A Sustainable Continuous Traditional and Bio Scouring Process for Better Fabric Dyeing

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Abstract

Conventional scouring has been replaced with Bio scouring process in recent days in textile industry keeping in mind the advantage of bio scouring over dyeing. Though bio scouring is advantageous in terms of dye processing, both the processes lags when it comes to sustainability, where the resources utilized from scratch to processed fiber is huge and harmful. Keeping this in mind, we have proposed a process where a continuous bio scouring process was used. The results obtained in terms of material properties were equal to the bio scouring process, but from sustainability point of view, the novel process has saved around 42% of energy, 50 % of water and 33.33% of time with respect to bio scouring. The results obtained were reproducible and this method can have a huge implication on textile processing as it is aligned to one of the sustainability goals.

Keywords:*Bio scouring, Enzymes, Energy conservation, Sink test, Wicking test.*

1 Introduction

The processing of textiles is a booming sector that utilizes a lot of water, energy, and harsh chemicals traditionally. Typically to produce one kg of textile approximately 200 liters of water is used. In the complex structure of the natural fibre, presence of pectin is one component which hinder textile processing drastically. The pectin content of cotton fibers disrupts the uniform dyeing of cotton materials, thereby decreasing their quality and aesthetic properties. One efficient way of side lining pectin is via scouring by chemical method. The process for pectin elimination, known as scouring, may be realized by classic alkaline treatment or by ecological enzymatic procedures. These processes, not only utilize hazardous chemicals, and bacteria, they are also a major threat to the environment as specified in the sustainability goals by WHO. In short, to achieve the sustainability goal, the main emphasis should be on producing less waste that is safe to dispose of, use less energy, water, and chemicals, with recycling and adopting ethical production practices [1]. The role of Enzymatic processes and biotechnology became more attractive in recent days in textile processing industry, as it is possible to create a practical, more environmentally friendly, and economically viable method using this technology [2]. High molecular weight protein bio-catalysts called enzymes used in the above process have very focused action and they can quicken chemical reactions because they are biological catalysts.

Raw fibers, yarns, and fabrics can contain a variety of impurities, including motes, fragments of seed coat, pesticides, dirt, chemical residues, different forms of metallic salts, and immature fibers. Cotton fabrics are subjected to enzyme scouring to eliminate any non-cellulose contaminants. Such a procedure would aid with proper fabric dyeing and finishing as well as increase the cloth's absorbency without significantly reducing its strength. It was discovered that protease and pectinase was utilized as bio-scouring agents to treat textile materials when they were applied to scouring cotton cloth [3]. The capability of an enzyme called a cutinase from the fungus Fusarium solani pisi to degrade cotton wax was attempted to create a productive low temperature scouring procedure [4]. Significant comparison between enzymatic and traditional scouring processes, proves that the contribution of enzyme to reduce cost and the pressure on environment can be contained.When compared to the researched enzymatic scouring treatments, conventional alkali scouring resulted in greater weight and tensile strength loss, but it also produced worse whiteness index and inferior color strength when the treated fabrics were coloured with one direct dye and two reactive dyes [5]. The water absorbing character of the Bio scoured fabric was found to be considerably higher than that of the conventionally scoured fabric . The bio scouring process performed with these optimal values is suitable for pre-treatment of cotton fabrics [6]. By means of continuous bio scouring process minimizing the required enzymatic incubation time. To enhance this and reduce the time usage of surfactant is essential. It is clear that the presence of a sufficient level of surfactant is of major importance in obtaining a satisfying level of water absorbency in a limited time frame [7].

Although the effectiveness of scouring is the basis for this study, comparing performances should also be assessed following additional processes to determine their overall efficacy. The ultimate aim of the work is to study the effect of continuous bio enzymatic process towards scouring process, especially focusing on the time taken for the treatment. Effectiveness and performance are evaluated for this purpose at several steps, even after dying and completing. The following figure 1 is the plan of work towards the process.

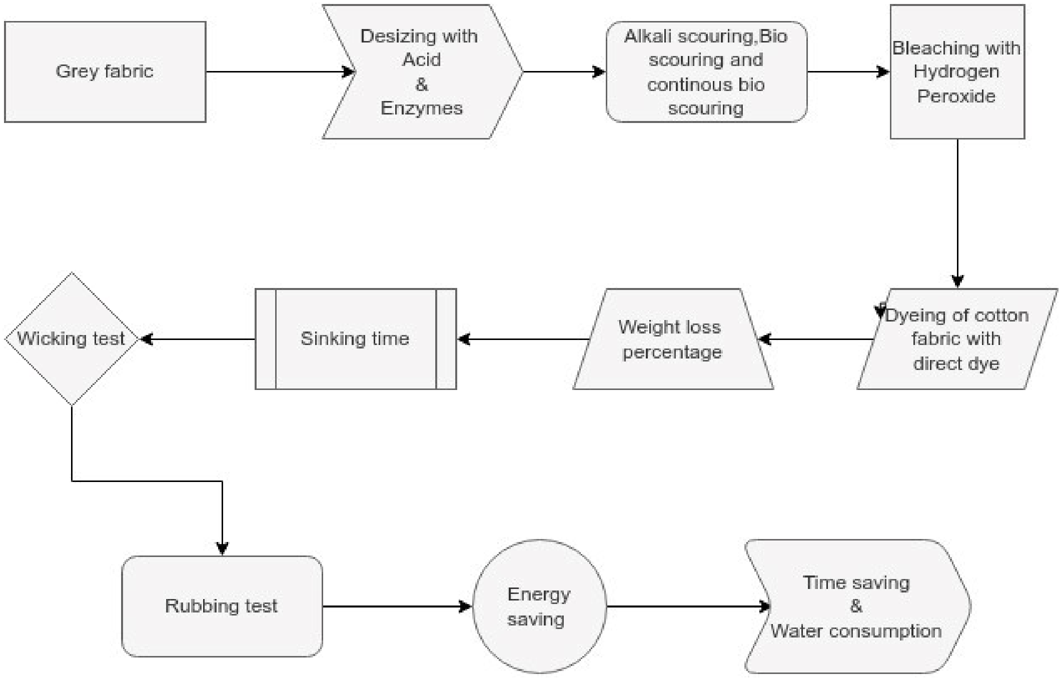


Figure 1. Process Flow Chart

2 Materials and Methods

2.1 Raw Materials

The raw materials used are

- 100% cotton fabrics (Grey) Fabric
- Fabric Construction: Plain
- Fabric type: 100% Cotton (Grey), GSM: 150-155.

1. Enzymes-Pectinase, Amylase.

- Caustic soda, Sodium Carbonate, Detergent(lebolene), EDTA, HCL, Sodium silicate, Hydrogen Peroxide, Sodium silicate.
- Dye-Direct dye (Incomine blue)

2.2 Processing of Cotton Fabric(Desizing)

2.2.1 Desizing with dilute HCl

The removal of starch or other sizing materials that are put to yarn before weaving in order to promote absorption and improve weavability is the first stage of wet pre-treatment. Below figure 2 shows the apparatus arrangement of desizing process.The fabrics were desized with 1% hydrochloric acid for 2hours at a Material Liquor Ratio (MLR) of 1:20, then thoroughly washed with hot water followed by cold water and dried.

