# Short and Efficient Desizing and Scouring Process of Cotton Textile Materials

Mangesh D. Teli*and Tesfaye Tolessa Adere

*Institute of Chemical Technology, Matunga (E), Mumbai 400019, India*

***Abstract***

*Now days, all research efforts in the field of wet processing of textiles are directed towards sustainable process through chemical substitution, shortening and simplification of the processing sequence for minimizing water and energy consumption and reducing effluent load and the number of operations or shorten the process time. Thus, it has become necessary to combine several textile processing stages. This part of research work deals with design of combined enzymatic desizing and scouring process for cotton textile by using a mixture of BEISOL T2090 and BEISOL PRO enzymes. To optimize the combined bio-desizing and bioscouring, the Box-Behnken design (BBD) was utilized during the investigation. The range of process parameters were taken in three different levels at equal intervals. The treatment effectiveness on fabric properties was evaluated via weight loss (%), TEGEWA rate, tensile strength, and water absorbency (wettability). Furthermore, the properties of the combined treatment of the fabric after common bleaching process were investigated and compared to the conventional processes.*

**Keyword:** *Cotton fabric, Enzyme, Desizing, Bioscouring, Bleaching, Sustainable Process.*

## I. INTRODUCTION

Cotton grows on the seeds of the cotton plant and is one of the most recognized textiles in the world. It is considered as one of the oldest natural materials used to make fabric. Cotton fibre is a single biological cell with a multilayer structure [1, 2]. These layers are structurally and chemically different, and contain approximately 10% by weight of non-cellulosic substances such as lipids, waxes, pectic substances, organic acids,proteins/nitrogenous substances, non- cellulosic polysaccharides, and other unidentified compounds included within the outer layer of the fibre. These non-cellulosic materials create a physical hydrophobic barrier which protects the fibre from the environment throughout development; they provide lubrication during textile processing, and affect the enhancement of the fabrics wettability and absorbency [3, 4].

The processing of raw cotton in order to improve its performance in further finishing stages consists of three consecutive steps: desizing, scouring and bleaching. Desizing removes the size applied to warp yarns prior to weaving; scouring breaks down pectins and waxes and helps remove other impurities present in cotton fibres to improve water absorptivity; and bleaching commonly done with hydrogen peroxide under near boiling temperature, removes coloured impurities from fabrics that may produce an undesirable appearance and hinder dyeing performance[5,6].

In conventional textile wet processing, the above sequences are often done separately which involve high resource consumption and the chemicals used for all these steps are quite toxic and the process is costly because it consumes large quantities of energy, water, and auxiliary agents, as well as requiring neutralization that generates substantial levels of electrolytes in effluent. In addition, conventional scouring can give rise to undesirable reduction of fibre strength [7,8].The potential for the environmental contamination and depletion of natural resources is also serious [9].

Now days, industry has become increasingly aware about the optimal use of resources like water, energy. Also on the other hand as the fallout of pollution caused by industrial textile processes through chemical substitution, use of enzymes and process optimization have become essentials. It is possible to combine any of the two or all processes that can result in huge savings in terms of water, energy and reduced effluent load. This approach supports sustainable textile processing that is now becoming inevitable for the textile industries [10, 11].

The use of enzymes in the textile industry is an example of white industrial biotechnology, which allows the sustainable processing in fibre processing, and strategies that are, non-polluting, conserving of energy and natural resources, economically viable, safe and healthy for workers, and communities [12,13]. Therefore, consumption of energy and raw-materials, as well as increased awareness of environmental concerns related to the use and disposal of chemicals into landfills, water or release into the air during chemical processing of textiles are the principal reasons for the application of enzymes in wet processing of textile materials.

The present work aims at: i) Optimizing combine process parameters including BEISOL T2090, BEISOL PRO enzymes concentration, and temperature of reaction. (ii) Comparing the combined use of the desizing, and scouring processes using BEISOL T2090 and BEISOL PRO enzymes, respectively with the combined process of chemical treatment through measuring quality of treated cotton fabric in terms of weight loss, TEGEWA rate, tensile strength, and fabric absorbency.

Through this attempt, alternative preparatory processes have been brought under focus successfully by application of biotechnology in desizing and scouring for cotton preparation. Thus, the efforts were made towards reducing the water intake and minimizing the intermediate number of washings and also to minimize the intake of chemicals wherever possible to make existing process, 'more sustainable' and 'environment friendly'.

## II. MATERIALS AND METHODS

### *A. Fabric*

Greige cotton was used for the experiment. The process trials were carried out on the fabric of plain weave 100% raw cotton fabric with 120 GSM.

### *B. Chemicals*

Two commercial grade enzymes namely BEISOL T2090 and BEISOL PRO and auxiliary chemicals namely Felosan NFG (wetting agent) and Beixion NE (sequestering agent) were kindly supplied by CHT Indian Pvt.Ltd. Sodium hydroxide and sodium bicarbonate were of laboratory grade chemicals supplied by S.D Fine Chemicals, Mumbai.

## III. CONVENTIONAL METHODS

### *A. Desizing process*

The desizing was carried out in in Rota dyer laboratory machine at pH 7 at 60 °C for material liquor ratio 1:20 with BEISOL T2090 concentration 2% (o.w.f) and wetting agent Felosan NFG 1.5 % (o.w.f) and sequestering agent Beixion NE 2% (o.w.f). The process time for the de-sizing enzymes was 30 minute excluding the time required for heating at heating rate of 3°C /min.

### *B. Chemical Scouring process*

Initially weighed desized woven cotton fabric was treated in Rota dyer machine with 3% (o.w.f) NaOH, and wetting agent Felosan NFG 1.5 % (o.w.f) and sequestering agent Beixion NE 2% (o.w.f) at boil for 1h, excluding the time required for heating at a heating rate 3°C/min, at MLR of 1:20. After this, the sample was given hot wash at 90°C for 10 min and at 60 $^{o}$C for 10 min followed by cold wash and dried.

