# Comparative Performance Evaluation of Conventional and Ultrasonic Assisted Bleaching of Cotton Fabric

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**y:** Conventional bleaching process is an important and quality influencing process for textile wet processors. However, the process requires high energy consumption, and is slow and time consuming. In the present research work, cotton woven fabric was bleached with different bleaching agents using conventional and ultrasonic assisted techniques. After bleaching whiteness index, weight loss and tensile strength of samples were measured and compared statistically. The results showed that ultrasonic energy intensifies the diffusion of chemicals and increases the production of hydroxyl radicals which catalyze the bleaching process. Ultrasonic assisted bleaching proved to be a novel technique that can produce better results than conventional bleaching process even at low temperature and in less time.

## Introduction

The non-lint constituents of raw cotton include proteins, pectins, organic acids, oil, fats, waxes, mineral matter and moisture [1]. Greige cloth as received in the textile wet processing section contains all these impurities. Moreover, the sizing material applied to the warp yarns in order to impart strength during weaving process is also present. The bleaching process ought to remove all intrinsic as well as acquired impurities from the greige material completely and efficiently without damaging the fibre and giving the fabric a perfectly white and bright appearance.

Several types of chemicals are used as bleaching agents, and their selection depends upon the material of fabrics as well as their intended use. The most commonly employed bleaching agents are hydrogen peroxide, sodium hypochlorite and sodium chlorite. Hydrogen peroxide is the most commonly employed bleaching agent for pure cotton and cotton blends. Although it gives permanent and high whiteness but it has some draw backs such as high energy consumption [2]. The textile wet processing industry face problems of high energy costs and time constraints.

Sound waves above the human's audible range having frequency from 20 kHz to 500 kHz are termed as ultrasound. Unlike other waves ultrasound waves propagate only in longitudinal direction. During their propagation they produce compression and rarefactions which results in the formation of cavities. Cavitation is the main phenomena behind the ultrasound treatments in which small bubbles of air forms and collapse due to the effect of ultrasonic waves [3]. The collapse of these bubbles at material surface results in the formation of micro jets having velocities 100 m/s to 150 m/s directed towards the material surface. These micro jets give rise to intra yarn flow and increase mass transfer between intra and inter yarn pores [4].

Therefore the present research work has been planned to evaluate and compare the properties of the ultrasound assisted bleached cotton fabric with conventionally bleached fabric under multiple process parameters.

## Results and Discussion

The results obtained after testing the bleached samples for weight loss, whiteness index and tensile strength are presented and discussed here under.

### *Weight Loss*

The analysis of variance (ANOVA) for weight loss of the fabrics showed the highly significant effects of bleaching techniques (P), bleaching agents (B), concentrations(C), temperatures (T) and bleaching durations (D) on weight loss. The interactions B×C, C×T and C×D also have highly significant effect on weight loss but all other interactions remained non- significant.

The statistical comparison of individual treatment means with regards to weight loss is presented in Fig. 1. Duncan's multiple range tests for the comparison of individual means showed that the maximum weight loss was recorded for $P_1$ (Ultrasonic technique) with the mean value 2.31% followed by $P_2$ (Conventional bleaching technique) with mean value 2.27%. These results show that

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weight loss was slightly greater for ultrasonic assisted bleaching. This was due to better removal of impurities from the cotton fabric. Ultrasonic irradiation appears to be an effective method for the destruction of organic contaminants because of localized high concentrations of oxidizing species such as hydroxyl radical and hydrogen peroxide in solution, high localized temperatures and pressures, and the formation of transient supercritical water [5]. The impurities in cotton are oxidized by oxidizing bleaching agents and finally removed by washing with water. Further alkaline solution increases fibre swelling, thus facilitate the release of impurities from the fibre.

The individual comparison of mean values for different bleaching agents given in Fig. 1 for weight loss, shows that there exists significant difference between the values. The maximum weight loss was recorded for $B_2$ (NaOCl) with mean value 2.39 % followed by $B_3$ ($NaBO_3$) and $B_1$ ($H_2O_2$) with mean values 2.29 % and 2.19 % respectively. Shad *et al*. [6] reported that the cotton fabrics treated with different bleaching agents reduced the weight of the fabric significantly after bleaching process.