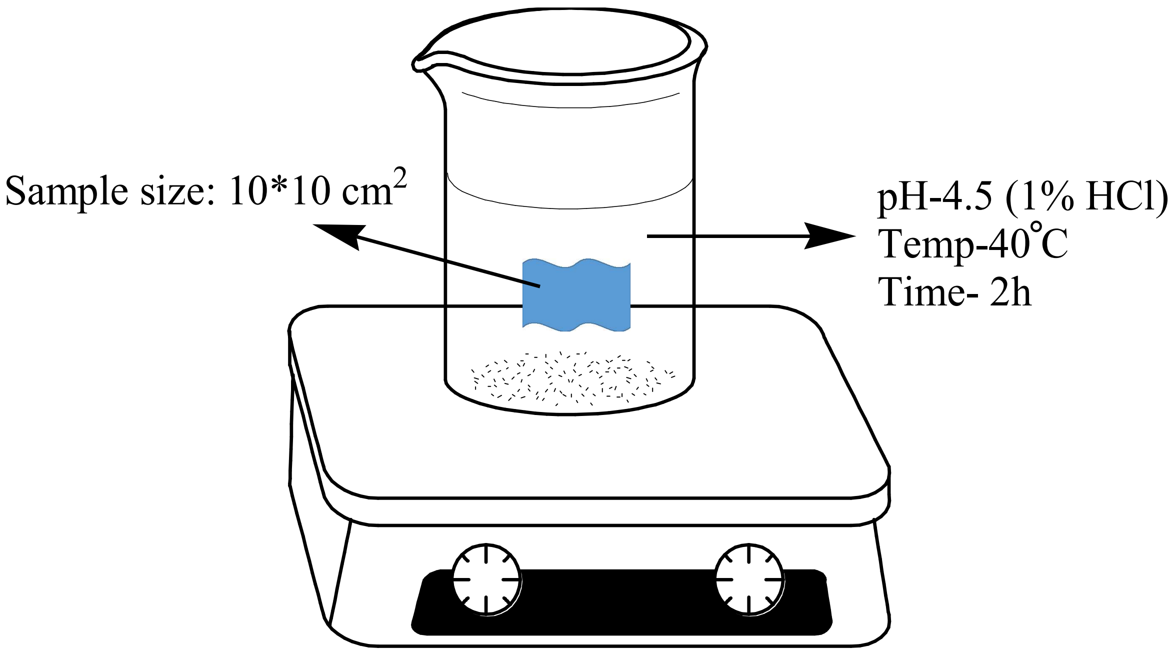


Figure 2. Acid desizing

2.2.2 Desizing with amylase

The fabrics were desized by containing 1% of amylase enzyme for 45 min using a Material Liquor Ratio (MLR) of 1:20 and thoroughly washed with cold water and dried in air. Figure 3 shows the enzyme desizing apparatus.

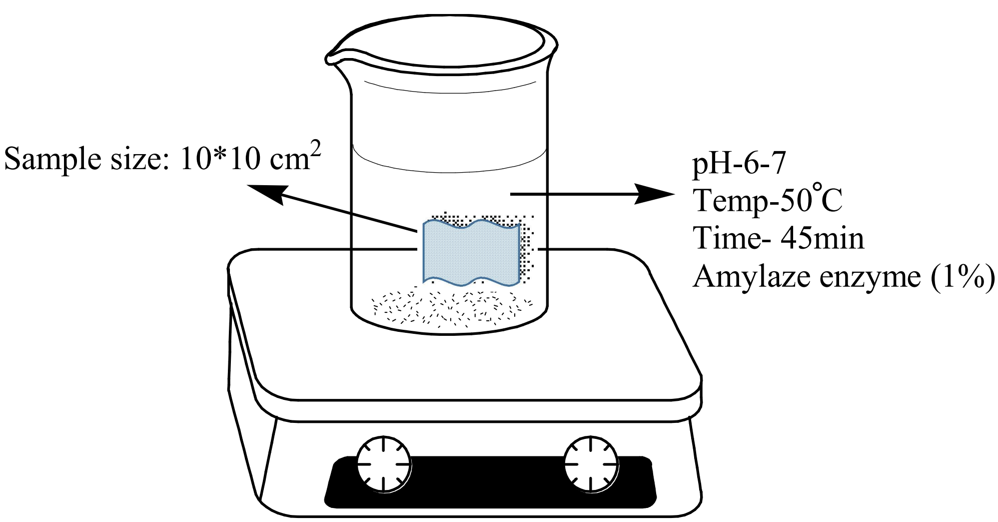


Figure 3. Enzyme desizing

2.3 Scouring Process

2.3.1 Traditional Scouring Process

For Traditional scouring, 2-3 % NaOH was used. generally, for wet processing carried out with soft water. In case when hard water components are used, the water softened by using, 1-2% of sequestering agent (EDTA). Moreover, 1-3% detergent (lebolene) and, Process carried over around 90 min at 80-90°C. Process curve for scouring is shown below in figure4.

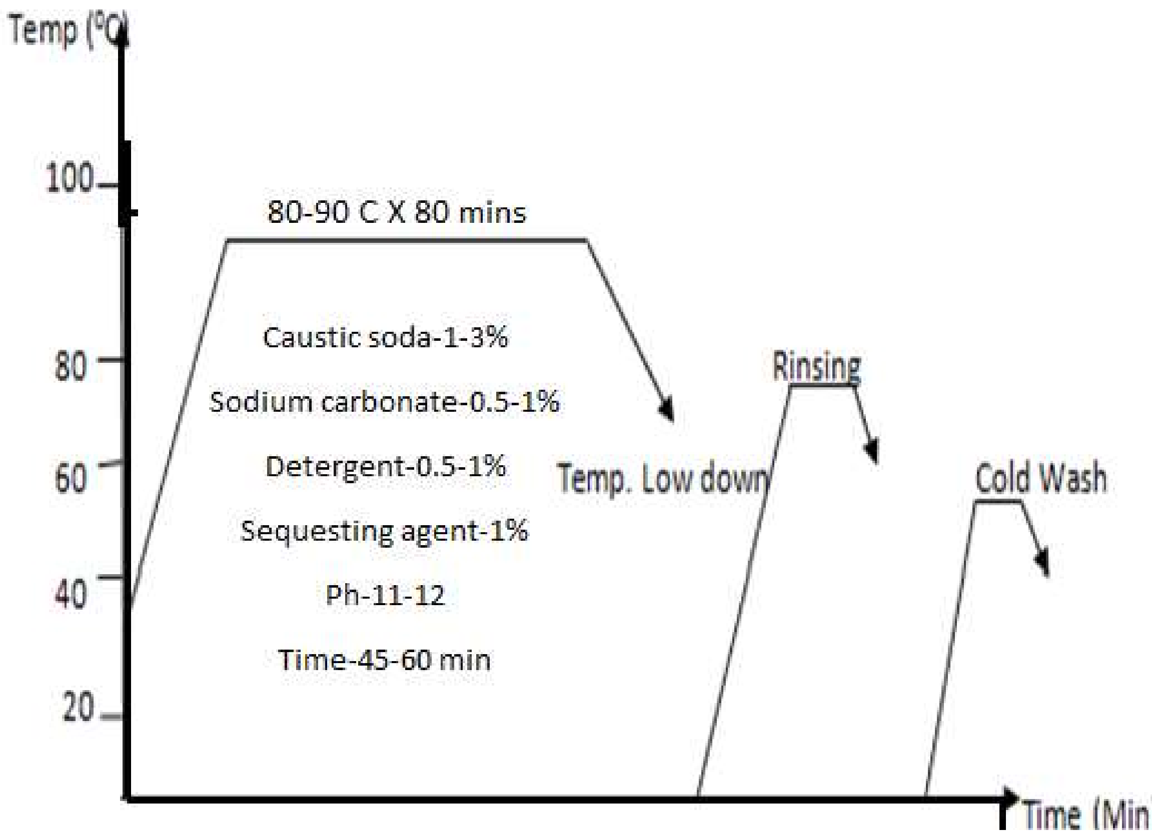


Figure 4. Conventional Scouring curve for cotton fabric

2.3.2 Bio scouring Process

3%OWF (On the Weight of Fabric) Enzyme pectinase type enzyme was used bio scouring. The scouring bath's pH was maintained between 6 to 9 in presence of 0.5-1.5 g/l detergent (lebolene) at a temperature of 50°C for a period of 45 min.The below graph figure 5 shows the process curve of bio-scouring process.

