UTILIZATION OF CHICKEN FEATHER WASTE TO IMPROVE THE PROPERTIES OF FABRICS MADE OF SOME EGYPTIAN COTTON VARIETIES

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Abstract

This work aimed to use chicken feathers wastes (CF) as a natural source of active amino acids after alkali treatments with 0.95N NaOH solution. The soluble feather was analyzed using liquid chromatography amino acid analyzer and applied to both the bleached and mercerized cotton fabrics made from Egyptian cotton varieties namely Giza 89 (G89), and Giza 90 (G90) of crop season 2002/2003. The treated and untreated fabric samples were tested for their mechanical properties expressed as the tensile strength N/cm^2, and elongation%. The dyeing behavior expressed as color strength (K/S) using Kubelka-Munk equation, and UV protection values were also investigated. The fixation of CF on the cotton fabric was done by the padding of CF solution onto fabrics followed by dry-cure process. The factors affecting the fixation processes were systematically studied. The finished fabrics show higher tensile strength, more dyeing uptake, more reduction of the UV transmitted, and higher fastness properties (for wash, light, and perspiration) as compared to the untreated samples.

INTRODUCTION

The utilization or recycling of chicken feather waste to a useful material as a cleaner product in the industrial processes has proceeded in the recent years. Poultry chicken feathers represent about 6.0% of the total weight of mature chicken lead to environmental problems as waste – by product at commercially poultry plants (Allen, 2002, and Stoltz, 2003). Schmidt W (1999) showed that approximately two or four billion pounds of poultry feathers as a natural source of active amino acids are produced every year by the poultry producing industry. Most of the feathers are usually ground up and used as filler for animals. However, this use has the potential to pass harmful bacteria along to the animals that ingest the feather meal. CF is bio-source with high keratinaceous protein content (more than 750 g kg^{-1} crude protein).

The durable press (DP) finishes used by the textile industry now are formaldehyde- based reagents. N-methylol reagents are efficient low cost and effective. However, the release of formaldehyde vapor during a finishing process, as well as, during the subsequent storage and consumers used for finished cotton products have caused world wide concern for their impact on human health. Severe fabric strength loss is another disadvantage associated with the formaldehyde based finishing system.

The durable press finishing with polycarboxylic acids has been used as crosslinking of cellulose to develop inexpensive and environmental formaldehyde free processing methods. A disadvantage in spite of; low cost, widespread, availability, ecological acceptability, and it is not satisfactory in its performance, less durable to home laundering, and tendency to impart noticeable yellowing under the condition of heat cure.

Treating textile materials with selected amines from natural resources as cheaper and environmental friendly chemicals provide the aesthetics and/or make the materials more respective to dyes, and more UV-protective for the human skin have been used recently. The treatment causes cellulosic material to become more cationic and thus more respective to anionic dyes without stiffening (Login et al. 2002). Two kinds of alpha-amino acids are used to combine with dimethylol-dihydroxyethyleneurea (DMDHEU) as crosslinking agents for cotton cellulose, and the specific rate constants and other activation parameters are discussed. The results revealed that the wet crease recovery angle (WCRA) and tensile strength retention (TSR) values of the treated fabrics are in the order of DMDHEU-glutamic acid > DMDHEU-aspartic acid > DMDHEU; however, the dry crease recovery angle (DCRA) values are in the inverse rank (Shih, Ming-Kuang et al. 2004).

Dyeable smooth-dry crosslinked cellulose fabrics characterized by an amino acid derived of an N-methylol crosslinking agent on a cellulose substrate which can be dyed with basic or direct dyes are disclosed. Exemplary amino acids can be selected from the group such as glycine, alanine, serine, aspartic acid and glutamic acid.

Recently, considerable attention has been paid to the barrier properties of textile designed for clothing as a protection against UV radiation using selected amines from natural resources. The findings reported in the literature concerning the barrier properties of fabrics in relation to UV radiation show that attention has been focused on the physical aspects of barrier properties of fabrics or yarns used for fabric production (Joana et al. 2003).

The effect of enzymatic and chemical treatments on feather solubility and digestibility was studied by (Kim et al.2002). The experimental treatments were as follows: 1) control, 2) 24-h enzyme, 3) 24-h NaOH, 4) 2-h NaOH, and 5) 2-h NaOH, and 24-h enzyme (Kim et al. 2002).

