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Characterization of Biobleaching of Cotton/Linen Fabrics

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ABSTRACT

Environment protection is becoming a serious concern for textile industries. In recent years, there has been a tremendous growth in the use of enzymes in wet processing of textiles due to its ecofriendly images. Glucose enzyme suitable for textile applications, glucose oxidase enzyme is one of the most important. By blending linen (Hibiscus cannabinus L.) with cotton (Gossypium hirsutum L.), new high-end uses for kenaf have been identified. In this work the biobleaching of cotton, Linen and their blends with glucose oxidase enzyme (GOE) was optimized for enzyme concentration, D-glucose dosage, temperature, duration, and pH values and compared with conventional bleaching technique. The optimum conditions existed with 25 U/ml enzyme concentrations, 10 g/l D-glucose, 85°C-bleaching temperature, 90 minutes duration and pH value was 10. Biobleaching technique showed good results when compared to the conventional one with respect to the whiteness and yellowness indices, in addition a comparable mechanical behaviors to the conventional bleaching.

Keywords: Cotton, Linen, Bleaching, Enzyme, and Eco-friendly

INTRODUCTION

The bleaching step decolorizes the natural cotton pigments and removes any residual natural woody cotton trash components, which are not completely removed during ginning, carding or scouring. The main process in use today is alkaline hydrogen peroxide bleach. However, in many cases, especially when a very high whiteness is not needed, bleaching can be combined with scouring. The combined process does however require higher doses of bleaching chemicals. [1,2]

Chemicals that are widely used in the conventional bleaching process may include some of the following chemicals: sodium chlorite & hypochlorite, detergents, wetting agent, optical brighteners, urea, trisodium phosphate, oxalic acid, formic acid sodium nitrate and peroxides. These chemicals off course have many drawbacks including the corrosive actions on the construction materials including the stainless steel and toxic fumes as well as the consumed time and energy, loss of fiber strength and the environmental pollution [1,3,4,5]. The choice of agent depends on many factors such as the end use of the fabric, the required handle and whether or not it is to be dyed. Various fibers require different bleaching agents and sometimes combination of more than one chemical be used [6,7]. Linen and its blended fabric require special bleaching condition due to its impurities [8].

Many activities have been done to eliminate the drawbacks of the conventional bleaching. These methods have the advantage that it is not danger and corrosive. The use of high-pressure steam technique enables saving time and energy to a very large extent [1]. Nowadays the need of integrated chemical pretreatment is highly interested for the environment and cost efficiency consideration [8,9,10,17].

The use of enzymes in textile industries started in the middle of 19th century. Today the use of clean chemistry and green chemistry has trigged the use of enzymes in all areas of chemical technology [11]. Using enzymes is becoming increasingly popular because of the mild temperature and pH conditions that are required and their capability for replacing harsh organic/inorganic chemicals. Moreover, the wastewater effluent from enzymatic treatments is readily biodegradable and does not pose environment pollutions [10]. Peroxidase, laccase/mediator systems, glucose oxidase cellulose, hemicelluloase and catalase are example of the enzymes that may be used in the bleaching process [11,12,13,14].

EXPERIMENTAL WORK

Materials

Fabrics: Treatments were carried on three scoured cotton/linen fabrics with the following identification:

Sample code	Blending ratio (cotton/linen)	Weaving structure	Yarn count/cm		Supplier
			Weft	Warp	
1	65/35	Plain 1/1	36	28	Wagdi Ghonaim Co., Shobra El-Khima, Egypt
2	75/25	Plain 1/1	33	15	
3	100/0	Plain 1/1	40	40	Misr for weaving and spinning Co El-Mahala El-Kobra, Egypt

***Enzyme*:** Glucose oxidase enzyme was used for biobleaching. It was purchased from Novo Nordisk- Denmark.

Chemicals: hydrogen peroxide, sodium silicate, sodium carbonate, magnesium sulphate, sodium acetate, acetic acid, disodium hydrogen phosphate citric acid and D (+) glucose were of grade chemicals purchased from Al-Gomheria Company, Egypt.

Conventional bleaching [4,16]: Scoured fabric was impregnated in bath containing the following recipe:

1.5 g/l sodium hydroxide,
0.4 g/l sodium silicate,
0.2 g/l sodium carbonate,
0.2 g/l magnesium sulphate,
25 ml/l 35% hydrogen peroxide.

The liquor ratio was 1:50 at boiling for 90 minutes. The samples were finally thoroughly washed with hot water followed by cold water.

Biobleaching: The scoured samples were bleached with Glucose oxidase enzyme, with different enzyme concentrations (7, 15, 25, 30 u/ml), and d-glucose (5, 10, 15, 20 g/l) at pH 5 and 35^{o}C with agitation and liquor ratio of 1:20 for 60 minutes. Afterward the pH was changed to (5, 7, 8, 10). 2 g/l magnesium sulphate was added as peroxide activator. In addition to a small amount of nonionic surfactant (triton-x-100) was also added. Treatment system was performed at different temperatures (35, 50, 70 and 85oC) for different times (30, 60, 90 and 120 minutes). The fabrics were then rinsed, and the enzyme solution discarded.

