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Sustainability Based Upcycling and Value Addition of Textile Apparels

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Abstract

Because of alarming level of green house gases (GHG) in the environment, fast depleting natural resources such as water, petroleum products and increasing level of industrial effluents, every single manufacturing activity has come under the scrutiny of sustainability. Textile materials form a large chunk of human consumption and as the standard of life is improving globally the per capita consumption of textiles and apparels is also increasing. In this backdrop, the affluent segment of the society is adopting "make-use-and-throw" approach, which is giving rise to large scale manufacturing on one hand and the pressure of disposing of the used clothing on the other. The researchers in the field of sustainability are thus talking about responsible consumption and recycling of used materials. By refurbishing of such used apparels by involving minimum processing and value addition technique, it is possible that once again, such products can be put into useful purpose. The present research work addresses this issue of converting once used clothing by refurbishing and value addition. In developing countries a large chunk of food grains are spoiled and left to germinate due to improper storage conditions and their dampening. Hence in another piece of research explores the possibility of extracting of the starches from the waste products such as germinated food grains and investigates its applicability as a thickener in textile printing. This attempt has dual purpose of waste utilization on one hand and value addition to the once used textile garments. Hence, this attempt also advocates sustainability in manufacturing by reducing considerably the overall carbon foot prints.

Keywords— Sustainability, Upcycling, Biopolymers, Printing, Value addition

Introduction

Over the past two decades, large amount of carbon dioxide and other greenhouse gases have been released in the atmosphere due to human actions. Burning fossil fuels to produce energy, deforestation, industrial processes and some agricultural practices are the major source of greenhouse gases emitted in atmosphere. Due to these reasons the scientists, researchers and the government are taking effective steps to control the emission. The Kyoto Protocol was an outcome of these situations which was framed and signed by the developed countries. The protocol stated that the industrialized countries should reduce the emission of greenhouse gases and they can also trade emissions quotas among themselves and can also receive credit for financing emission reductions from developing countries .

United Nation World Commission on Environment and Development (1987), terms sustainability as the, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The world is facing a series of challenges including resource degradation, climate change and a global economic crisis. Europe had taken the lead and contributed guidance to the rest of the world concerning climate change lessening commitments (Nilsson, M et.al,2009). In Europe, people buy more clothes and other textiles materials than anywhere else in the world. The demand for cheap fashion is high and the fast-fashion clothing market has grown significantly in response to the trend. Today's consumption carries more wear and tear, where the prices

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are lower and thus quality is low. These circumstances contribute to the increasing textile waste and the future decreasing textile supply. Mankind has created an abundance of clothes through textile manufacturing and only mankind could bring an end to it. It is our responsibility to get the abundance under control and eliminate it as soon as possible (Morgan, L. R., & Birtwistle, G. 2009).

According to the William McDonough and Michael Braungart (2002) when all kinds of waste end up in the landfill such as clothes, old furniture, carpets, televisions, shoes, paper, food wastes and much more. Some of these things can be decomposed, other recycled – and some even upcycled. Textile waste basically divided into three groups post-consumer waste, pre-consumer waste and production waste based on their sources (McDonough, W., & Braungart, M. 2002).

Today, products are designed with "built-in obsolescence" to only last for a short time. The purpose of this is to allow or even to encourage the customer to get rid of it as soon as possible and buy a new item. That was common in the fashion industry. What most customers do not know was that once the product becomes garbage, it is just the tip of a material iceberg of large pile of waste material.

Economic growth is the main goal of today's industrial infrastructure which happens, at the expense of the world's health. The damage was definite and severe. The world is waiting for manufacturers or designers to decide that was a strategy that can no longer be supported and maintained, the strategy of tragedy (McDonough, W., & Braungart, M. 2002).

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Standing in this crossroad of sustainability and profitability, the well wishers of mankind have joined hand to find out the several ways to utilize these old and waste materials. One of the most economic yet fashionable ways to do so is to "upcycle."

