Investigating the properties of cotton fabric coating with polyacrylic rubber and using this polyacrylic rubber coated fabric as an alternative to polyethylene bags

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Abstract. Cotton fabric coated with polyacrylic rubber can be used as a replacement for polyethylene bags to avoid plastic pollution. In this research, we have investigated the use of polyacrylic rubber with 100% cotton fabric as a finishing agent where 2% of ammonium chloride was used as a catalyst. A pad-dry-cure technique was applied for the preparation of cotton fabric samples varying 6%, 8%, 10%, 12%, and 14% polyacrylic rubber. Tensile strength, tear strength, and bursting strength produced a balanced improvement in properties. After appealing gyro wash on each sample, it is established that the strength of the fabric has decreased slightly. Assessment of these properties has had a good impact on the strength of the fabric making which is a viable substitute for polyethylene bags.

1. Introduction

Plastic is entering the human body by exploiting the food chain may cause severe health damage, even death, and a direct effect on wildlife and plants as it harms the soil. While plastic bags never degrade completely, companies are manufacturing more of them. More of them are being dumped into our surroundings, so there is more plastic pollution and its repercussions when there are more plastic bags in use. Using sustainable cotton bags instead of plastic bags can help minimize this significant impact. Polyacrylic rubber (PAR), with carboxyl-containing vinyl copolymer owing to a suitable esterification catalyst (NH_4Cl), may prove more promising due to its environmentally friendly and non-toxic characteristics.

The coating on textile materials relies on the polymer and chemical industries for polymers, processing aids, additives, and many other chemicals necessary to produce goods in conformity with

consumer requests that meet quality standards and durability demanded [1]. Because of rising environmental threats, textiles should be provided the most significant protective equipment to protect people and fortune in different surroundings [2-4]. Compounds derived from methylated urea, namely, dimethylol dihydroxy ethylene urea (DMDHEU), can be used as a resin for the finishing of cotton textiles which results in significant improvement in wrinkle recovery despite having some poor abrasion resistance, lowering in whiteness index, and poor tensile strength retention [5]. Some disadvantages of formaldehyde eruption have been found with methylated resin finishes while production and use, which endanger the health of consumers and processors [6].

Several works have been done on the finishing of cotton fabric. Some authors have studied on finishing treatment of cotton fabric by utilizing PAR in the presence of NaH_2PO_4 as a catalyst [7]. A variety of surface finishing techniques, ranging from layer-by-layer (LBL) assembly [8- 9], chemical grafting, to propane sultone chemical grafting, were used [10-11]. Many authors have also been studied on sol-gel coating for coating [12-14] to make functional textiles with flame retardant [15], antibacterial [16], UV protective and self-cleaning properties [17], and water repellent [18]. In a study, PAR was also used for the surface modification of jute fabric catalysts, such as $MgCl_2$, NH_4Cl, as well as sodium salts of phosphoric acid acting as the catalyzers. [19]. In another study, the combination of sustainable substances silica sol and phytic acid in the presence of sodium alginate resulted in an effective and eco-friendly flame retardant coating for cotton fabric [20].

In line with those previous findings and subsequent development, this paper surprisingly found out that the strength of cotton canvas bags can dramatically outnumber the strength of polyethylene bags after the treatment of polyacrylic rubber (PAR). Hence, this paper aims to create a product that will be an alternative to polyethylene bags that will be sustainable, eco-friendly, and biodegradable. This paper has also calculated the cost of cotton canvas bags compared to polyethylene bags and considered a crucial study on customer demand for fabric bags varies by gender and age, indicating that all buyers, regardless of gender or age, are increasingly concerned with eco-friendly bags [21].

2. Materials and Methods

2.1. Materials

2.1.1. Fabric

100% cotton bleached and plain weave fabric was used in this work. The cloth has a GSM of 290 (before washing), an EPI of 32, and a PPI of 32. This fabric was gathered in Gulshan Ara City, Sadarghat, Dhaka, Bangladesh.