Testing and Analysis:

Tensile strength and elongation percentage: tensile strength and elongation was tested according to ASTM 23 test method using Shimadzu S-500, Japan at the national institute for standards.

Whiteness and yellowness indices: the whiteness index (WI) and yellowness index (YI) were measured using the double beam spectrophotometer that was manufactured by Perkin Elmer Company –USA, of model Lambda 35 and operated with UV-Win lab computer software. The measurement was done in accordance to ASTM E313-96 using CIE color system coordinates.

The morphological investigation: It was carried out using a scanning electron microscope (SEM) manufactured by Joel Co., Japan. The cotton fibers were deposited on the sample-holder, coated with a layer.

RESULTS AND DISCUSSIONS

Effect of linen content on the mechanical behaviors of the fabrics bleached with conventional method or by enzyme.

Figure (1) shows that the biobleaching protect the fabric from the degradation caused by oxidation during the bleaching as the tensile strength of all fabrics with different linen contents is higher than those of the conventional bleaching. The reduction in the tensile strength by the biobleaching is only ranged from 4-7% while the reduction by the conventional bleaching was 11-14% of the scoured unbleached fabric due to the reduction in the degree of the polymerization by the wet conventional bleaching. The figure also reveals that the tensile strength of the fabric containing linen is higher than that of cotton fabric, this can be attributed to the fact that, the degree of crystallinity in the linen is higher than that of cotton fabrics. Figure (2) shows that the elongation % of the linen containing fabrics is lower than that of cotton fabric; this also can be attributed to the crystalline natures of the linen and cotton fabric.

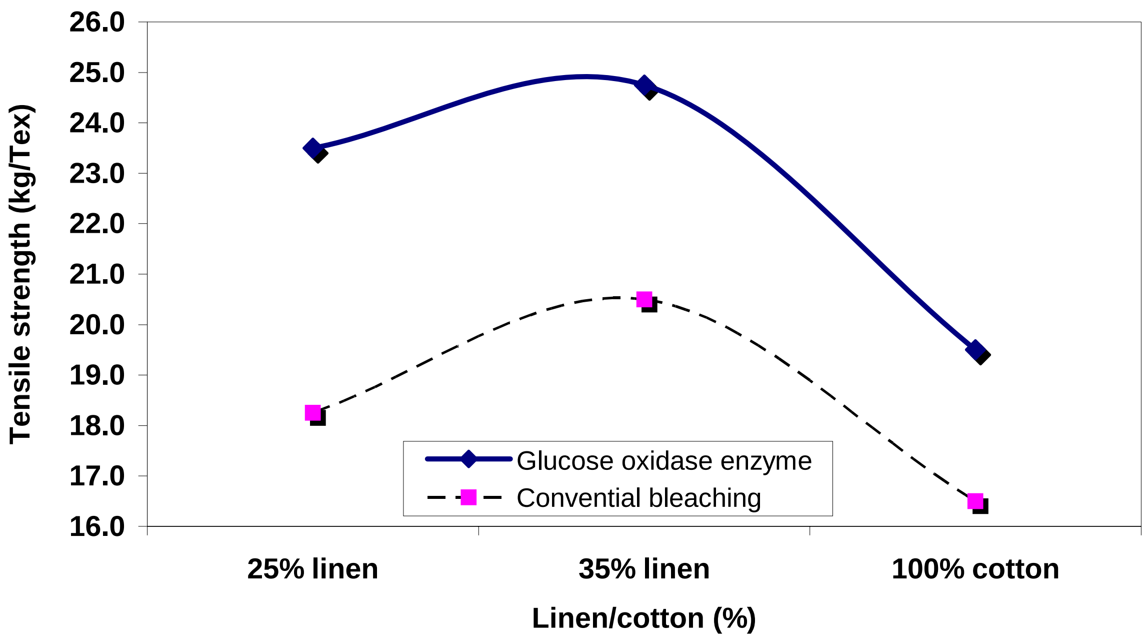

Figure 1: Effect of linen content on the tensile strength of the fabrics bleached with conventional method or by enzyme