The application of chicken feathers in textile industries has proceeded by several researchers. Schmidt (2001) has patented a method of removing the stiff quill from the fiber that makes up the feather to produce pure fibers and pure quill material. Polyethylene-based composites are prepared using keratin feather fiber obtained from CF's, (Schmidt et al. 2005).

The aim of the present work is to utilize the soluble chicken feather waste as a useful material in the finishing processes for cotton cellulose as a durable press agent. It is hoped that it will save production cost, reduce energy consumption, production time, dyeing and finishing chemicals, and water in an ecological processes to improve the cotton fabrics dye ability, the tensile strength, and the UV protecting agent.

MATERIALS AND METHODS

Materials

Unbleached raw cotton fabrics with the same structure of two Egyptian cotton varieties namely Giza 89, and Giza 90 were purchased during the crop season 2002-2003 and used throughout this study. All chemicals used were of analytical grade using doubly distilled water (18.5 MΩ.cm^{-1}). NaOH was analytical grade (Koch-Light Co.), petroleum ether (40-60°C), ethanol (95%). Hydrogen peroxide (30%. LR grade) from Aldrich. Sodium carbonate (LR grade), and sodium silicate (136°Tw, 27% SiO_2). The wetting agent was the commercially mercerol supplied by Merck. The hydrogen peroxide bleach liquor for each bleaching process was analyzed by titration with potassium permanganate.

Methods

Pretreatment of CF

Freshly plucked wet feathers were cleaned with water at 60°C and water at room temperature. Wet feather were dried in a ventilated oven (Memmert-UL500-Italy) at 40°C for 72 hrs. The feather was cut into small filaments. 50 g of these materials were treated in a Soxhlet device for 12 hrs with petroleum ether (boiling range 40-60°C) to remove grease. The petroleum ether was evaporated and the dry feathers were stored at room temperature under closed conditions.

Treatment with alkaline solutions [NaOH]

2.0g of CF were stirred at 80 rpm with 20 ml 0.95N NaOH at 70°C for one hour. The produced solutions were filtered to remove any ash and wax residues.

Bleaching treatment

For each of the experiments, 1 g of the unbleached cotton fabrics was immersed in an alkaline bleach liquor (180 ml deionized water) containing sodium carbonate (0.2 gl^{-1}), sodium hydroxide (1.5 gl^{-1}), sodium silicate (0.4 gl^{-1}), magnesium sulphate (0.2 gl^{-1}), wetting agent (0.5 gl^{-1}) and hydrogen peroxide (10 ml^{-1}) was added to the bleach liquor and bleaching was done. The samples were removed from the liquor and neutralized with aqueous solution containing 0.1% acetic acid, followed by a stream of hot water (80-85°C) washing to ensure removal of residual chemicals. Samples were dried in an oven at 100°C for 60 minutes.

Mercerization treatment

The cotton fabrics were treated with aqueous solution of NaOH (25%) at room temperature. The samples were removed from the liquor and neutralized with aqueous solution containing 0.1% acetic acid, followed by washing thoroughly with hot water (80-85°C) washing to ensure removal of residual chemicals. Samples were dried in an oven at 100°C for 60 minutes.

Immobilization of amino acid residues on cotton fabrics

Pretreatment consisted of different concentrations of the produced amino acid hydrolyzates of high pH as the pad bath. Fabric was two-dipped/ two-nipped in the bath with a wet pickup of 95 to 100%. After padding, it was dried at 80-85°C for 15 minutes and cured at temperature of 130°C for 3 minutes.

Dyeing procedure

The pretreated samples were dyed in a bath containing 4g/l of the dye (Remazole Reactive Yellow R. R), with a liquor-to-goods ratio of 30:1. After dyeing, fabric was rinsed in water at 25°C for 10 minutes and then air-dried.