Upcycling is the process of converting waste materials or useless products into new materials or products of better quality by value addition or refurbishing. Upcycling is necessary as a substitute to producing new things to meet the increasing demands by the consumers. If the demand will not slow down, it has to be met, and since new production will only support the evil cycle of over consumption and all its problems, the demand has to meet in a different way such as the new products to be made of already existing materials. Such a problem is particularly evident in the textile industry. The concept is increasing in popularity among those concerned about climate change. Upcycling is to say that recycling is great, but it requires energy and resources to gather, sort and process the waste only to make something less out of it. Hence, upcycling is an even greener way of recycling, and better environmentally. Moreover, by making use of already existing waste materials, the consumption of new raw materials for new products is reduced which could result in a reduction of energy usage, air pollution, water pollution and CO_2 emission. For vendors and consumers concerned about the environment, upcycled products are therefore a way for the vendor to make business and for the consumer to keep shopping, hence the purpose of business is not changed.

A garment is considered to be serviceable when it is fit for its particular end use. After being used for a certain length of time the garments ends up to be serviceable when it can no longer fill its intended purpose in the way that it did when it was new. The particular factors that reduce the service life of a garment are heavily dependent on its end use. Various factors involved in the serviceability of garment are as follows - (Saville, B. P.1999).

- Changes in fashion which means that the garment is no longer worn irrespective of its physical state.
- Shrinkage or other dimensional changes of such a magnitude that the garments will no longer fit.
- Changes in the surface appearance of the fabric which includes; the formation of shiny areas by rubbing, the formation of pills or surface fuzz, the pulling out of threads in the form of snags.
- Fading of the colour of the garment through washing or exposure to light. The bleeding of the colour from one area to another.
- Failure of the seams of the garment by breaking of the sewing thread or by seam slippage.
- Wearing of the fabric into holes or wearing away of the surface finish or pile to leave the fabric threadbare. Wearing of the edges of cuffs, collars and other folded edges to give a frayed appearance.
- Tearing of the fabric through being snagged by a sharp object.

Some of the above stated causes are irreversible in nature and therefore those kinds of faulty garments cannot be upcycled. However, other than that all the fabrics can be reused for upcycling. There are many fashion designing professionals as well as textile engineers who have worked in this avenue successfully, yet many ways are still to be explored. In the present work an attempt is made to refurbish the waste garments by upcycling it with various chemical processing.

Along with this severe problem of wastage of textile materials, the improper utilisation of food materials must not be overlooked. Now a day as the production of grains is increased at a faster pace its storage needs

consideration in particular. Every year millions of tonnes of food grains go waste in India because of inadequate storage and infrastructure facilities. According to the survey conducted on global food wastage, it was found that about 21 million tonnes of grains go waste in India and 50% of all food produced across the world meets with the same fate and never reaches the needy.

In Countries like India, Bangladesh, Sri Lanka, China and many others, millions of tonnes of food grains produced by the farmers (generally wheat and jowar) is purchased and stored in the government controlled granaries.

The food stocked by government in these granaries is then diverted for distribution for various welfare schemes for underprivileged families and the poor. But seldom does that happen. Government granaries are generally unequipped to store such large amount of food grains and are severely affected because of improper management and facilities, thus putting at risk millions of tonnes of food grains. Most of these food grains perish with time and is never able to reach the market where it was supposed to be and turn out to be mere waste. Many times, these storage houses are loaded with food grains much more than their capacity. The present work is undertaken with a view to make use of the starches extracted from these waste grains for printing on textile garments and thereby upcycling of the same.

Material and methods

Materials

The old clothes used for upcycling were purchased from Thane Local market, Mumbai, India. It basically contains the garments made of cotton, polyester and cotton/polyester blended fabric. It involves a lot of variety of goods like jeans, kurtis, top, t-shirt, pyjamas, leggings, shirt, etc. Some of the goods were also collected by friends. All the dyes and chemicals involved in upcycling of garments were of laboratory grade. A 100% cotton fabric ready for printing was used with the fabric specifications of EPI – 86 and PPI – 80. GSM of fabric was 120 gm/m^2. Cereal grain likes Sorghum and jute sack used for starch extraction was obtained from local grocery store. A 200 mesh Nylon bolting cloth was used for the extraction of starch.

