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Supplementary Materials for

Chemical recycling of mixed textile waste

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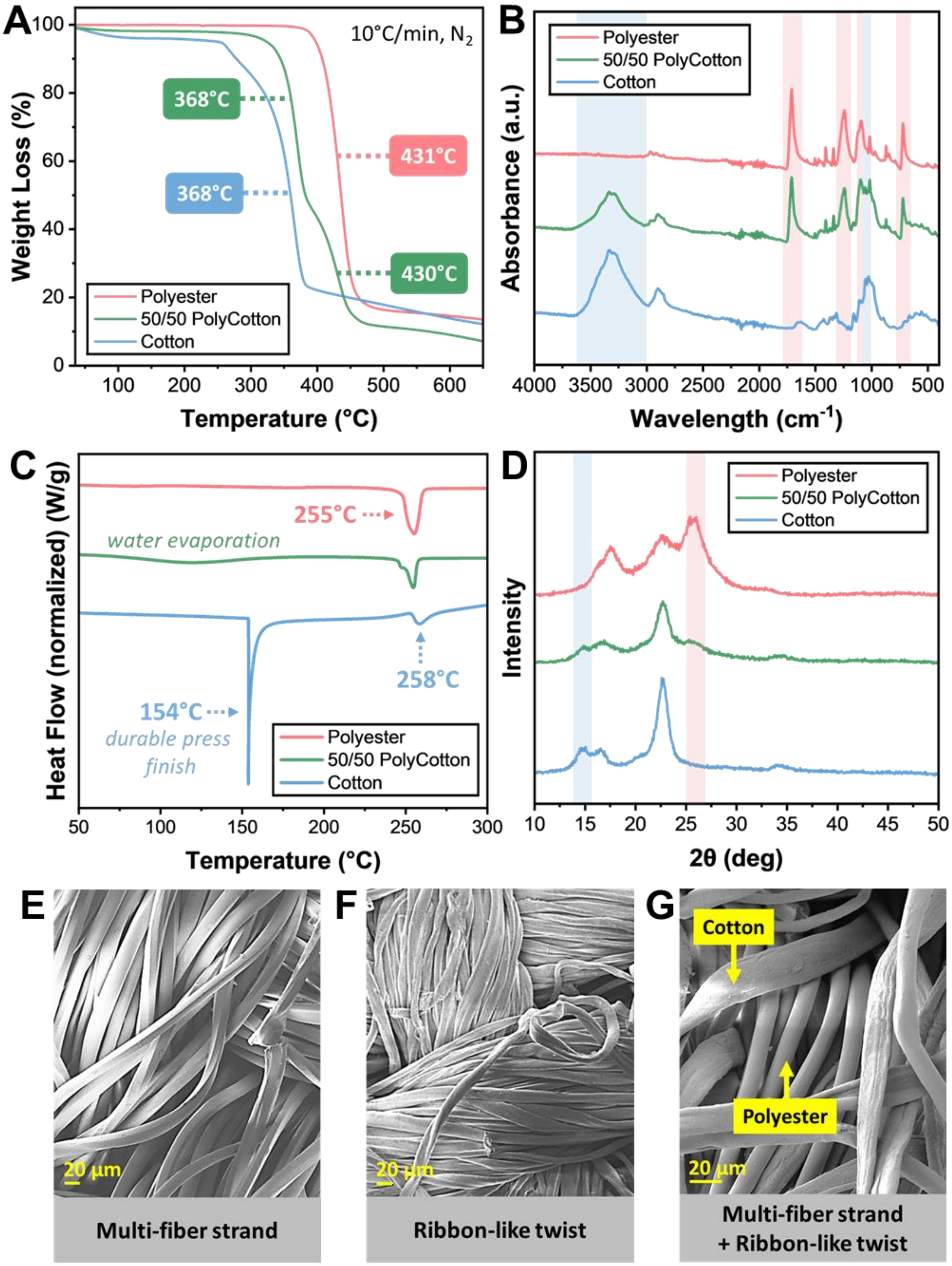
This PDF file includes:

Feedstock Characterization



Multi-fiber strand

Ribbon-like twist

Multi-fiber strand + Ribbon-like twist

Figure S1. Characterization of 100% polyester and 100% cotton textiles. (A) TGA, (B) FTIR, (C) DSC, (D) XRD, and SEM micrographs of (E) 100% polyester, (F) 100% cotton, and (G) 50/50 PolyCotton T-shirt.

Figure S1A displays TGA profiles for various samples. The polyester textile exhibits a single peak at 430 °C due to PET decomposition. The cotton textile shows three peaks: water loss below 100 °C (**Table S1**), durable press degradation at 280 °C, and cotton decomposition at 360 °C (**Figure S2**). Cotton's water absorption is attributed to hydroxyl groups, serving as moisture absorbers (*67*), and durable press is typically utilized for textiles with a high content of cellulosic fibers to resist shrinkage and enhance wrinkle recovery (*68*). The 50/50 PolyCotton T-shirt exhibits peaks for both polyester and cotton without durable press. Prolonged heating results in carbonized residues for all samples (*69*).

FTIR (**Figure S1**B) examined the chemical structure of all samples. Polyester's peaks (1700, 1200, 1100, 700 cm^{-1}) are in light pink; cotton's peaks (3300 – 3600, 1000, 1100 cm^{-1}) in light blue. The 50/50 PolyCotton T-shirt displays key peaks for both polyester and cotton.

In **Figure S1**C, the polyester DSC curve displays a melting peak at 255 °C. Cotton's curve shows a peak at 258 °C and a sharp event at 154 °C related to durable press decomposition. The 50/50 PolyCotton T-shirt exhibits peaks for polyester and cotton, along with a broad endothermic peak (80 – 160 °C) indicating water evaporation. Durable press treatments alter moisture-wicking properties, seen in the absence of a water evaporation peak in 100% cotton (*68*).

XRD examined textile crystallinity (**Figure S1**D), color-coded for polyester and cotton peaks. Polyester shows peaks at $2\theta = 17.5°$, 22.5°, and 26°; cotton has a strong peak at $2\theta = 23°$ and a weaker peak at $2\theta = 15°$. The 50/50 PolyCotton T-shirt displays all these peaks. Reduced peak intensity in the T-shirt suggests decreased crystallinity in both polyester and cotton, likely due to processing (*e.g.*, temperature or mechanical deformation during T-shirt making) disrupting crystalline regions (*28*).

SEM micrographs in **Figure S1**E-G confirm the structures of 100% polyester and 100% cotton textiles (woven) and the 50/50 PolyCotton T-shirt (knit) (**Figure S3**). Cotton fibers show a ribbon-like twist, while polyester fibers resemble multi-fiber strands. The 50/50 PolyCotton T-shirt displays fibers with characteristics of both polyester and cotton.