Testing and analysis

Chromatographic analysis of hydrolyzed CF

The effect of NaOH concentration (0.5-1.0M), temperature (50-90°C), time (30-150 min) and CF weight (1.0-2.5g) on the total amino acids were studied by LC 3000 amino acids analyzer of model Eppdrof- Germany. The analysis conditions were as follow: Flow rate = 0.2 ml/min, buffer pressure = 25 bar, reagent pressure = 100 bar, and reaction temperature = 123°C

Mechanical properties

Both the treated and untreated samples were preconditioned before testing at the standard environmental conditions at temperature of 20 ±2°C and relative humidity of 65 ±5 for 24 hrs. This conditioning was performed using standard conditioning room (SDL-UK 1998). The tensile strength (kg/cm^2) and elongation (%) were measured according to ASTM D412-98a using Zwick testing machine of model Z010 and equipped with 10Kn load cell and the testing was conducted at speed of 100mm/min.

Color strength

The color strength expressed as (K/S) was measured using Perkin-Elmer double beam spectrophotometer of model Lambda 35 that is equipped with integrating sphere. The diffuse transmittance was detected at the wavelength 307.02 nm. This wavelength falls in the spectral range of 305-315 nm that is the greatest importance in the various daylight phases (EN13758-1: 2001). According to the Kubelka-Munk equation given by:

$$K/S = (1-R)^2/2R$$

UPF (Ultra violet protection factor) value

UPF is the scientific term used to indicate the amount of UV protection provided to skin by fabric. UPF is defined as the ratio of the average effective irradiance calculated for skin to the average UV irradiance calculated for skin protected by the tested fabric. UPF is defined as the ratio of ED and ED_m measured using Perkin-Elmer double beam spectrophotometer of model Lambda 35 according to the following equation:

$$UPF = \frac{ED}{ED_m} = \frac{\sum_{290nm}^{400nm} E, S, \Delta_\lambda}{\sum_{290nm}^{400nm} E, S, T, \Delta_\lambda}$$

Where:

E_λ = erythermal spectral effectiveness

S_λ = solar spectral irradiance in $Wm^{-2}\ nm^{-1}$

T_λ = spectral transmittance of the fabric

Δ_λ = the bandwidth in nm

λ = the wavelength in nm

ED = a dose for unprotected skin calculated by convolving the incident solar spectral power as relative spectral effectiveness function and summing over the wavelength of 290-400nm.

Fastness properties

(a) Washing fastness (WF)

Washing fastness of the untreated samples was done according to ISO 105-C01: 1998(E). Two single fiber adjacent fabrics complying with the relevant sections of F01 to F08 of ISO 105-F: 1989. One adjacent fabric of cotton and the second of wool.

(b) Respiration fastness (PF)

Fastness to synthetic perspiration was measured according to ISO-E04: 1994.

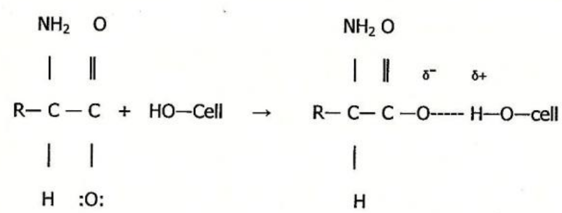
(c) Light fastness (LF)

Fastness to light was measured according to ISO 105:1997 using standard wool blue scale as a reference in all tests. The grads used throughout this work were (1 not fast and 8 is greatly fast to light).

RESULTS AND DISCUSSION

Immobilization and Liquid chromatographic analysis of the CF on cotton fabric

Immobilization of amino acid residues on cotton fabrics is due to the H- bonding formed between free hydroxyl groups of the cellulose with carboxylate anion of the amino acid as shown in the following diagram:



CF amount, NaOH concentration, temperature and time for CF hydrolysis yielding maximum total amino acids concentration were examined.

Table 1 shows that, total amino acids concentration of hydrolyzate is increased with NaOH concentration till 0.95N, due to decrease in crosslinkage of CF keratin and hydrolysis of peptide bonds yielding active amino acid residues. It is also observed that, as CF amount, temperature and time increased till reach (2.0g, 70 °C, 1h), total amino acids concentration increased, due to the enhanced in keratin hydrolysis rate. However after these obtained values, some decrease in total amino acids concentration were observed, due to destruction and racemization of some amino acids as threonine, arginine and cysteine in highly alkaline environment (Fountoulakis *et al.* 1998).