### *C. Combined Treatment of Desizing and Bioscouring*

Conventionally desizing is carried out with acid or enzymes (starch based sizes) and is carried out in acidic medium. This type of desizing cannot be combined with alkaline scouring where higher pH is required. A possibility of combining desizing with scouring arises if desizing can be carried out in alkaline conditions. This is possible if oxidative desizing is carried out, but it has its own limitations.
In using enzymatic processes, the combined treatment of desizing and bioscouring was carried out with an aqueous solution containing a mixture of BEISOL T2090 and BEISOL PRO enzymes of different concentrations and wetting agent Felosan NFG 1.5% (o.w.f) and sequestering agent Beixion NE 2% (o.w.f) at varying temperatures. A material to liquor ratio of 1:20 was used. The treated samples were washed with soap at 90 $^{o}$C and then washed with cold water and finally air dried.

### *D. Hydrogen Peroxide Bleaching*

Both conventional enzymatic desizing and alkaline or enzymatic scouring processes were first carried out. Samples were then bleached separately with aqueous solution containing 4g/l $H_2O_2$, X g/l NaOH and wetting agent Felosan NFG 1.5% (o.w.f) and sequestering agent Beixion NE 2% (o.w.f) and 2g/l sodium silicate for 60 min using a material to liquor ratio of 1:20 in Rota dyer machine. After the treatment, the fabric was washed two times with hot water and cold water and finally air dried. The bleaching experiments were carried out in triplicate in Rota dyer machine.

### *E. Design of Experiment*

To optimize the combined enzymatic desizing and bioscouring, the Box-Behnken design (BBD) was utilized during the investigation. The range of process parameters were taken in three different levels at equal intervals such as, enzyme concentration of BEISOL T2090 (2%, 3%, 4%) o.w.f and BEISOL PRO (2%, 3%, 4%) o.w.f, and temperature (80 $^{o}$C, 90 $^{o}$C, 100$^{o}$C). The independent variables (enzymes concentration and temperature) and their levels (low, medium, high) were chosen based on supplier's recommendation. These variables, in three levels, were used in different combinations according to the Box - Behnken three level designs as shown in Table 1. The samples were subjected to combine enzymatic desizing and bioscouring as per the 17 trials suggested by the design. After each process the fabrics were dried and tested for weight loss and tensile strength loss, TEGEWA rate and absorbency to evaluate the efficiency of the processes.

### *F. Testing and analysis Testing of Desized fabric*

With starch sizes, the iodine reagent (Iodine+ Potassium Iodide) produces a coloured complex of intense violet blue colour. The coloured complex formed is a two-dimensional complex, where iodine, the linear chain, is included in a two-dimensional structure of the starch. This test is practical because it directly indicates either the presence of the starch by a characteristic deep blue colouration or the absence of the starch by a yellowish orange or no colouration on the fabric.

***Preparation of the iodine solution***

For preparation of iodine solution 10 g of potassium iodide was dissolved in 100mL of water and 0.65g of iodine was added into it. This solution was stirred for complete dissolution. To the above solution, 800mL water was added and further ethanol was added to make up the volume up to 1L. The samples were stained with iodine solution and the degree of desizing was evaluated on the basis of violet scale (Tegewa) calibrated from 1 to 9 as a reference. Rating 1 is poor, and a 9 rating is the best which indicates complete removal of size. For effective desizing of the samples, grade 6 or more is needed

***Testing of scoured fabric***

Standard drop penetration test was carried out for the absorbency. The absorbency test standard is AATCC-79-2000. A drop of water allowed to fall from a fixed height on to taut fabric and the time required for specular reflection of the water drop to disappear is measured and recorded as wetting time.

***Loss in tensile strength***

Tensile strength and elongation were measured as per ASTM D5034. A sample of 16x2.5cm was taken for the test. The tensile strength of the fabric was determined by cloth tensile strength tester. Four readings for every sample were taken and the average was calculated. The performance of scouring was evaluated by calculating the tensile strength (TS) loss% as follows:

$$\text{TS Loss (\%)} = \frac{T_1 - T_2}{T_1} \times 100$$

Where $T_1$ is tensile strength-before treatment and $T_2$ is tensile strength after treatment.

## IV. RESULTS AND DISCUSSION

As already stated, this study aims at establishing conditions for sustainable pre-treatment of cotton textiles. Conditions for desizing and bioscouring have been thoroughly studied and reported by carrying out experiments given by the Box-Behnken design. The optimal conditions using enzymes for combined processes of 100 % cotton-based fabrics were established. The design experiment and results of the 17 trials are presented in Table 1

**TABLE 1**: Treatment conditions and the responses observe

| Run | Temp. ($^oC$) | BEISOLT 2090 (%o.w.f) | BEISOL PRO(%) o.w.f | TEGEWA ratings | Weight loss (%) | Absorbency (Sec). | Tensile strength Loss (%) |
|---|---|---|---|---|---|---|---|
| 1 | 90 | 3 | 3 | 6 | 9.87 | 2.34 | 3.19 |
| 2 | 100 | 4 | 3 | 8 | 11.21 | 1.24 | 5.58 |
| 3 | 100 | 3 | 4 | 8 | 11.24 | 1.19 | 6.12 |
| 4 | 100 | 3 | 2 | 8 | 11.2 | 1.22 | 4.85 |
| 5 | 80 | 3 | 4 | 5 | 9.74 | 5.47 | 3.06 |
| 6 | 90 | 3 | 3 | 6 | 9.88 | 2.34 | 3.22 |
| 7 | 90 | 3 | 3 | 7 | 9.97 | 2.31 | 3.34 |
| 8 | 80 | 3 | 2 | 4 | 9.56 | 6.91 | 2.54 |
| 9 | 90 | 2 | 4 | 7 | 10.12 | 2.27 | 3.79 |
| 10 | 80 | 2 | 3 | 4 | 9.6 | 6.61 | 2.57 |
| 11 | 90 | 3 | 3 | 6 | 9.85 | 2.32 | 3.2 |

| **Run** | **Temp. (°C)** | **BEISOLT 2090 (%o.w.f)** | **BEISOL PRO(%) o.w.f** | **TEGEWA ratings** | **Weight loss (%)** | **Absorbency (Sec).** | **Tensile strength Loss (%)** |
|---|---|---|---|---|---|---|---|
| 12 | 90 | 3 | 3 | 6 | 9.95 | 2.34 | 3.25 |
| 13 | 80 | 4 | 3 | 5 | 9.68 | 6.12 | 2.94 |
| 14 | 100 | 2 | 3 | 8 | 11.14 | 1.37 | 5.25 |
| 15 | 90 | 4 | 2 | 7 | 9.91 | 2.67 | 3.68 |
| 16 | 90 | 4 | 4 | 8 | 10.39 | 1.68 | 4.63 |
| 17 | 90 | 2 | 2 | 7 | 9.81 | 2.67 | 3.12 |