2.1.2. Polyacrylic Rubber (PAR)

Macromols India Ltd. provided the material such as PAR. It contained mostly various co-polymers (see Table 1):

Table 1. Composition of PAR

Alkoxyalkyl Acrylate	Mercaptobenzothiourum	Silica	Ethacrynic Acid	Vinyl Tri-Methoxy Silane	Methacrylic Acid
80 parts	0.8 parts	120 parts	8 parts	0.2 parts	7 parts

2.1.3. Catalyst

This study employed ammonium chloride as a catalyst for esterification while pad–dry–cure of cotton utilizing PAR, and was manufactured by ReAgent, originated in the United Kingdom, and was obtained from Officina+39 BD.

2.2. Methods

2.2.1. Working procedure of sample preparation

Padding recipe for cotton with PAR is shown in the below (see Table 2):

Table 2. Recipe for sample preparation

Polyacrylic Rubber (PAR) (conc.)	Ammonium Chloride (g/L)	Wetting Agent (g/L)	M:L
6%, 8%, 10%, 12%, and 14%	2	1	1:10

So as to apply a water-based solution of PAR on cotton fabric, the padding technique was used in the laboratory padding mangle. The sample was pushed through a nip of a couple of squeezing rollers after two subsequent dips in the aqueous PAR formulation. The squeezing rollers' pressure was regulated to get a 100% total pick-up. For 5 minutes, the padded and compressed fabrics were stented at 140°C. They were studied for textile-related properties.

2.2.2. Measurement of tensile strength

Tensile strength for strip method, ASTM D5035-11 (2015) Standard was used, and specimens of 16 cm× 5 cm were used for treatment. In addition, tensile strength for grab method, ASTM D5034-09 (2013) Standard procedure was applied, and specimens of 16 cm× 10 cm were used for treatment. Each test specimen for woven fabrics was cut with its length parallel to the warp or weft of the fabric and must be sufficiently wide to allow for the requisite fringes. For strip, the thread should be obviated in roughly equal numbers from each of the long edges of the cut strip until the test sample's width is reached.

2.2.3. Measurement of tear strength

The procedure conducted measurement of tear strength explained in EN ISO 13937-3:2000 Standard. Thus, specimens of 20 cm× 10 cm were used for treatment. In the case of woven fabrics, each test specimen was cut with its length parallel to the warp or weft of the fabric and sufficiently wide to allow for the necessary fringes, then cut the sample at the width direction to half its length. The width of the fringes was such that no longitudinal threads escaped from the fringes during testing. The jaw was at least half the width of the test specimen.

2.2.4. Measurement of bursting strength

Measurement of bursting strength was carried out by the procedure narrated in ISO 13938-1 Standard. An elastic rubber diaphragm that can be inflated by hydraulic pressure is used in this method to apply perpendicular force to the fabric sample. To prevent slippage of the specimen during the test, the sample is tightly clamped on the diaphragm. A specified rate of hydraulic fluid is applied behind the diaphragm to inflate it and provide pressure to the fabric.

2.2.5. Working procedure of gyro wash

Washing recipe is shown in the below (see Table 3):

Table 3. Composition of washing recipe

M:L ratio	Fabric Dimension	Sodium Perborate	ECE detergent	Steel ball (6 mm diameter)	Temp.	Time
1:50	10 cm × 4 cm	1 g/L	4 g/L	25	60^0C	30 min

First of all, the specimen was placed in the container, and the required amount of detergent solution was added, which had earlier been heated to 60°C for the ISO105 C03 technique, which result in a liquor ratio of 1:50. Specimens of 10 cm× 4 cm were used to treatment. After 30 minutes of treatment

at the required temperature, the specimen was removed, washed and rinsed in cold running tap water for 10 minutes, and squeezed. The specimen was then opened and dried by hanging it in air at a temperature no higher than 60°C (see Figure 1).