Steps involved in Upcycling of garments

Collection of the old garments The used garments were procured from the Thane Local Garment Market, near Thane station. Most of the garments were procured at a price rate of Rs.10/piece and few of them procured at the rate of Rs.5/piece. Cost variation in the price of garment was observed on the basis of initial quality and overall appearance of garment during purchasing. Almost 64 garments were procured from the Thane local market. Around 8 old used garments were also collected from the friends at free of cost. Thane local market is huge which covers almost 400-500 meters of area of both side of public road. The most of buyers were belonged to third party who purchase the garment at lower price from market and sell it to the other party, who process the garment as per need and again sell the garments.

Segregation of the old garments The collected garments were segregated based on the quality of clothes, fibre composition (like cotton, polyester, tricot), colour (light or dark), gender of user (male or female), age group (kids, young, etc.), etc.

Cleaning of old garments After the segregation, garments were subjected to washing with detergent to remove the dust, dirt and soil present on the surface of the goods. Washing was carried out by two ways, hand wash in some cases and machine wash or both techniques depending upon the requirements. Hand wash basically was given for cuffs, collar, under arms portion of the garments. Otherwise machine wash was sufficient to make the garment clean.

Refurbishing of old garments Due to regular usage of the garments most of the garments get faded or torn at a particular area or get stained due to which they can't be used further for the wearing. Refurbishing is a way to make the garments again beautiful and attractive in appearance. Refurbishing of the old garments can be carried out in a physical as well as chemical way. Physical way involved the stitching of garments or clothes while chemical way can be divided into four groups like bleaching, dyeing, printing and finishing. The ways of refurbishing of old garments include soaping, bleaching, dyeing, printing, finishing, stitching, etc.

Visual testing and analysis of garments

Testing of garment was carried out by practical visual observation to analyze that the improvement in the quality of the garment. Performance was rated according to the improvements in the quality of each garment. Rating was done on the basis of overall aesthetics, attractiveness and acceptability compared to the original article. Rating was given as follows. Rating 1 showed 10% improvement whereas rating 2, 3, 4, 5, 6, 7, 8, 9 and 10 showed improvement of 20, 30, 40, 50, 60, 70, 80, 90 and 100%.

Cost Analysis

It was carried out to find the percentage profitability of the upcycled goods. It involved the total cost of upcycled goods which includes purchase cost, water cost, power cost, dyes and chemical cost, labour cost along with miscellaneous cost, etc.

$$Profitability\ (\%) = \frac{(\text{upcycled goods selling price} - \text{Total cost involved to upcycle good})}{\text{Total cost involved to upcycled good}} * 100$$

Extraction of Starch

The starch was extracted from the Great Millet (Sorghum), following the alkali steeping method (Nilsson, M et.al,2009).

Printing

Printing with Natural Dyes was carried out using starch extracted from Sorghum.

Results and Discussions

Once the garment being treated as per the need to upcycle them, they were subjected to the evaluation of improvement in its performance in terms of the process efficiency and effectiveness in addition to aesthetic attractiveness and acceptability. A total of 65 people were involved for the evaluation. It consisted of the approximately 60% females and 40% males with the different age group comprising with 20 years to 40 years. They practically visited during the exhibition of the articles in the conference room and analyzed the improvement in the upcycled goods by not only seeing their pictures before and after, but also by practically judging the final goods. After a very stringent observation everybody analyzed all 72 different articles very carefully and gave the ratings to their respective products along with the estimated approximate cost, at which they may prefer to buy.

The ratings of product were given in range of 1 to 10 in which 1 is for poor (10% improvement) while 10 is for excellent (100% improvement). Similarly approximately estimated price was decided by their own perception of the viewer. The average value quoted by 65 different persons and the mean value of the product rating as well as approximately estimated price were taken.

Table 1
Overall summary of ten samples in terms of their process, rating and profitability

Sample No.	Product	Gender category to which dress belongs	Processes carried out to Upcycle	Rating (1 - 10)	Profitability as upcycled product (%)	Profitability as new product (%)
1	White Jacket	Boy	Dyeing	7.41	68.93	142.89
2	Baby Frock	Girl	Dyeing	7.02	63.60	146.76
3	Baby Top	Girl	Dyeing	7.55	93.30	133.29
4	Printed Shirt	Boy	Dyeing	6.84	90.80	191.47
5	Violet Top	Girl	Print	6.83	250.39	409.64
6	White Frock	Girl	Print	6.72	501.00	766.09
7	Torn jeans	Boy	Stitch	6.83	106.35	199.09
8	Torn jeans	Boy	Stitch	6.73	181.94	344.76
9	Violet T-Shirt	Boy	Enzyme wash	6.56	156.44	250.01

10	Black Top	Lady	Dyeing+ Print + Stitch	6.44	257.88	444.24

Appearance wise product rating and approximately estimated profitability (%) as an upcycled garment and as a new garment.

