COMPOSTING TO COLORANTS: A NOVEL APPROACH FOR SUSTAINABILITY AND CIRCULARITY

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ABSTRACT

This project was an attempt to apply innovative ideas and methods to tackling textile waste by building on existing knowledge and approaches. Fabric waste generated at the design stage was biodegraded, and the compost was used as an addition to agriculture growth media to cultivate natural dye plants. The dye plants were then used to extract dyes as potential substitutes for synthetic dyes. The paradigm shift was to demonstrate the potential for transforming fabric waste from any point in the supply chain to create new materials, specifically natural colorants that can be used to reduce pollution at the manufacturing stage.

Key Words: waste to materials, sustainable manufacturing, muslin, natural dyes

1. INTRODUCTION

Textile waste accounts for approximately six percent of the total generated municipal waste. Since population growth and consumption of textiles are closely intertwined, the problem of waste generation and disposal with consequent strain on the environment will only intensify in the coming decades. Novel approaches to sustainability in the textile and clothing supply chain that will have an impact on reducing the stress on the environment are greatly needed. Ideas include measures to reduce pollution at the manufacturing stage, as well as actions to reduce waste after consumer use. At the manufacturing stage, the potential of natural colorants to reduce pollution is an intriguing idea. On the other end of the spectrum, biodegradation or composting of textiles instead of disposing in landfills is a potential solution to the textile waste problem. This study explored a route between the two seemingly disparate solutions, namely composting of textile waste and use of natural colorants for textiles.

2. MATERIALS AND METHODS

The FIT campus generates an estimated 100 lbs of cotton muslin fabric waste each week. In this pilot project, the waste was diverted from landfill and transformed into a useful product: compost. In turn, fabric compost was used to grow natural dye plants. Colorants obtained from the plants were in turn used to dye cotton fabrics as a substitute for synthetic dyes. In addition to the environmental aspect of sustainability, the project enhanced the social aspect of sustainability through education of the community and the student population. The economic aspect of sustainability was addressed by the project's potential for adoption and long-term viability. Figure 1 illustrates the closed-loop approach of this research. The phrase "Threading the Needle" was used in the context of navigating the link between two seemingly disparate ideas, namely composting and natural colorants.

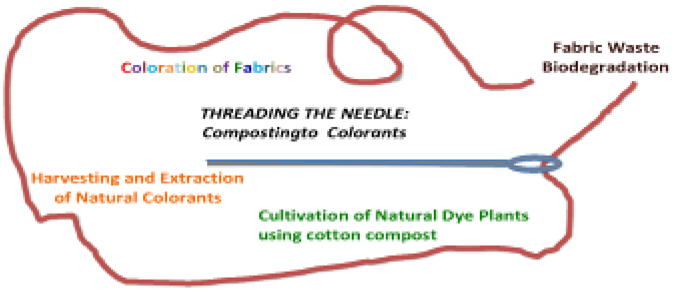

Figure 1: Composting to Colorants

For this project, cotton muslin collection bins were placed in classrooms. Fabric was then shredded and readied to be biodegraded. Compost mixtures were started with 50% food waste and 50% cotton muslin plus added moisture. After all of the water, food, and textile waste were added to the composter, they were mixed thoroughly by spinning the composter. The composter was spun every other day to increase available oxygen and maintain aerobic conditions. Finally, the decomposed material was moved to a vermicomposting system containing redworms (*Eisenia foetida*) for final decomposition and maturation. Upon completion of composting, the finished humus was tested for overall agricultural quality using the US Composting Council's Test Methods for the Examination of Composting and Compost by an independent certified testing laboratory.

The second objective of the study was to utilize cotton compost as addition to agriculture growth media to cultivate dye plants. The purpose of the agriculture portion of the study was to determine whether the benefits from adding composted cotton to agriculture media are significant. The study was conducted in controlled greenhouse environments to determine whether there is a noticeable difference in germination rate and seedling development comparing plant medium with 10% composted cotton and the same soil without cotton compost. The study focused specifically on two plants that yield natural colorants. Japanese Indigo was explored partly due to the popularity of denim, and partly due to current re-shoring activity of major U.S. textile mills. Dyers' Coreopsis also called plains coreopsis or calliopsis, was studied due to its popularity with craft dyers, as it provides a variety of colors including yellow, orange, red, and brown. In order to control variants, the indigo plants and coreopsis plants were grown separately under lights in two unattached grow tents to avoid light, pathogen or pest contamination. Both sets of plants were grown from high-quality, professionally collected and winnowed seed. The indigo variety used was *Polygonum tinctorum*, and the coreopsis used was *Coreopsis tinctoria*. Each tent contained one 540 watt LED (9 bay lights each), emitting the proper red and blue color spectrum [based on the manufacturers specifications of Photosynthetic Active Radiation (PAR)] to bring the plants from germination (blue) through harvest (red).