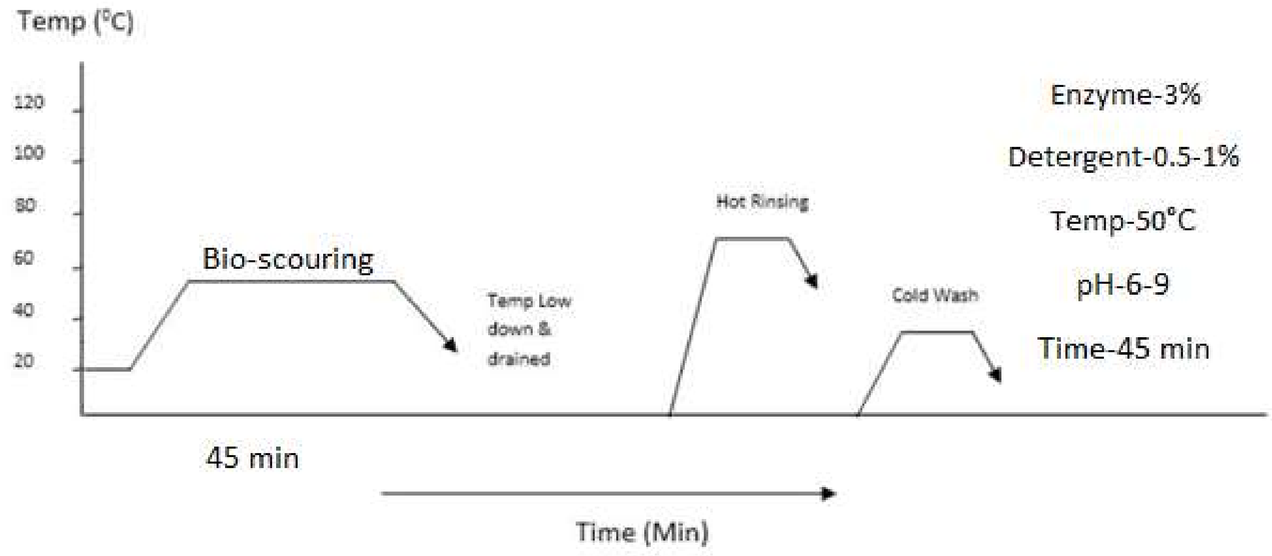


Figure 5. Bio-Scouring curve for cotton fabric

2.4 Continuous bio desizing and Bio scouring Process

Though it looks promising when both the processes are done separately. To decrease the time from 2 hrs to lower we propose a continuous desizing and bio scouring process. The methodology and the procedure is discussed here in figure 6 and 7. In continuous process, for desizing 1 %OWF amylase Enzyme was used and for Bio scouring process 3% OWF of pectinase enzyme was used. The pH of the desizing and scouring(combined)bath ranged from 6 to 9, with 0.5-1.5 g/l of detergent was used. After the process is over, to deactivate the enzyme bath temperature was increased. The combined process in schematically given in figure 7.

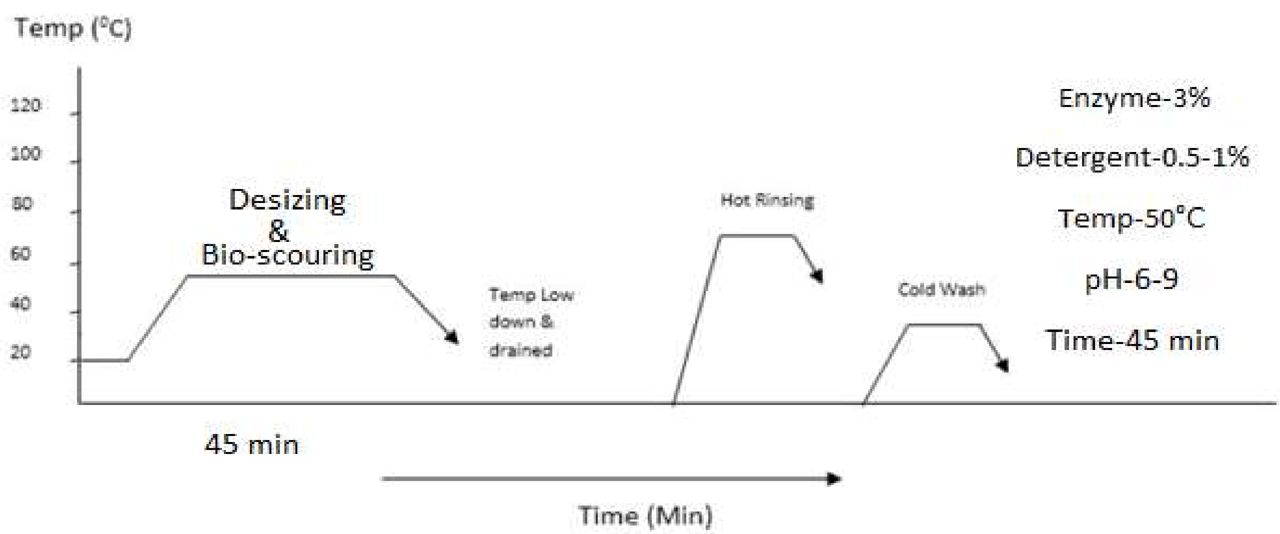


Figure 6. Desizing and Bio-Scouring curve for cotton fabric

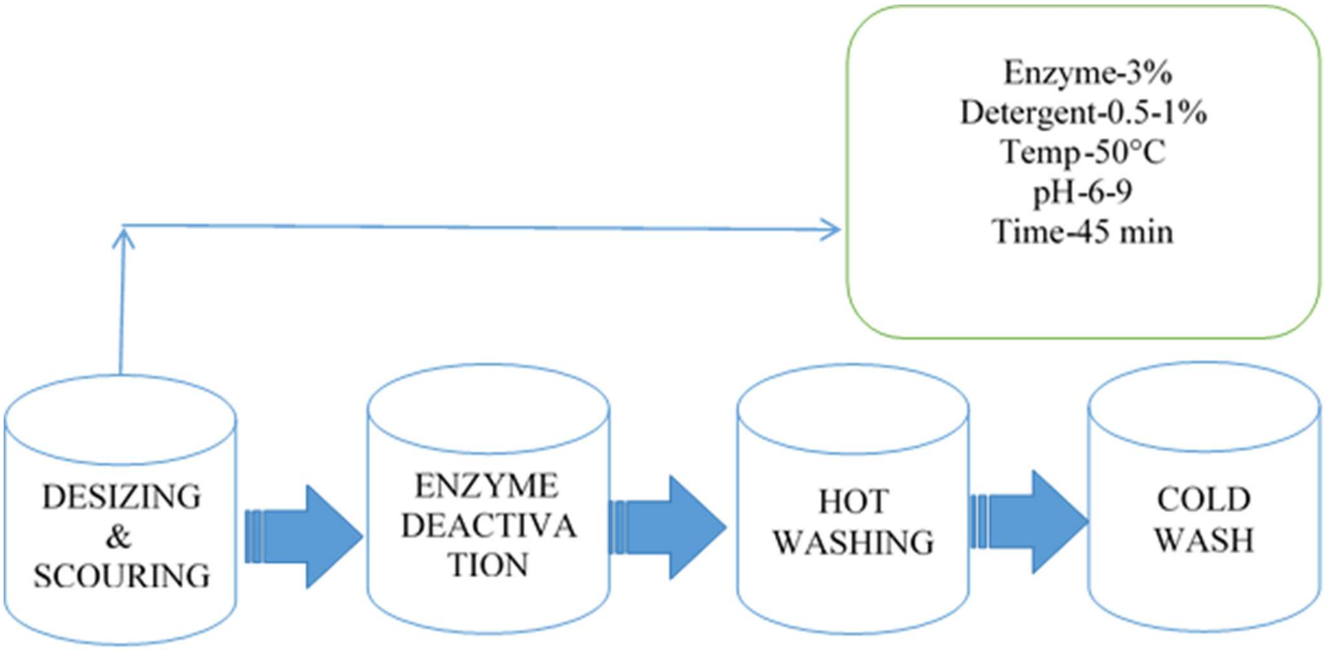


Figure 7. Continuous desizing and scouring

2.5 Bleaching of cotton fabric with Hydrogen Peroxide

To study the effect of scouring from different methodology, the following treatments were done to measure the properties. The samples (both traditional and bio-scoured) were all bleached with 3% OWF hydrogen peroxide (35%). The bath was filled with sufficient amount of water and 1 % EDTA, sodium carbonate 1- 2% and 2% of sodium silicate were added. A cotton fabric sample was introduced into dyeing bath and the pH of the bath was adjusted to 10-11 using sodium carbonate. The required amount of hydrogen peroxide was added and the pH was maintained at 10. The temperature of bath was gradually increased at the rate of 2˚C up to 98 °C and maintained for 60 min. After the samples were bleached the samples were removed and washed with cold water followed by hot wash. The excess alkali in the fabric after bleaching was neutralized with 0.5% of acetic acid then washed and dried.the below figure 8 shows the bleaching process curve of cotton fabric.