The Sample 1 i.e. a jacket was randomly contaminated by fungi attack and rust giving blackish spots which were even unable to be removed during soaping. Hence it was subjected to reactive dyeing in order to hide the black spots by using the reactive orange with 2% shade. After dyeing it gave a beautiful look to the garment. From Table 1, we can see that its product rating was 7.41 and the profitability (%) as upcycled product and as a new product were approximately 68.93% and 142.89% respectively.

Sample 2 was an original yellow colour stained baby frock which was subjected to soaping followed by dyeing using Coracion G. Yellow HER with 1.5% shade to enhance the aesthetic value. Dyeing easily covered the yellow spot giving the uniform colouration effect. After survey it was found that its product rating was 7.02 with profitability (%) of approximately 63.6% and had it been a fresh article, it would be 146.76%.

The dyeing of the baby top (Sample 3) was carried out with reactive dye. The uneven fading of the top was covered by uniform dyeing. The survey result showed that the product rating for baby top was 7.55 and the estimated profitability percentage was 93.30 and 133.29 as upcycled product and new product, respectively.

The dyeing on printed shirt (Sample 4) of small boy was subjected to reactive dyeing using Reactive Red with 5RB 0.5% shade to improve its appearance value. After survey it was found that its product rating for baby top was 7.55 and the estimated profitability (%) was approximately 90.8% and had it been a fresh article it would fetch a profitability of 191.47%.

Original top was having the duller appearance (Sample 5) and hence it was subjected to Gold printing to catch the buyer's eyes by print-dry-cure process. After survey (Refer Table 1) it was found that its product rating was 6.83 and the estimated profitability (%) was approximately 250.39%. Had it been a fresh article, it would fetch the profitability of 409.64%.

The original white top (frock) (sample 6) was subjected to printing with red pigment using 1% Imperon Red in printofix 200 by print-dry-cure process which gave a different look as compared to traditional one. After survey it was found that its product rating was 6.72 and the estimated profitability (%) was approximately 501% and had it been a fresh article, it would fetch profitability of 766.09%.

These jeans samples were torn (Sample 7 and 8) in such a way that they couldn't further be used, and hence they were cut and stitched in proper way to make a strong carry bag with both side pockets, with longer length size, mobile cover and other accessories, etc. After survey (Refer Table 1) it was found that its product rating was 6.83 and 6.73, respectively and the estimated profitability (%) was approximately 106.35% and 181.94%, respectively. Had it been fresh articles, those would fetch profitability percentage of 199.09 and 344.76, respectively.

Huge amount of pills were appearing on the T- shirt surface (Sample 9) and to overcome the same it was subjected to enzyme wash using 1.5% owf KEM 240. After survey (Refer Table 1) it was found that its product rating was 6.56 and the estimated profitability (%) was approximately 156.44%. If it was a fresh article, it would fetch profitability of 250.01%.

Original lady top (Sample 10) was showing faded effect and dull appearance. In order to overcome the problem, it was subjected to dyeing with dark black colour (Direct Dye) using Solar black with 2% shade to give newer appearance. After survey (Refer Table 1) it was found that product rating was 6.44 with estimated profitability (%) of 257.88%. Considering it as a fresh article, it would have fetched a profitability of 444.24%.

In other words, psychological factor influenced the purchase price for all the above garments. Similarly other 62 garments were upcycled, rated and there profitability was calculated.

Colour Values of fabric Samples Printed with Sorghum starch

The cotton fabric samples were printed with natural dyes using sorghum starch as a thickener in various blend proportions comprising of starch extracted from Sorghum. The samples were also printed using maize starch thickener which was considered as a standard thickener for comparison. The colour strength of these printed samples was then analyzed by comparing K/S values. The CIE colour co-ordinates, are given for the natural dye printed fabrics, where the L* and a*, b* values denote the brightness of shade and tonal variations of the shade respectively. Higher L* values relate to increase in brightness. It is considered that if the L* values are closer to 100; the corresponding shades obtained are brighter. If the a* values are positive then it indicate that the respective shade has a redder tone and if negative it indicates greenness of shade and b* values if positive indicate yellowness and negative value of b* refers to the blue tone of the shade. These values help to detect the brightness and tonal variations of natural dye printed shades.