Figure 1. Apparatus for fabric wash fastness test

3. Results

This experimental section is divided into three significant sections. This paper calculated the tensile strength, tear strength, and bursting strength of raw sample along with sample treated with different PAR percentages (6%, 8%, 10%, 12%, and 14%), which is also divided into two different exploratory stages: before wash, and after wash, in order to analyze the strength of PAR coated cotton.

3.1. Effect of polyacrylic rubber on tensile strength

Tensile strength test can be performed using both the strip and grab methods in not only the weft directions but also warp directions, as seen in the figures below (see Figures 2, 3, 4, and 5)

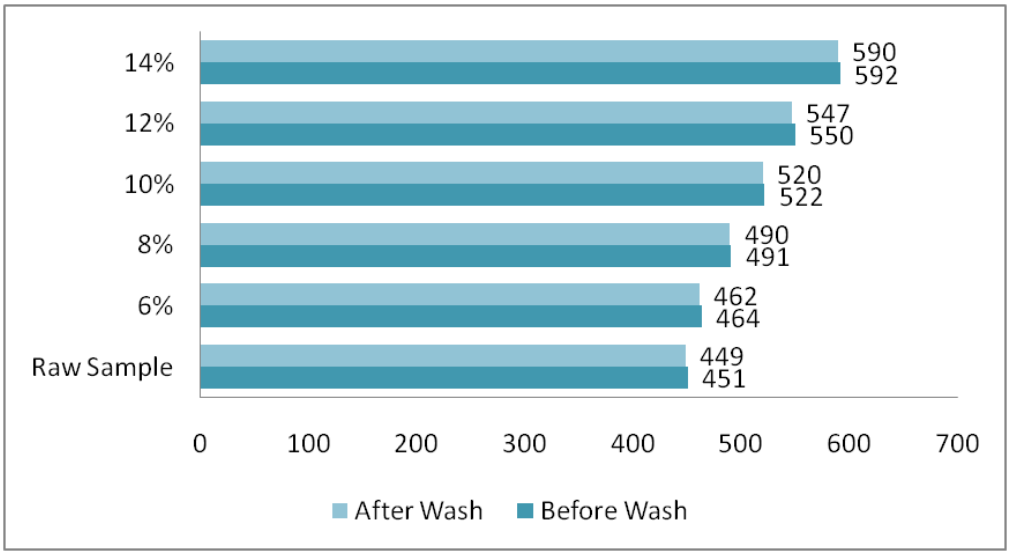

Figure 2. Effect of polyacrylic rubber tensile strength (strip) in weft direction

3.2. Effect of polyacrylic rubber on tear strength

The two following figures (see fig. 6 and 7) show the calculated value of tear strength in the weft and warp directions of different PAR coated cotton fabrics compared to raw samples.

3.3. Effect of polyacrylic rubber on bursting strength

The following graph depicts the numerical value of bursting strength of various PAR-coated cotton fabrics compared to raw samples.

