REDUCTION OF STIFFNESS IN 100% POLYESTER WOVEN FABRICS USING COCONUT OIL DERIVED BIO-SOFTENER: A SUSTAINABLE FINISHING APPROACH

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Polyester fabrics, though valued for their strength, dimensional stability, and low maintenance, are often criticised for their stiffness and poor comfort when used in apparel worn next to the skin. Conventional chemical softeners, typically petroleum-based, are non-biodegradable and raise environmental and health concerns. This study investigated the feasibility of using coconut oil–based BIO-softener as a sustainable alternative for 100% virgin polyester woven fabrics. Softener emulsions were prepared with food-grade coconut oil, Polysorbate 80 as a non-ionic emulsifier, and citric acid as a pH adjuster, at concentrations of 2%, 5%, and 10% (w/w). Fabric samples were treated using a dip-squeeze-air dry method and evaluated for drapability (ISO 9073), stiffness (ASTM D1388), tensile strength (ISO 13934-1), fabric weight (GSM), and surface pH, with wash durability tested according to ISO 105-C01. For each test, three readings per sample were taken, and mean values were used for analysis.

Results indicated that increasing BIO-softener concentration reduced stiffness and improved flexibility, with the 10% treatment giving the highest and most balanced improvement. Drapability improved by lowering the drape coefficient by 14.77%, while flexural rigidity reduced by 22.86% in the warp and 23.08% in the weft directions. GSM increased proportionally with softener concentration due to surface film deposition, but remained above untreated values even after washing, confirming acceptable durability. All treated fabrics maintained skin-safe surface pH (7.0–7.3). At the 95% significance level, tensile strength in the warp direction increased consistently and significantly ($p < 0.05$), while weft changes were minor and statistically insignificant ($p > 0.05$); the 10% treatment showed the greatest improvement in both directions. Concentrations above 10% led to undesirable oiliness and non-uniform appearance, limiting practical application.

In conclusion, coconut oil–based BIO-softener proved effective in enhancing drapability and flexibility of polyester fabrics while maintaining mechanical integrity, wash durability, and wearer safety. Future studies should include thermal comfort and subjective hand-feel assessments for a more holistic evaluation of fabric performance. These findings confirm its potential as an eco-friendly alternative to petroleum-based softeners, supporting sustainable finishing practices for synthetic textiles.

Keywords: Bio-softener, Coconut oil, Polyester, Fabric stiffness, Drapability, Sustainable finishing

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INTRODUCTION

Polyester is a widely used synthetic fibre in the global textile industry due to its high strength, dimensional stability, ease of maintenance, etc. However, its low moisture absorption and high crystallinity result in a rigid fabric in handle (stiffer the fabric) and poor comfort properties, especially when they are used in next-to-skin applications. These limitations are commonly addressed through chemical softening finishes, many of which are petroleum-based and raise environmental concerns due to their non-biodegradability and potential toxic residue (Fahmy & Amr, 2024).

Recent studies have explored bio-based softeners such as castor oil, palm oil, and coconut oil as sustainable alternatives to conventional softening agents. Research done by Nair *et al.* (2020) demonstrated that a combination of coconut oil and vegetable ghee improved fabric flexibility and tactile softness in cotton and viscose substrates. Similarly, Trajković *et al.* (2017) evaluated the performance of recycled fibres treated with vegetable oils used in building insulation, highlighting the potential of plant-based materials in improving functional properties. While these developments are promising, most published studies have focused on cellulose-based fabrics, and inattention has been given to synthetic fibres such as 100% polyester, which are inherently more resistant to chemical modifications, due to their hydrophobic structure.

The main objective of this study is to assess the feasibility of using coconut oil–based softeners at varying concentrations (2%, 5%, and 10%) as a sustainable alternative to synthetic fabric softeners for 100% virgin polyester fabrics to investigate the effect on drapability, stiffness, tensile strength, GSM, pH, and wash durability of prepared fabric samples.