### *A. Desizing efficiency in terms of TEGEWA ratings*

As per results in Table 2, the Model F-value of 28.62 implies the model is significant and there is only a 0.01% chance that a "Model F-Value". Values of "Prob > F" less than 0.05 indicate model terms are significant. In this case A, $A^2$, $B^2$, and $C^2$ are significant model terms. Values greater than 0.10 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The "Lack of Fit F-value" of 0.00 implies the Lack of Fit is not significant relative to the pure error.

**Table 2:** ANOVA for TEGEWA ratings

| **Source** | **Sum of Squares** | **DF** | **Mean Square** | **F Value** | **Prob >F** | |
|---|---|---|---|---|---|---|
| Model | 29.44 | 9 | 3.27 | 28.62 | 0.0001 | Significant |
| A | 24.50 | 1 | 24.50 | 214.38 | <0.0001 | |
| B | 0.50 | 1 | 0.50 | 4.38 | 0.0748 | |
| C | 0.50 | 1 | 0.50 | 4.38 | 0.0748 | |
| $A^2$ | 0.95 | 1 | 0.95 | 8.31 | 0.0235 | |
| $B^2$ | 1.16 | 1 | 1.16 | 10.15 | 0.0153 | |
| $C^2$ | 1.16 | 1 | 1.16 | 10.15 | 0.0153 | |
| AB | 0.25 | 1 | 0.25 | 2.19 | 0.1827 | |
| AC | 0.25 | 1 | 0.25 | 2.19 | 0.1827 | |
| BC | 0.25 | 1 | 0.25 | 2.19 | 0.1827 | |
| Residual | 0.80 | 7 | 0.11 | | | |
| Lack of Fit | 0 | 3 | 0 | 0 | 1.0000 | not significant |
| Pure Error | 0.80 | 4 | 0.20 | | | |
| Cor Total | 30.24 | 16 | | | | |

**Final Equation in Terms of Coded Factors:**

**TEGEWA Ratings** $=+6.20+1.7A+0.25B+0.25C-0.48A^2+0.53B^2+0.53C^2-0.25AB-0.25AC+0.25BC$

In Fig.1 (a), the response surface plot shows that the highest TEGEWA rate was seen when BEISOL T2090 concentration and temperature were in the high levels. It shows that the TEGEWA rate was 8 (as it is also indicated in Table.1) when BEISOL T2090 concentration of 4% (o.w.f) and temperature 100 $^{o}$C with constant BEISOL PRO were used. This result proves that the high levels are the ideal conditions for the optimization process as the standard TEGEWA rate is being greater than 6.

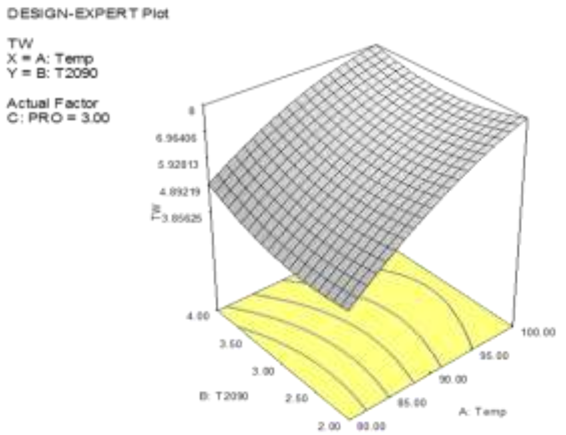


**Figure 1(a):** Effect of BEISOL T2090 concentration and temperature on TEGEWA rate at constant concentration of BEISOL PRO.

In Fig.1 (b), the response surface plot shows that the highest TEGEWA rate was seen when BEISOL PRO enzyme concentration and temperature were at the higher levels. It shows that the TEGEWA rate was 8 when BEISOL PRO concentration of 4% (o.w.f) and temperature 100 $^{o}$C were used with constant BEISOL T2090. This result proves that the high levels are the ideal conditions for the optimization process as the standard TEGEWA rate is being greater than 6.

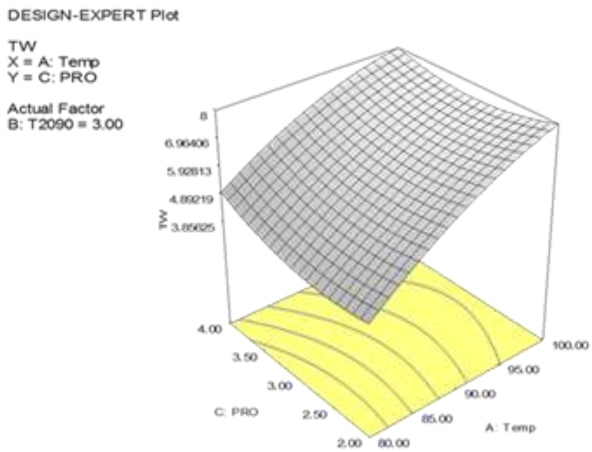


**Figure1 (b):** Effect of BEISOL PRO concentration and temperature on TEGEWA rate at constant concentration of BEISOLT209

Fig.1(c) shows that the TEGEWA rate was 8 (Table.1) when the two enzymes concentration BEISOL PRO and BEISOL T2090 were 4% (o.w.f) at constant temperature of 90$^{o}$C. This result proves that the high levels are the ideal conditions for the optimization process as the standard TEGEWA rate being greater than 6

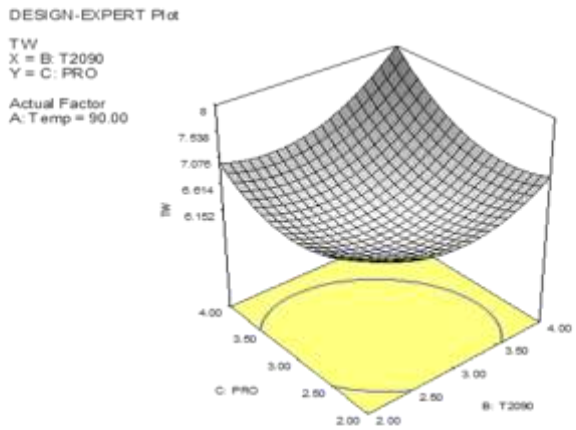


**Figure 1(c):** Effect of enzymes concentration, BEISOL T2090 and BEISOL PRO, on TEGEWA rate at constant temperature of 90 $^{o}$C.

