Assessing Chemical Processing and Electrospinning As Alternative Textile Recycling Methods

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Background & Purpose

The apparel and textiles (AT) industry is one of the most globalized industries in the world (Palamutcu, 2015). The AT industry contributes to pollution during each phase of a textile's life cycle including the production and finishing of fibers and textiles, the use and maintenance of the product, and finally the disposal of the product (Chen & Burns, 2006). Current (fast) fashion practices drive the industry forward economically but contribute to an un-sustainable 'throw-away' mentality (BSR, 2017; Stephens, 1985; Claudio, 2007) further exacerbating environmental problems. Textile recycling (breaking down textiles back to fiber-form) offers an alternative option for fiber resource by using pre-existing materials rather than virgin fibers, thus reducing negative environmental impact needed to produce new yarns and textiles. Difficulties related to the quality of recycled textiles deter the industry from implementing textile recycling on a large scale. However, chemical recycling has proven to maintain the integrity of the fiber resulting in no degradation during recycling processes (Zamani, 2011). Therefore, the chemical recycling method provides a feasible option when considering a circular, closed-loop, life cycle (McDonough & Braungart, 2002). Circularity within a life cycle calls for the recycling and repurposing of materials within a closed-loop system. Chemical recycling combined with electrospinning is one example of a system change for positive environmental impact that has yet to be explored through research. Electrospinning is an electrostatic fiber fabrication technique to develop nanofibers with an enormous variety of applications.

This experimental study was conducted to explore an alternative textile recycling method for the production of single-fiber content nanofiber textiles. The purpose of this research addressed the concept of life cycle circularity through the recycling of textiles. This research is significant as it provided valuable feedback regarding the potential to remove textiles from solid waste streams while adding to the body of knowledge of chemical textile recycling procedures and introducing the potential of electrospinning processes for textile production.

Methods

Chemical Processing. Chemical processing testing occurred to acquire findings regarding the processes and percentages necessary for successful fiber dissolution and fiber blend separation. To determine the optimal ratio for fiber blend dissolution, a series of ratios were tested for the following fabrications: 100% nylon, 50% nylon/50% polyester blend, and 100% polyester. Formic acid (88%) was used for the dissolution of nylon fibers, while a 50/50 mixture of trifluoroacetic acid (TFA 99%) combined with dichloromethane (DCM >99%) was used for the dissolution of the polyester fibers (Kayaci, Aytac, & Uyar, 2013). The quantitative fiber analysis standard (AATCC

TM20A-2004) was modified to test blend dissolution and separation for the 50% nylon/50% polyester blend, otherwise this test method was followed for the single-fiber content specimens.

Nano-Textile Production. The final testing for this study included documenting the procedures for recycled nano-textile production via electrospinning. This study followed the electrospinning set up outlined by Kayaci, Aytac, and Uyar (2013). However, each fabrication required adjustments in voltage, distance, and flow rate in order to create a uniform nonwoven structure.

Results

Chemical Processing. Dissolution findings for single-fiber content fabrication (100% nylon & 100% polyester) showed that the overall optimal ratio of solvent to fabric weight was the 80:20 ratio, as it provided the best consistency for electrospinning. The time for dissolution using the formic acid or TFA/DCM blend required a 3-5-minute total time for full dissolution from the initial addition of the chemical solvent to the fabric. Dissolution findings for blended fiber content (50% nylon/50% polyester) showed optimal dissolution at the 80:20 ratio for the nylon fiber content and 90:10 for the polyester fiber content. The increased amount of chemicals necessary for full dissolution of the polyester was caused by the structure of the polyester post separation and neutralization. After neutralization occurred, the remaining polyester fibers hardened into a plastic mass in areas, which was more difficult to break down for spinning. Additionally, the TFA/DCM chemical combination evaporated quickly when combined so a higher initial amount was necessary to break down the hardened mass of fibers. The time for dissolution using formic acid occurred quickly at first, however it took 12 hours in order to filter the blend and produce the solution for spinning. Overall, as the chemical solvent increased, the time for dissolution decreased.

Nano-Textile Production. Findings from electrospinning research resulted in extreme variations for the necessary flow rate for each fabrication. Because the process for fiber blend separation and dissolution is quite different from the process for single fiber content dissolution, the resulting 80:20 nylon solution (from blend) developed had a higher liquidity. This in turn created variances in the voltage, the flow rate, and the time required for production. Findings were used to produce a final calculation of the requirements needed to create an electro spun textile with similar properties to the preliminary textile.

Discussion & Conclusion

Findings of this study indicate that fiber-blend separation is more difficult to achieve and requires larger quantities of chemical usage compared to the dissolution process for single-fiber textiles. Therefore, when blended fibers are separated during textile recycling, it would be more efficient to keep the fibers separated in single-fiber form for systematic ease in the circular system. Research findings contributed to the current knowledge and literature regarding both chemical textile recycling and electrospinning nanofibers. Additionally, this research provides a detailed methodology for the alternative textile recycling explored combining chemical processes with electrospinning. Future studies may include conducting multiple trials for electrospinning to ensure the formulas generated provide reliable and expected results.

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