Table 1. Effect of CF amount, NaOH concentration, temperature and time on CF alkaline treatment.

a) NaOH conc., mole/l	0.5	0.75	0.85	0.95	1.0
Total amino acids conc., mg/l	258.6	281.2	290.7	298.9	296.5

b) Temperature, °C	50	60	70	80	90
Total amino acids conc., mg/l	298.8	321.2	334.0	333.1	331.5

c) Time, min	30	60	90	120	150
Total amino acids conc., mg/l	293.4	334.0	333.9	333.2	333.4

d) CF amount, g	1.0	1.75	2.0	2.25	2.5
Total amino acids conc., mg/l	169.7	298.2	334.0	334.1	334.0

a) Effect of alkali concentration, using 2.0g CF, at 50°C, for 1h.

b) Effect of temperature, using 2.0g CF, 0.95N NaOH for 1h.

c) Effect of time, using 2.0g CF, 0.95N NaOH at 70°C.

d) Effect of CF amount, using 0.95N NaOH at 70°C for 1h

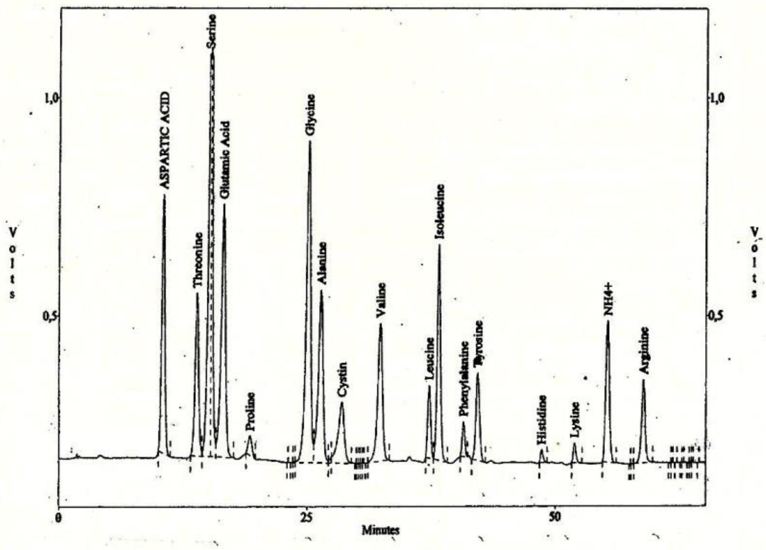


Fig. 1. Amino acid analysis of CF hydrolysis with 6N HCl, at 110°C, for 24 hrs.

These values obtained were confirmed (i.e. no great difference observed), by comparison of amino acid analysis after hydrolysis 2.0mg of CF with 4ml 6N HCl at 110°C for 24h (Fig.1) according to (AOAC, 1984), and amino acid analysis of CF hydrolyzed at these experimental conditions (Figs.2).

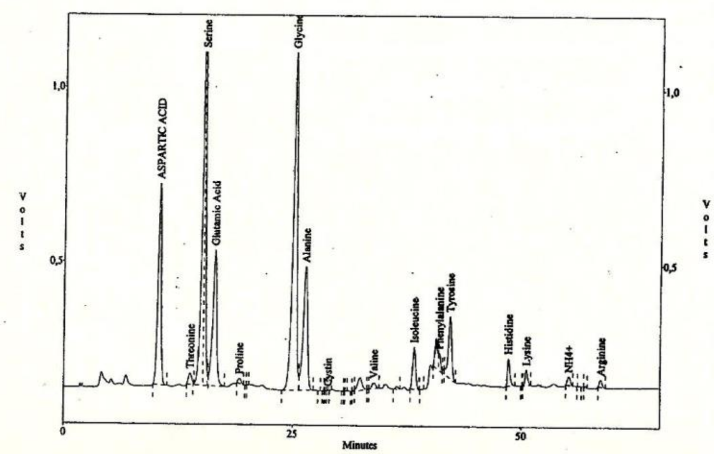


Fig. 2. Amino acid analysis of CF hydrolysis with 0.95N NaOH, at 70°C, for 1h.

Dye uptake effect

As shown in Fig.4, the K/S values of the samples are influenced by the pH of solution. The pH of solution was shown to be the key parameter influencing the structural formula of active amino acid molecules bonded to cotton. The general structural formula of most natural amino acids contain both (-COOH) and ($-NH_2$) groups, which give them ability to exist either as a cation, anion, or Zwitterions depending on pH as shown in Fig. 3. For this reason pH governs the ionic form of the active amino acid sites on cotton.