In case of the effect of concentration, the individual comparison of mean values given in Fig. 1 shows significant differences between the mean values. The maximum weight loss was recorded for $C_3$ (30 mL/L) with the mean value 3.17 % followed by $C_2$ (20 mL/L) and $C_1$ (10 mL/L) with their mean values 2.06% and 1.64% respectively. The results show that weight loss was increased by increasing the concentration of bleaching agents. Bleaching treatments improve whiteness by removing its non cellulosic constituents and colouring matters which on the other side reduces yarn strength [7].

The individual comparison of mean values presented in Fig. 1, regarding temperature (T) shows significant differences between the mean values. The maximum weight loss was recorded for $T_3$ (90 ˚C) with mean value 3.05% followed by $T_2$ (60 ˚C) and $T_1$ (30 ˚C) with mean values 2.09 % and 1.72 % respectively. The results show that weight loss percent was increased by increasing the temperature. The losses in fabric weight as well as the improvement in degree of whiteness are governed by the pre-treatment method, gives rise to better bleaching, fabric softness, higher strength retention along with greater depth of shades [8].

In case of the effect of bleaching duration (D), the individual mean values given in Fig. 1 shows significant differences with respect to each other. The maximum weight loss was recorded for $D_3$ (60 min) with mean value 2.74 % followed by $D_2$ (45 min) and $D_1$ (30 min) with mean values 2.25 % and 1.87 % respectively. The trend is evident i.e. as we increase duration weight loss also increased. In a previous study Aamer concluded that under all the bleaching treatments, the impurities were removed. The bleaching of fabric obviously reduced the weight and consequently caused degradation of fabrics [9]. The overall results show that weight loss was slightly greater for ultrasonic assisted bleaching technique due to better removal of impurities.

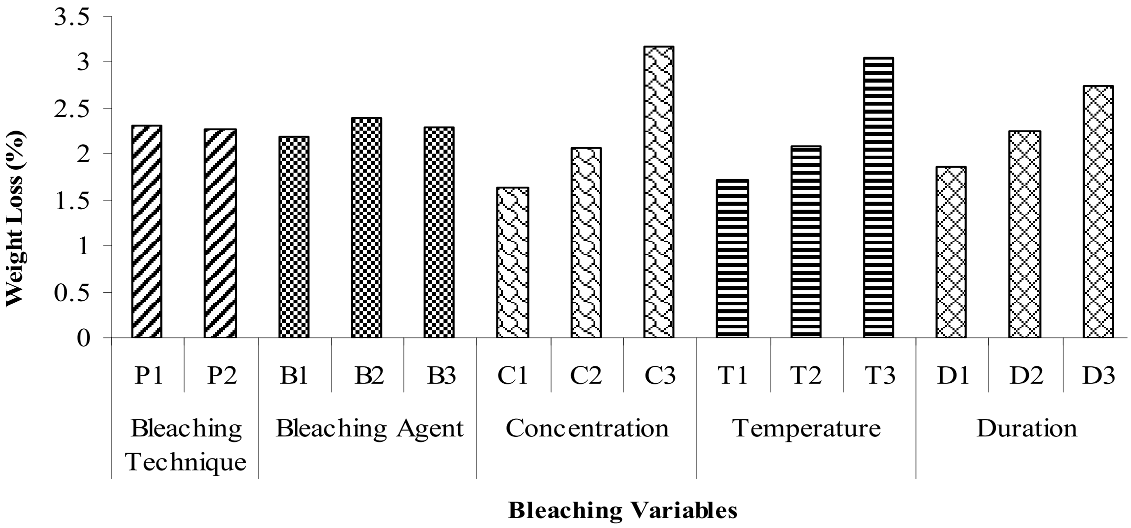


Fig. 1: Graphical representation of individual mean values of weight loss.

*Fabric Whiteness*

The results of whiteness under the effect of bleaching techniques(P), bleaching agents(B), concentrations(C), temperatures(T) and bleaching durations(D) when subjected to analysis of variance revealed highly significant effect for all sources of variances. However all of their interactions remained non-significant.

The statistical comparison of individual treatment means for whiteness is presented in Fig. 2. Duncan's multiple range tests for the comparison of individual means showed that the maximum whiteness was recorded for $P_1$ (Ultrasonic technique) with mean value 52.26 followed by $P_2$ (Conventional technique) with mean value 49.48. It is therefore concluded that maximum whiteness was achieved by ultrasonic assisted bleaching. The maximum whiteness was achieved by ultrasonic assisted bleaching of cotton fabrics with hydrogen peroxide [10].