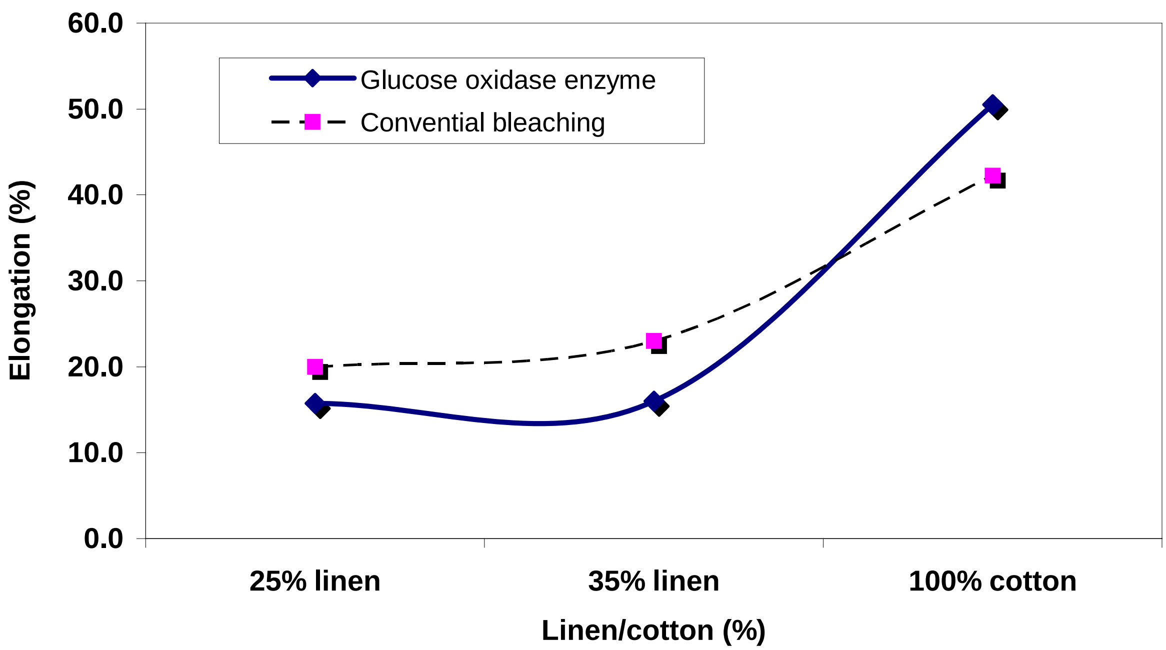

Figure 2: Effect of linen content on the elongation % of the fabrics bleached with conventional method or by enzyme

It is clearly seen from figure (1) that the biobleached fabrics have higher values than that of conventional bleached ones. This can be attributed to the more degradation in the conventional samples. Moreover figure (2) reflects the elongation % of the samples which have higher linen content are slightly with low elongation % in contrast to the sample with major cotton content. This may be attributed to the high hydrolysis action caused by the enzyme on the cotton fiber than the linen fibers due to the high wax, lignin, pectin content and low cellulose content in linen fibers.

Effect of enzyme concentration in biobleaching bath

It is clear from figures (3 and 4) that with increasing the enzyme concentration the whiteness increases (yellowness decreases) up to 25 U/ml then it tend to decrease. It is possible that this effect is a consequence of simultaneously increasing concentrations of gluconic acid, which might led to over-stabilization of the bleach bath.

The results reveal that the whiteness of bleached samples by conventional method is slightly higher than those of biobleached samples. The whiteness decreases as the linen content increases due to the impurities in the flax.

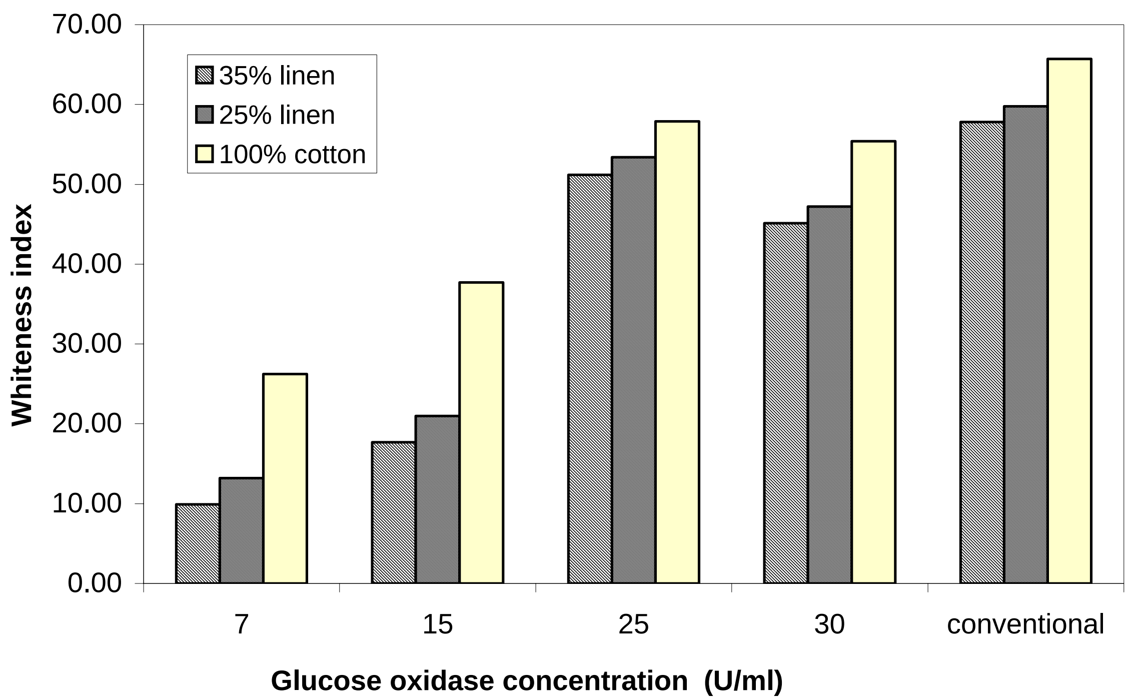

Figure (3) Effect of enzyme concentration in biobleaching bath on the whiteness index.