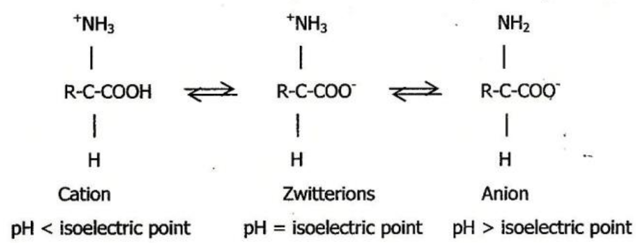


Fig. 3. The general structural formula of most natural amino acids

The open bond of oxygen atoms of the amino acid connect with cotton. In pH < isoelectric point, nitrogen on the amino acid adsorb hydrogen ions to create positively charged sites. These sites have a strong attraction to negatively charged dyes, so that the dye uptake increases considerably and the K/S values increased for both mercerized Giza 89, and Giza 90, and slightly increased for the bleached samples as compared with the untreated samples (scoured samples). Increasing dyebath pH decreased the concentration of hydrogen ions, so the K/S values decrease for the mercerized cotton samples. When pH was equal to or larger than 6, hydrogen ion concentration was so low that the number adsorbed decreased extraordinarily. The treated cotton fabric was not able to adsorb much dye through ionic attraction. Above pH 10, further increase in dye sorption. This effect due to the hydrolysis of the amino acid from cotton. The decrease in crosslinkages between cotton and the CF amino acid increased dye sorption. Metal can be also coordinated to side chain charged groups (-OH, -COOH and –SH) of some amino acids depending on type of amino acid to complete its coordination sphere (Osamu *et al.* 2002).

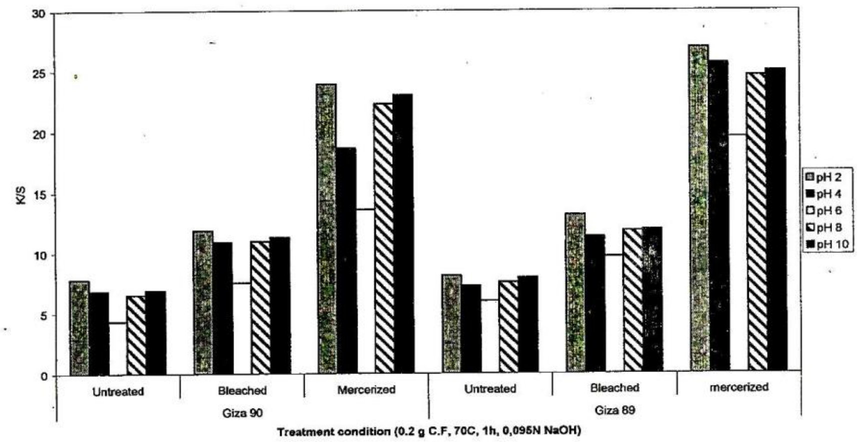


Fig. 4. Effect of pH on the color strength of Giza 89 and Giza 90 cotton fabrics.

CF uptake by the cotton fabrics

As shown in Fig.5, the K/S values of the samples influenced with the concentration of the CF due to the increase of total amino acids concentration and a strong attraction to negatively charged dyes occurred, so that the dye uptake increases considerably and the K/S values increased for both mercerized Giza 89, and Giza 90. No significant difference between the untreated samples (scoured samples), and the bleached samples observed for both cotton varieties.