In case of the effect of bleaching agent, the individual comparison of mean values shown in Fig. 2 for bleaching agent shows significant differences between the mean values. The maximum whiteness was recorded for $B_1$ ($H_2O_2$) with mean value 54.34 followed by $B_2$ (NaOCl) and $B_3$ ($NaBO_3$) with mean values 50.38 and 47.89 respectively. Mahmood concluded that greater whiteness could be achieved by using hydrogen peroxide bleaching than other bleaching agents. He noted that maximum degree of whiteness was achieved at the higher level of hydrogen peroxide concentration [11].

The individual comparison of mean values of whiteness for concentration shows significant differences between the values. It was found that maximum concentration $C_3$ (30 mL/L) recorded maximum whiteness with mean value 56.98 followed by $C_2$ (20 mL/L) and $C_1$ (10 mL/L) with mean values 50.23 and 45.41 respectively. The results revealed that by increasing concentration of bleaching agent whiteness was increased. In a previous study Shad *et al*. [6] concluded that maximum degree of whiteness of pure cotton fabric was achieved at maximum concentration of hydrogen peroxide used.

The individual comparison of mean values regarding temperature (T) shows significant differences between the mean values. The maximum whiteness was recorded for $T_3$ (90 ˚C) with mean value 66.22 followed by $T_2$ (60 ˚C) and $T_1$ (30 ˚C) with mean values 55.67 and 30.73 respectively. From Fig. 2 it is clear that as the temperature was increased the whiteness of the fabric is increased. Raza *et al.* reported that whiteness of fabric was increased by increasing the concentration and temperature [7].

In case of the effect of bleaching duration (D) the individual comparison of mean values for whiteness indicates significant differences between the mean values. The maximum whiteness was recorded for $D_3$ (60 min) with mean value 52.76 followed by $D_2$ (45 min) and $D_1$ (30 min) with mean values 50.99 and 48.87 respectively. It is concluded that whiteness of the fabric was increased by increasing duration of bleaching.

The overall results show that the whiteness of the cotton fabric is significantly increased by using ultrasonic assisted bleaching technique.

*Fabric Tensile Strength*

The results of tensile strength under the effect of bleaching techniques(P), bleaching agents(B), concentrations(C), temperatures (T) and bleaching durations(D) when subjected to analysis of variance revealed non significant effect of bleaching techniques, bleaching agents and bleaching durations. The analysis of variance shows that effect of concentration and temperature on fabric tensile strength is highly significant. However all of their interactions remained non-significant.

The statistical comparison of individual treatment means for fabric tensile strength is presented in Fig. 3. The individual comparison of mean values for bleaching techniques (P) shows non significant differences between the mean values. The mean value of tensile strength obtained for $P_1$ (ultrasonic technique) and $P_2$ (conventional technique) were 63.34 lbs and 63.78 lbs respectively. It is therefore concluded that both of the techniques i.e. conventional & ultrasonic assisted have equal effect on strength thus the use of ultrasound did not deteriorate the fabric strength.

The individual comparison of mean values for bleaching agents shows non significant difference between $B_2$ (NaOCl) and $B_3$ ($NaBO_3$) but these values are significantly different from $B_1$ ($H_2O_2$). The mean values of tensile strength obtained for different bleaching agents were 64.05 lbs, 63.12 lbs and 63.49 lbs for $B_1$ ($H_2O_2$), $B_2$ (NaOCl) and $B_3$ ($NaBO_3$) respectively.

In case of the effect of concentration (C), the individual comparison of mean values shows significant differences between the mean values.

From the Fig. 3 it was found that $C_1$ (10 mL/L) recorded maximum tensile strength with the mean value 67.86 lbs followed by $C_2$ (20 mL/L) and $C_3$ (30 mL/L) with mean values 63.97 lbs and 58.85 lbs respectively. The results show that tensile strength was decreased by increasing the concentration of bleaching agents. These results confirm the findings of Tzanov *et al.* who reported that the decrease in tensile strength is due to decrease in the degree of polymerization of cellulose because of oxidation [12].

The individual comparison of mean values presented in Fig. 3 for temperature (T) shows significant difference with respect to each other. The maximum tensile strength was recorded at $T_1$ (30 ºC) with mean value 65.47 lbs followed by $T_2$ (60 ˚C) and $T_3$ (90 ˚C) with mean values 63.39 lbs and 61.81 lbs respectively. The results reveal that fabric strength was decreased by increasing the temperature.