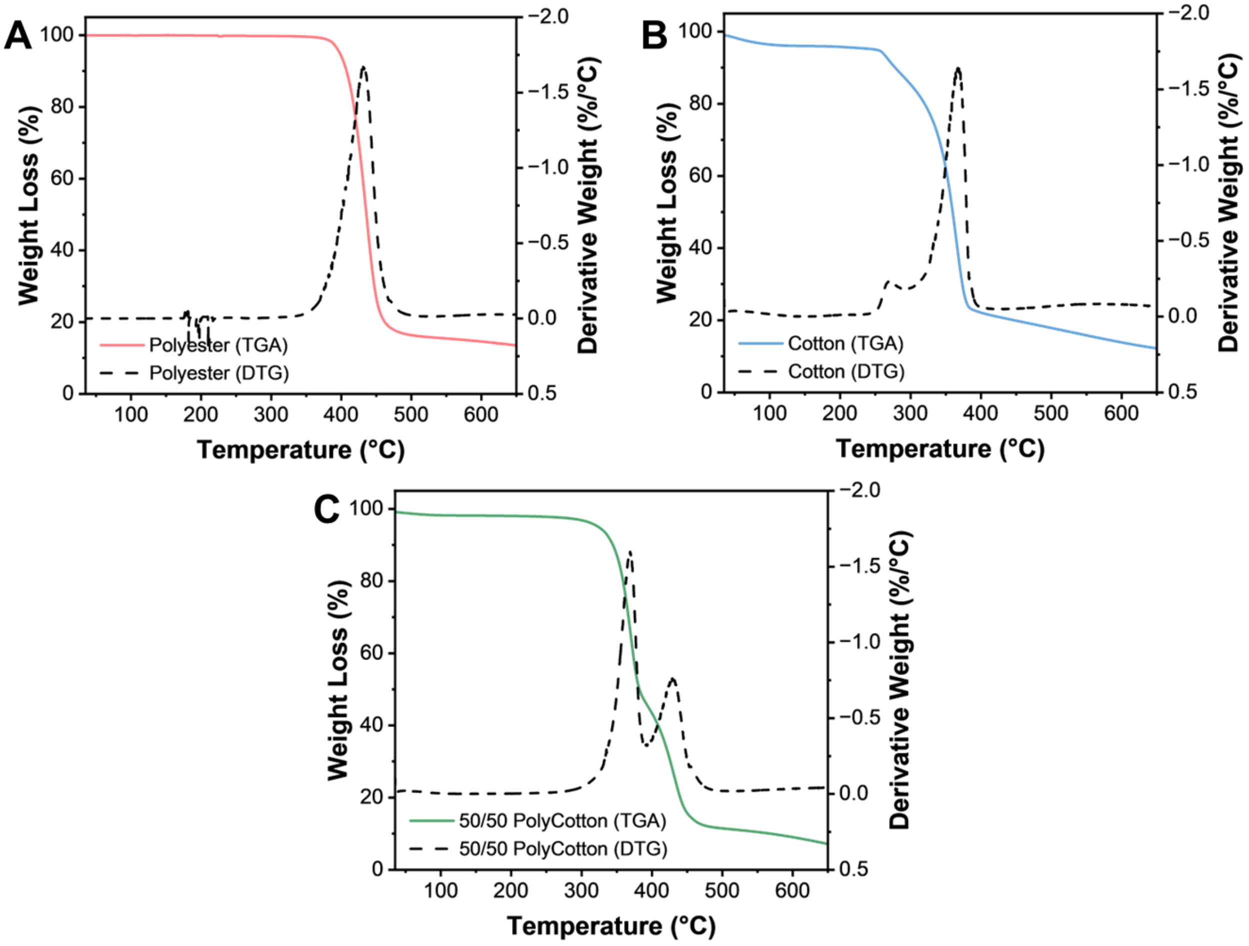


Figure S2. TGA and DTG of pure textiles. (A) white 100% polyester textile, (B) white 100% cotton textile, and (C) white 50/50 PolyCotton T-shirt at 35 °C to 650 °C for 10 °C/min rate under a N_2 atmosphere.

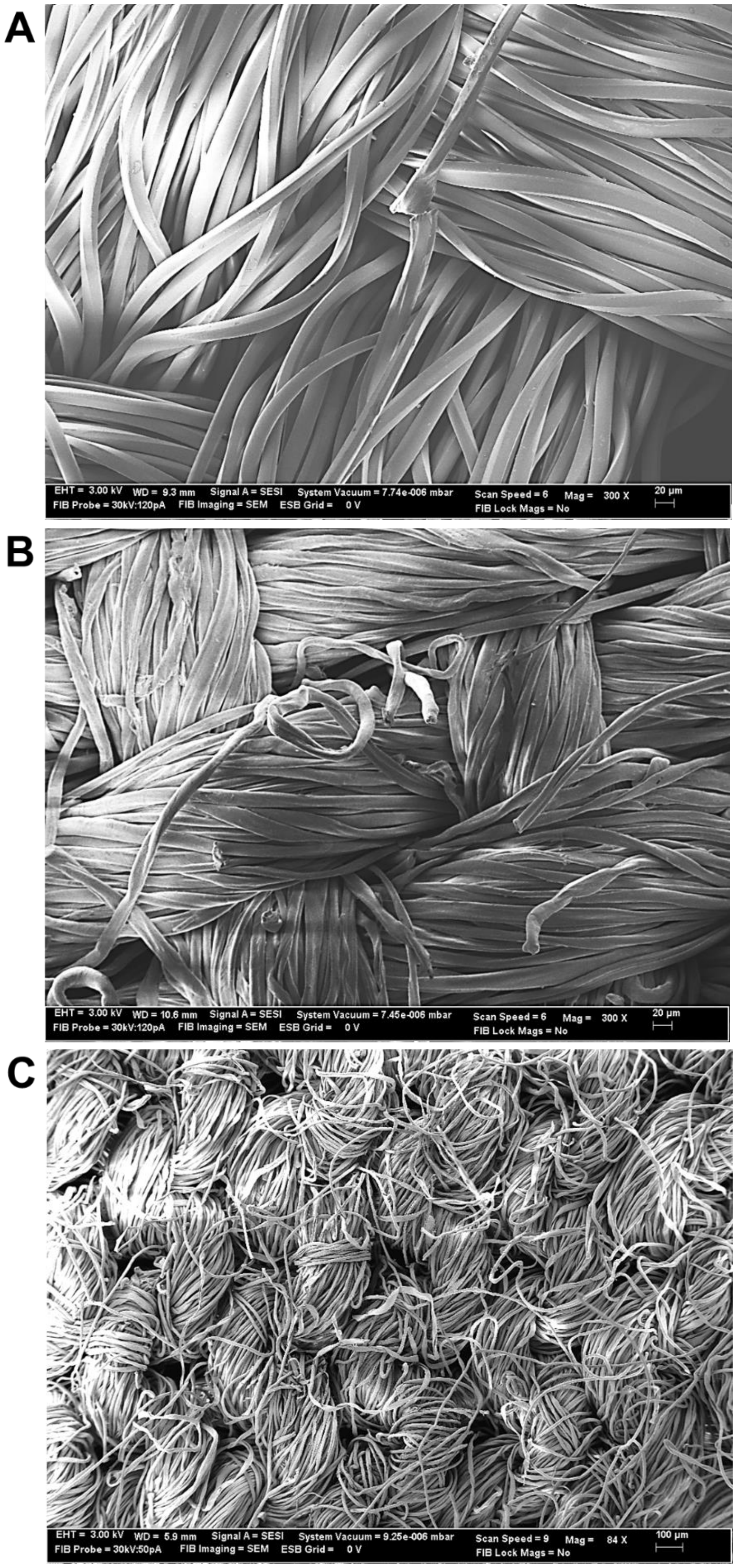


Figure S3. SEM micrographs of pure textiles. (A) 100% polyester, (B) 100% cotton, and (C) 50/50 PolyCotton T-shirt.

Table S1. Moisture content of 100% polyester and 100% cotton textiles. Both textiles were air-dried in the oven at 70 °C for 1.5 h.

Textile	**Mass**		
	Initial (g)	**Final (g)**	**Mass Loss (%)**
100% Polyester	0.492	0.487	1
100% Cotton	0.477	0.452	5

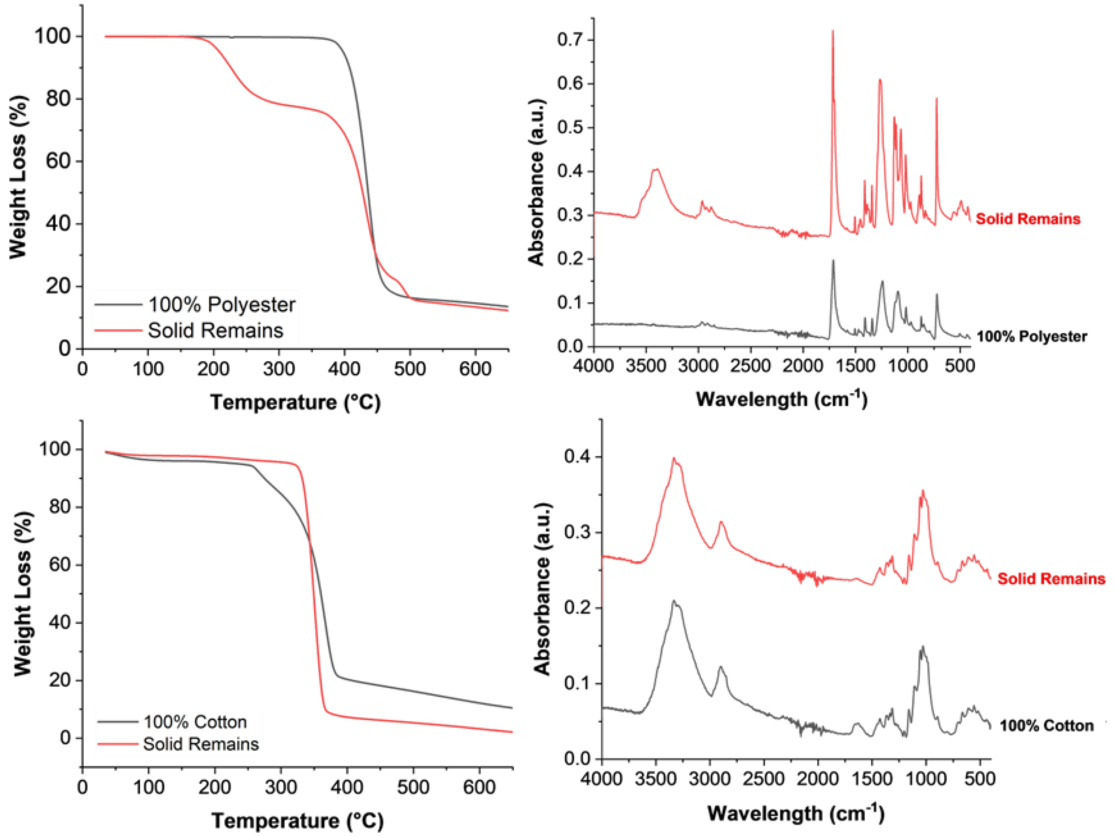


Figure S4. Effect of glycolysis on polyester and cotton. TGA and FTIR of 100% polyester (top) and 100% cotton (bottom) before and after MW-assisted depolymerization using ZnO.