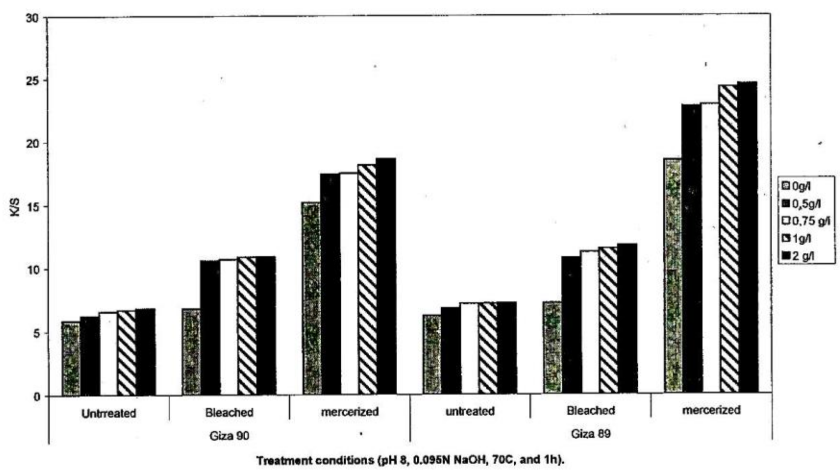


Fig. 5. Effect of CF on the color strength of Giza 89 and Giza 90 cotton fabrics.

UPF values

High, short-term exposure to ultraviolet radiation (UV) from the sun causes sunburns leading to skin cancer. A primary reason for the increased cancers is attributed to ozone depletion. Each one percent decrease in ozone concentration increase the rate of skin cancer by two percent to five percent. Other reasons for the skin cancer such as excessive exposure to sunlight. UVR band consists of three regions: UV-A (320-400nm), UV-B (290-320), and UV-C (200-290). UV-B is the most responsible for the development of skin cancers. Fabrics with a UPF values in the range 15-24 were classified as UV protection, when the UPF values were between 25-40 fabrics were classified as having UV protection. Excellent UV protection was used when the UPF value was 40 or greater as described by (Sarkar, 2004).

As shown in Fig. 6, the treated fabric samples with CF after mercerization treatment has the UPF value of more than 40, classified as excellent UV protection for both Giza 89, and Giza 90 compared with the untreated samples (scoured samples) or the bleached samples.

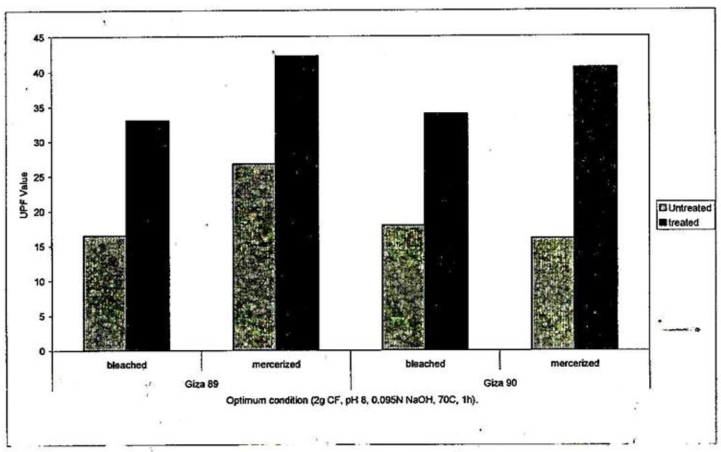


Fig. 6. UPF of the CF cotton fabrics of Giza 89 and Giza 90 cotton fabrics at optimum conditions.

Fastness properties

Table 2 shows that the fastness properties for the treated fabrics for both the bleached, and mercerized Giza 89, and Giza 90 increase than that of the untreated samples (scoured samples). This is due to the fixation of the dye as a result of the strong attraction of the dye with the amino acids of the CF.

Table 2. Fastness properties of the cotton fabric samples treated with CF

Variety	Giza 89								Giza 90							
Treatment	Scoured				Mercerized				Scoured				Mercerized			
F. P	L.F	W.F	P.F		L.F	W.F	P.F		L.F	W.F	P.F		L.F	W.F	P.F	
			ac	alk			ac	alk			ac	alk			ac	alk
Untreated	5	3/4	3/4	4/5	4	3/4	3	3/4	5	3/4	4/5	3/4	6	4/5	4	3/4
Treated	5	5	4	5	5	5	5	5	5	4	5	5	6	5	5	5

F.P fastness properties, L.F light fastness, W.F washing fastness, P.F perspiration fastness, ac. acidic, and alk. alkaline

Mechanical properties

Tensile strength at maximum force, and Elongation at break

It has been noted that the strength for the untreated Giza 89 is stronger than that of Giza 90 while the elongation for Giza 89 is lower than Giza 90. as shown in Figs.7, and.8. In the treated samples there is increase both tensile and elongation in the same trend. This is due to the crosslinking of the amino acids of the CF with the cellulose of the cotton samples.