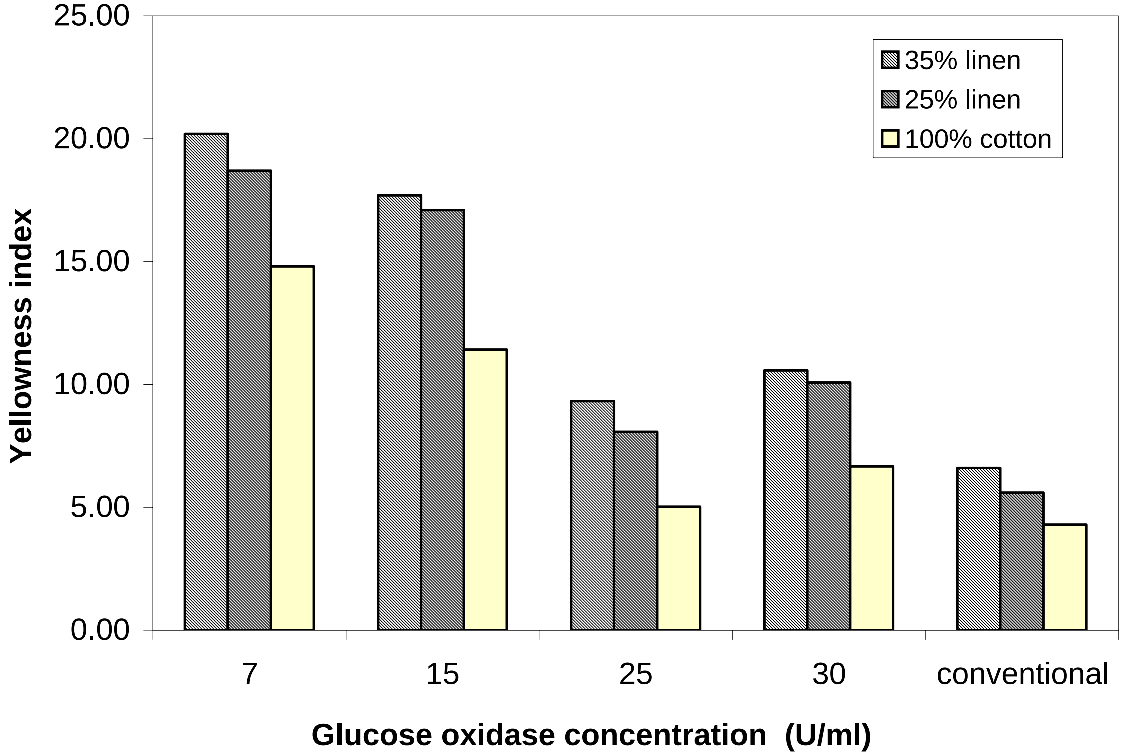

Figure (4) Effect of enzyme concentration in biobleaching bath on the yellowness index.

Effect of D-glucose dosage in biobleaching bath

Bleaching was conducted with glucose concentrations ranging from 3 to 15 g/l under fixed conditions of enzyme concentration, temperature, pH and time. The results in figures (5 and 6) showed that the whiteness increased with increasing glucose concentration up to 10 g/l and then decreases. Up to a certain concentration the presence of glucose in the bleaching bath improves the whiteness of the bleached fabric because the production of hydrogen peroxide is increased. Cotton fibers show higher whiteness more than the flax ones due to the wax, pectin and pigment impurities in the flax fibers.