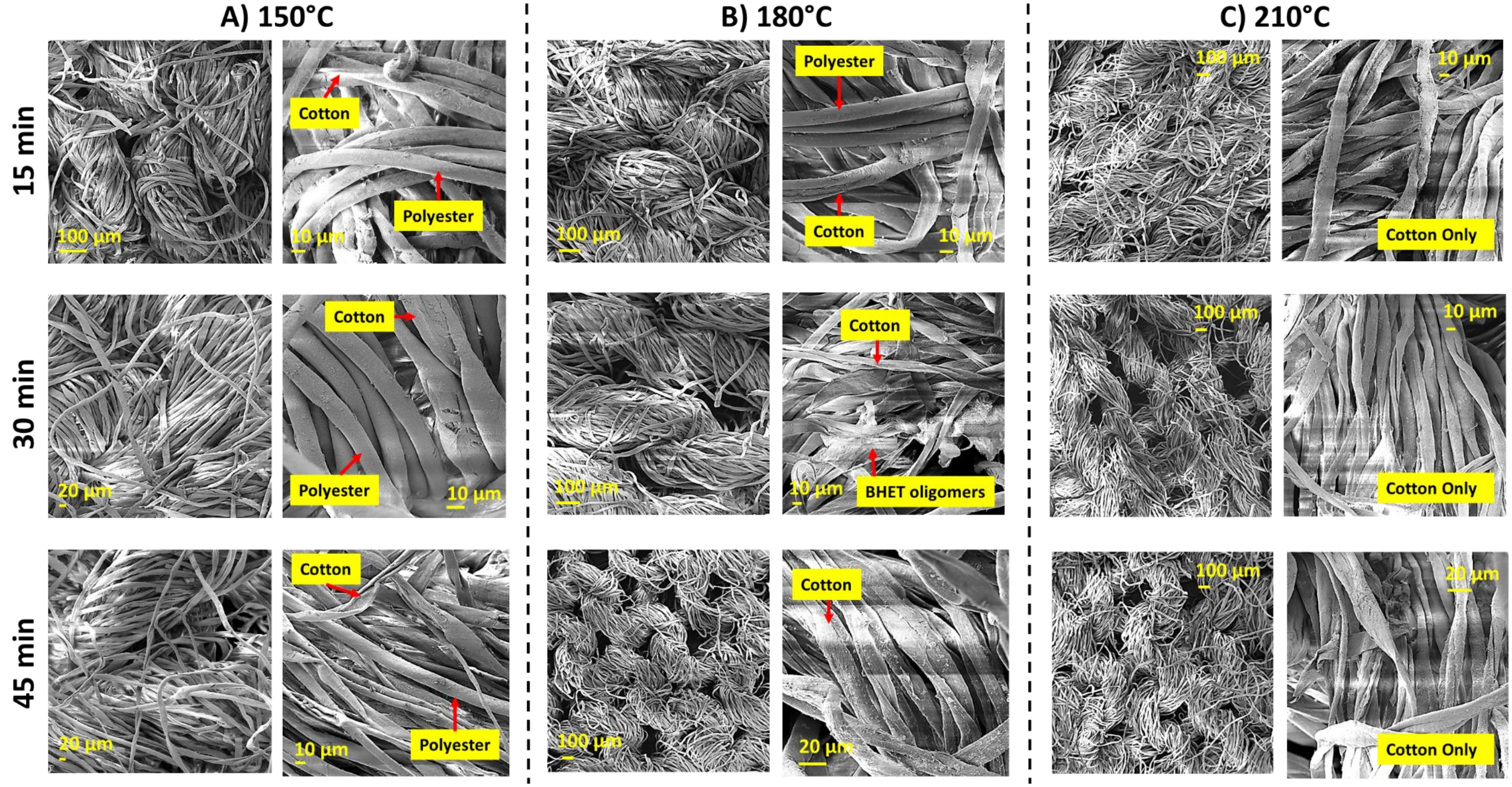


Figure S5. SEM micrographs of 50/50 PolyCotton remaining residues after MW-assisted glycolysis. A) 150°C, B) 180°C, and C) 210°C at varying reaction time.

Table S2. XRF of textile samples.

	100% Polyester									**White 100% Cotton**	**Blank**
	Blue	**Red**	**Yellow**	**Anti-Microbial**	**Anti-Static**	**Water & stain resistant**	**UV Resistant**	**Fire Resistant**	**White**		
Ti	✓	✓	✓	✓		✓	✓	✓	✓		
Fe	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cl	✓	✓	✓	✓	✓	✓	✓	✓		✓	
S	✓	✓	✓	✓	✓		✓	✓		✓	
Si	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Ca		✓					✓	✓		✓	✓
Ni		✓			✓					✓	✓
P								✓			
K	✓		✓	✓	✓		✓	✓		✓	✓
Br	✓						✓	✓			
Rb								✓			
Ru								✓			
Mo						✓	✓				
Ag	✓				✓						
Mg										✓	

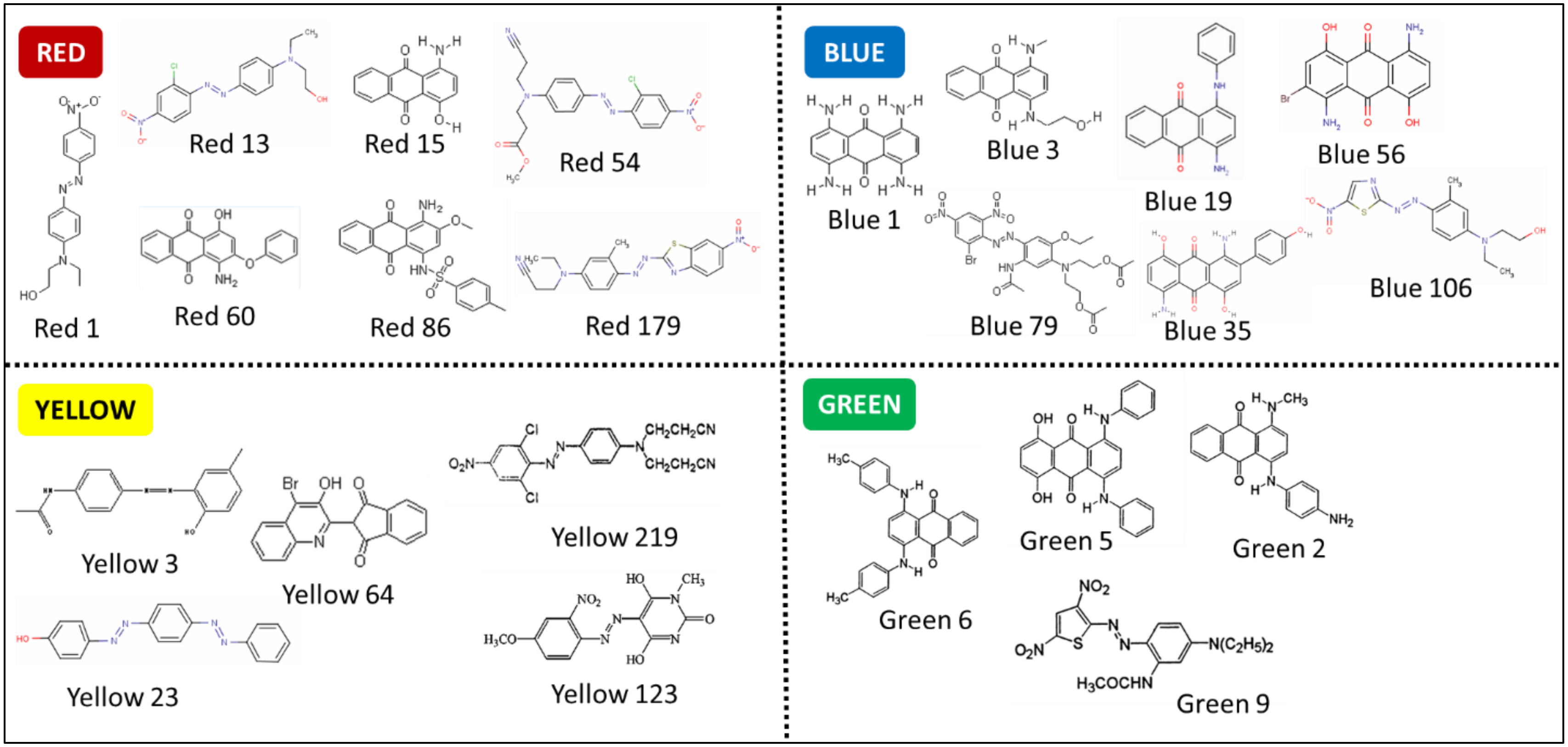


Figure S6. Chemical structure examples of disperse dyes primary colors. Primary colors include red, blue, yellow, and green.

