The scale has a linear correlation with the fuzz index; the images are recorded by the Videometer.

The multiwash effect on the fuzzing and pilling of a polyester fabric swatch is shown in **Figure 3**. New, unpilled polyester swatches were added to a front loading automatic washing machine. The pilling scale of the swatches was determined using the Videometer Lab4 for intermittent washes up to 18 wash cycles in total. Without polyesterase, the pilling scale drops significantly with increasing number of wash cycles. It shows that the multiple wash cycles result in mechanical abrasion of the polyester fabric.

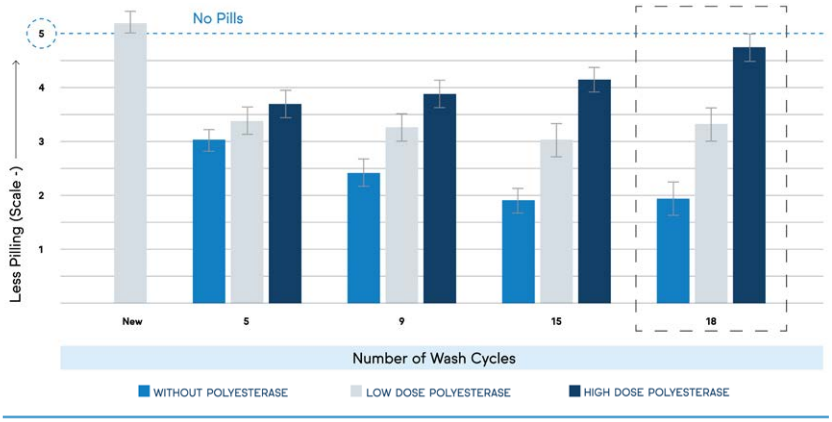


Fig. 3 Pilling scale measurements for WFK30A (100% polyester) swatches submitted to multiple wash cycles with and without polyesterase at wash temperature of 30 dC.

When adding 0.5 wt% of polyesterase to the detergent, the formation of fuzz and pills is reduced significantly for prolonged wash cycles. After the fuzz formation during the first washes, the pilling scale stabilizes at around three. It demonstrates a competing mechanism of pill formation through the action of the washing machine, and the de-pilling effect of polyesterase when present in the wash liquor. The de-pilling effect of polyesterase is even more visible when increasing the enzyme dosage in the detergent by an order of magnitude. In this case, the polyesterase activity is sufficient to nearly reach the initial condition of the new swatch.

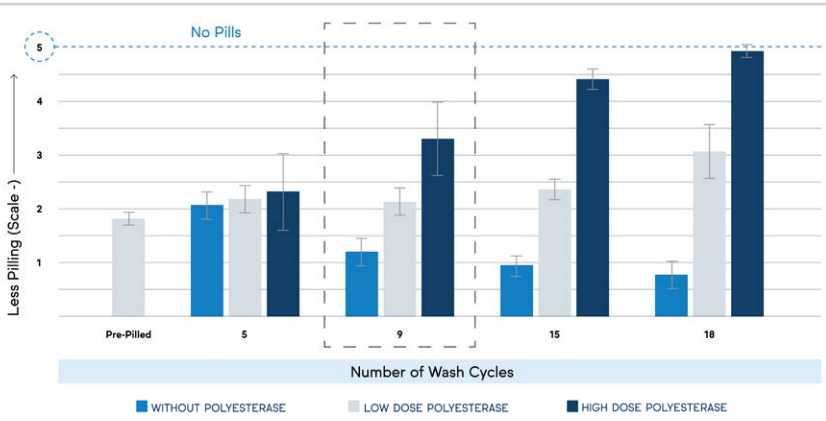


Fig. 4 Pilling scale measurements for pre-pilled WFK30A (100% polyester) swatches submitted to multiple wash cycles with and without polyesterase at wash temperature of 30 dC.

Even stronger de-pilling performance can be demonstrated when treating pre-pilled polyester swatches in a multi-wash experiment. This is shown in **Figure 4**. As a result of the pre-pilling treatment, the initial pilling scale is two compared to five for the new fabric indicating significant pill and fuzz formation. Without the addition of polyesterase, the pilling increases further when washing for up to 18 cycles. However, when adding polyesterase to the detergent, the pilling scale increases because of a reduction of fuzz and pills on the polyester fabric swatch. Complete de-pilling of the swatch after 18 cycles can be achieved when increasing the polyesterase dosage further.

Both multicycle washing experiments show that polyesterase can reduce the formation of fuzz and pills on 100% polyester fabric and even restore its initial condition, contributing to clothes longevity.

Fabric strength and microfiber release

Cellulase is known to cause significant tensile strength loss of cotton fabric when overdosed in the detergent formulation. Unlike cotton, polyester is hydrophobic and does not swell in the wash liquor. Still, a risk assessment was carried out to confirm that polyesterase does not negatively impact fabric integrity.