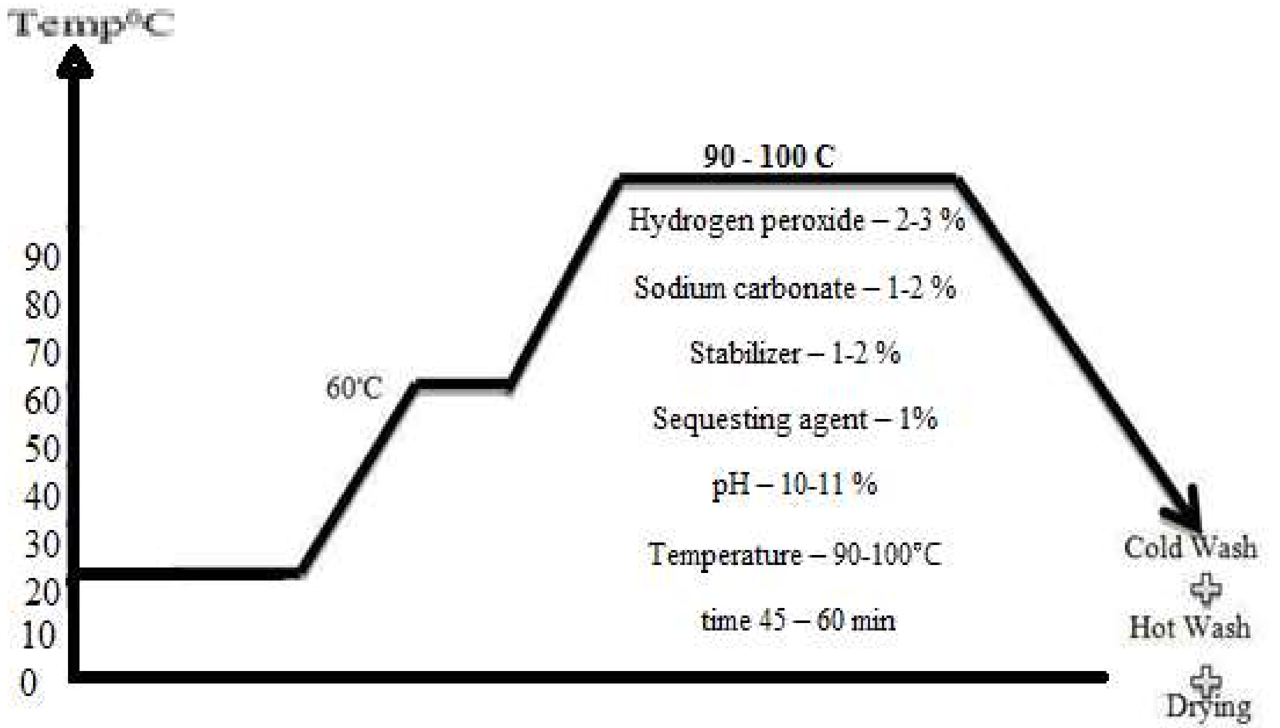


Figure 8. Bleaching curve for cotton fabric

2.6 Dyeing of cotton fabric with Direct dye

The dyeing with the direct dye (Incomine blue) was carried out by open bath dyeing machine using distilled water at materials to liquor ratio of 1:30. The dyeing bath was filled with predetermined amount of distilled water, dye (1%,2 %,3%,4% OWF) and exhausting agents (sodium chloride) 60 g/l (two phase addition). The machine was then operated for 20 min and 30 g/l NaCl was added as 1st phase electrolyte and then run for another 10 min followed by addition of 2nd phase electrolyte. The temperature of bath was raised to 98°C and carried the process for 60 min. The liquor was drained, and the coloured samples were washed and rinsed with cold water. The samples were then dried for 30 minutes at 60°C. figure 9 shows the direct dyeing process sequence curve.

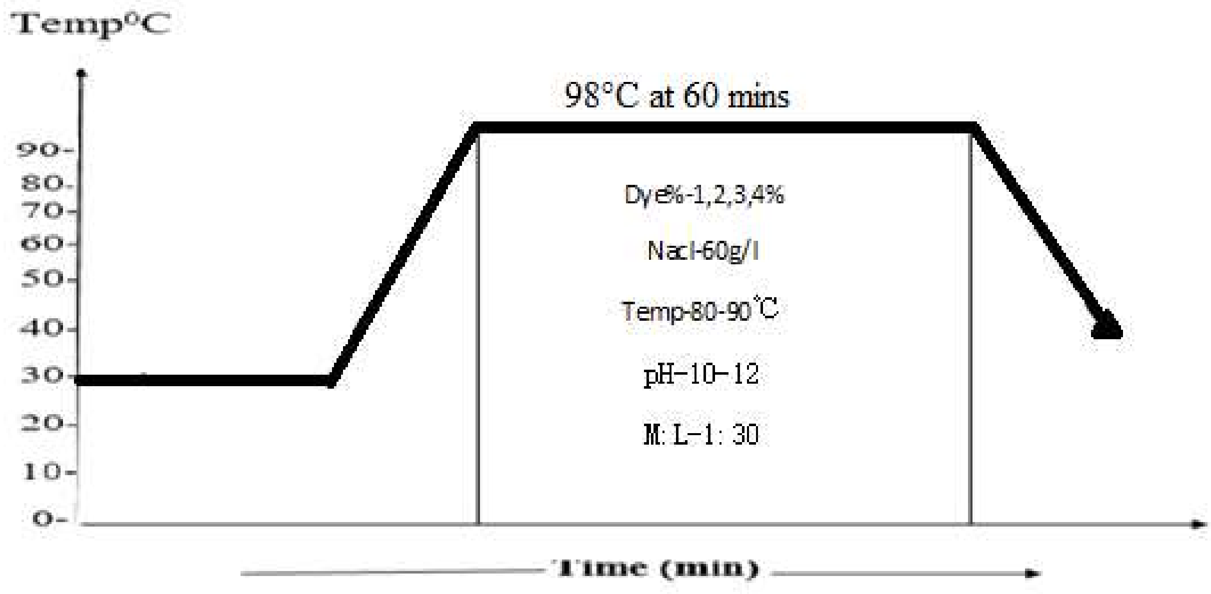


Figure 9. Process curve for dyeing is shown in the following

3 Evaluation of Fabric Properties

3.1 Weight loss percentage

After the traditional and bio-scouring processes, the weight loss was measured. Cotton fabric samples were weighed before and after going through processes at 105°C. The following equation was used to determine the weight loss:

Weight loss is calculated as = (W1-W2)/W1*100 (1)

where W1 and W2 are the pre- and post-treatment oven dry weights of cotton fabric, respectively.