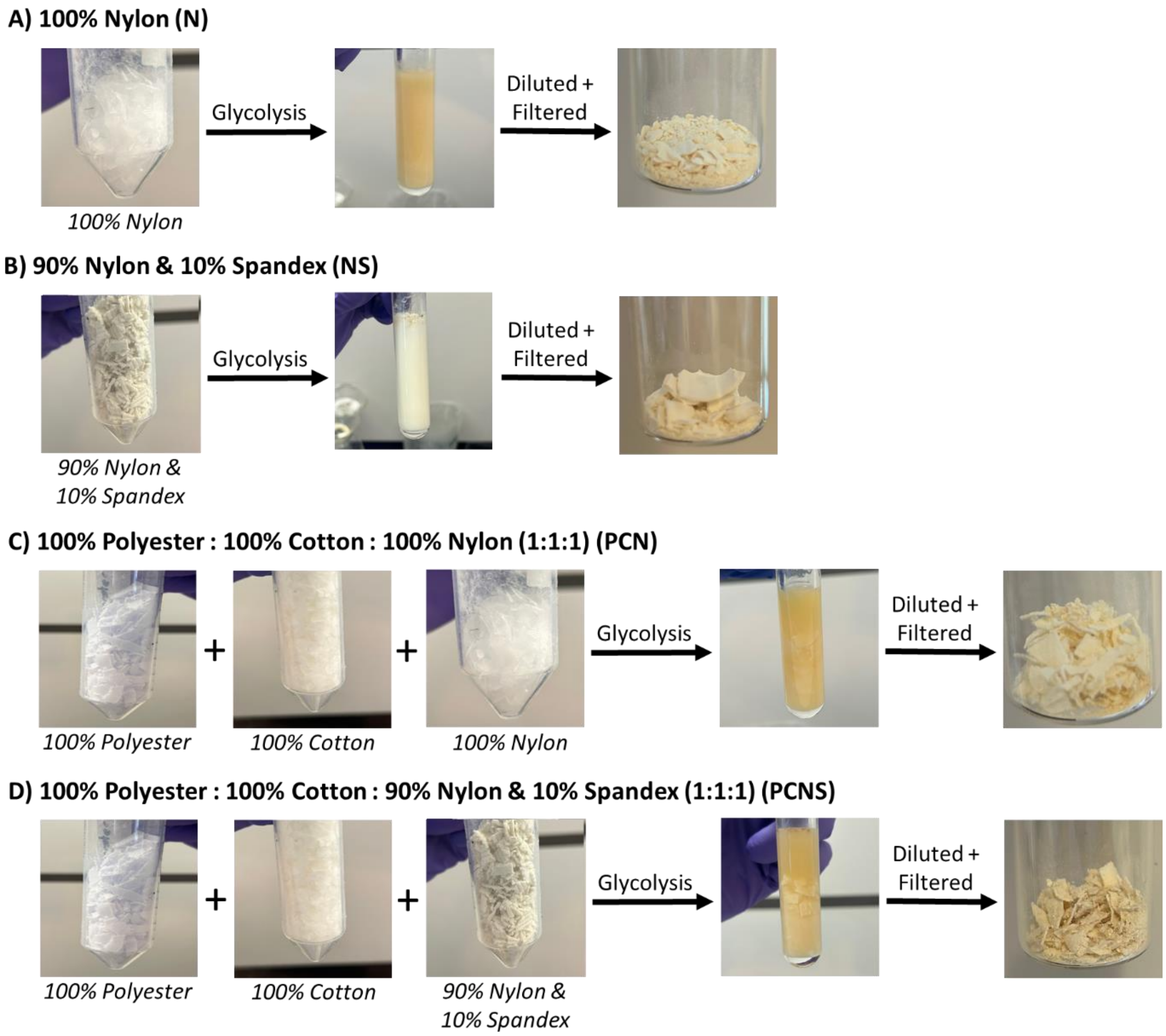


Figure S7. Polyester glycolysis in the presence of cotton, nylon, and spandex. Reaction conditions: 0.5 g textile, 5 mg ZnO, 5 mL EG, 210 °C, 45 min.

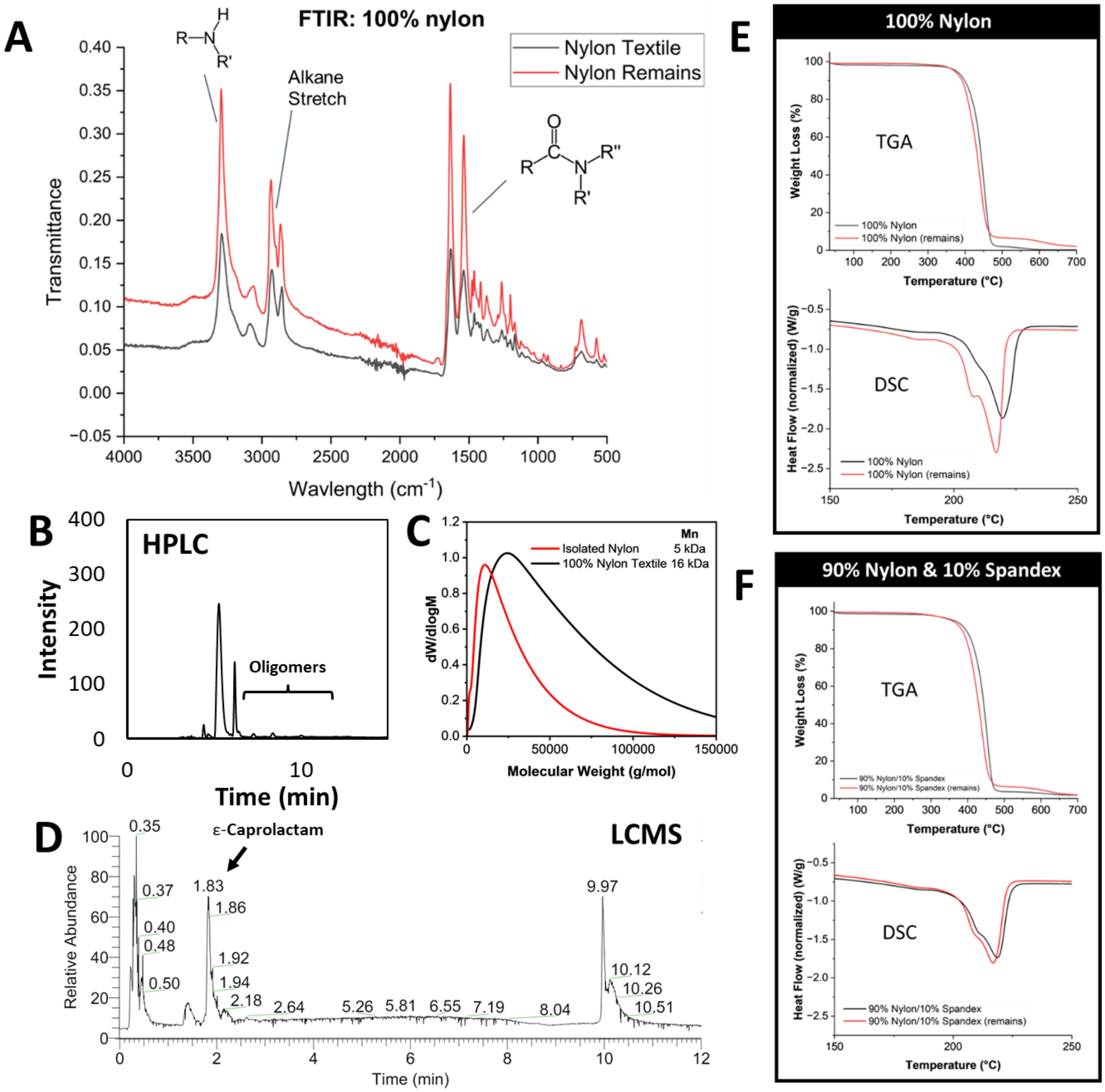


Figure S8. Effect of glycolysis on nylon and spandex. (A) FTIR and (C) GPC spectra of 100% nylon textile before and after glycolysis. (B) HPLC and (D) LCMS spectra of 100% nylon product solution after glycolysis. TGA and DSC of (E) 100% nylon and (F) 90% nylon/10% spandex textiles and solid residues.