### *B. Weight Loss*

The Model F-value of 78.61 implies the model is significant and A, C, A2 are significant model terms. Values greater than 0.10 indicate the model terms are not significant. The "Lack of Fit F-value" of 5.67 implies there is a 6.35% chance that a "Lack of Fit F-value". This large could occur due to loss.

**Table 3:** ANOVA for Weight Loss

| **Source** | **Sum of Squares** | **DF** | **Mean Square** | **F Value** | **Prob > F** | |
|---|---|---|---|---|---|---|
| Model | 5.90 | 9 | 0.66 | 78.61 | <0.0001 | Significant |
| A | 4.82 | 1 | 4.82 | 577.85 | <0.0001 | |
| B | 0.03 | 1 | 0.03 | 4.05 | 0.0840 | |
| C | 0.13 | 1 | 0.13 | 15.29 | 0.0058 | |
| $A^2$ | 0.82 | 1 | 0.82 | 97.94 | <0.0001 | |
| $B^2$ | 0.017 | 1 | 0.017 | 2.00 | 0.20 | |
| $C^2$ | 0.03 | 1 | 0.03 | 4.13 | 0.08 | |
| AB | 2.5E-05 | 1 | 2.5E-05 | 0.002 | 0.96 | |
| AC | 0.005 | 1 | 0.005 | 0.59 | 0.47 | |
| BC | 0.007225 | 1 | 0.007225 | 0.866084 | 0.3830 | |
| Residual | 0.058395 | 7 | 0.008342 | | | |
| Lack of Fit | 0.047275 | 3 | 0.015758 | 5.668465 | 0.0635 | Not significant |
| Pure Error | 0.01112 | 4 | 0.00278 | | | |
| Cor. Total | 5.960188 | 16 | | | | |

**Final Equation in Terms of Coded Factors: Weight Loss** =+9.90 +0.78A+0.065B+0.13C+0.44 $A^2$+0.063$B^2$+0.090 $C^2$- 0.03AB-0.035 AC+0.043BC

In Fig.2 (a), the response surface plot shows that the highest weight loss of 11.21% (Table.1) was obtained when the BEISOL T2090 concentration of 4% (o.w.f) and temperature 100 $^{o}$C with constant BEISOL PRO was used. This result proves that the high levels of enzyme concentration and temperature are the optimum conditions to obtain maximum removal of impurities.

Similarly Fig.2 (b) shows that the highest weight loss was seen when BEISOL PRO concentration and temperature were in the high levels. Hence the weight loss of 10.12% (Table.1) was obtained when BEISOL PRO concentration of 4% (o.w.f) and temperature 100 oC with constant concentration of BEISOL T2090 were used.

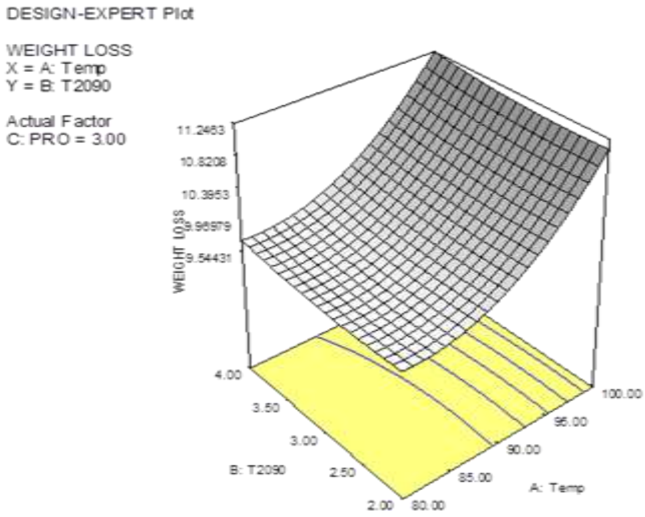


**Figure 2(a):** Effect of BEISOL T2090 concentration and temperature on weight loss at constant concentration of BEISOL PRO

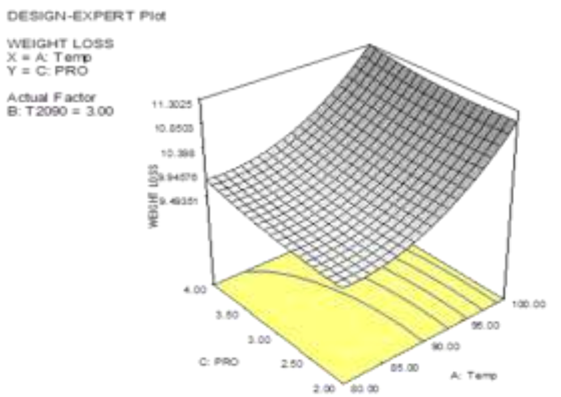


**Figure 2(b):** Effect of BEISOL PRO concentration and temperature on weight loss at constant BEISOL T2090

Fig.2 (c) also indicates the two enzymes with concentration of 4% (o.w.f) each at constant temperature of 90 °C gave highest weight loss of 10.39% (Table 1) and thus maximum impurities removal.