The final objectives were to extract natural colorants from plants and evaluate the extracted natural colorants for color depth and colorfastness properties on a cotton fabric. Flowers from the coreopsis plants were dried and pulverized. Extraction of colorant was done in a soxhlet apparatus using ethanol. The extractant was used as the dyeing medium for dyeing cotton fabric pre-mordanted with 10% concentration of aluminum sulfate at 70 ºC for 45 minutes at a liquor-goods ratio of 20:1. Distilled water extraction was another method that was investigated. Dried flowers were boiled in water for two hours. After filtration, the extractant was used as the dyeing medium along with a 10% concentration of aluminum sulfate as the mordant. The function of the mordant was to impart affinity and form a bridge between the natural colorant and the cellulosic fabric. For the aqueos extractant, dyeing was done in a computer-controlled IR dyeing machine with a liquor-goods ratio of 15:1. Fabric was introduced into the dyeing solution at room temperature. Temperature was raised to a boil, and dyeing continued at boil for 60 minutes. After dyeing, fabric was rinsed in deionized water, washed using a non-ionic detergent and air-dried.

Indigo pigment was extracted by steeping in warm water at 50 °C in an indigo vat for 48 hours. After straining the liquid, sodium carbonate was added to make the vat alkaline, followed by aerating the vat for 15 minutes to precipitate the pigment. Sodium hydrosulfite was then added and the bath allowed to stand for an hour. Subsequently, cotton fabric was introduced into the vat for ten minutes. After ten minutes, the fabric was removed and oxidized by drying in air for fifteen minutes. The process was repeated three times. Finally, the dyed fabric was air dried overnight, rinsed in deionized water and washed using a non-ionic detergent.

Colorfastness to washing and perspiration were done according to AATCC Test Method 61 and AATCC Test Method 15, respectively. Light-fastness testing was done according to AATCC Test Method 16E. Change in shade was evaluated using the AATCC Gray Scale for Evaluating Change in Color and color transfer was evaluated using the AATCC Gray Scale for Evaluating Staining. Scales ranged from 1 to 5 with higher grades indicating better performance.

3. RESULTS AND DISCUSSION

Parameters of the tested compost is included in Table 1 and indicates a good quality compost.

Table 1. TMECC compost analysis data

Analysis	**Dry Basis Data**
Total Nitrogen (N)	1.94 %
pH	7.7
Organic Matter (LOI @ 550 C)	50.84%
Carbon:Nitrogen Ratio (C:N)	13.1:1
Avg. height of seedlings in control	9.0 cms
Avg. height of seedlings in compost	13.2 cms

Colorfastness to washing, perspiration and light data are shown in Tables 2-4.

Table 2. Colorfastness to washing

Colorant		Change in Color (Gray Scale Grade)	Staining (Gray Scale Grade)
Coreopsis (ethanol extract)	Treated soil	2-3	4
	Untreated soil	3	4-5
Coreopsis (aqueous extract)	Treated soil	1	1
	Untreated soil	1	1
Indigo	Treated soil	4	4
	Untreated soil	3-4	3-4

Table 3. Colorfastness to perspiration

Colorant		Change in Color (Gray Scale Grade)	Staining (Gray Scale Grade)
Coreopsis (ethanol extract)	Treated soil	1	1
	Untreated soil	2	1
Coreopsis (aqueous extract)	Treated soil	2-3	1
	Untreated soil	2-3	1
Indigo	Treated soil	4	5
	Untreated soil	4	

Table 4. Colorfastness to light

Colorant		Change in Color (Gray Scale Grade)
Coreopsis (ethanol extract)	Treated soil	2
	Untreated soil	3-4
Coreopsis (aqueous extract)	Treated soil	2-3
	Untreated soil	2-3
Indigo	Treated soil	4
	Untreated soil	4

4. CONCLUSIONS

The results of the project demonstrated the potential for transforming fabric waste from any point in the supply chain — design, garment production, or post-consumer textile waste — to create new raw material, in particular, natural colorants, that can be used to reduce pollution at the manufacturing stage. The ultimate goal is to germinate the rudiments of a circular fashion economy where waste from one cycle is used to create raw materials for a successive cycle and create new jobs and opportunities in the process.