3. 2 Sinking time

This is a straightforward test for highly absorbent materials in which a fabric sample measuring 25 mm x 25 mm or 50 mm in length is thrown over the surface of distilled water, and the time taken for the fabric to sink is recorded. Where the sinking length and time are interdependent to each other. Length of water to be taken is 15 cm and the sinking rate is measured using a stop watch. From the sinking time taken for the sample, the absorbency nature was calculated.The below figure10 shows the sinking test arrangement for prepared samples.

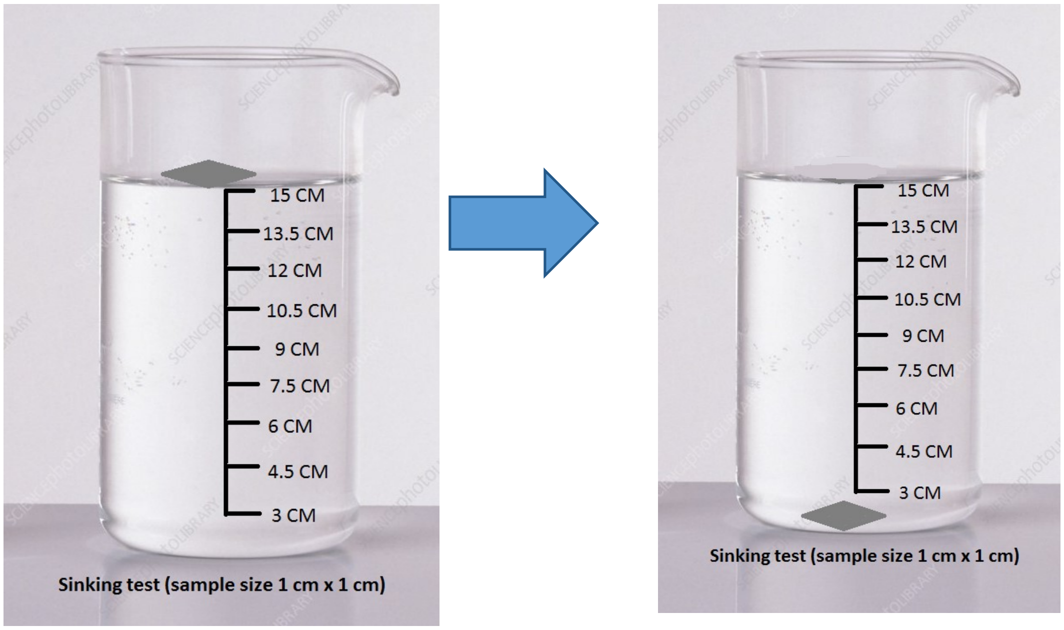


Figure 10. Sinking test

3.3Wicking test

As shown in Figure11, this test involves suspending a fabric strip vertically with its lower edge in a reservoir of distilled water. The leading edge of the water is then watched to see how quickly it rises. A dye can be added to the water to mark the water line, or in the case of dark-colored materials, an electrical circuit can be made using the water's conductivity. The measured height of rise in a specific amount of time is used as a direct indicator of the test fabric's ability to wick moisture. The simple form of the test will depend on the height to which the water has risen, the fabric's thickness, and the capacity of the fabric structure to hold water rather than the mass of the water that is absorbed.

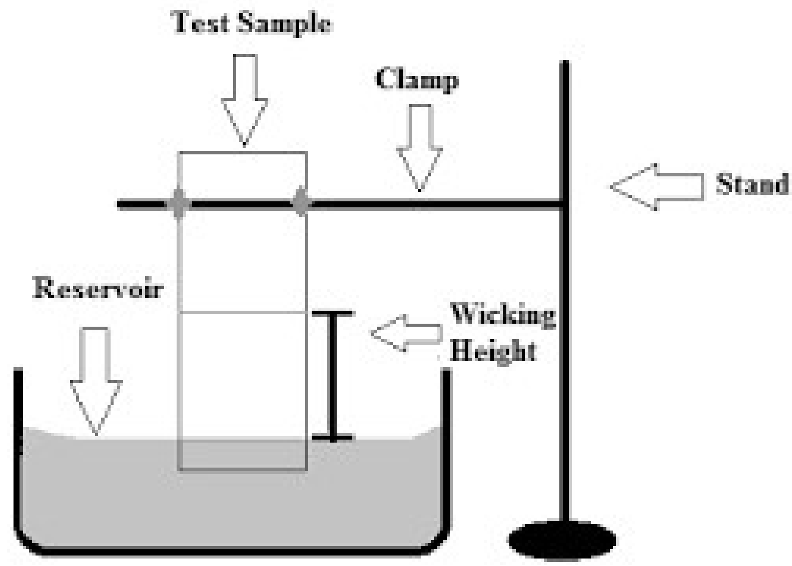


Figure 11. Wicking Test

For the sample chosen, spontaneous wicking was discovered which is due to the strong capillary force acting at the interface of water and cloth. The liquid rising boundary's peak was captured for 900 sec with minimal gaps of 30 sec and maximal gaps of 60 sec.

3.4 Rubbing test

In this test, a Crock meter with a weighted finger and a piece of un-dyed cotton cloth of 5cm X 5cm is used to rub the dyed sample ten times. Before rubbing the cotton cloth on the dyed sample, it is wetted out in preparation for wet rubbing. Next, the cotton rubbing cloth is checked for any color that may have been washed away and its staining is evaluated using the grey scale. Figure 12 shows the rubbing test equipment (crock meter).

Figure 12. Crock Meter (Rubbing Test)

4 Results and Discussion

The cotton sample in the prescribed size was desized and scoured separately and compared with a continuous desizing-scouring process. The processed material was further studied for % weight loss, sink test, wicking test and rubbing test. The results were compared and discussed in the following section.

4.1 Weight loss during pre-treatment process

Weight loss of the fabrics, fibers, or yarns is a crucial consideration for textile makers since it affects their profitability as well as the quality, comfort, and other attributes of the produced fabrics. Weight loss for the three different processes studied were done using 4 replicate measurements (4 samples under same condition) and the final data is averaged which is shown in figure 13 and 14. As the figure 13 shows the weight loss percentage of acid desizing and the weight loss percentage of enzyme desizing fabric samples.

After 4 measurements, the values didn't change much and the weight loss percentage was averaged to 6.84%. when comparing to enzyme desizing the acid desizing process decreased but not that significantly. As seen in the average, though not much change between acid and enzyme desizing. The change in the chemical structure of the fiber is envisaged for further processing. So the results obtained by WLP is a proof that the enzyme process doesn't degrade the fibre and retains the weight as same as the acid desized one.