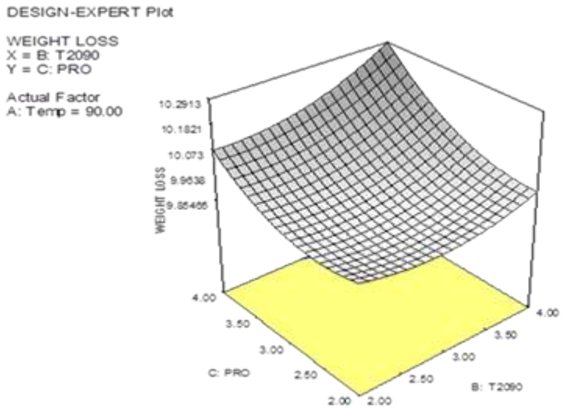


**Figure2(c):** Effect of enzymes concentration, BEISOL T2090 and BEISOL PRO, on weight loss at constant temperature of 90 °C

### *C. Absorbency*

The Model F-value of 10500.10 implies the model is significant. Values of "Prob > F" less than 0.05 indicate model terms are significant. In this case A, B, C, A2, B2, C2, AB, AC, BC are significant model terms. The "Lack of Fit F-value" of 6.21 implies, there is a 5.50% chance that a "Lack of Fit F-value". This large could occur due to noise.

**Table 4:** ANOVA for Absorbency

| **Source** | **Sum of Squares** | **DF** | **Mean Square** | **F Value** | **Prob > F** | |
|---|---|---|---|---|---|---|
| Model | 61.09 | 9 | 6.79 | 10500.10 | < 0.0001 | Significant |
| A | 50.45 | 1 | 50.45 | 78045.77 | < 0.0001 | |
| B | 0.18 | 1 | 0.18 | 283.11 | < 0.0001 | |
| C | 1.02 | 1 | 1.02 | 1581.69 | < 0.0001 | |
| $A^2$ | 8.73 | 1 | 8.73 | 13506.44 | < 0.0001 | |
| $B^2$ | 0.02 | 1 | 0.02 | 27.52 | 0.0012 | |
| $C^2$ | 0.02 | 1 | 0.02 | 34.24 | 0.0006 | |
| AB | 0.03 | 1 | 0.03 | 50.12 | 0.0002 | |
| AC | 0.50 | 1 | 0.50 | 768.88 | < 0.0001 | |
| BC | 0.09 | 1 | 0.09 | 134.62 | < 0.0001 | |
| Residual | 0.004525 | 7 | 0.00 | | | |
| Lack of Fit | 0.003725 | 3 | 0.00 | 6.21 | 0.0550 | not significant |
| Pure Error | 0.0008 | 4 | 0.00 | | | |
| Cor. Total | 61.09261 | 16 | | | | |

**Table 5:** Summary of statical data analysis

| | | | |
|---|---|---|---|
| Std. Dev. | 0.106754 | R-Squared | 0.995776 |
| Mean | 3.784118 | Adj R-Squared | 0.990346 |
| C.V. | 2.821108 | Pred R-Squared | 0.943581 |
| PRESS | 1.065613 | Adeq Precision | 44.16706 |

The "Pred R-Squared" of 0.9436 is in reasonable agreement with the "Adj R-Squared" of 0.9903. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Thus ratio of 44.167 indicates an adequate signal. This model can be used to navigate the design space

***Final Equation in Terms of Coded Factors:***

**Absorbency=**$+2.33-2.51A-0.1B$
$0.36C+1.44A^2+0.065B^2-$
$0.072C^2+0.090AB+0.35AC-0.15BC$

In Fig.3 (a), the response surface plot shows that the shortest absorbency time was seen when the BEISOL T2090 concentration and temperature were in the high levels. It shows that the absorbency time was 1.24 s when BEISOL T2090 enzyme concentration of 4% (o.w.f) and temperature 100 oC were used keeping constant BEISOL PRO concentration. This result proves that the high levels are the ideal conditions for the optimization process, as the standard absorbency time is being less than 5 s.

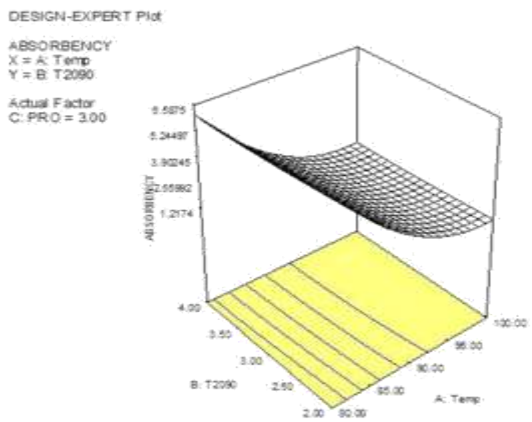


Figure 3(a): Effect of BEISOL T2090 concentration and temperature on absorbency time at constant concentration of BEISOL PRO.

In Fig.3 (b), the response surface plot shows that the shortest absorbency time was seen when the BEISOL PRO concentration and temperature were in the high levels. It shows that the absorbency time was 1.19s when BEISOL PRO of 4% (o.w.f) concentration and temperature 100 $^{o}$C were used with constant concentration of BEISOL T2090. This result is the best when compared with all other combinations of the levels of the variables, and also proved that the high levels are the ideal conditions for the optimization process as the standard absorbency time is being less than 5 s.

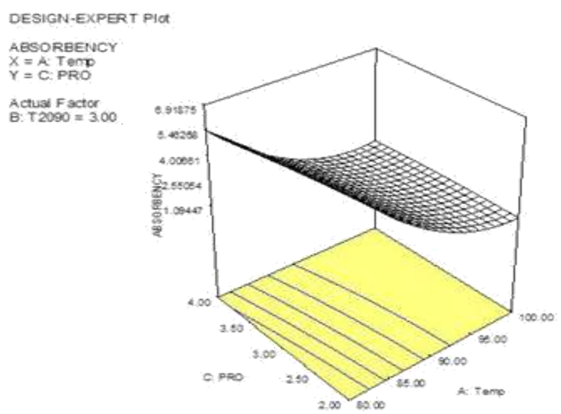


**Figure 3(b):** Effect of BEISOL PRO concentration and temperature on absorbency time at constant concentration of BEISOL T2090.

In Fig.3 (c), the response surface plot shows that the shortest absorbency time was seen when the concentration of BEISOL PRO and BEISOL T2090 were 4% (o.w.f) i.e. in the high levels. It gives absorbency time of 1.68 s when reaction was carried out at 90°C. This result is the best, when compared with all other combinations of the levels of the variables, and also proves that the high levels are the ideal conditions for the optimization process as the standard absorbency time is being less than 5 s.