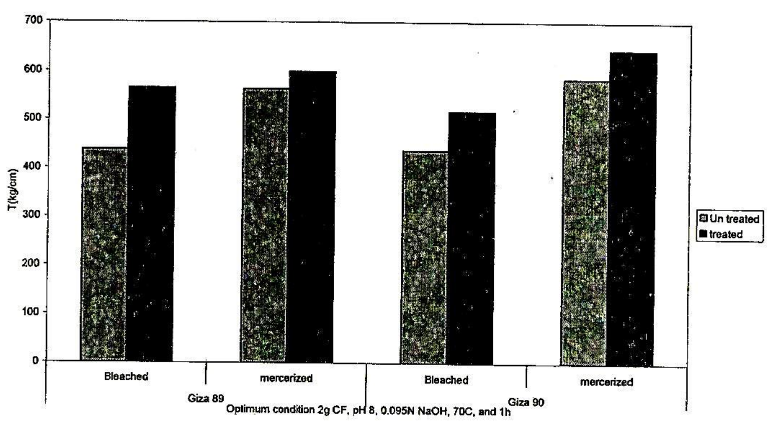


Fig. 7. Tensile Strength of Giza 89 and Giza 90 cotton fabrics at the optimum conditions.

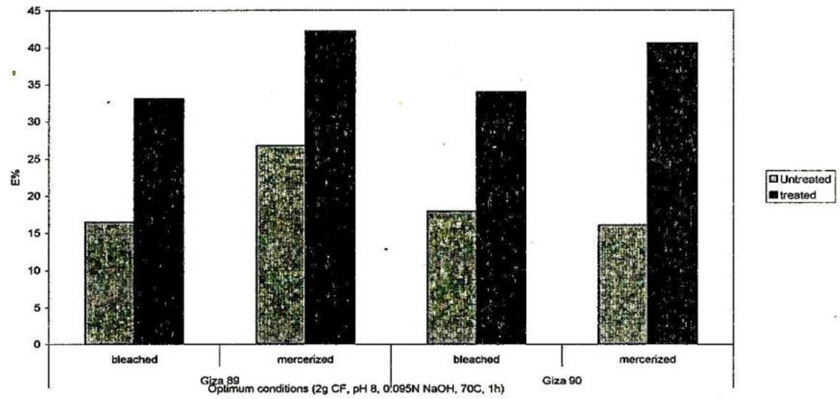


Fig. 8. Elongation at break of Giza 89 and Giza 90 cotton fabrics at the optimum conditions.

CONCLUSION

This work contributes a new application of the chicken feather wastes as a natural source of active amino acids after alkali treatments with 0.95N NaOH solution in the textile industry by applying the chicken feather onto both Giza 89, and Giza 90 cotton fabrics. The finished fabrics showed high tensile strength, more dyeing uptake, and more reduction of the transmitted UV as compared to the untreated samples. These achievements will reduce the chemicals and dyes in the wastewaters of the textile industry. Furthermore, this will provide protective textiles to the human skin.

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الاستفادة من مخلفات ريش الطيور لتحسين خواص الأقمشة لبعض أصناف القطن المصري

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أصبحت عمليات التجهيز النهائي للأقمشة القطنية المصرية من العمليات الصناعية الهامة لإعطاء المنتج النسجي صفات ذات جودة معينة.

تعتبر مشتقات الفورمالدهيد من المواد التي أستخدمت في عمليات التجهيز النهائي و رغم رخص ثمنها فأن لها أضرار بيئية منها إنبعاث الأبخرة السامة التي تصيب العاملين في المصانع بامراض سرطانية مما أدي الي منع استخدامها. و قد كانت الأحماض الكربوكسيلية هي البديل في عمليات التجهيز النهائي للأقمشة القطنية حيث انها مواد صديقة للبيئة و رخيصة الثمن و لكنها في نفس الوقت تعمل علي إصفرار اللون و كذلك الفقد الملحوظ في متانة الأقمشة. ويتم حديثا استخدام الأحماض الأمينية في عمليات التجهيز النهائي حيث انها مواد صديقة للبيئة و رخيصة الثمن و ليس لها الأضرار التي تحدث من المواد الأخري المستخدمة.