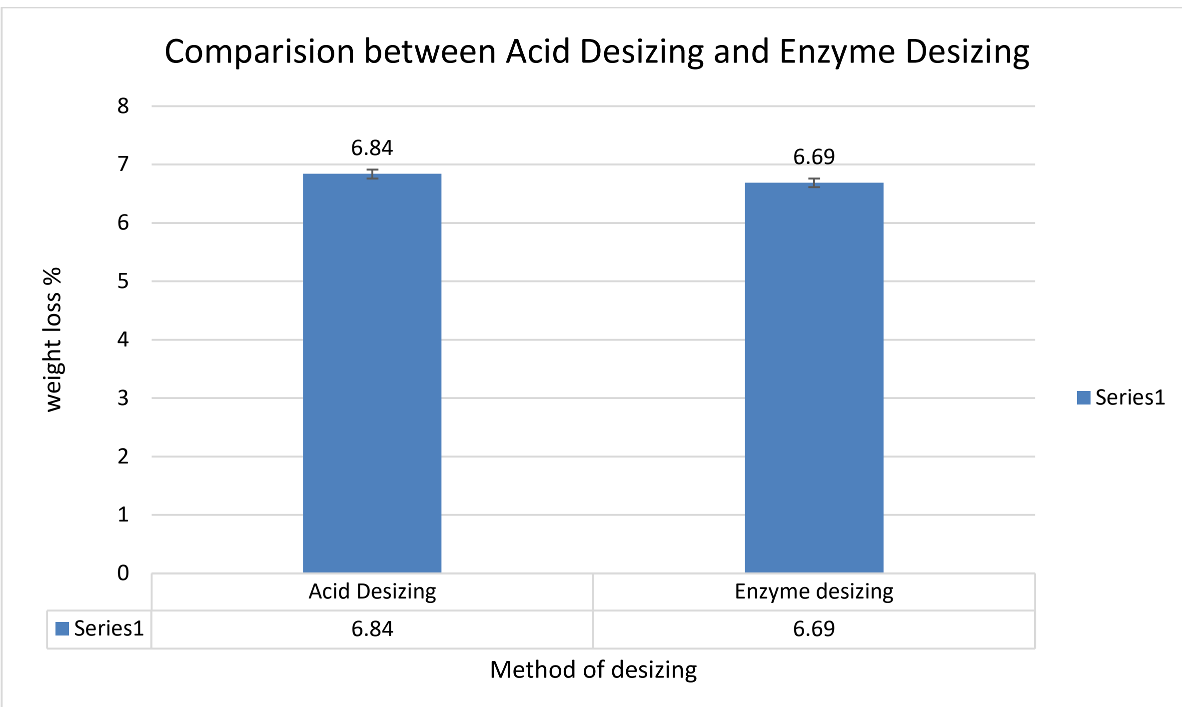


Figure 13. weight loss % of acid and enzyme desizing

From the results(figure 13) we observed that the weight loss % doesn't show any change with respect to varying desizing conditions like acid and enzyme. so we assumed that both acid and enzymes are removed size paste as equal efficient. Despite the negligible weight loss, the enzyme process was advantages considering the time taken for the process. Whereas for the acid process it was three times greater when compared to the enzyme process. Based on this it was concluded that enzyme based processes are much time efficient for fabrication over acid processing.

4.2 Weight loss during scouring process

As it relates to fabric quality, durability, comfortability, and other qualities, weight loss of scoured fabric is a crucial factor for textile manufacturers. As a result, after careful consideration, the following figure 14 shows the weight loss percentage of traditional (with NaOH),Enzyme scouring and continuous enzyme scouring process samples. In comparison to the bio scouring in continuous process, where the desizing and scouring processes were carried out in the same bath, the data above fig.14 show that the weight loss% is larger in traditional and continuous processes. so, it may be assumed that comparatively more impurities have been removed from the fabric treated than alkali scouring process and hence higher effectiveness. However, in continuous scouring process, the weight loss observed will be more as both sizing and impurities are removed effectively.