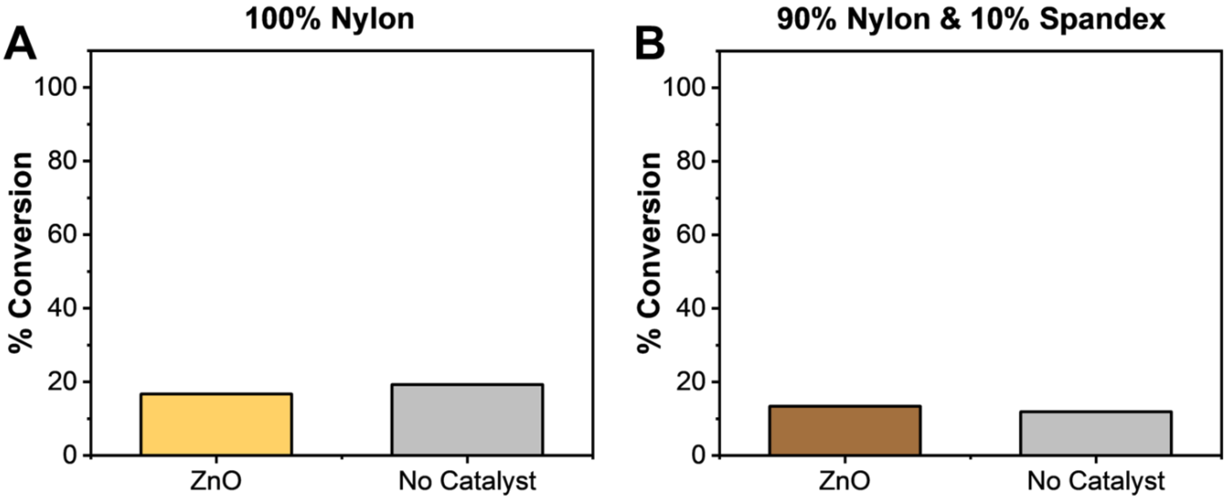


Figure S9. Catalyst effect on nylon and spandex. MW-assisted depolymerization of A) 100% nylon and B) 90% nylon/10% spandex textiles using ZnO. Reaction conditions: 0.5 g textile, 5 mg ZnO, 5 mL EG, 210 °C, 45 min.

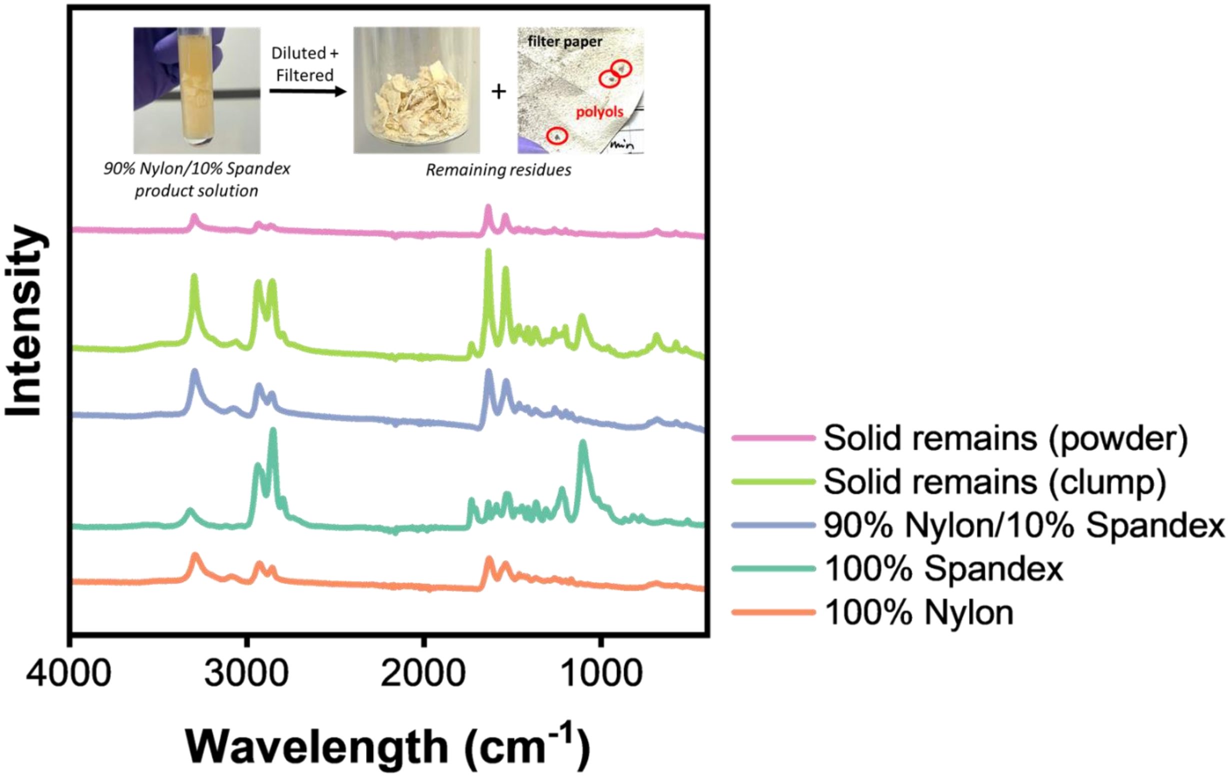


Figure S10. FTIR of 90% nylon/10% spandex remaining solids upon glycolysis. Reaction conditions: 0.5 g textile, 5 mg ZnO, 5 mL EG, 210 °C, 45 min.

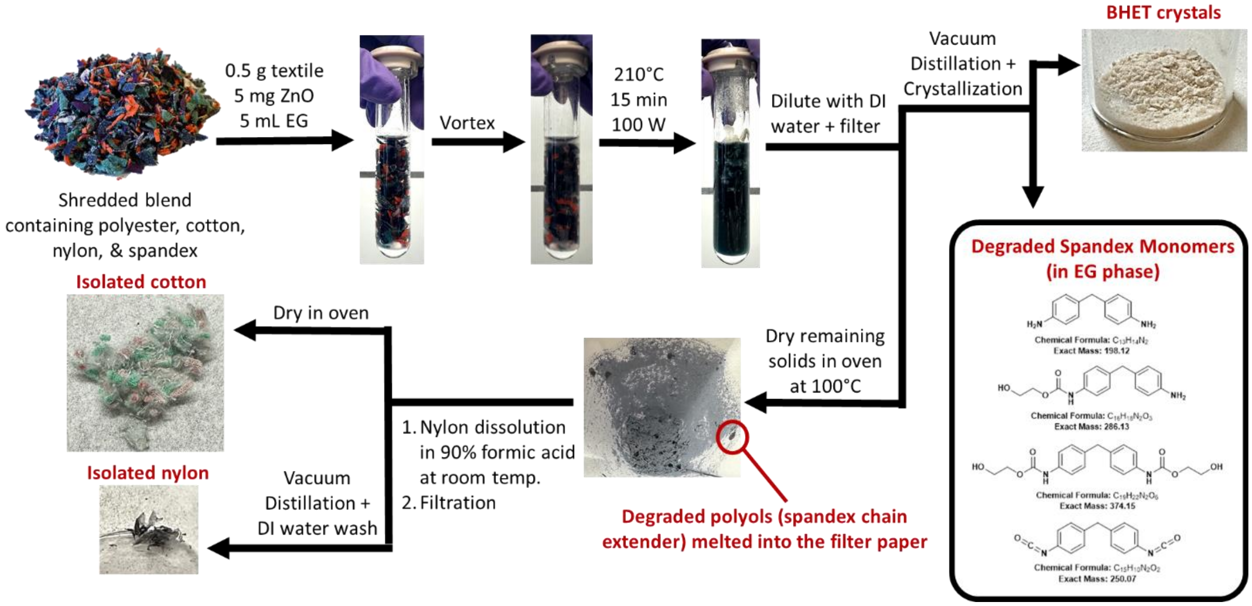


Figure S11. Proposed process for recycling of real mixed textile waste. Reaction conditions: 0.5 g textile, 5 mg ZnO, 5 mL EG, 210 °C, 15 min.