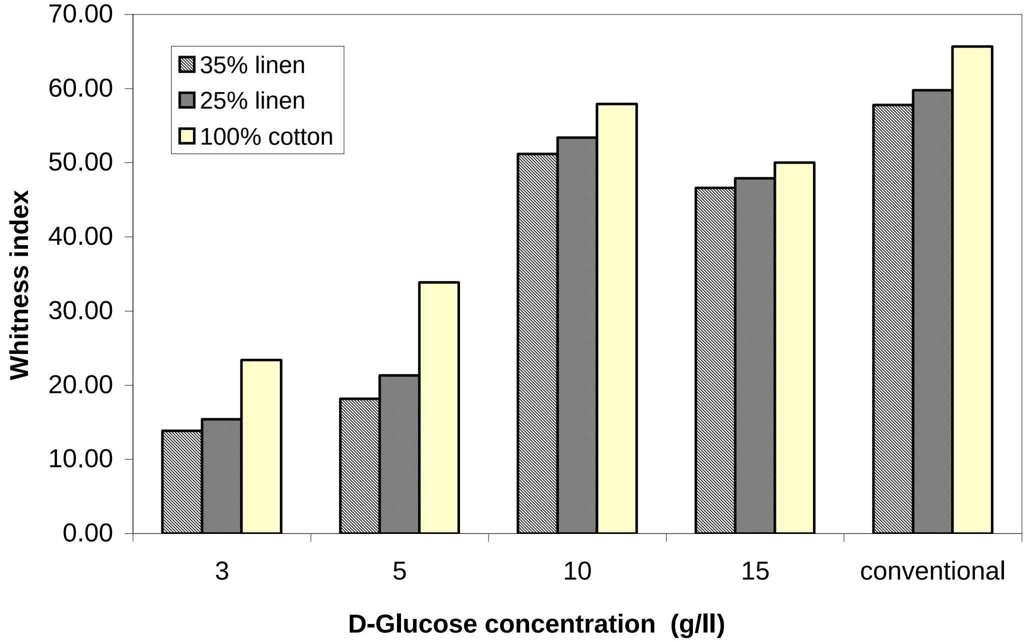

Figure (5) Effect of D-glucose concentration in biobleaching bath on the whiteness index.

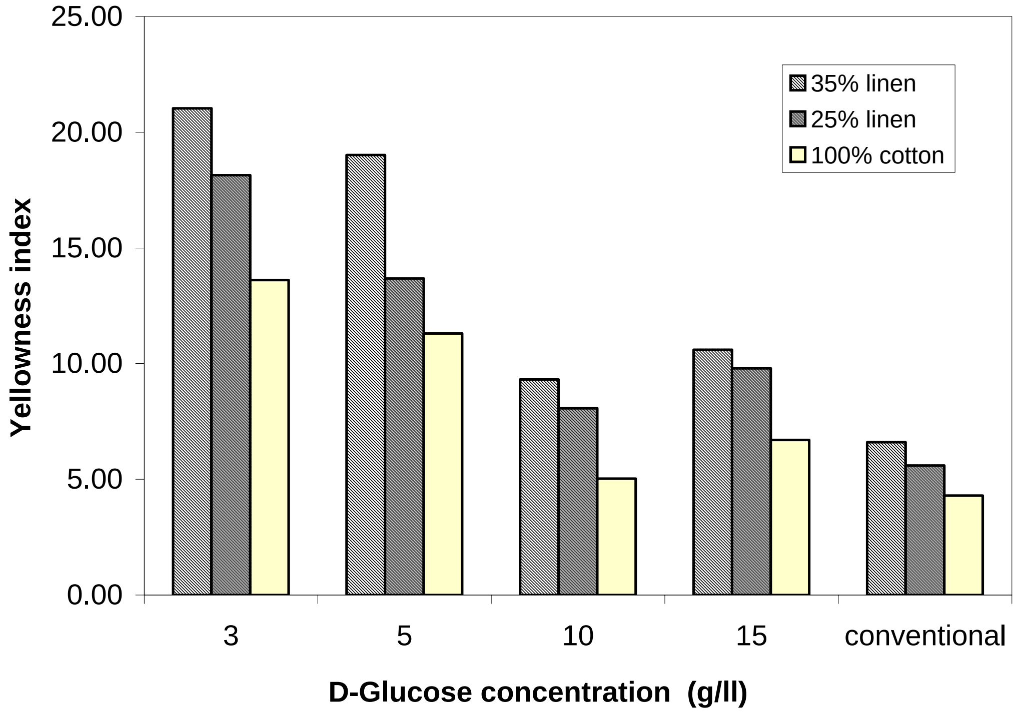

Figure (6) Effect of D-glucose concentration in biobleaching bath on the yellowness index.

<u>Effect of bleaching treatment time on the whiteness and yellowness indices</u>

Yellowness and whiteness are the two faces of the same coin. Yellowness reflects the degradation that might be happened due to the action of the bleaching bath on the fiber surface. Whiteness indicates the quality of bleaching, as the more whiteness is the more efficient bleaching. Figure (7) shows that when cotton content increased the more whiteness is produced; this can be attributed to the more absorbency of the cotton fibers than linen ones which means that more bleaching action occurs. Conventional bleach shows higher values than those of the biobleached technique below 90 minutes treatment time. Biobleaching has good whiteness values at duration 90 and 120 minutes. Figure (8) shows that the biobleached treatment time for 90 minutes is good enough when compared with the conventional techniques.