The individual comparison of mean values for bleaching duration (D) shows non significant differences between the mean values. The mean value of fabric tensile strength obtained for different bleaching durations were 63.69 lbs, 63.56 lbs and 63.43 lbs for $D_1$ (30 min), $D_2$ (45 min) and $D_3$ (60 min) respectively. The results show that fabric strength was decreased by increasing the bleaching duration.

From the overall results of tensile strength it is evident that ultrasonic assisted bleaching process did not greatly reduce strength of fabric.

*Comparison of Conventional and Ultrasonic Bleaching*

In the following Fig. 4, the values of the whiteness index resulted from conventional and ultrasonic bleaching were compared. The graph presents the values of whiteness index for bleaching agent (hydrogen peroxide) with concentration (30 mL/L) at various temperatures and time durations. The results reveal the difference of conventional and ultrasonic bleaching, as in case of temperature $T_1$ (30 $^0$C), the value of whiteness index achieved by conventional bleaching (42.87) at bleaching duration of 60 min has been nearly achieved by ultrasonic bleaching (42.45) at bleaching duration of 30 min. Whereas whiteness index of 49.99 has been achieved at time 60 min with the use of ultrasonic bleaching. This can be inferred that with use of ultrasonic bleaching the same whiteness can be attained in less time as compared to conventional bleaching. Thus time and energy costs can be saved. Similar conclusion can be deduced from the graph at temperatures $T_2$ (60 ˚C) and $T_3$ (90 ˚C).

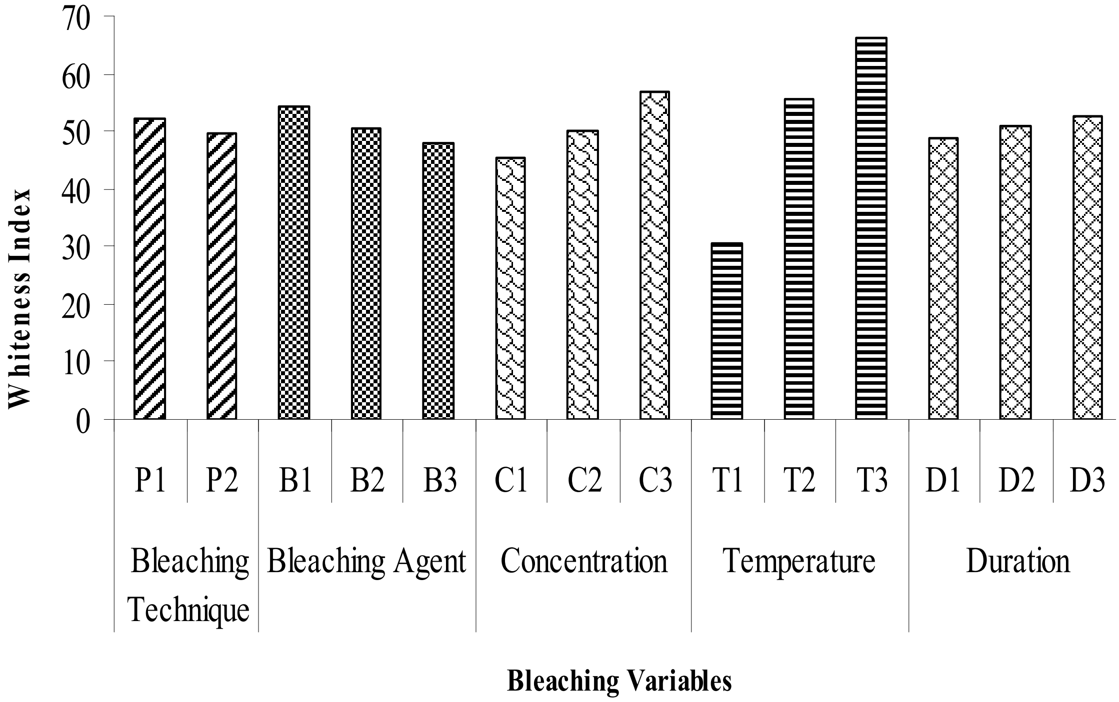


Fig. 2 Graphical representation of individual mean values of fabric whiteness.