METHODOLOGY

1. 100% virgin polyester woven fabric (120 GSM) was used as the base material for the experiment. The fabric was cut into standard 50 × 50 cm swatches.
2. A coconut oil–based softener emulsion was prepared using food-grade coconut oil and a non-ionic emulsifier (Polysorbate 80) in distilled water. Emulsions were prepared at concentrations of 2%, 5%, and 10% (w/w) coconut oil content, and citric acid was used to adjust the pH. BIO-softener from coconut oil shows a softening effect, due to its Esterquats (a type of

cationic surfactant from fatty acids), which acts as a softening agent by coating the fibres, reducing static cling, and making fabrics feel smoother. Table 1 shows the composition of coconut oil softener emulsions.

Table 1: Composition of Coconut Oil Softener Emulsions

Sample Number	Coconut Oil (% w/w)	Polysorbate 80 (% w/w)	Citric Acid (pH adjuster)	Distilled Water (% w/w)
1	2	1.0	3 drops	97.0
2	5	1.5	3 drops	93.5
3	10	2.5	3 drops	87.5

3. Fabric treatment was carried out using the dip-squeeze-air dry method. Each fabric sample was dipped in the coconut oil softener emulsion for 5 minutes, then manually squeezed using a glass rod to remove excess liquid. The samples were then dried under sunlight at ambient temperature (28–32 °C) for 2-3 hours until completely dry. No mechanical curing or oven heating was used in this process.
4. While analysing the effect of BIO-softener application to reduce fabric stiffness, it was also decided to analyse further changes in fabric GSM, fabric surface pH, drapability, and tensile strength resulting from BIO-softener treatment. Therefore, the following tests were carried out for all treated samples. For each fabric sample, three readings were taken, and the mean value was used for analysis.
    - Drapability using ISO 9073 (ring method)
    - Fabric weight (GSM) via standard fabric cutting and weighing
    - Tensile strength (ISO 13934-1)
    - Stiffness using ASTM D1388 (cantilever method)
    - Surface pH by aqueous extraction and digital pH meter

    To evaluate wash durability, samples were then subjected to one washing cycle as per ISO 105-C01, using a standard non-softening detergent at 40 °C for 30 minutes, followed by rinsing and air drying. After washing, Drapability, Fabric weight, and Stiffness were re-tested.
5. Results were analysed, comparing all three softener concentrations against the untreated control sample. The evaluation was based solely on standardised test results.

Although higher concentrations may improve softness further, 10% was selected as the upper threshold limit due to practical limitations. Concentrations beyond this point resulted in uneven oil deposition**,** surface oiliness**,** and undesirable yellowing**,** which negatively affected the appearance of the fabrics. Additionally, one of the previous research studies indicates that exceeding optimal softener levels can reduce wash durability and also attract dust (Nair *et. al.*, 2020).

RESULTS AND DISCUSSION

The samples were subjected to the following textile physical tests.

(i) Drapability test: Drapability is calculated as the drape coefficient (DC) in this test. The DC and drapability of a fabric have an inverse relationship. More drapability means that the fabric shows higher flexibility with lower DC. While 2% and 5% BIO-softener treatments showed no significant difference in DC, the 10% treatment led to a dramatic improvement in reducing DC by 14.77%, compared to the untreated control sample having DC = 88% as given in Figure 1. It implies that the fabric drapability and flexibility of selected polyester fabric can be increased by applying the prepared BIO- softener. Therefore, it can be shown that a proportionate relationship exists between Polyester fabric drapability and the BIO-softener applied percentage. However, it needs further research to optimise the softener applied percentage In figure 1, further, the drapability and flexibility of all non-treated and treated samples have been increased after washing. This would be due to the removal of softening agents from fabric and mineral deposits and the introduction of more flexible fibres, owing to the disruption of fibre-to-fibre bonds.