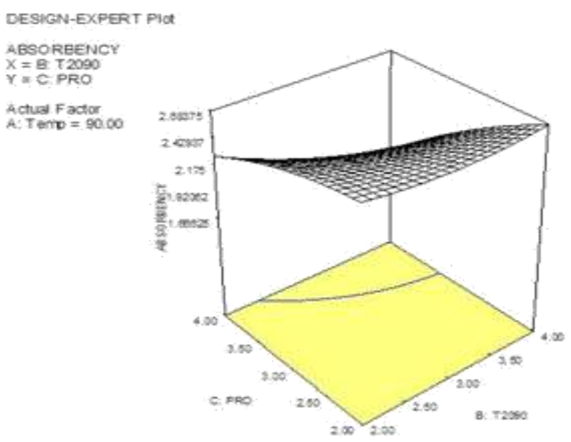


**Figure 3 (c):** Effect of enzymes concentration, BEISOL T2090 and BEISOL PRO, on absorbency time at constant temperature of 90 °C

### *D. Tensile strength*

The Model F-value of 183.37 implies the model is significant and in this case A, B, C, $A^2$, $B^2$, $C^2$, AC are significant model terms

**Table 5:** ANOVA for Tensile strength

| Source | Sum of Squares | DF | Mean Square | F Value | Prob > F | |
|---|---|---|---|---|---|---|
| Model | 18.80784 | 9 | 2.08976 | 183.3697 | < 0.0001 | Significant |
| A | 14.28451 | 1 | 14.28451 | 1253.42 | < 0.0001 | |
| B | 0.55125 | 1 | 0.55125 | 48.37042 | 0.0002 | |
| C | 1.453513 | 1 | 1.453513 | 127.5411 | < 0.0001 | |
| $A^2$ | 1.471901 | 1 | 1.471901 | 129.1546 | < 0.0001 | |
| $B^2$ | 0.271112 | 1 | 0.271112 | 23.78919 | 0.0018 | |
| $C^2$ | 0.407901 | 1 | 0.407901 | 35.79203 | 0.0006 | |
| AB | 0.0004 | 1 | 0.0004 | 0.035099 | 0.8567 | |
| AC | 0.140625 | 1 | 0.140625 | 12.33939 | 0.0098 | |
| BC | 0.0196 | 1 | 0.0196 | 1.719837 | 0.2311 | |
| Residual | 0.079775 | 7 | 0.011396 | | | |
| Lack of Fit | 0.065175 | 3 | 0.021725 | 5.952055 | 0.0588 | not significant |
| Pure Error | 0.0146 | 4 | 0.00365 | | | |
| Cor. Total | 18.88761 | 16 | | | | |

Final Equation in Terms of Coded Factors:
**Strength Loss**
$=+3.24+1.34A+0.26B+0.43C+0.59A^2+0.25B^2+0.31 C^2 0.01AB+0.19AC+0.07BC$

Fig.4 (a) shows that the lowest strength loss was seen when BEISOL T2090 concentration and temperature were in the lower levels. Table.1 also shows that the tensile strength loss was 2.54% when BEISOL T2090 concentration of 4% (o.w.f) and temperature 100 °C with constant BEISOL PRO concentration were used. However, this gave longest absorbency time of 6.61second which is not acceptable, as the standard absorbency time has to be less than 5 second. This result proves that with decreasing BEISOL T2090 concentration and temperature strength loss decrease but wettability also decrease and hence one need to increase the concentration and temperature for better absorbency while keeping the strength loss in acceptable limit.

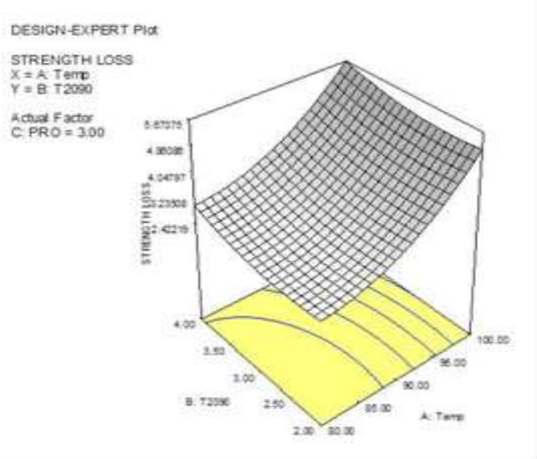


**Figure 4(a):** Effect of BEISOL T2090 concentration and temperature on tensile strength loss at constant concentration of BEISOL PRO

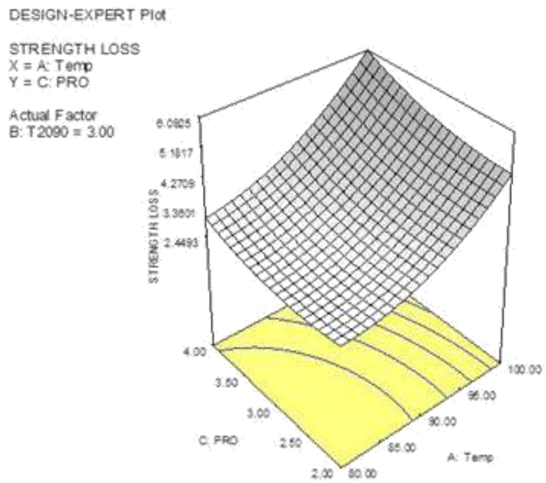


**Figure 4(b):** Effect of BEISOL PRO concentration and temperature on tensile strength loss at constant concentration of BEISOL T2090.

Fig.4 (b) also indicates as BEISOL PRO concentration and temperature increased, strength loss also increased, but absorbency time was reduced (Table.1).Lowest strength occurs at lowest concentration of enzymes as well as temperature. But this gives less absorbency and time taken for drop absorption is highest i.e. 6. 91 second this is not acceptable

Fig.4 (c) shows that the lowest strength loss was seen when BEISOL PRO concentration and BEISOL T2090 were in the low levels. It shows that the lowest strength loss was 2.57% (Table.1) when BEISOL PRO and BEISOL T2090 concentrations of 2% (o.w.f) were used at constant temperature of 90°C. The shortest absorbency time was seen of 2.67 second which was acceptable. This result proves that with lower level of BEISOL T2090 and BEISOL PRO concentration and constant temperature of 90°C strength loss was found to be lower within acceptable absorbency.