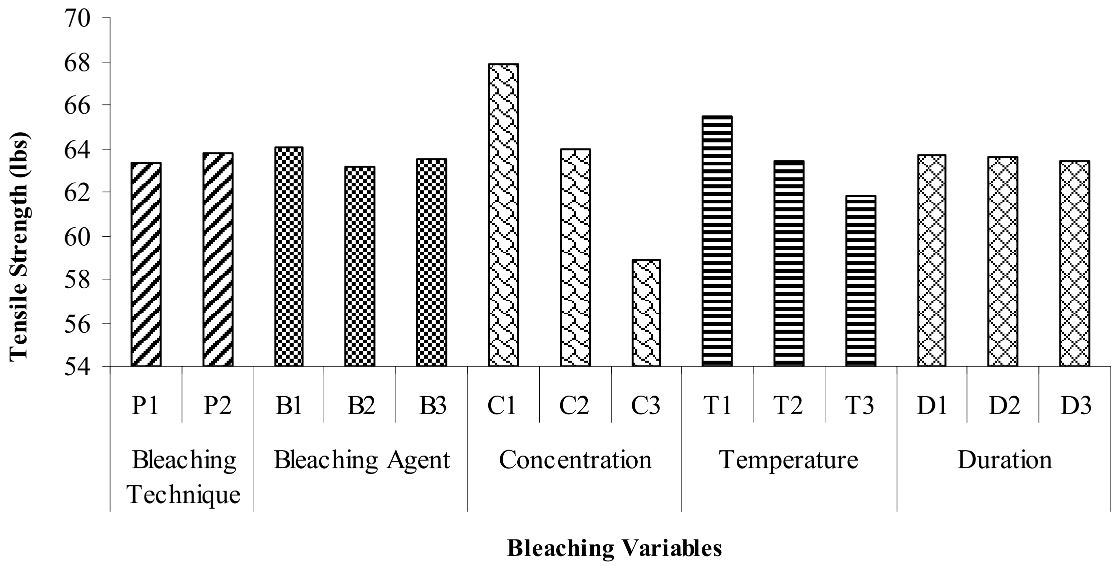


Fig. 3: Graphical representation of individual mean values of fabric tensile strength.

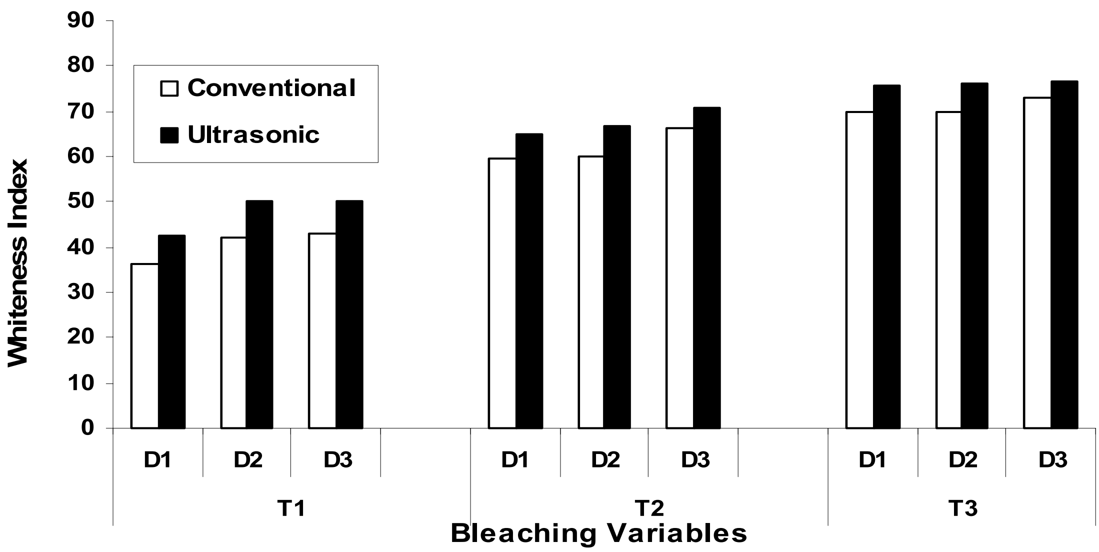


Fig. 4: Graphical representation of comparison between conventional and ultrasonic bleaching.

## Experimental

The research work entitled "Comparative Performance Evaluation of Conventional and Ultrasonic Assisted Bleaching of Cotton Fabric" was initiated in the Department of Fibre & Textile Technology, University of Agriculture Faisalabad, and mainly conducted in Central Hi-tech laboratory, Faculty of Agriculture, University of Agriculture Faisalabad and AMTEX Pvt. Ltd. Faisalabad, Pakistan.

100% woven cotton fabric having construction (72 warp yarns and 72 weft yarns) with yarn count 40s was selected from the running stock of the mills. As the pre-treatments play an important role in subsequent processing of textiles singeing, desizing and scouring processes were carried out with standard process parameters.