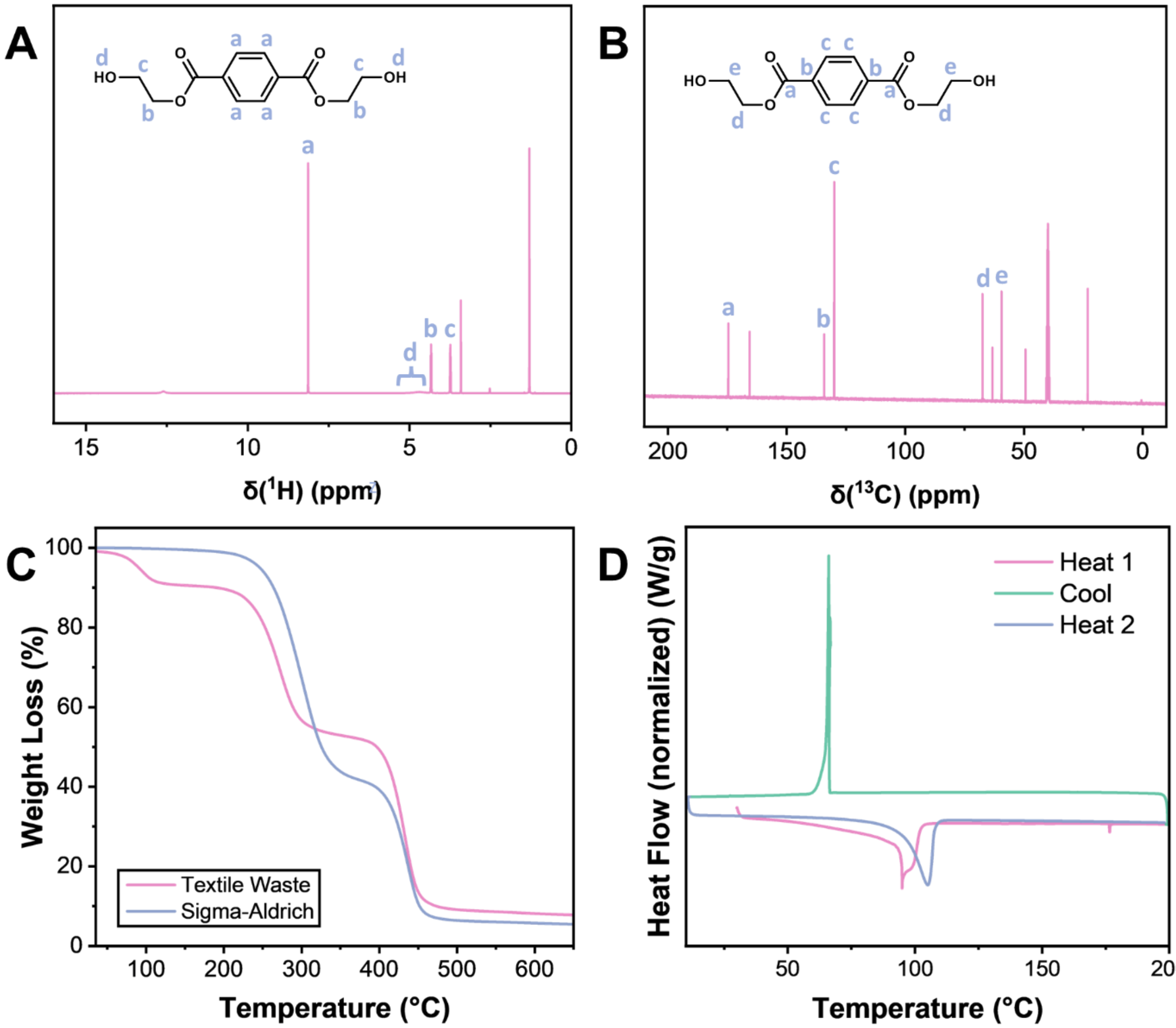


Figure S12. **Characterization of recovered BHET after 1st crystallization.** A) ^{1}H-NMR spectra, B) ^{13}C-NMR spectra, C) TGA, and D) DSC of BHET obtained from the microwave-assisted glycolysis of mixed textile waste using ZnO catalyst.

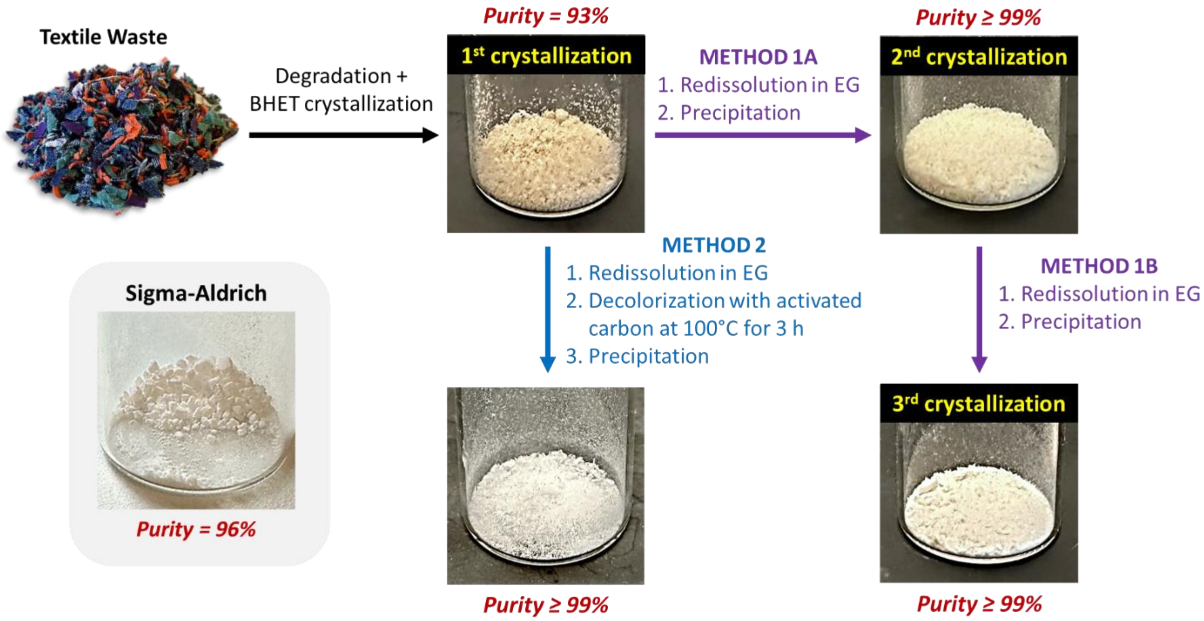


Figure S13. BHET purification. Color comparison of BHET crystals obtained from textile waste (before and after subsequent purification) vs. Sigma-Aldrich.