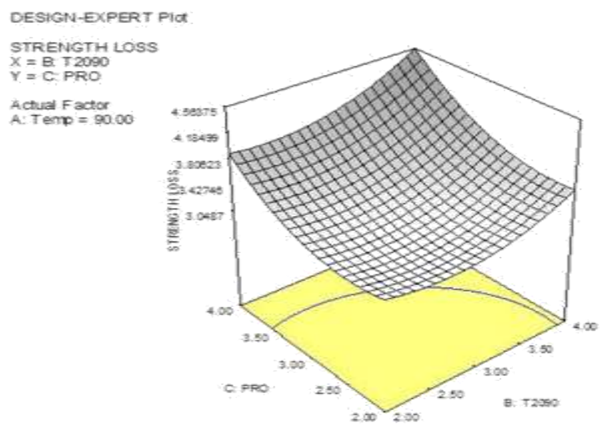


Figure 4(c): Effect of enzymes concentration, BEISOL T2090 and BEISOL PRO, on tensile strength loss at constant temperature of 90 °C.

## V. OPTIMIZATION

The process parameters such as (enzymes concentration and temperature) had been optimized by using the Box-Behnken design experiment and their output values are executed by the designed expert software, as shown in Table 6.The optimum conditions of the combined process were enzyme concentration BEISOL T2090 2% (o.w.f) and BEISOL PRO 2% o.w.f, time 30 minutes and temperature 90 oC at pH 7.5. The output result of the designed expert software to achieve the desired parameters for predicted process variables of solution are shown in Table 7.

**Table 6:** The optimum condition's variables and their levels

| **Name** | **Goal** | **Lower Limit** | **Upper Limit** | **Lower Weight** | **Upper Weight** | **Importance** |
|---|---|---|---|---|---|---|
| Temp | is target = 90.00 | 80 | 100 | 1 | 1 | 3 |
| BEISOLT2090 | is target = 2.00 | 2 | 4 | 1 | 1 | 3 |
| BEISOL PRO | is target = 2.00 | 2 | 4 | 1 | 1 | 3 |
| TEGAWA Scale | Maximize | 4 | 8 | 1 | 1 | 3 |
| Weight Loss | Maximize | 9.56 | 11.24 | 1 | 1 | 3 |
| Abso. | Minimize | 1.19 | 6.91 | 1 | 1 | 3 |
| Strength Loss | Minimize | 2.54 | 6.12 | 1 | 1 | 3 |

**Table 7:** Predicted processes variables of solution

| | **Temp. °C** | **BEISOL T2090** | **BEISOL PRO** | **TEGEWA Scale** | **Wt. loss %** | **Abs. Sec** | **Strength. Loss. %** |
|---|---|---|---|---|---|---|---|
| Predicted | 94.08 | 2.00 | 2.00 | 7.88 | 10.31 | 1.72 | 3.76 |
| Actual | 94.08 | 2.00 | 2.00 | 7 | 10.36 | 1.82 | 3.88 |
| Predicted | 90 | 2 | 2 | 7 | 9.91 | 2.68 | 3.19 |
| Actual | 90 | 2 | 2 | 7 | 9.81 | 2.67 | 3.12 |

## VI. COMBINED ENZYMATIC DESIZING AND SCOURING IN COMPARISON WITH ALKALINE SCOURING

Properties of cotton fabric treated with a BEISOL PRO and BEISOL T2090 enzyme, at optimum conditions of a pH 9 at temperature of 90 °C for 30 minutes are given in Table 8. Weight loss, tensile strength and absorbency of treated samples were measured and compared with the corresponding properties of conventionally scoured cotton fabric treated in highly alkaline solution at boil.

**Table 8:** Properties of combined enzymatically desized and scoured cotton with conventionally scoured cotton fabric

| Treatment type | Property | | | | |
|---|---|---|---|---|---|
| | Weight loss (%), | Absorbency. sec. | Tensile strength Loss (%), | Whiteness index | Yellow index |
| Enzyme desizing and Alkali scouring | 12.07 | 0.86 | 5.18 | 41.11 | 19.73 |
| combined enzymatically desizing and scouring | 9.81 | 2.67 | 3.12 | 36.36 | 21.36 |

**Absorbency:** The absorbency time of the fabric treated with combined enzymatic desizing and scouring enzyme under optimized conditions was found to be 2.67 second (Table 8) which was way of below the standard absorbency time of 5s. This indicates that the scoured fabric was absorbent and acceptable for subsequent processes.

**Weight loss (%):** On analysing the fabric treated with combined enzymatic desizing and scouring enzyme under the optimized conditions, the weight of the fabric reduced up to 9.81 % in comparison with the 12.07 % reduction in weight of the fabric of the conventional alkali scouring. The total saving in the weight loss can be close to 2.38%. In this era, where the cotton fabric that is sold on weight Kg for knitted fabric, a considerable advantage will be obtained on this account.

**Tensile strength and Elongation:** The strength of enzyme treated fabric was greater than alkali treated fabric. Treated fabric with combined enzymatic desizing and scouring enzymes facilitate the removal of the cuticle components by partial hydrolysis. After this bioscouring process, the cotton maintaining its intact cellulose structure with lower strength loss of just 2.06% (Table 8). This proves that alkali scouring apart from showing more weight loss from the fabric also reduces the strength of the fabric due to the harsh treatment conditions. Furthermore, the fabrics found from the enzymatic scouring process show more softer handle and hence it requires much less softening agent in finishing process than needed in conventional process.