Then the bleaching was carried out using the different research variables as given in Table-1.

Table-1: Research variables and their selected levels.

| Bleaching Technique | Bleaching Agent | Concentration (mL/L ) | Duration ( minutes ) | Temperature ( $^0$C ) |
|---|---|---|---|---|
| $P_1$=Ultrasonic<br>$P_2$=Conventional | $B_1=H_2O_2$<br>$B_2$=NaOCl<br>$B_3=NaBO_3.H_2O$ | $C_1 = 10$<br>$C_2 = 20$<br>$C_3 = 30$ | $D_1 = 30$<br>$D_2 = 45$<br>$D_3 = 60$ | $T_1 = 30$<br>$T_2 = 60$<br>$T_3 = 90$ |

Table-2: Recipes for different bleaching agents.

| | Bleaching Agents | | |
|---|---|---|---|
| | Hydrogen Peroxide (50%) | Sodium Hypochlorite (12%) | Sodium Perborate (10%) |
| Liquor Ratio | 1:20 | 1:40 | 1:20 |
| Auxiliaries | NaOH (50%) 6 mL/L | Soda Ash 5 g/L | Sodium Silicate 1g/L |
| Stabilizer (Alkavan GAL) | 1 mL/L | ---- | ---- |
| Wetting Agent (Sandozine MRN) | 1 mL/L | 1 mL/L | 1 mL/L |

*Conventional Method*

The scoured samples were put into the bleaching baths prepared according to the recipes mentioned above one by one. The bleaching was carried out for 30 min, 45 min and 60 min at temperature 30 ˚C, 60 ˚C and 90 ˚C respectively. The stirring was continuously done by a glass rod to ensure the uniform bleaching. After the required time cooling was allowed and samples were taken out of the bleaching baths. The samples were washed twice in hot and cold water and dried. The recipes for the bleaching agents (Hydrogen peroxide, Sodium Hypochlorite and Sodium perborate) are given in Table-2.

*Ultrasonic Assisted Method*

The scoured samples were put into the bleaching baths prepared according to the recipes mentioned in Table-2. Then, the bleaching baths were placed in ultrasonic instrument ELMA TRANSSONIC T 460/H. It has a 35 kHz frequency, 170 W output and a stainless steel round bath to which one barium titanate piezoelectric spread-beam sandwich transducer was firmly fixed beneath the bottom. The bleaching was carried out for 30 min, 45 min and 60 min at temperature 30 ˚C, 60 ˚C and 90 ˚C respectively. After the required time the bleaching baths were removed from the ultrasonic instrument and allowed to cool. Then the samples were taken out, rinsed in hot and cold water respectively and dried.

*Bleaching Evaluation*

After bleaching treatments following tests were carried out to check the bleaching performance.

*Weight Loss*

Weight loss means decrease in weight of the fabric due to bleaching treatment. The weight loss percentage was calculated by the following formula.

$$\text{Percentage of weight loss} = \frac{W_0 - W_1}{W_0} \times 100$$

where $W_0$= Weight of fabric before bleaching.
$W_1$= Weight of fabric after bleaching.

*Fabric Whiteness (AATCC 110)* [13]

The basic aim of bleaching process is to improve the whiteness of the textile material. In the present research the whiteness of the bleached samples was measured on Datacolor Spectraflash SF600 CT-Plus.

*Fabric Strength (ASTM D-5034)* [14]

The breaking strength is a measure of the resistance of the fabric to a tensile load or stress. The test was carried out on tensile testing machine operating on the principle of constant rate of elongation.

*Atmospheric Conditions*

The testing of samples was carried out in laboratories where standard atmospheric conditions at 65 ± 2% relative humidity and 20 ± 2˚C temperature were maintained.

*Statistical Analysis*

The data obtained was statistically analyzed by the analysis of variance technique using factorial experiment as suggested by Muhammad [15]. Duncan's Multiple Range test was also applied for individual comparison of means.

## Conclusion

Ultrasonic energy assisted bleaching was found to be a better technique than conventional bleaching technique as it produced more whiteness at low temperature. The ultrasonic energy produces better results in hydrogen peroxide bleaching than other bleaching agents. This could be due to increased production of hydroxyl ions. On the basis of present investigation it is concluded that ultrasonic assisted bleaching technique can successfully be used in the bleaching of cotton fabric as it produced significantly better results.

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