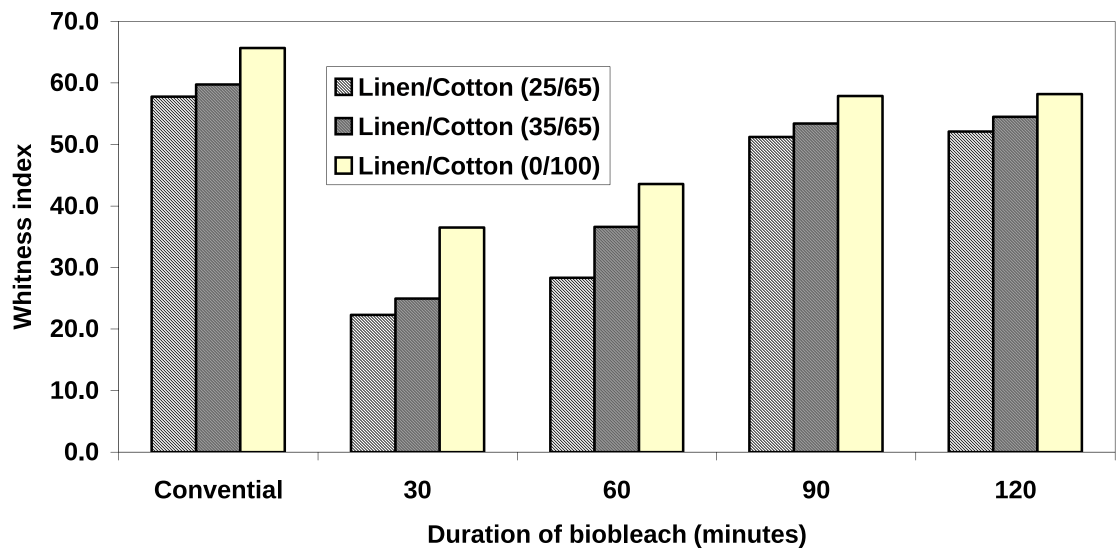

Figure (7): Effect of biobleaching treatment time (minute) on the whiteness index.

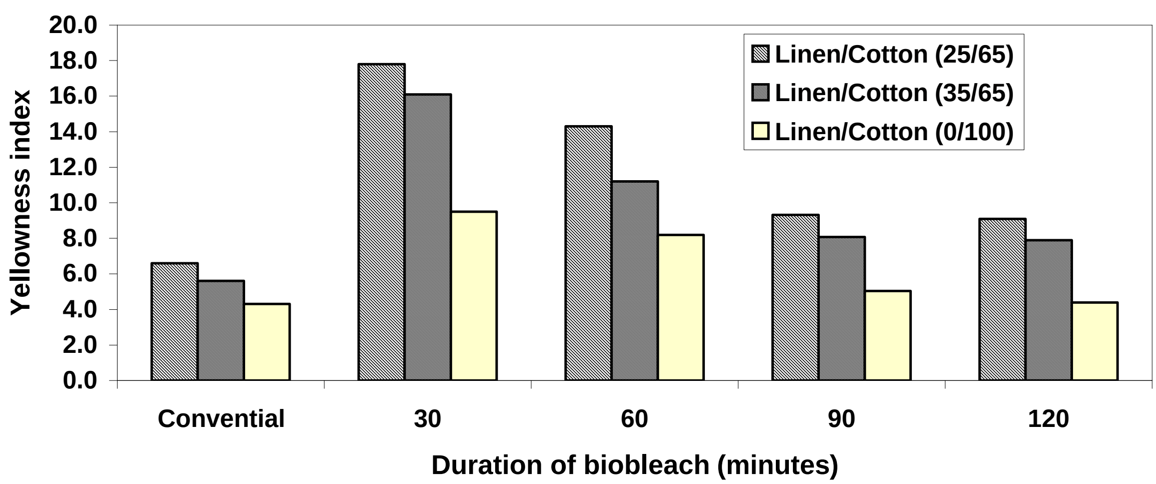

Figure (8): Effect of biobleaching duration (minute) on the yellowness index.

Effect of temperature of enzymatic bleaching on whiteness and yellowness indices

Bleaching was conducted at 35^oC to 85^oC under fixed conditions of enzyme concentration, glucose dosage, pH and time. The bleaching process involved two steps: peroxide was generated by the enzyme and d-glucose at temperature 35^oC and then the temperature was increased to the studied value.