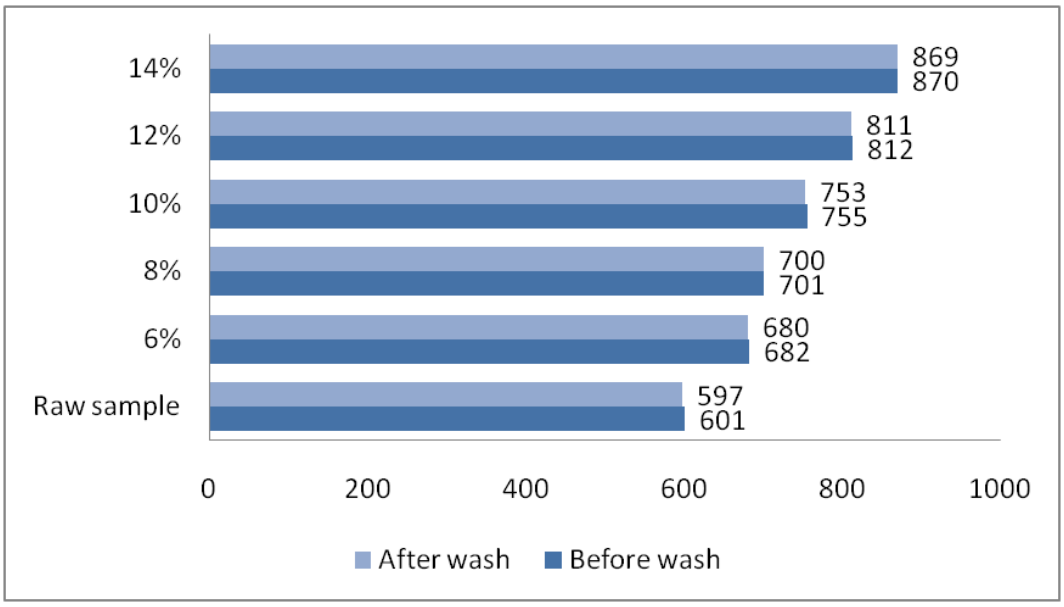

Figure 3. Effect of polyacrylic rubber tensile strength (strip) in warp direction

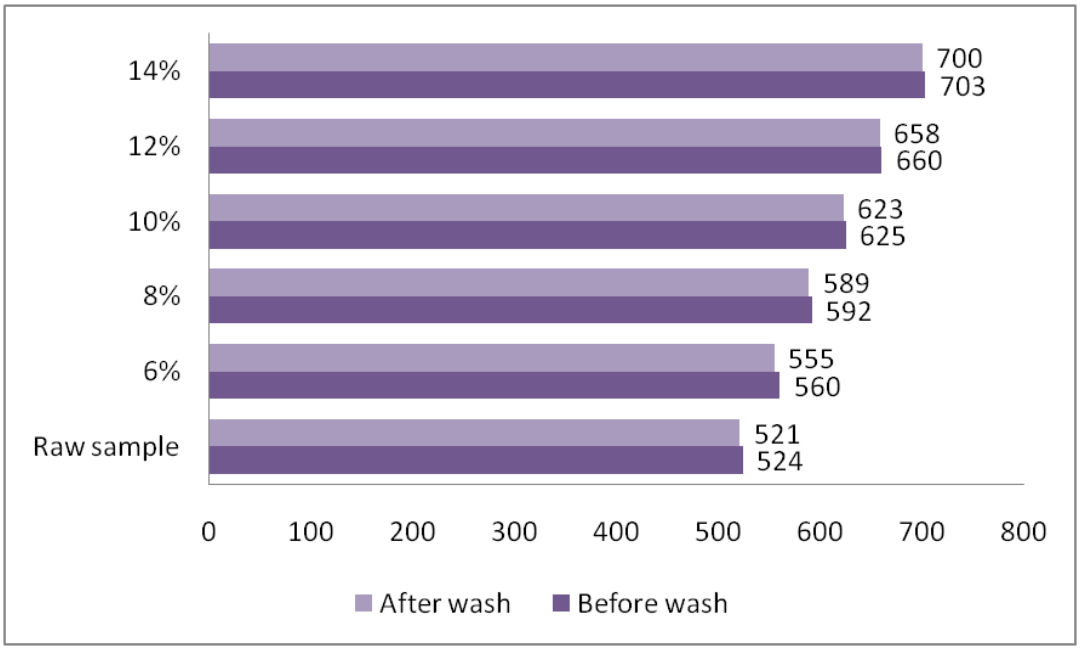

Figure 4. Effect of polyacrylic rubber on tensile strength (grab) in warp direction

4. Discussions

The tensile strength for strip and grab methods was evaluated in both warp and weft directions which are represented in the above figures (see Figures 2, 3, 4, and 5), tear strength in warp and weft directions is represented in Figures 6 and 7, and bursting strength is represented in Figure 8 with varying 6%, 8%, 10%, 12%, and 14%. Certain similarities are evident in these seven graphs, which clearly follow the same trend in all three strength testers. When 2% NH_4Cl (as a catalyst) was used for fabric treatment, the strength of the fabric increased as the amount of PAR concentration increased.