يهدف البحث إلى استخدام مخلفات ريش الطيوركمصدر طبيعي للأحماض الأمينية في عمليات التجهيز النهائي لتحسين خواص بعض الأقمشة القطنية المصرية وتحويلها من مواد تسبب مشاكل كبيرة بيئيا الي مواد صديقة للبيئة.

تم في هذا البحث تجهيز مخلفات ريش الطيور كمصدر طبيعي للأحماض الأمينية كما يلي:

- مرحلة جمع و تنظيف الريش و معالجته لتحويله الي مصدر للأحماض الأمينية.
- التحليل الكروماتوجرافي للمحتوي الأميني للريش و دراسة العوامل المؤثرة علي إستخلاص اكبر كمية من الأحماض الأمينية مثل تركيز هيدروكسيد الصوديوم و الزمن ودرجة الحرارة.
- إستخدام هذه الأحماض الأمينية في معالجة الأقمشة القطنية من صنفي جيزة ٨٩ وجيزة ٩٠ والتي تم الحصول عليها كخام من شركة النصر للغزل و النسيج– المحلة الكبري بعد عمليات التبييض و المرسرة.
- تم قياس صفات المتانة و الإستطالة و كذلك درجة عمق اللون و ثبات الألوان بالنسبة للضوء والعرق (حامضي أو قاعدي) و الغسيل و أيضا درجة الأمتصاص للأشعة فوق البنفسجية .

و يمكن تلخيص النتائج التي تم التوصل إليها كما يلي :

١. زادت استجابة الأقمشة المستخدمة للصباغة نتيجة عمليات المرسرة بدون إضافة المحلول الأميني ووجد أن صنف جيزة ٨٩ أكبر في الإستجابة من صنف حيزة ٩٠.
٢. زادت استجابة الأقمشة المستخدمة للصباغة بإضافة المحلول الأميني بدرجة كبيرة و تزداد هذه الأستجابة كلما زاد تركيز هذا المحلول.

٣. وجد أن درجة الأس الهيدروجيني لها دور هام جدا في زيادة إستجابة الأصناف للصباغة، حيـــث تزداد الاستجابة للصباغة في الوسط الحامضي اكثر من الوسط القاعدي إلا إن ذلك يؤثر بالسلب علي المتانة.
٤. ازدادت جميع صفات الثبات للصباغة للعينات التي تم معالجتها بالمحلول الأميني عـــن العينـــات الغير المعالجة و صنف جيزة ٨٩ أكبر في الإستجابة من صنف حيزة ٩٠.
٥. وجد ان العينات المعالجة بالمحلول الأميني لها قدرة ممتازة علي امتصاص الأشعة فوق البنفسجية و ذلك لحماية الجلد من الأصابة بسرطان الجلد عن العينات غير المعالجة وصنف جيزة ٨٩ أكبر في الإستجابة من صنف حيزة ٩٠ وهذه النتيجة مهمه في الملابس الطبية والمحبة للبيئة.
٦. ازدادت متانة العينات المعالجة بالمحلول الأميني عن العينات غير المعالجة أو علي أقل تقدير لم تتأثر سلبا.
٧. جميع المعاملات بالنسبة للعينات الممرسرة و المعالجة بالمحلول الأميني كانت افضل من العينات المبيضة أو العينات غير المعالجة.

يتضح مما سبق ان استخدام مخلفات الريش كمصدر طبيعي للأحماض الأمينية يعمل علي:

١. تحسين خواص الأقمشة القطنية بزيادة درجة عمق الصبغة و ايضا زيادة ثبات اللون.
٢. توفير تكاليف عمليات التخلص من هذه المخلفات و تحويلها الي مواد مفيدة.
٣. توفير التكاليف لمصانع الغزل و النسيج و ذلك بتوفير شراء مواد غالية الثمن و ايـــضا تـــوفير كميات كبيرة من الصبغات و الكيماويات و الوقت و الزمن اثناء هذه العمليات.
٤. القدرة الممتازة علي امتصاص الشعة فوق البنفسجية و بذلك ينـــصح بإســـتخدام هـــذه الأقمـــشة المعالجة قي ملابس العاملين الذين يتعرضون لأخطار التعرض لهذه الأشعة مثل الملابس الصيفية و الطبية الصديقة للبيئة و كذلك أقمشة الستائر.