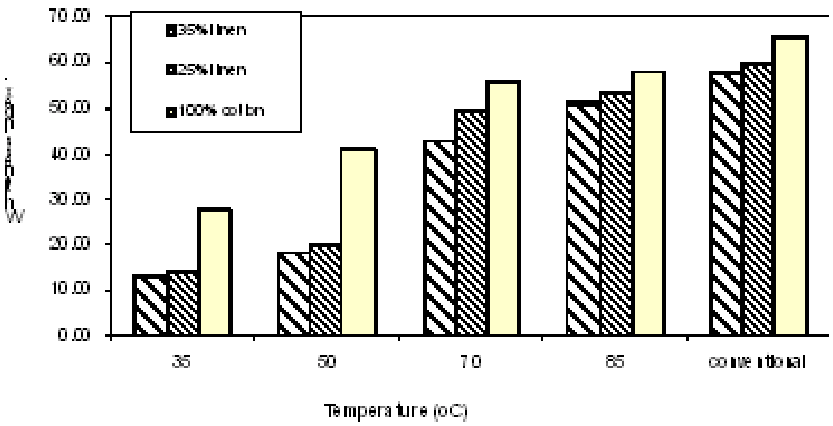

Figure (9) Effect of temperature of enzymatic bleaching on whiteness index

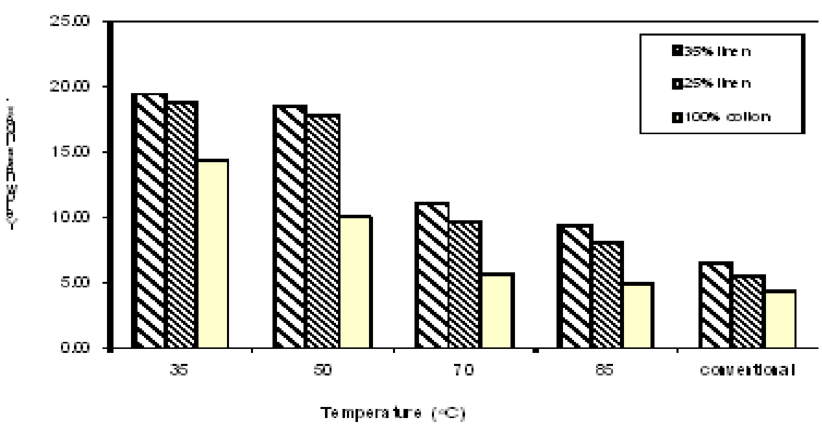

Figure (10) Effect of temperature of enzymatic bleaching on yellowness index

From figures (9 &10) it is clear that the higher temperature is accompanied with higher whiteness values and lower yellowness. The results indicate the best whiteness and yellowness indices produced at temperature of 85^{o}C for 90 minutes.

Effect of pH of enzymatic bleaching on whiteness and yellowness indices

The pH is the most important parameter of the bleach bath since it controls the rate and extent of bleaching and the effect of the bleaching bath on the various fiber present. Bleaching was conducted on a pH ranging from 5 to 12 under fixed conditions of enzyme concentration, glucose dosage, temperature and time. The bleaching process involved two steps: peroxide generated at the enzyme optimum conditions at pH 5 then pH is increased and finally the fabric bleached with the available hydrogen peroxide.

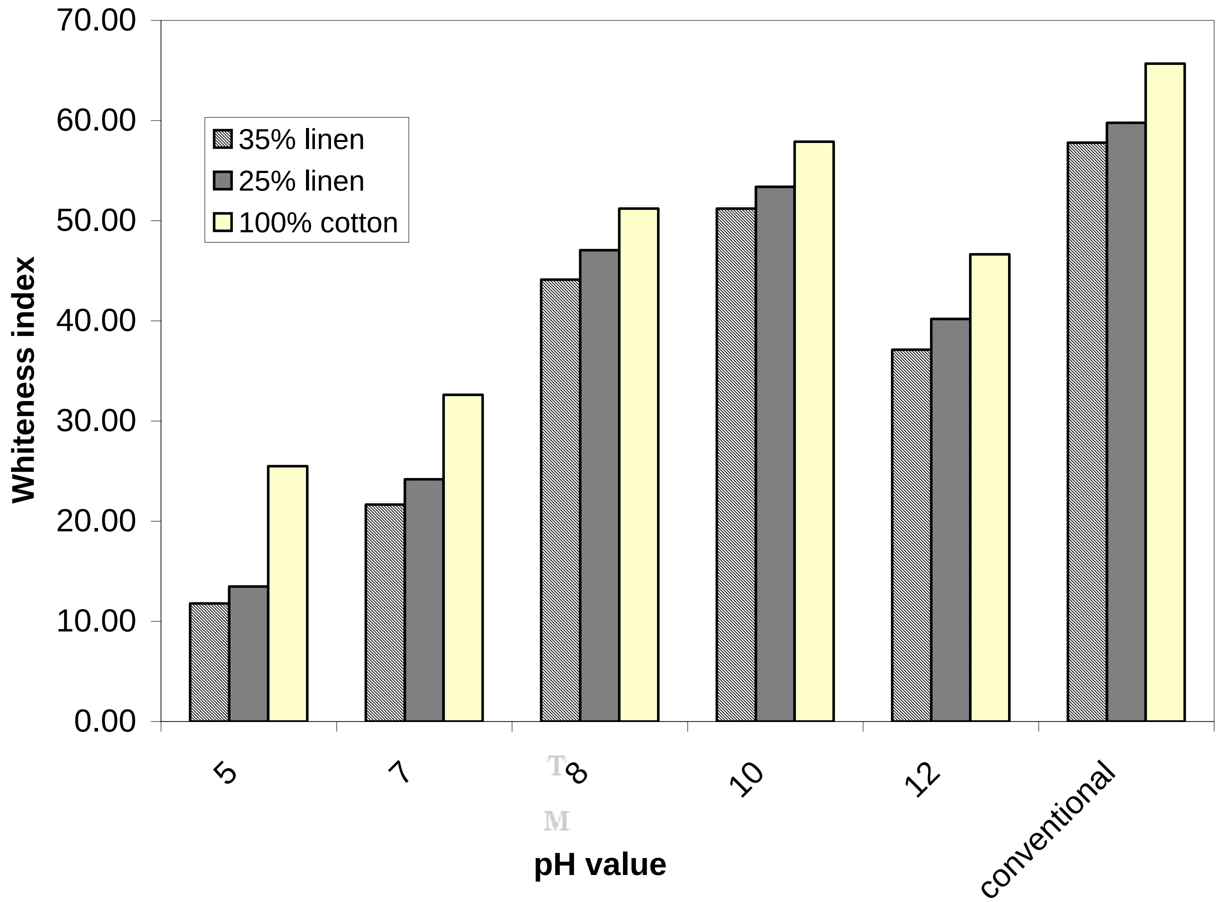

Figure (11) the effect of biobleaching pH of glucose oxidase enzyme on whiteness.