Tensile strength in the warp direction is considerably higher than in the weft direction due to the extra strength of warp yarn. There are also some differences. In all seven categories, the tensile strength rises roughly 1.5 times from raw fabric to 14 percent PAR treated fabric before washing; this is a strong indicator of the increased strength of the PAR coated proposed cotton bag.

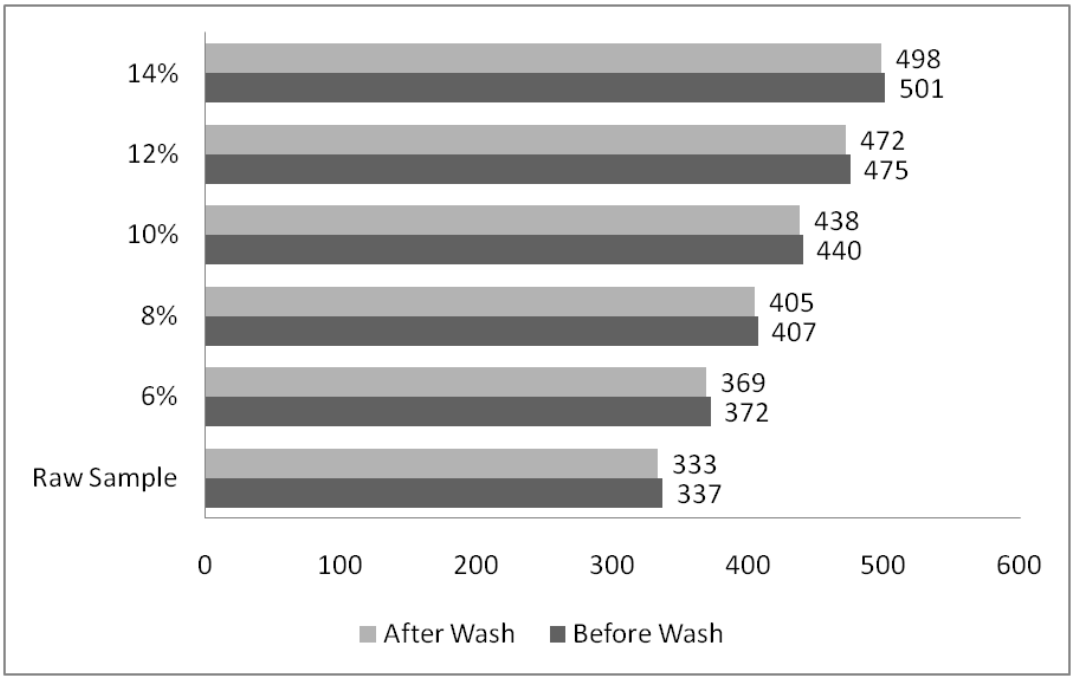

Figure 5. Effect of polyacrylic rubber on tensile strength (grab) in weft direction