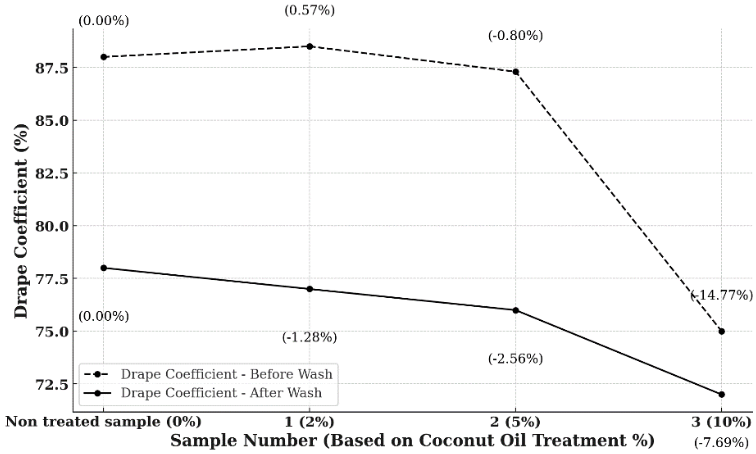

Figure 1: Variations of Drape Coefficient (DC) before and after washing

(ii) Fabric Stiffness Test: Stiffness is measured using flexural rigidity value in the test. Flexural rigidity and fabric stiffness are directly related: a higher flexural rigidity indicates a stiffer fabric. According to Figure 2, before and after washing, DC has significantly reduced with increasing BIO-softener% from 2-10%, both in the warp and weft direction of cut samples. It has been found that 10% treated sample (Sample 3) exhibited the lowest flexural rigidity among the tested samples compared to the non-treated sample. At 10% in sample 3, it shows 22.35% and 22.86% reductions in the warp direction and 5.41% and 23.08% reductions in the weft direction, before wash and after wash, respectively. It means that fabric stiffness can be reduced by applying a higher % of BIO-softener, especially in the warp direction compared to the weft direction of the selected fabric. However, it needs further research to optimise the application of BIO-softener.

Thus, it is a well-known fact that fabric stiffness is generally higher in the warp direction of a fabric than its weft direction, because of the higher density of warp yarns and their orientation during weaving. The warp yarns, running lengthwise, are under greater tension and contribute more to the fabric's structural integrity, resulting in increased bending resistance and overall stiffness in that direction. The decrease in the warp direction rigidity with the application of BIO-softener, will therefore help to increase the fabric flexibility. Another feature in Figure 2 is a slight increase in rigidity, which was observed after washing the samples at every treatment level of applying 2-10% BIO-softener. That would be mainly due to removing applied softener emulsion chemicals on the fabric surface during washing, as well as a combination of factors, such as primarily detergent residue, mineral buildup from hard water, and the drying process. However, comparing Figures 1 and 2, one can assume that the stiffness increase after washing does not show a significant impact on the flexibility of fabrics.

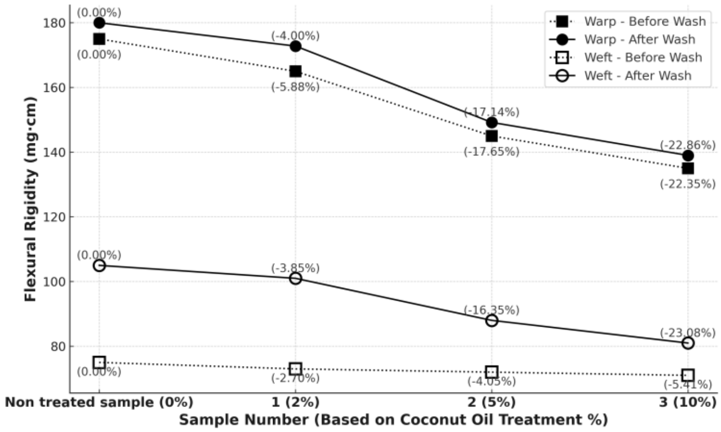

Figure 2: Flexural rigidity variations after the treatments

(iii) GSM and Fabric surface pH tests: Table 2 shows the GSM changes before and after washing the samples. Fabric GSM increased proportionally with applied BIO-softener%, due to formation of surface film coat, hence, the sample 3 with 10% treatment recorded the highest GSM (140.18 g/m^2 before washing) among all tested samples.

Table 2 further indicates a 3-14% reduction in GSM in tested samples after washing, which is given in percentages in Table 2, compared to the GSM of samples before washing. The reason would likely be due to the removal of loosely bound surface residues. However, the post-wash GSM remained consistently higher than that of the untreated control, suggesting that the BIO-softener was largely retained and did not undergo significant degradation after washing. pH tests revealed that all treated samples were within the neutral to mildly alkaline range (7.0–7.3) in tested samples, which is considered safer for skin contact. pH level has a maximum of 4.28% increase with changes in BIO-softener application percentage, compared to non-treated samples, which is not harmful to human skin.