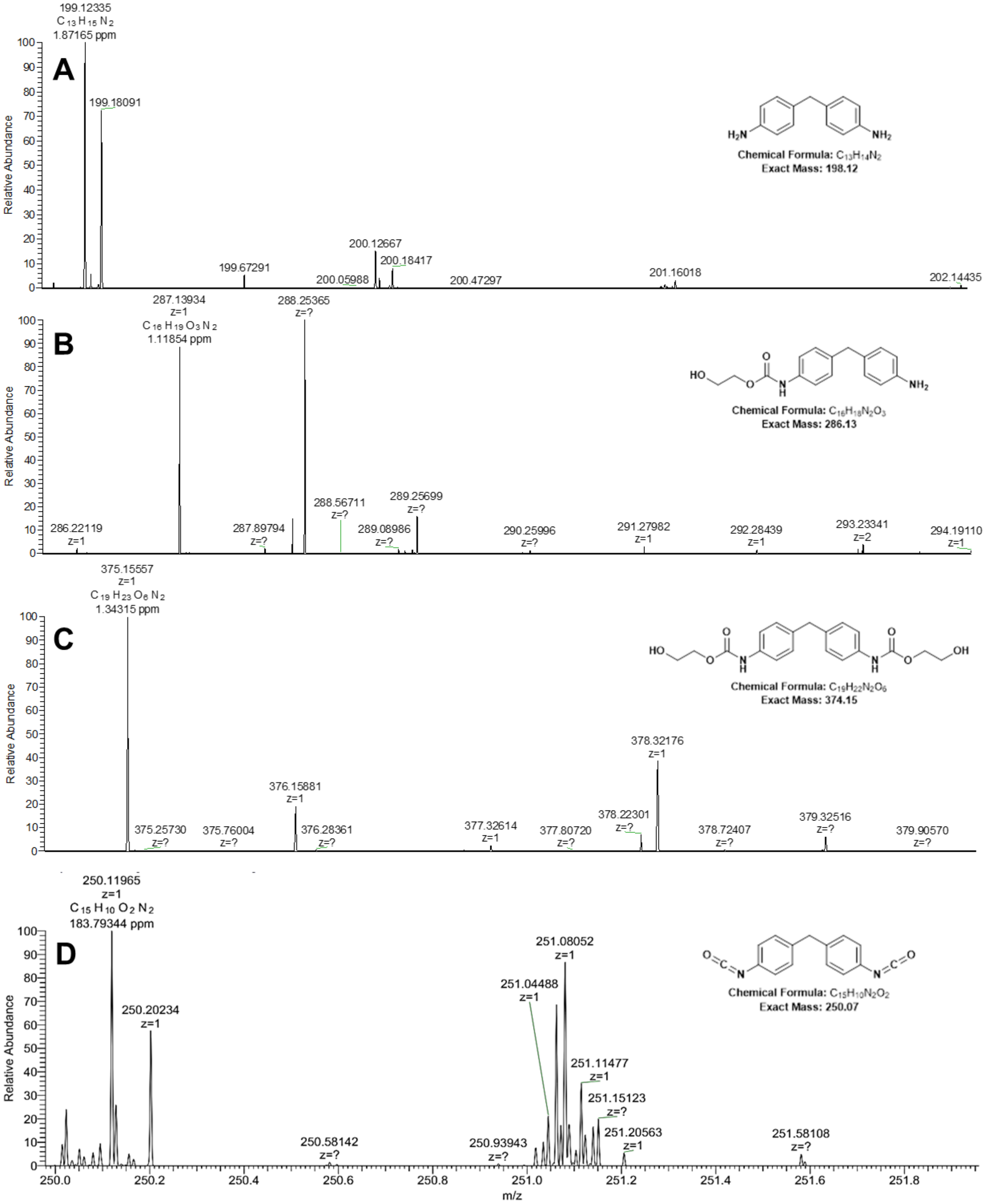


Figure S14. Detection of spandex monomers in product solution by LCMS. EG was removed prior to analysis and the remaining residue was dissolved in MeOH.

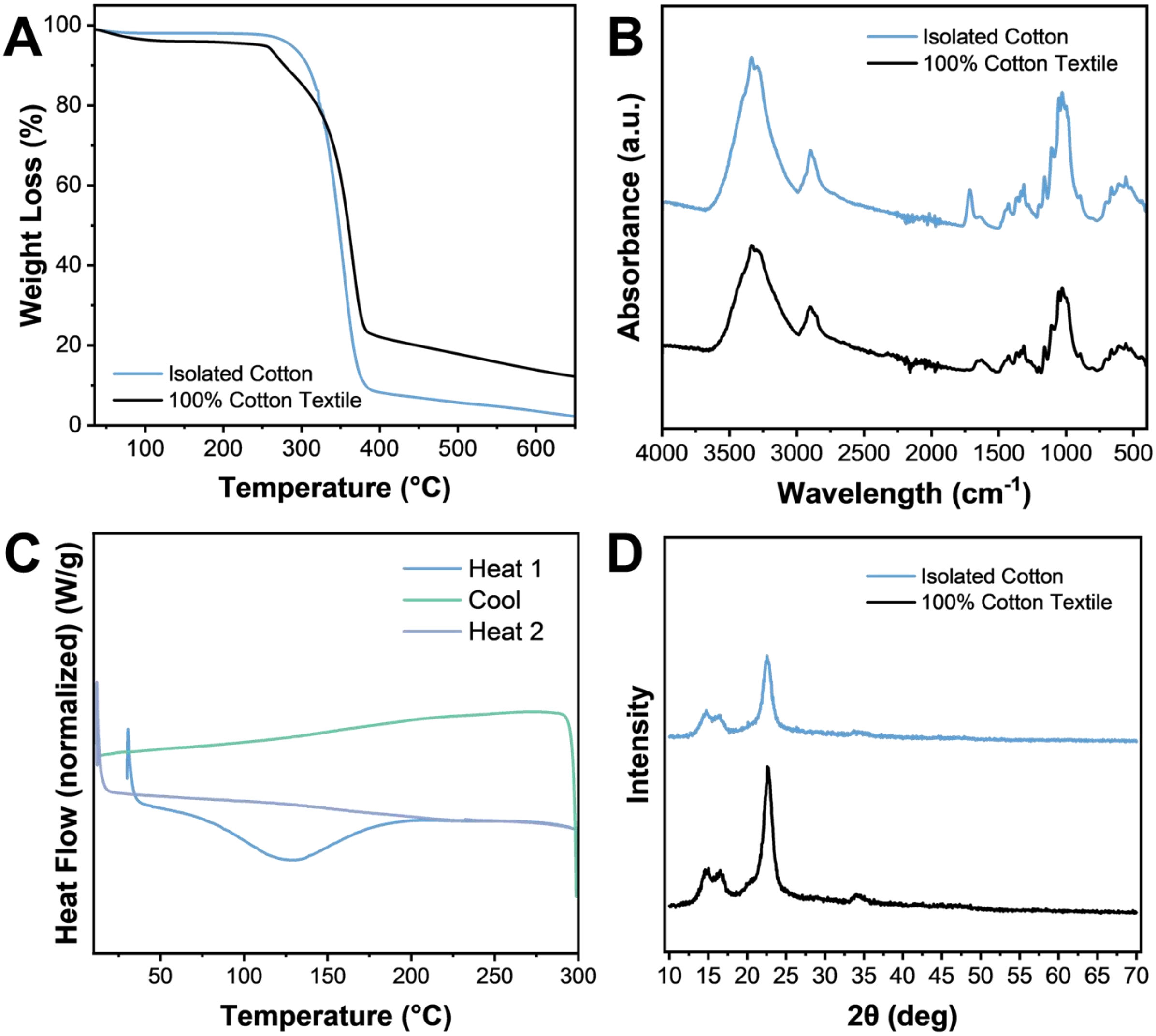


Figure S15. Characterization of recovered cotton. A) TGA, B) FTIR, C) DSC and D) XRD of isolated cotton obtained from the microwave-assisted glycolysis of mixed textile waste using ZnO catalyst.

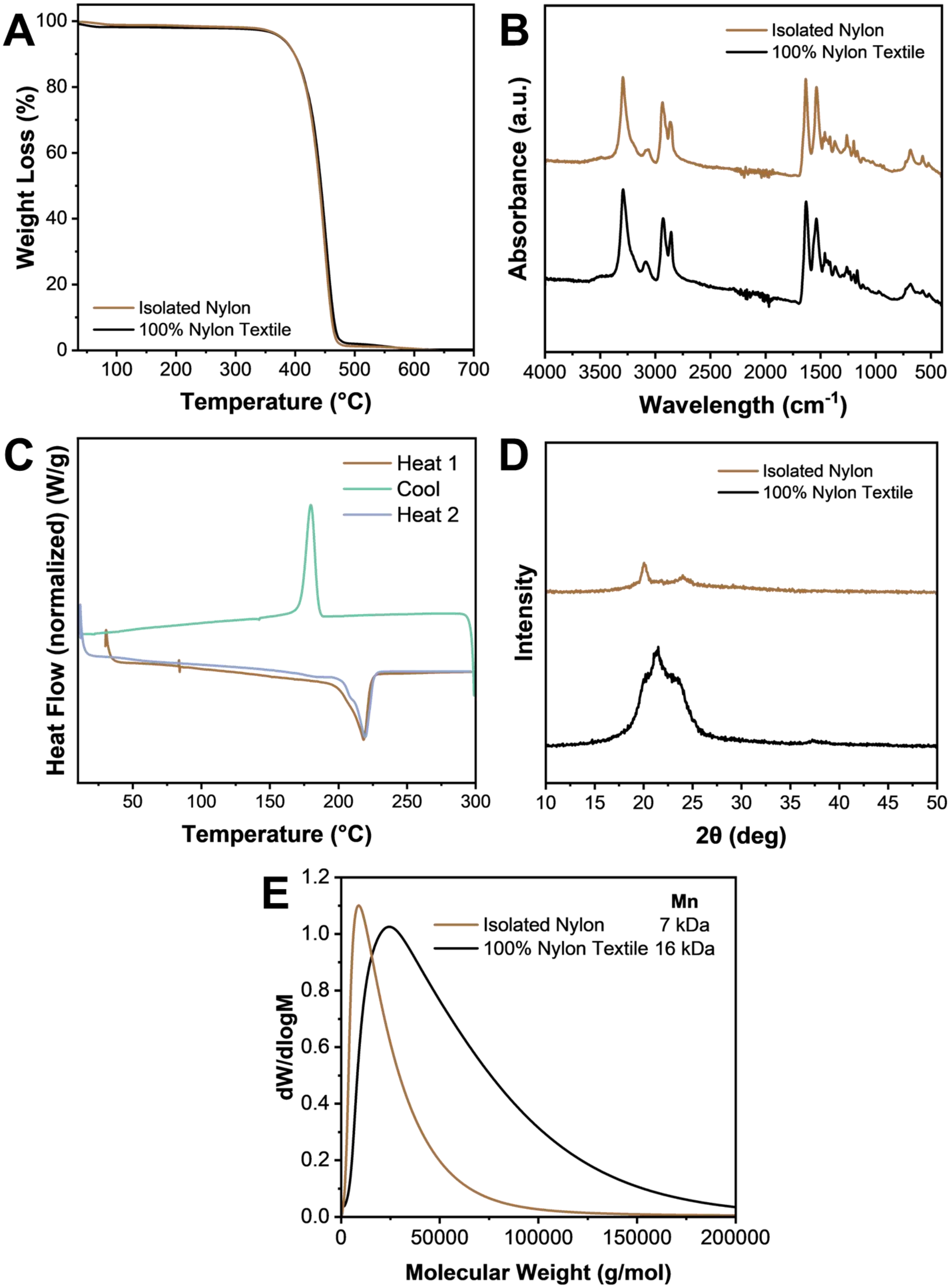


Figure S16. Characterization of recovered nylon. A) TGA, B) FTIR, C) DSC, and D) XRD of isolated nylon obtained from the microwave-assisted glycolysis of mixed textile waste using ZnO catalyst.