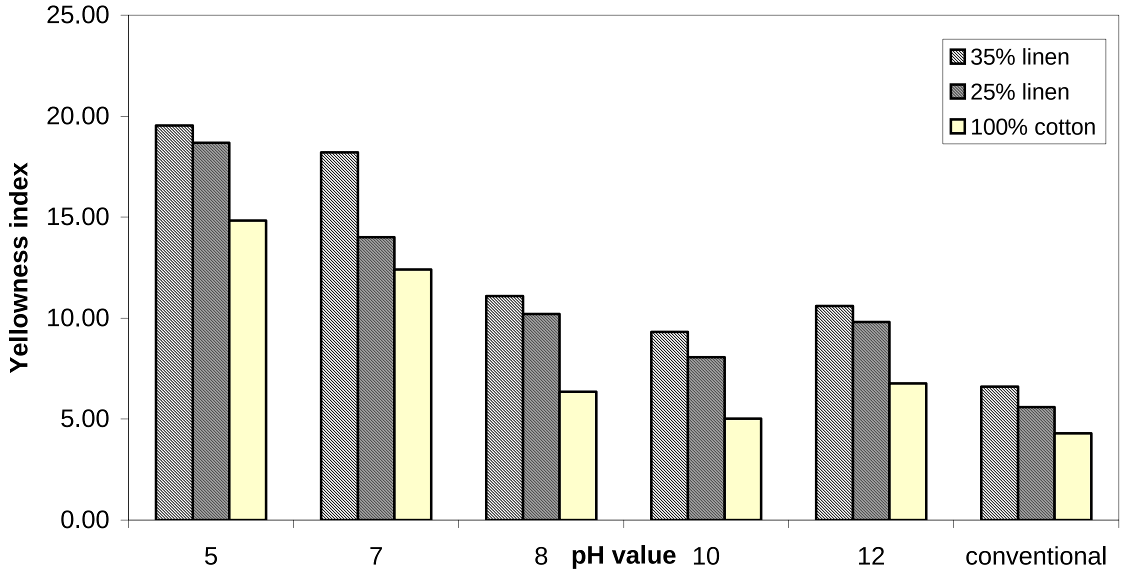

Figure (12) the effect of biobleaching pH of glucose oxidase enzyme on yellowness index.

Figures (11 and 12) show that the highest whiteness and lowest yellowness indices produced at pH 10 (alkaline) beyond this value the hydrogen peroxide decomposes. The figures also showed that the cotton fibers have more accessibility towards the bleaching action.

<u>Effect of biobleaching on the fiber morphology</u>

Scanning electron microscopy was done on the cellulose treated and untreated sample. The untreated fiber showed parallel ridges, which is characteristic of cotton fiber. However, micrograph of the fiber after enzymatic treatment revealed smoothened faces. The enzyme attacks the cellulose of cotton progressively, the primary wall being the first target. The enzyme peels off the cellulose, which results in the formation of protruding fibrils and formation of more polished faces (Figure 13).

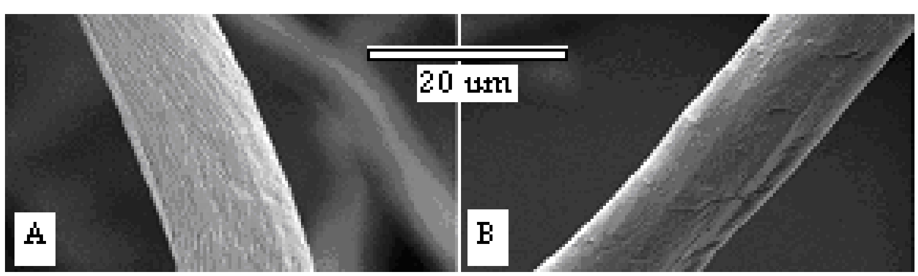

Figure (13): Scanning electron micrographs of (A) untreated cotton fibers and b) biobleached cotton fibers (treated for 90 minutes).

CONCLUSION

The optimum conditions were found with 25 U/ml glucose oxidase enzyme, 10 g/l D-glucose, 85^{o}C temperature, 90 minutes duration time and 10 pH value. Biobleaching technique showed good results when compared to the conventional one with respect to the whiteness and yellowness indices, in addition to a comparable mechanical behavior to the conventional bleaching. When comparing the cost of conventional chemical and biobleaching technique the second is slightly higher but when putting into consideration the environmental issues for sure a lot of money will be saved due to the reduction of pollutants in the industrial effluents and cost of health care.

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