Table 2: GSM and pH value variations under the treatments

Sample number (based on the coconut oil treatment %)	GSM (Before Wash)	GSM (After Wash)	pH
Non treated sample (0%)	115.98	114.99	7
1 (2%)	120.89	116.7 *(-3.46%)*	7.14
2 (5%)	121.85	116.32 *(-4.54%)*	7.3
3 (10%)	140.18	120.44 *(-14.08%)*	7.25

(iv) Tensile Strength test: According to Table 3, tensile strength in the weft direction has reduced with the application of 2% and 5% BIO-softener, but it has increased with 10% treatment. Reduction in tensile strength in samples 1 and 2 in the weft direction may be due to lowering the friction at interlacing points in the fabric structure, but with 10% treatment, it has increased tensile strength in the weft direction, which would be due to higher lubrication between fibres, allowing them to slide more easily and evenly under stress. This can help to distribute the force more uniformly across the fabric, potentially leading to a higher breaking point. Thus, tensile strength in the warp direction has continuously increased after the BIO-softener treatments compared to non-treated samples. The possible reasons would be that the softener's ability to fill gaps between fibres creates a more cohesive structure, improving the fabric's resistance to stretching forces in the warp direction. To validate these observations, statistical analysis (t-test) based on three replicates per sample was done under a 95% significance level and it confirmed that the warp direction increases were significant ($p < 0.05$, where p represents the probability that the observed differences occurred by chance), while the weft variations did not reach to statistical significance ($p > 0.05$). Given the limited number of replicates, these results should be interpreted with caution and validated through further testing.

Table 3: Tensile Strength of tested samples in warp and weft directions under the treatments

Sample number (based on the coconut oil treatment %)	Tensile Strength (N)	
	Warp direction	Weft direction
Non-treated sample (0%)	940	480
1 (2%)	998	454
2 (5%)	996	455
3 (10%)	967	486

CONCLUSION

This study investigated the effect of coconut oil–based BIO-softener on stiffness reduction in 100% virgin polyester woven fabrics, while also analysing drapability, GSM, tensile strength, fabric surface pH, and wash durability. Increasing softener concentration improved flexibility and reduced stiffness, with 10% treatment providing the highest and most balanced improvement, though exceeding this level caused oiliness and non-uniform appearance. All treated samples maintained skin-friendly pH values, and GSM increased proportionally with treatment. Tensile strength in the warp direction was consistently and significantly enhanced ($p < 0.05$), with the 10% concentration showing the greatest improvement, while weft variations were minor and statistically insignificant ($p > 0.05$). Overall, coconut oil–based BIO-softener proved effective in improving fabric flexibility and handle without compromising structural integrity. Future studies should include the evaluation of thermal comfort and subjective hand-feel to provide a more holistic understanding of fabric performance.

REFERENCES

Fahmy, H., & Amr, A. (2024). *Environmental concerns of petroleum-based textile softeners: Challenges and alternatives*. Journal of Sustainable Textile Chemistry, 12(1), 45–56.

Nair, M., Radhakrishnan, R., & Kumar, V. (2020). *Softening performance of coconut oil and vegetable ghee blends on cotton and viscose fabrics*. Indian Journal of Natural Fibers and Finishing, 8(3), 121–130.

Trajković, D., Milanović, J., Nikolić, M., & Dudić, S. (2017). *Application of vegetable oil treatments on recycled textile fibers for thermal insulation*. Journal of Industrial Textiles, 47(6), 985–1002.

Periyasamy, A. P., & Militky, J. (2017). Effect of natural oils as softeners on cotton fabrics: A sustainable finishing approach. *Journal of Cleaner Production, 149,* 425–432. https://doi.org/10.1016/j.jclepro.2017.02.113

Hearle, J. W. S., Grosberg, P., & Backer, S. (1969). *Structural mechanics of fibers, yarns, and fabrics* (Vol. 1).Wiley-Interscience.

Hu, J., & Chan, C. K. (1998). Effect of fabric structure and finishing on the mechanical properties of woven fabrics. *Textile Research Journal, 68*(10), 772–779. https://doi.org/10.1177/004051759806801010