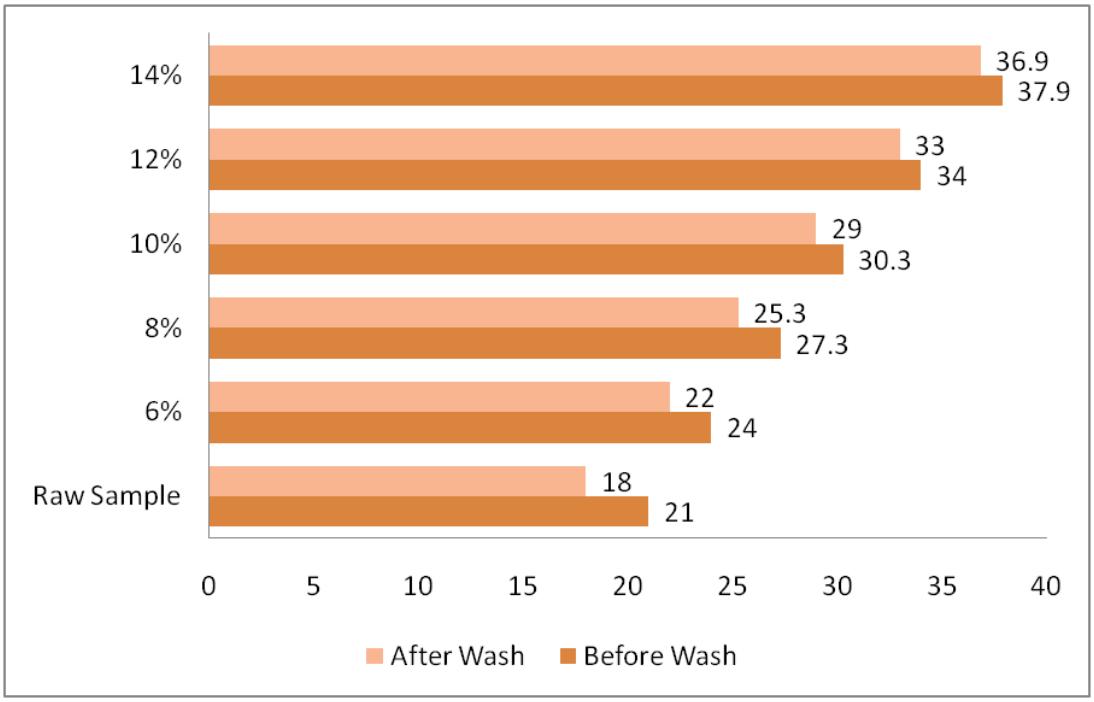

Figure 6. Effect of polyacrylic rubber on tear strength in warp direction

There is a small degree of strength (tensile, tear, and bursting) loss after five times of washings, indicating the wash ability of the proposed cotton bag. There is a significant amount of strength

(tensile, tear, and bursting) loss after rubbing, which means that after a long time rubbing, the finished fabric will gradually lose its strength; a key finding would give cotton an advantage over polyethylene bags in terms of degradable nature of used waste, especially since cotton is a biopolymer. The results of the three strength testers can provide a clear indicator of the suggested cotton bag's washable, durable, long-lasting, eco-friendly, and bio-degradable nature.