Tensile strength measurements were carried out on 100% polyester fabric swatches. The tensile strength was measured in both the longitudinal and cross direction of the fabric after washing for 20 cycles in a front-loading washing machine. A representative low duty liquid detergent was used, and a test leg without polyesterase was included as a control. For the detergent with polyesterase the maximum tensile strength loss was 8% in the longitudinal and 4% in the cross direction. No significant difference was observed versus the control leg without polyesterase, which confirms that polyesterase does not contribute to significant fabric strength loss.

Another potential concern is the release of microfibers due to the treatment with polyesterase. Recent studies have shown that fiber release during domestic textile washing is a cause of marine microplastic pollution, although the fiber released from soiled consumer wash loads were mainly composed of natural fibers. Also, consumers can reduce the levels of microfibers generated per wash by moving to colder and quicker wash cycles [4]. Based on its mode of action, polyesterase could contribute to the biodegradation of polyester microfibers by reducing its length distribution and generating soluble oligomers. Typically, microfiber release in the washing process is measured gravimetrically by collection after the wash by means of a cascade of filters. Our lab experiments showed a rapid decrease of the mi-

crofiber mass after the first few washes, and no direct measurable impact of polyesterase. Indirectly, by extending the lifetime of clothing, polyesterase can have a positive contribution when consumer purchase fewer new garments.

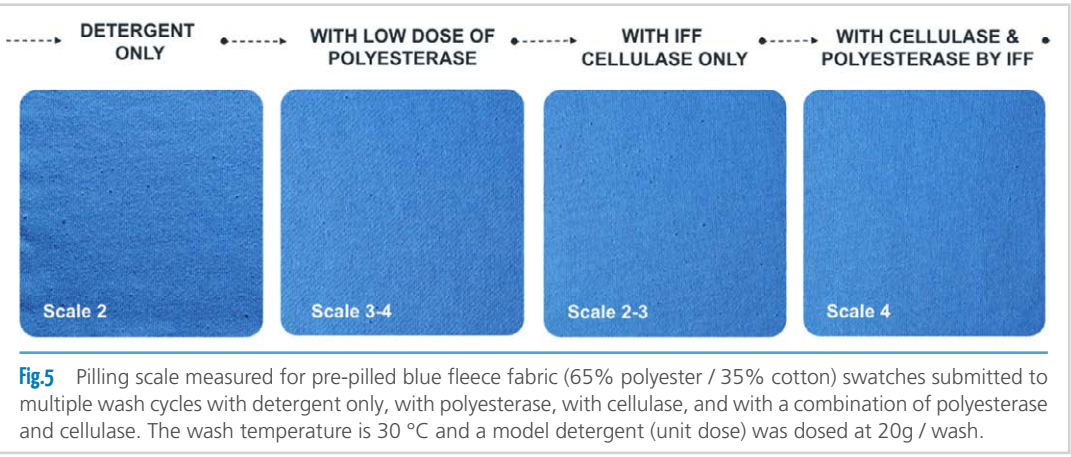


Fig.5 Pilling scale measured for pre-pilled blue fleece fabric (65% polyester / 35% cotton) swatches submitted to multiple wash cycles with detergent only, with polyesterase, with cellulase, and with a combination of polyesterase and cellulase. The wash temperature is 30 °C and a model detergent (unit dose) was dosed at 20g / wash.

Synergy with cellulase on poly-cotton blends

Most fabrics consist of poly-cotton blends that could benefit from an enzymatic detergent comprising both polyesterase and cellulase. Both enzymes have a defibrillation action on specific fibers of the fabric and therefore could provide a synergistic effect. This is demonstrated in **Figure 5** by carrying out an experiment of ten wash cycles using a pre-pilled polycotton blue fleece swatch. Without enzymes, the pill level remains at a scale of two. Both polyesterase and cellulase result in a higher scale and therefore less fuzz and pills. When combining polyesterase and cellulase in the detergent, an even stronger de-pilling performance can be achieved, achieving a scale of four after ten cycles. This could not be achieved with either one of the enzymes alone.

Conclusions and outlook

The increased demand for polyester fiber in the textiles industry has an impact on the fabric care needs of consumers. Polyesterase, a novel enzyme class in laundry, adds a new dimension to fabric care. It can remove fuzz and pills formed on the surface of polyester garments and works synergistically with cellulase for polycotton blends. By using IFF's protein engineering toolbox an enzyme has been developed with improved properties suitable for liquid detergents. Polyesterase can address an unmet consumer need and help to keep polyester-based garments looking better for longer.

Acknowledgments

The authors acknowledge Annemarieke van Heeswijk and Sina Pricelius for a critical review of the article and its figures, and correction of the German translation.

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