**Water Saving:** In combined enzymatic desizing and scouring enzyme process only 3 baths are used before the actual dyeing starts, whereas in conventional process 3 baths for enzymatic desizing and a minimum of 5 baths for alkaline scouring are used for intensive rinsing and neutralization before dyeing. Owing to the high sodium hydroxide concentration and it's corrosive nature and also due to the fact that the process is carried out at high pH range (12-14), there is more chemicals and energy input which can be saved in combined desizing and enzymatic scouring process. This is also leads to a total bath saving which is around 60 % reduction in water consumption.

**Energy Saving:** The entire process takes place at a temperature of 90 $^oC$ as against 100 $^oC$. The temperature difference is about 10 oC. In order to heat water from 90 $^oC$ to 100 $^oC$ the amount of heat energy required will be saved in addition to some amount of energy saved in intensive washing after alkali treatment relative to combined processes. (The specific heat of water is 4.186 Joule/ gram K. It requires 4.186 joules of energy to heat 1 gm. of water by 1 Kelvin).

**Time Saving:** The process of conventional desizing and scouring takes place about 3 hours and 40 minute whereas the bio-scouring process will not take more than 75 min. Thus for every batch dyed a saving of 2 hours and 15 minute per batch is possible. A conventional dyeing process takes place in about 7 hours. Whereas using combined enzymatic desizing and scouring the same dyeing can be completed in 5 hours and 25min. In terms of percentage the time saving will be 29%. Thus any process house can raise its production by 29% approximately by using the combined enzymatic desizing and scouring process. Because it results in lower weight and strength loss, lower pollution load, comparable whiteness and it is adequate for further dyeing.

**Environmental Benefits:** Reduced effluent treatment cost, as avoiding too much of caustic soda, which in turn reduces TDS in a great extant and hence the removal of total dissolved solid requires high operating cost of effluent treatment. This can be totally avoided.

## VII. Combined Desizing and Scouring and Conventionally Scoured Cotton Fabric after Common Bleaching

The effect of the $H_2O_2$ bleaching of the differently pre-treated (enzymatic, caustic) fabric was studied the fabrics properties in terms on the comparing of the afore mentioned properties of enzymatically and conventionally pre-treated and $H_2O_2$ bleached (Table9), the results show that the application of $H_2O_2$ bleaching subsequent to combined desizing and scouring is beneficial.

**Table 9:** Properties of enzymatically combined desizing and scouring and conventionally scoured cotton fabric after common bleaching

| Treatment type | Property | | | |
|---|---|---|---|---|
| | Whiteness index | Yellow Index | Absorbency. sec. | Tensile strength loss (%), |
| Bleached fabric after Alkali Scouring | 69.42 | 6.29 | <1 | 8.08 |
| Bleached fabric after combined enzymatically desizing and Scouring | 67.22 | 7.91 | <1 | 5.33 |

## VIII. CONCLUSION

The optimum conditions of the combined process of enzymatic desizing and scouring were enzyme concentration of BEISOL T2090 for desizing and BEISOL PRO for scouring at 2% o.w.f (on weight of fabric), time 30 minute and temperature 90$^{o}$C and pH 7.5.

Throughout the cotton fabric treatment, the effects of enzyme admixture with each other were assessed via determination of the response in terms of absorbency, TEGEWA rate, weight loss and tensile strength loss. The optimized conditions met the pretreatment requirements within acceptable limits and were suitable for 100% cotton. The outcomes of these studies reflect the role of enzyme in general and BEISOL T2090 and BEISOL PRO enzymes in particular for the sustainable pretreatment of cotton textiles in combine process. The combined treatment of enzymatic desizing and bioscouring is a low cost process because it shows reduction in water and energy consumption, reduction in the generation of effluent and it is also ecofriendly and gave higher productivity for cotton pretreatment processes than that of existing process. It is thus 'more sustainable' and 'environment friendly'.

## IX. ACKNOWLEDGEMENT

One of the co-author Tesfaye Tolessa Adere is grateful to authorities to ICT and ETIDI for giving him an opportunity to undertake this work in ICT. He is also thankful to Mr. Pintu Pandit for assisting him in using statistical Box-Bohnken Design.

## X. REFERENCE


[1] Gordon and Y-L. Hsieh, *Cotton, Science and technology*, Cambridge, England,2007

[2] W. E. Morton and J. W. S. Hearle, *Physical properties of textile fibres,* Boca Raton Boston New York Washington, DC, 2008.

[3] Mena Chem Lewin and Stephen B-Sello, *Handbook of Fibre, Science and Technology*-Volume NY, 1985S.

[4] Howard L. Needles, *Textile Fibers, Dyes, Finishes, and Processes,* University of California, Davis, March, 1986

[5] S.R. Karmakar, *Chemical Technology in the Pre-treatment Processes of Textile,* Elsevier, Amsterdam, 1999

[6] Charles Tomasino, *Chemistry & Technology of Fabric Preparation & Finishing,* Raleigh, North Carolina, 1992.

[7] Lange, N.K.; Liu, J.; Husain, P.A.; Condon, B. *Biopreparation the new advanced way of preparing of fabric and yarn*. Sept. 1999

[8] Mohamed M. Hashem, *FIBRES & TEXTILES in Eastern Europe* April / June 2007, Vol. 15, No. 2 (61)

[9] N. A. Ibrahim; Seham Z. Abd Allah; Hala A. T.Borham b & Talaat M. Hassan.. *Polymer-Plastics Technology* .(2002)

[10] Edward Menezes and Mrinal Choudhari, *Pre-treatment of Textiles Prior to Dyeing,* Mumbai,India,2011

[11] Abu Bakar Siddiquee, Md. Mahbubul Bashar, Priti Sarker, Tanzina Tasmina Tohfa, Md. Amjad Hossan, Md.Ibrahim Azad, Nazma AkhtarInternational Journal of Engineering & Technology, 3 (1) (2014)

[12] Aiteromem, A.L, *International Dyer*, Vol.7, 2008:

*[13] Kiro Mojsov, International Journal of Management, 4(1), 2014.*

*[14] A. Cavaco-Paulo and G. M. Gübitz, Textile processing with enzymes, Portugal, 2003.*

[15] BASF. *Pretreatment of Cotton and Cotton/Polyester*, Technical Information, 1999.

[16] Bhuvenesh C. Goswami, Marcel Dekker, *Textile Sizing,* South Carolina, U.S.A. 2004.