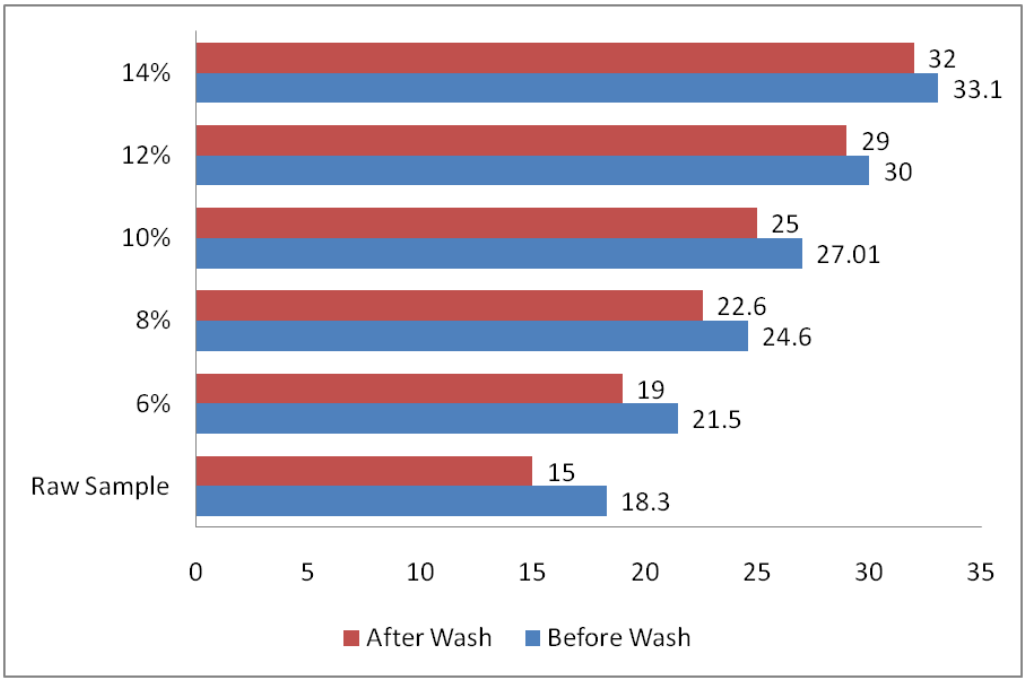

Figure 7. Effect of polyacrylic rubber on tear strength in weft direction

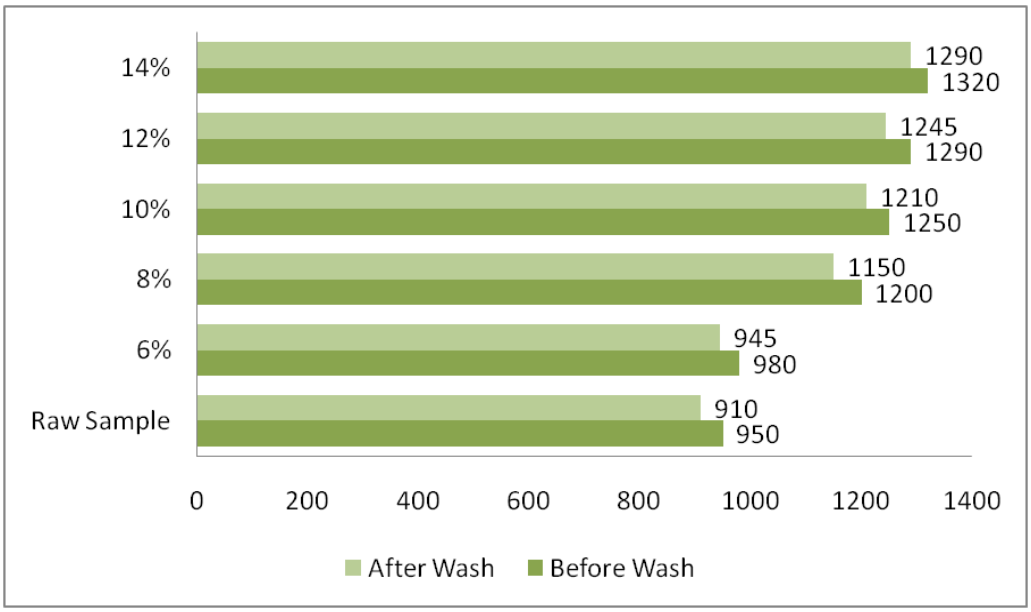

Figure 8. Effect of polyacrylic rubber on bursting strength

4.1. Cost comparison

A 100% cotton canvas fabric bag (44 cm X 34 cm) costs $0.50, as shown in the table above (see Table 4). On the other hand, a polyethylene bag (44 cm X 34 cm) costs $0.059. If price is the sole

