Product Development from End-of-Use Cotton Textiles to Reclaim Value from Waste

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Cotton fiber, commonly used in apparel and home textile products, is the second most widely used textile with a global production of 26.2 million tonnes and 24.4% textile fiber market share in 2020 (Textile Exchange, 2021). The huge amount of textile production and consumption generates a large quantity of textile waste after consumers' use. In 2018, the U.S. generated 17.03 million tons textile waste, among which 2.51 million tons (14.7%) were recycled, 3.22 million tons (18.9%) were combusted with energy recovery, and 11.3 million tons (66.4%) were landfilled (U.S. Environmental Protection Agency, 2021). Cotton textile can be recycled either mechanically or chemically (Textile Exchange, 2021). Chemical recycling of cotton textile waste is to dissolve cotton in organic solvent and then spun into regenerated cellulosic fibers using a wet spinning process (Asaadi et al., 2016; Haule, Carr, Rigout, 2016). Mechanical textile recycling is to shred textile scraps into fibrous form (Yasin, Behary, Curti, & Rovero, 2016; Lewis, Park, Netravali, & Trejo, 2017).

The purpose of this research was to reclaim the value of end-of-use cotton apparel products by developing textile fabrics and products using the fabrics from end-of-use apparel. The researchers collected used cotton apparel products that cannot be sold in Goodwill stores. In addition to end-of-use apparel, the researchers also used a limited amount of other cotton textile waste (e.g., leftover textile fabrics from school projects and deadstock fabrics) and a very small amount of new cotton textiles (e.g., fibers and yarns) in the textile development.

After removing non-textile materials such as zippers and buttons from the end-of-use garments, the researchers shredded end-of-use textiles (overall more than 80% cotton content) using scissors or a textile shredder (Taskmaster® Model TM8512). The researchers carded a mixture of shredded textiles, new cotton sliver, and recycled fibers (acquired as a packaging material, fiber content unknown) to develop batting that can be used in nonwoven production. The researchers also used scissors or a rag cutter (Bliss Model A) to cut the end-of-use textiles to ¼ to 1 inch wide strips that can be used as "yarns" in the weaving or tufting processes. To increase the length of the fabric strips and make "continuous yarns", the researchers knotted or sewed the fabric strips.

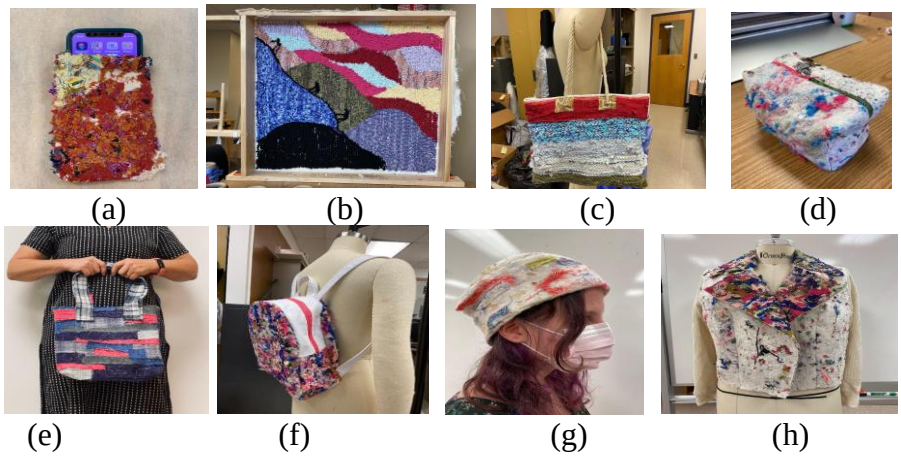
Nonwoven, woven, quilted, and loop tufting fabrics were developed from end-of-use cotton garments and other textile materials. The needle punched nonwoven fabric was developed using a Feltloom (Model Lexi, Feltloom, Sharpsburg, KY). There were two or three layers of materials used in the Feltloom nonwoven development. The ground fabric (bottom layer) was a fabric cut from end-of-use garment. The middle layer (which is optional and can be skipped) was recycled textile fiberweb. There were two types of top layer material, i.e., the batting material and shredded end-of-use textile waste. The woven fabrics were developed by two looms, i.e., a Macomber Add-a-harness floor loom and a frame loom, using new cotton yarn as warp yarns and

narrow strips cut from end-of-use cotton apparel as filling "yarns." Water soluble stabilizer Solvy was used in the confetti quilting process. There were two ways to develop confetti quilting fabric: with a big piece fabric as a base or without a base. When a base fabric was used, the shredded textiles were placed on top of a big piece of cotton woven fabric cut from an end-of-use shirt or a 100% cotton muslin fabric waste, and then covered with Solvy. When a base fabric was not used, shredded fabric scraps were layered between two layers of Solvy and pinned. The researchers used free-form embroidery technique to quilt the fabric, and hand laundered in warm water to remove the Solvy substrate. Textile strips (¼-inch wide) cut from end-of-use garments were used as tufting yarns. The tufting was conducted by a loop-pile tufting machine (Tuft the World) on a 100% cotton open weave cloth, supported by an 18-inch by 18-inch wooden frame.

A selected fabric samples made from cotton waste were tested for thickness, thermal resistance (R_{ct}) (ASTM F1868 standard), stiffness/softness (ASTM D6828 standard), and air permeability (ASTM D737 standard). Table 1 shows the test results. The results indicate the fabrics are appropriate for products such as apparel, decorative textiles and accessories. A variety of products (Figure 1) were designed and developed including a cellphone case (confetti quilt, Figure 1(a)), decorative textile (tufting, Figure 1(b)), a tote bag (woven textile, Figure 1(c)), a makeup bag (nonwoven, Figure 1(d)), a handbag (nonwoven, Figure 1(e)), a backpack (nonwoven, Figure 1(f)), a hat (nonwoven, Figure 1(g)), and a jacket (nonwoven, Figure 1(h)).

Table 1. Fabric thickness, thermal resistance, stiffness, air permeability test results

Sample	Thickness (Mean ±SD) (mm)	R_{ct} (Mean ±SD) (°C·m^2/W)	Stiffness (Mean ±SD) (g)	Air permeability (Mean ±SD) (mm/s)
Nonwoven 1	3.04±0.28	0.0797±0.0025	122.45±3.76	423.01±30.71
Nonwoven 2	3.32±0.44	0.1080±0.0003	319.70±20.15	333.98±52.18
Woven	3.96±0.51	0.0937±0.0011	230.10±3.54	694.99±95.69
Confetti quilt	2.34±0.19	0.0430±0.0009	77.75±8.58	409.79±41.60
Tufting	8.58±0.39	0.0892±0.0034	>1000	313.38±61.29



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 1. Products made from cotton textile waste

In conclusion, the researchers developed and tested a variety of fabrics made from end-of-use cotton apparel products. Using these fabrics, a number of apparel, accessories, and decorative textile products were designed and developed. This research provided viable methods to reclaim the value of end-of-use cotton apparel products.

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