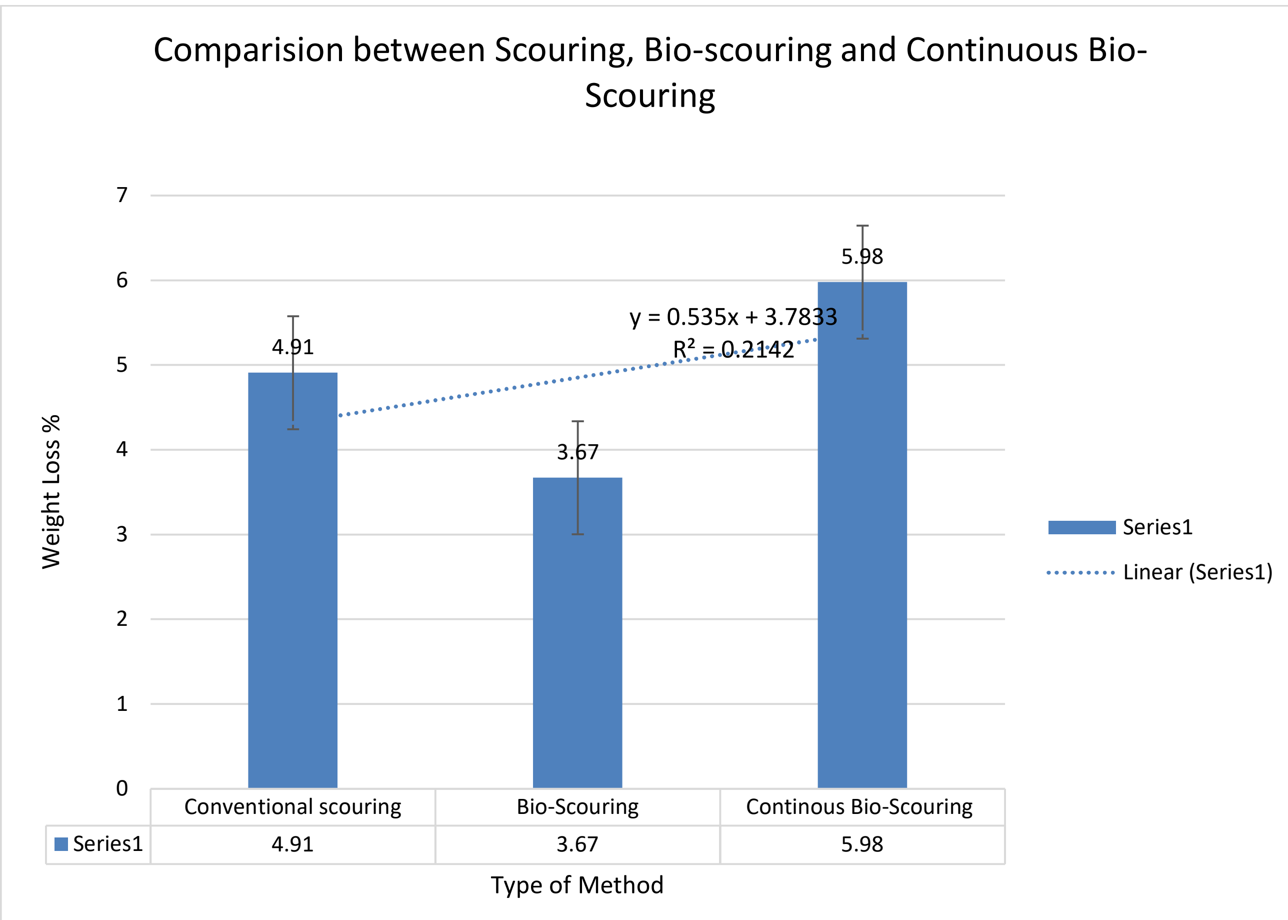


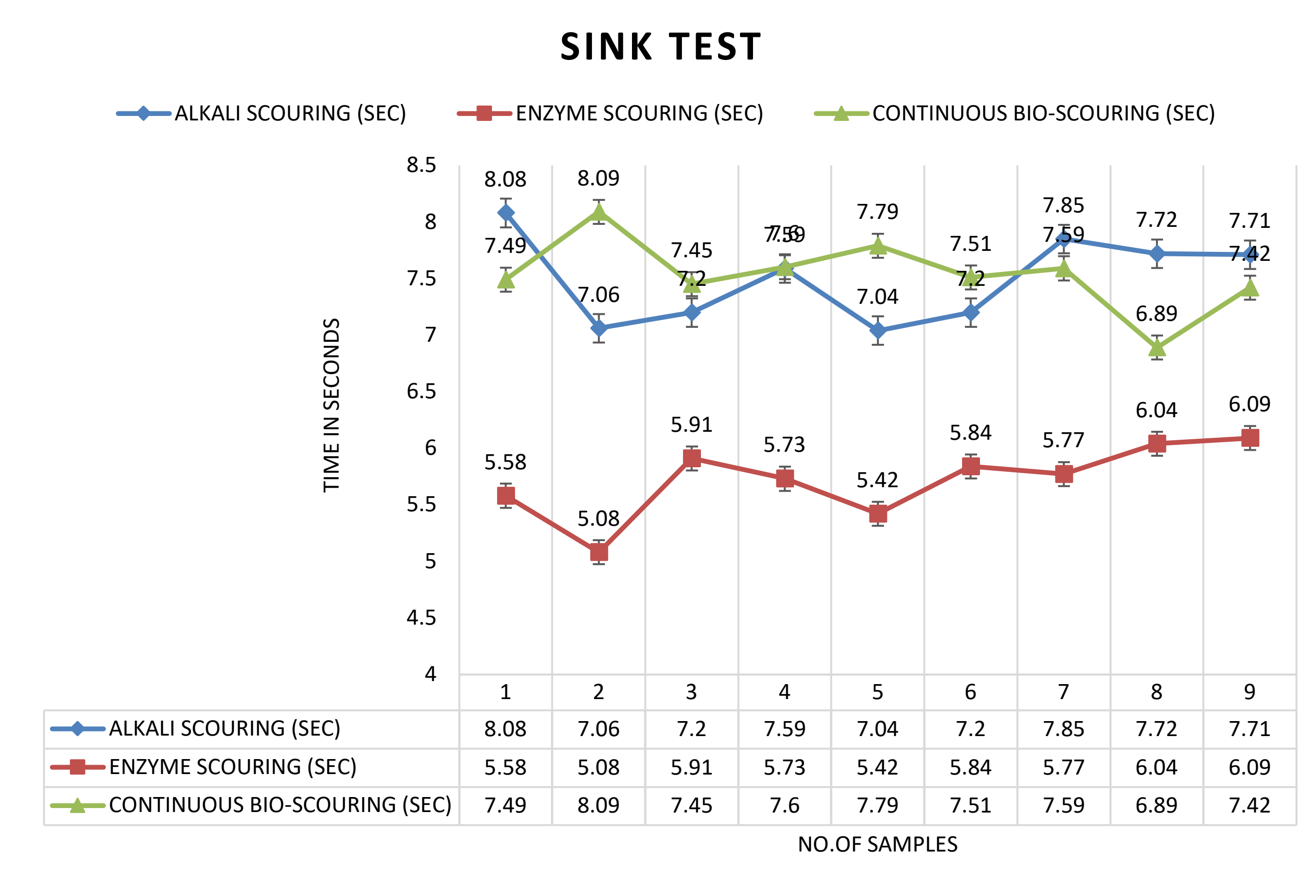
Figure 14. Weight loss % of Alkali and Enzyme Scouring

On the whole, it can be assumed that the efficiency was not substantially higher than the alkali scouring process. Comparing the time taken for both the processes we can conclude that continuous process is effective, where we can anticipate more cleaning of the fibers (wt%) with increasing time of process.

4.3 Sink Test

The next test to probe the continuous process is effective is to check their rate of water absorbency as it is the primary goal of the work. The absorbency of the scouring materials should be assessed because the primary goal is to increase the absorbency of the textile materials. The length of time needed in this approach to allow distilled water to settle to a known height.

Here the time taken for the material to sink at the bottom is measured and the % of absorbency is calculated at a fixed bath height. For the measurement the size of the sample was 1cm x 1cm and the height of the bath was 15cm The results obtained for all the 3 scoured material is given below in figure 15. From these results we see that in figure 15, the enzyme scoured sample was well scoured over traditional and continuous scouring process. It was also noted that bio scored samples are more effective in removing the impurities than conventional methods without damaging the chemical structure of the cotton fiber. The time taken to settle down the sample is minimum 5-6 sec in bio scouring when compared traditional scouring (>8 sec), which makes this process better in terms of absorbency. so we can clearly visible that the absorbency property will more when compared to those two processes.



	1	2	3	4	5	6	7	8	9
ALKALI SCOURING (SEC)	8.08	7.06	7.2	7.59	7.04	7.2	7.85	7.72	7.71
ENZYME SCOURING (SEC)	5.58	5.08	5.91	5.73	5.42	5.84	5.77	6.04	6.09
CONTINUOUS BIO-SCOURING (SEC)	7.49	8.09	7.45	7.6	7.79	7.51	7.59	6.89	7.42

Figure 15. Sink Test Results

4.4 Wicking Test

According to the figure 16, most bio - scoured samples had adequate absorption lengths when compared to traditional scoured samples and continuous scoured samples. This also demonstrates a significant distinction between traditional and continuous scouring.

The reason for decreased time in the continuous scouring when compared to the other two can be due to better removal of pectin in the fiber, which decreases the contact angle and increases the rate of water absorption via capillary rise. This results in highly promising as the rate of absorption increase, which will be beneficial for further processing especially while drying. The above graph figure 16 shows the wicking behavior of three different treated samples.

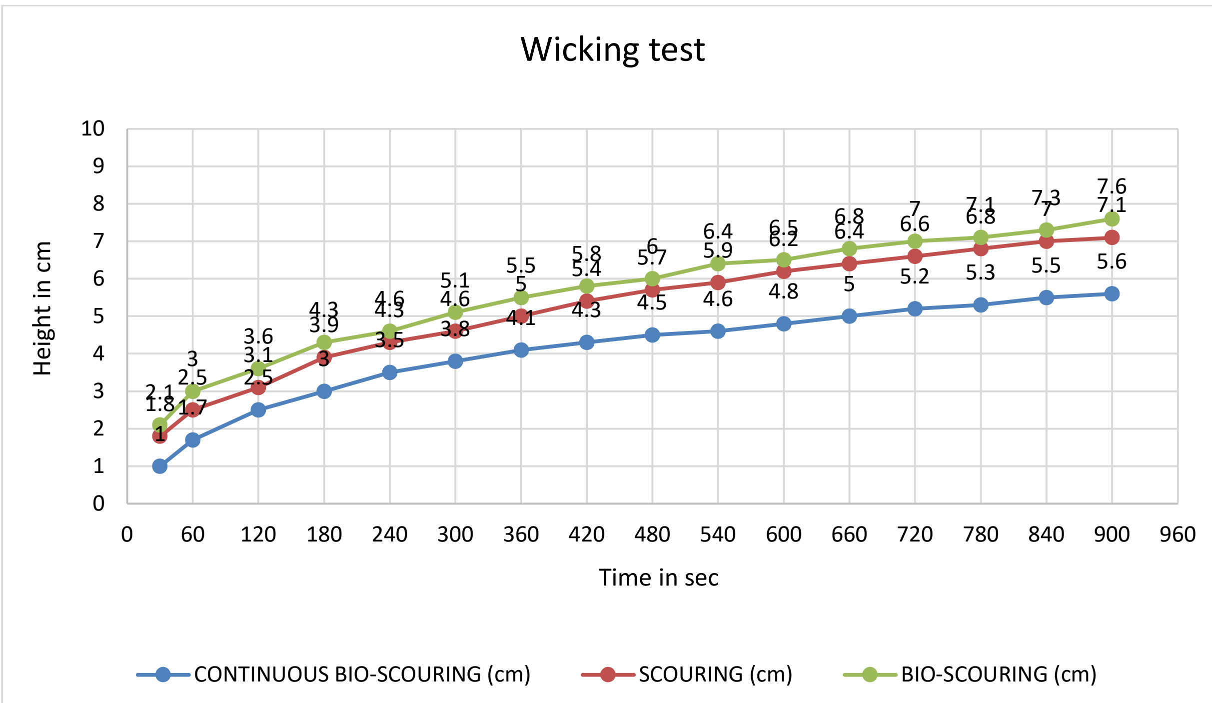
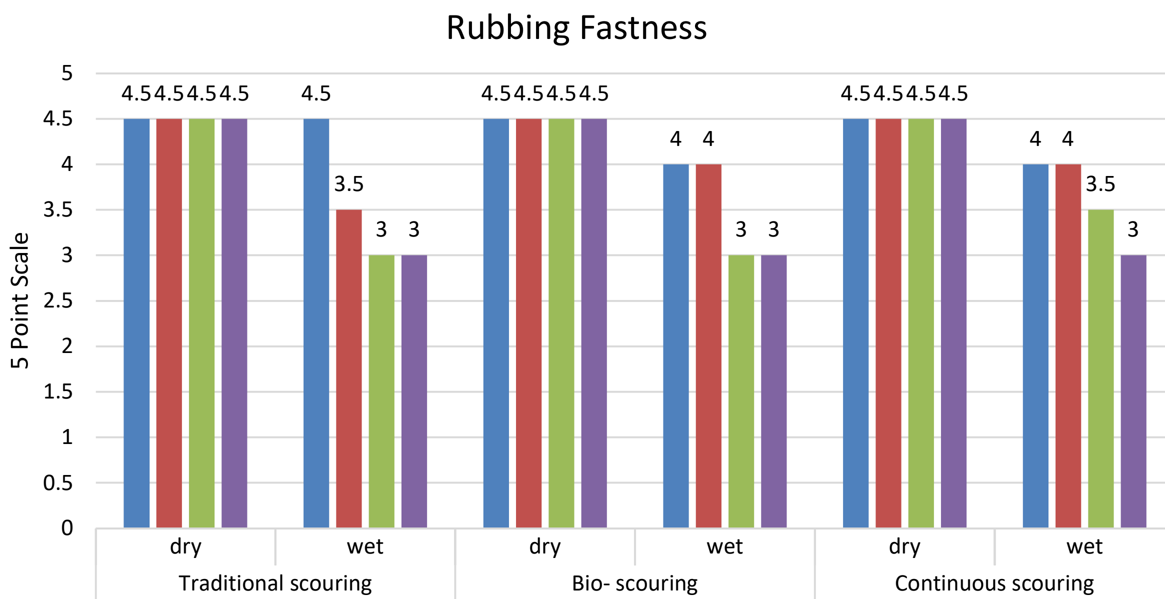