consideration, it may appear unfeasible to move from polyethylene to cotton canvas bags due to the nearly 8.5 times price difference between them. However, it may appear meaningful after evaluating two other determinants: the strength of the cotton canvas bag and the long-term environmental concerns of utilizing polyethylene bags (see Figure 9 (b)). Because the strength of a cotton bag is over 12 times greater than that of a polyethylene bag, one cotton bag treated with PAR (see Figure 9 (a)) can replace at least 50 polyethylene bags while remaining unmodified or with negligible loss to its properties. In such a situation, the cost of 50 polyethylene bags is roughly $3, whereas the cost of one cotton bag is $0.5, so the price gap is still six times. Changing the variable to the second would make this finding more logical. Although plastic bags are durable, lightweight, economical, water-resistant, and require extensive chemicals for production and less energy, they have resulted in many negative environmental effects such as animal choking, pollution, channel, river, and stream blockage, global warming, landscape disfigurement, marine life, and agricultural land. As the world moves toward greener and more sustainable products, natural products such as cotton may be the best replacement for polyethylene bags. Cotton treated with PAR is biodegradable, sustainable, and renewable, which makes it an excellent choice as an environmentally friendly fiber throughout the product life cycle.

Table 4. Total Cost of manufacturing a cotton bag

Particulates	Amount (BDT)
100% cotton canvas fabric (0.46 yd)	33
Polyacrylic Rubber	2
Ammonium Chloride	1
Utility service	2
Sewing thread & Sewing cost	1.5
Packaging	1
Transportation	1.5
Total	42
Total	$0.45 (apprx.)

a) *b)*

Figure 9. (a) Bag made of cotton with PAR and (b) bag mad of polyester

In terms of sustainable policy, many merchants believe that cotton bags are environmentally beneficial and that to protect the environment for the future, they are willing to spend whatever price. The primary issue is that there is no advertising or understanding of how cotton carry bags would preserve

our environment. Cotton carry bags will be preferred by every retailer (supermarkets as well as small retailers, namely, grocery stores) if corporations begin to create awareness of them. For example, in the United States, IKEA will no longer provide consumers with free plastic bags. Every plastic bag at every IKEA U.S. shop throughout the country will cost five cents beginning March 15, 2007. IKEA has also reduced the cost of their reusable 'Big Blue Bag' from $.59 to $.99 in the hope that one blue bag will replace hundreds of single-use bags. What appears impracticable at first when contemplating the price tag is far more compelling when considering two essential variables of strength and environment, albeit the price is still higher. Public awareness and effective policymaking, along with the required assistance for retailers, can reduce the price difference while producing the best results in terms of long-term environmental consequences.

5. Conclusions

Without adding formaldehyde to the process for modifying cotton, it is possible to improve the fabric's physical and mechanical characteristics if it is treated with the proper PAR finish. Significant improvements in the abrasion resistance, flexibility, tensile strength, and bursting strength can be obtained from poly acrylic rubber finishes using the pad-dry-cure technique were under the catalytic impact of NH_4Cl, the esterification reaction resulted in significant cross-linking of cotton fiber chain molecules across segments of polyacrylic rubber. Apart from their excellent strength, cotton bags outperform all other carry bags because they have outstanding qualities such as being able to replace hundreds of polyethylene bags, being environmentally friendly, and being easy to wash and reuse. The main disadvantage of switching to cotton bags is their high price if just direct costs are considered. Though there is no solid calculation for this assumption, it may appear credible that this price may be further reduced if large-scale manufacturing is combined with supportive policies from key stakeholders. This policy could range from a favorable subsidy, a low-interest loan to a startup, to raising awareness among the general public about the benefits of using cotton bags, as well as a long-term plan to ban polyethylene bags entirely. However, when the indirect cost of long-term environmental risks of using polyethylene bags is considered, as well as the higher strength of cotton bags, it appears that switching to cotton bags is a smart idea. Considering all of the ifs and does of large-scale collaboration of global policymakers and enlightened customers' willingness to buy stylish, eco-friendly, high-priced products, this paper can confidently conclude that PAR coated cotton fabric canvas bags can be a good replacement for environmentally hazardous polyethylene bags.

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