Table 2.
Colour Values for Madder, at 10% shade

Composition of Blend Pastes NG:G	**K/S**	**L***	**a***	**b***	**% Decrease in K/S**	**% Change over Standard Thickener**
100:0	1.04	70.06	19.93	15.026	-	+18.18
70:30	0.79	70.237	16.58	15.689	-24.03	-10.22
50:50	0.67	71.297	17.22	17.44	-35.57	-23.86
30:70	0.55	71.479	17.76	17.599	-47.11	-37.5
0:100	0.23	70.589	16.94	16.26	-77.88	-73.86
Standard	0.88	70.93	19.628	16.797		

NG: non-germinated sorghum starch, G: germinated sorghum starch

It was observed from the results in Table 2, that in case of fabric samples printed with 10% madder dye, highest K/S reading (average taken of triplicate) of 1.04 was obtained with 100:0 i.e. pure non germinated sorghum thickener paste. It is noted that as the proportion of germinated starch increased in the blend of pastes the K/S values showed a peculiar decreasing trend. Thus when pure germinated starch was used, the percentage decrease of 77.88% was observed in K/S values. However, when compared with the standard fabric sample printed using maize starch the K/S values obtained with pure non germinated sorghum thickeners, they were higher and comparable with the standard. In other words, non germinated pure sorghum thickeners (at 7.5% solid content) gave better K/S values as compared to standard maize starch thickener.

Table 3
Colour Values for Lac, at 5% shade

Composition of Blend Pastes NG:G	**K/S**	**L***	**a***	**b***	**% Decrease in K/S**	**% Change over Standard thickener**
100:0	3.58	53.78	23.43	-7.54		+70.02

70:30	3.47	53.94	24.01	-7.58	-2.92	+64.71
50:50	2.84	53.32	21.95	-6.26	-20.59	+34.72
30:70	2.63	53.95	24.31	-8.03	-26.48	+24.72
0:100	1.72	54.13	24.63	-6.73	-51.82	-18.26
Standard	2.11	54.90	26.45	-6.16		

NG: non-germinated sorghum starch, G: germinated sorghum starch

In the case of fabric samples printed with 5% Lac dye, it was observed that maximum K/S reading of 3.58 was achieved with pure non germinated sorghum thickener and it was much higher as compared to that of the print when standard maize starch thickener was used. As the proportion of germinated starch increased in the blend, the K/S values steadily declined. In this case the samples printed with NG: G:: 30:70 blend proportions also depicted higher K/S values than the standard. Thus here even with 70% of germinated starch in the blend the K/S values obtained were better than standard thickener maize starch (Refer table 3). This itself justifies, that the starch from germinated sorghum can also be put to use as thickener.

Conclusion

Out of 72 samples upcycled, 29 of them gave profitability of the order of 99.34%. However rest all the samples (43 sample) gave the profitability of the order 821.93% making the upcycling business financially sustainable model.

It is to be noted that all prices quoted by the dummy purchasers (respondents), were lower when they knew that the products were upcycled indicating the influence of psychological barrier on their purchase price. Thus profitability calculated on this purchase price is considered to the most assured profitability.

However these articles have a lot of potential to get sold in tier 2 and tier 3 cities and towns and here, nobody will have fairest idea with regards to quality of upcycled product and in that case the purchase price in absence of such a knowledge will be much higher and in that case the initial profitability which ranged from 100% to 893% will be increased in many fold. In other words, upcycling is not only environment friendly and sustainable operation, but also it can open up another avenue for entrepreneurs to obtain high level of profitability and one can work on it as a solid business model.

The germinated starch which is otherwise treated as waste was thus being put to use in textile printing as a thickener. If this technique comes into use, the grains which are declared as waste by the government and used for the purpose of fodder for animals can be used for applications in textiles as thickener. The prints obtained with natural dyes gave comparable colour yield as well as good fastness properties.

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