Figure 16. Wicking Test Results



	dry (Traditional scouring)	wet (Traditional scouring)	dry (Bio- scouring)	wet (Bio- scouring)	dry (Continuous scouring)	wet (Continuous scouring)
1%	4.5	4.5	4.5	4	4.5	4
2%	4.5	3.5	4.5	4	4.5	4
3%	4.5	3	4.5	3	4.5	3.5
4%	4.5	3	4.5	3	4.5	3

Figure 17. Rubbing fastness test of bio, continuous, and traditional scouring (dry and wet) sample

4.5 Rubbing Fastness

The samples were dyed using direct dye. They were subjected to rubbing action by using a rubbing tester. The sample was tested in dry and wet conditions. The samples tested are 1, 2, 3, and 4% dyed materials. The results show both dry and wet state fastness properties in figure 17.

As the result shows(figure 17) In all three-scouring process like traditional, bio and continuous - bio scouring process the dry rub fastness property is similar. But in wet rubbing the traditional scouring shows lesser wet rubbing fastness over the bio scouring process.

4.6.*Comparison of time, water and energy*

In bio scouring process and continuous bio-scouring, enzymes does its work properly at a temperature of 55°C. On the other hand to work out the scouring process traditional scouring needs a temperature of 95°C. Now if we apply bio–scouring process over traditional one then we can save 42% energy, which is beneficial to the overall process in terms of energy saving shown in Figure 18. In Traditional scouring process, to complete scouring process chemicals a total time of 60-90 minutes is required. On the other hand, in bio – scouring and continuous scouring process it took only 45 minutes to complete the entire scouring process. So, it’s clearly a huge time saving (nearly 50 %) if we take the bio – scouring and continuous process instead of traditional scouring process.

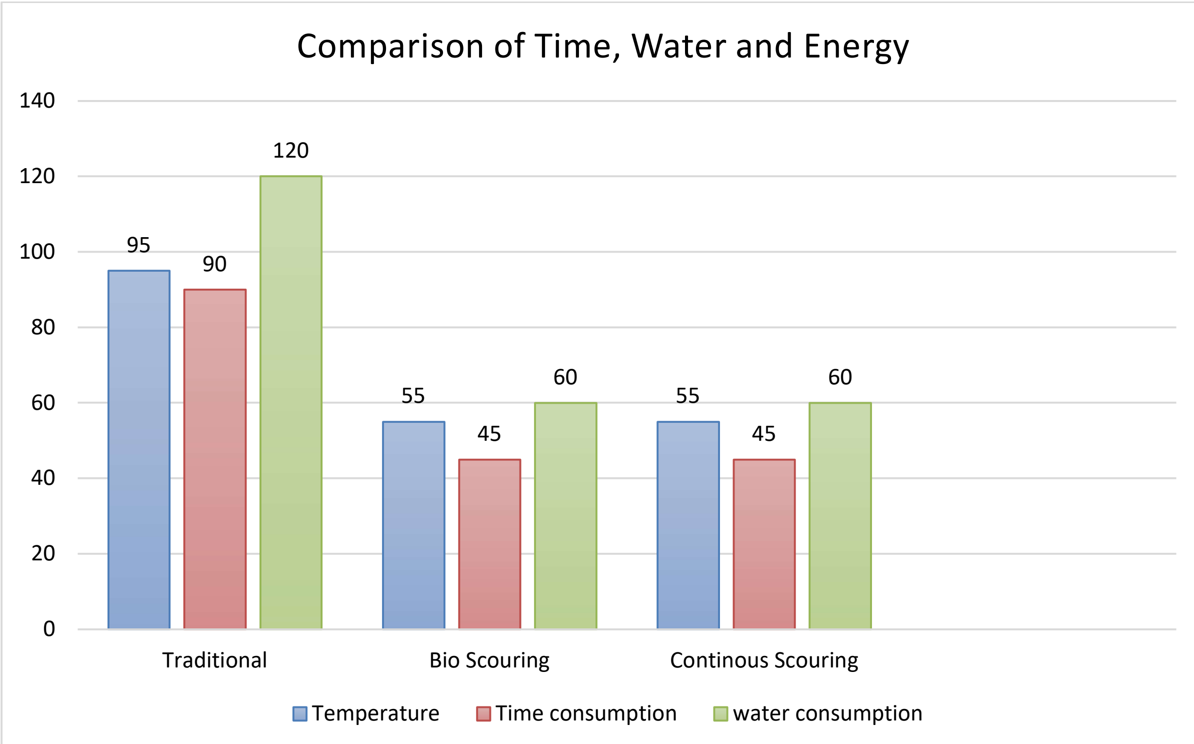


Figure 18.Comparison of time, water and energy

In traditional scouring we use a numerous chemical to complete the process. As a result, we also need a lot of water for rinsing. On the other hand, on bio-scouring and continuous scouring we use enzyme instead of using chemicals which shown in figure 18. It results a less water use in this process. In the experiment we found that we need less water in fact nearly half the amount we used in traditional scouring if we used bio – scouring. This is helps us to maintain the environmental balance and protects it from being polluted.

5 Conclusion

Though traditional scouring is widely used nowadays, it has a negative impact on the environment. As a result, many wealthy countries are abandoning traditional scouring techniques in favour of enzymatic, eco-friendly scouring processes. Because bio-scouring is an environmentally benign scouring method, it has a bright future. In textile processing, enzymes can be employed efficiently for preliminary processes such as desizing, scouring, and bleaching. The novel enzymatic technique plays an important role in reducing the need for energy, water, chemicals, time, and thus expenses. The results from the above methodology confirms that the enzyme process is much efficient than traditional following method. Following bio-scouring, fabric can be coloured immediately without bleaching, reducing additional costs in this stage. However, light-colored colors cannot be produced or are extremely difficult to match during this process. Light-colored tints dyed materials are easier to generate with traditional scouring and bleaching. Though both methods have pros and cons, considering the energy efficiency and less water consumption along with the eco-friendlyiness and less expensive bio-scouring technique seems to be promising, despite some operational challenges. Though the study considered only one kind of fabric, the results from this study is a breakthrough in textile processing, which has a strong chance of replacing conventional scouring in future world textile wet processing, where the same results can be expected from other types of fabric material.

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