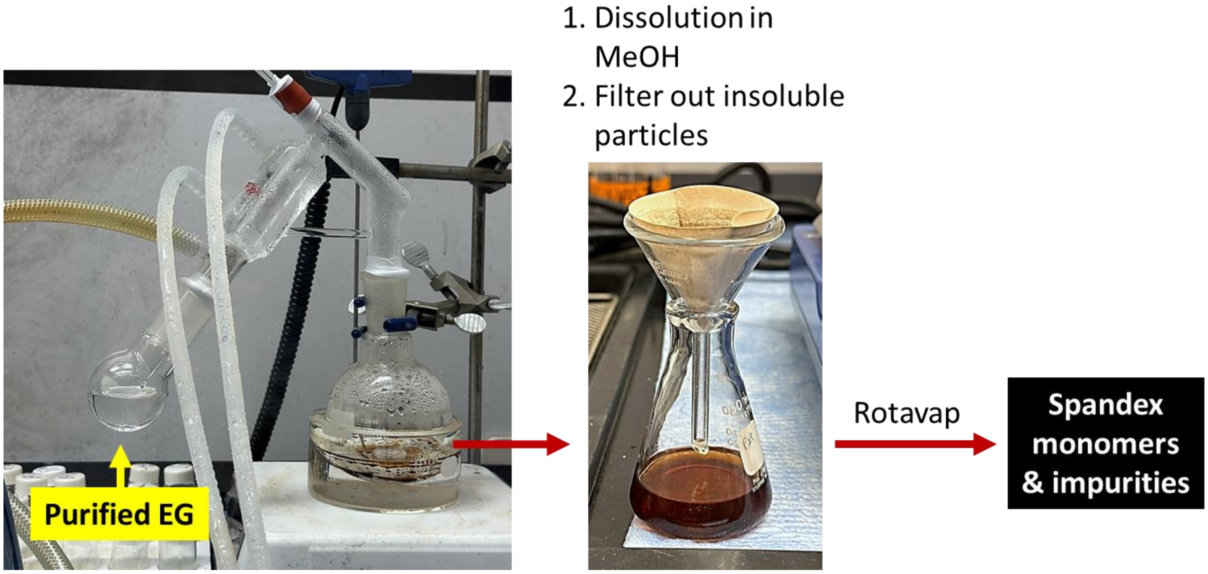


Figure S17. Spandex monomers recovery by removing EG through vacuum distillation. The remaining residue was collected with MeOH. Insoluble particles were removed prior to spandex monomers recovery.

Process development and techno-economic analysis.

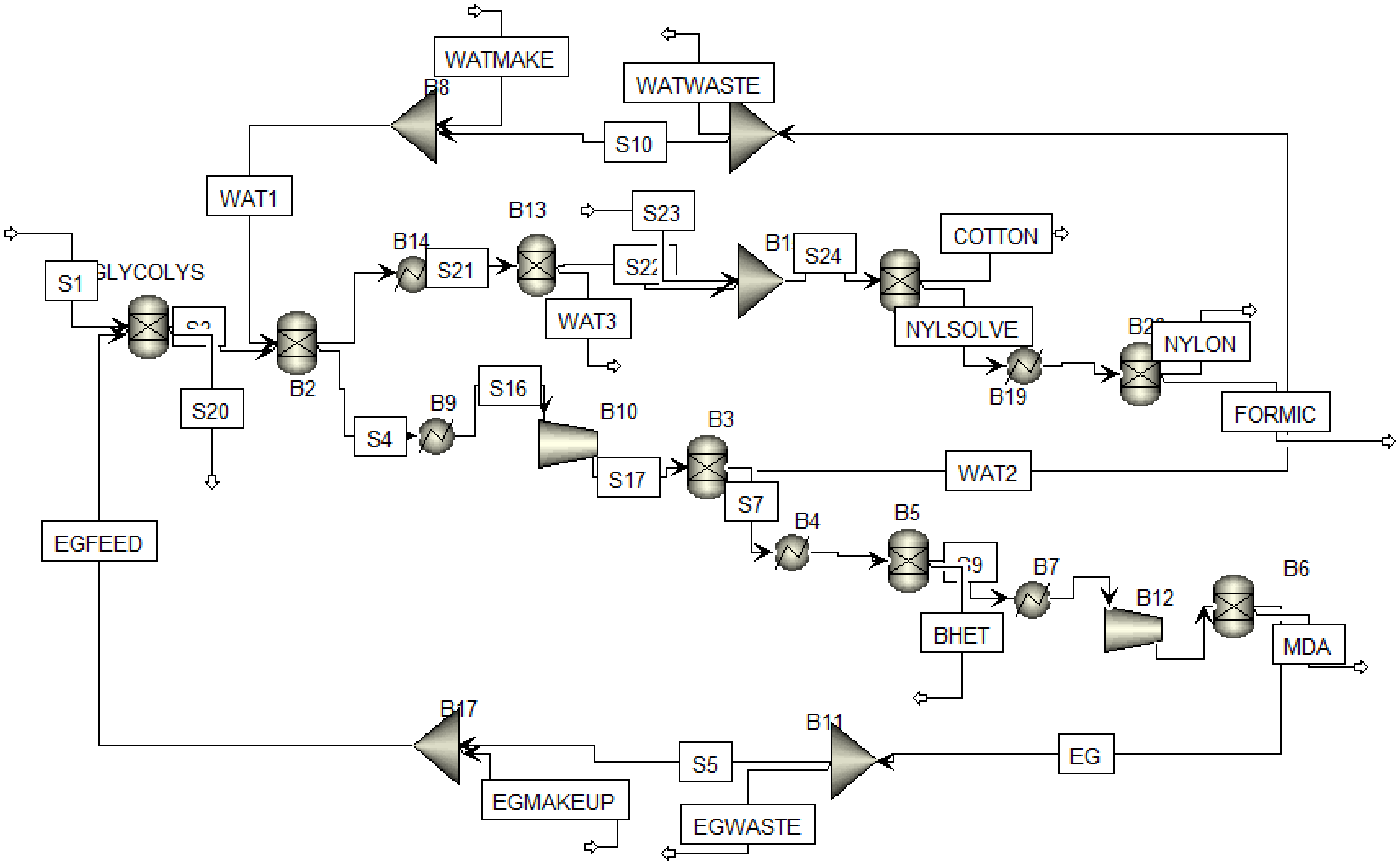


Figure S18. Process flowsheet of mixed textile waste recycling. Process flowsheet was developed in ASPEN Plus.

Table S3. Flowrates for process streams.

	BHET	**COTTON**	**EG**	**FORMIC**	**MDA**	**NYLON**	**FEED**	**EGMAKEUP**
Mass Flows (kg/hr)	317.05	93.32	5496.76	12000.00	57.06	32.57	500.00	550.00
COTTON	0.00	93.32	0.00	0.00	0.00	0.00	93.32	0.00
EG	0.00	0.00	5496.76	0.00	0.00	0.00	0.00	550.00
BHET	317.05	0.00	0.00	0.00	0.00	0.00	317.05	0.00
WATER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NYLON	0.00	0.00	0.00	0.00	0.00	32.57	32.57	0.00
FORMIC ACID	0.00	0.00	0.00	12000.00	0.00	0.00	0.00	0.00
MDA	0.00	0.00	0.00	0.00	57.06	0.00	57.06	0.00

Table S4. Overall cost distribution for two cases.

Total costs (USD/year)	**Low**	**High**
Capital Cost	\$6,489,103.22	\$6,489,103.22
Operating Cost	\$92,002,865.47	\$92,335,443.10
Raw material Cost	\$83,597,167.67	\$83,905,109.92
Product Sales	\$85,339,601.32	\$148,663,134.84

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