THE MECHANOPTICAL PROPERTIES OF AWASSI IRAQI WOOL FIBRES

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ABSTRACT

The mechanoptical properties of dyed and undyed Awassi Iraqi wool fibres were studied extensively for the first time. The load-extension curves were used to calculate the average breaking strength, tenacity, elongation at break and stiffness for 149 and 175 dyed and undyed wool fibers respectively. The results showed that the average values of these four parameters were 24.151 g, 2.098 g/dtex, 66.389% and 3.165 g/dtex respectively for undyed Awassi wool fibers. In case of dyed wool fibers the average values of the above mentioned parameters were 24.020 g, 2.053 g/dtex, 51.996 % and 3.960 g/dtex respectively.

The spectral reflectance values of the dyed and undyed wool fibres were measured spectrophotometrically. The ratios of the extinction to the scattering coefficients were calculated from the diffuse reflectance according to the Kubelka - Munk theory. The optical energy gap, $E_{opt.}$, for the undyed wool fibres was 2.639 eV, and the width of the tails of localized states in the band gap region, E_e, i.e Urbach edge was 0.395 Ev. For dyed wool fibres the values of these two parameters were 2.376 eV and 0.133 eV respectively.

دراسة الخواص الميكانوضوئية للصوف العواسي العراقي

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الملخص :

تم في هذا البحث دراسة الخواص الميكانوضوئية للصوف العراقي العواسي المصبوغ وغير المصبوغ بشكل كامل ولاول مرة. تم فحص حوالي 149 و 175 من ألياف الصوف العراقي المصبوغ وغير المصبوغ على التوالي، استخدمت منحنيات التحميل – الاستطالة لحساب معدل قوة القطع والمتانة والاستطالة عند القطع والصلادة، وكان معدل القيم لهذه المعلمات الأربع 24.151g, 2.098 g/dtex, 66.38% 3.165 g/dtex على التوالي لألياف الصوف غير المصبوغ، أما ألياف الصوف المصبوغ فكان معدل القيم للمعلمات المذكورة اعلاه 24.020 g, 2.053 g/dtex, 51.996% و3.960g/dtex على التوالي .

استخدم السبكتر وفوتوميتر لقياس معاملات الانعكاس الطيفي لألياف الصوف المصبوغ وغير المصبوغ وتم حساب نسبة معامل الامتصاص الى معامل الاستطارة من معاملات الانعكاس الانتشاري ووفق نظرية كوبيكا-ونك. كانت قيمة فسحة الطاقة الضوئية (Eopt.) 2.693 eV لألياف الصوف غير المصبوغ وعرض المواقع المتموضعة في فسحة النطاف (Ee) (حافة اورباخ) 0.395eV. أما في حالة ألياف الصوف المصبوغ فكانت قيم هذين المعلمين 2.396 eV و0.133eV على التوالي.

INTRODUCTION

The Awassi breed of sheep is one of the three major native breeds of Iraqi sheep, namely Arabi, Awassi, and Karadi[1-3]. It belongs to the fat tailed type, and represents about 55-60% of the total sheep population in Iraq[3,4], it is raised in the North-West part, but largely concentrated in the central part of

Iraq. The fleece is usually white in colour and the wool is coarse, medullated and contains a high percentage of kemp[4]. Awassi sheep in common is found in most of the middle east countries, especially Iraq, Syria, Palastine and Jordan [5]. The quality of Iraqi Awassi wool was found to be 46's-50's[5], so it is classified as carpet type and considered as the best carpet wool in the country when blended with nylon, it is good for blanket manufacturing also when blended with viscous rayon[5].

Few studies have been done on the tensile properties of Iraqi wool[1,6,7], especially for Awassi[1,8], but non on dyed wool fibres. Furthermore, there is hardly any report about the optical properties of wool fibres (neither Iraqi nor others) except one[37]. Some physicochemical properties of Iraqi Awassi wool fibres have been studied extensively by the authors [9,10]. The aim of the present work is to study the mechanoptical properties of this dyed and undyed type of wool fibres, such properties affect its quality and use in industry. The results obtained will fill a gap in the available information's that characterize Awassi wool fibres and may help in further research, and enable the authors to further elucidate the relationship between the mechanical properties of wool fibres and structure, as well as the effects of dyes on these properties.

EXPERIMENTAL

Materials

Scoured Awassi Iraqi wool was obtained from the General Establishment for Woolen Industries. Random samples (taken from shoulders, sides and back sections) underwent a prolonged treatment with ethanol, this was followed by a long rinse in distilled water (24hr), after which they allowed to dry at room temperature and moisture.

Before measurements, some wool fibres were dyed with Lanasyn Yellow 2GLN 250%, this dye is a 1:2 metal complex dye[11]. Metal complex dyes are chemically closely related to chrome dyes, but from the dyre's point of view they are acid dyes[12]. Standard dyeing processes were conducted as that being followed in the General Establishment for Woolen Industries and according to that recommended for Lanasyn[13].

MEASUREMENTS

1- Mean Fibre Diameter

Mean fibre diameter was measured by airflow method using a calibrated Wool Industries Research Association (WIRA) Fineness Meter operated at a constant pressure difference [14-16]. The test was carried out according to the American Society for Testing and Materials (ASTM) procedure[17]. About 5-6 readings were taken for each sample and the mean value was calculated to the nearest 0.05 µm. Samples, prior to measurements, were conditioned overnight in the laboratory atmosphere and the results were corrected to the standard conditions, 65% RH and 20°C[18]. The mean fibre diameter in dtex* was obtained from the curve representing the dtex-micron relationship for wool fibre diameter [18].

The mean fibre diameters of dyed (7 samples) and undyed (8 samples) of wool fibres were measured by this technique.

2- Mechanical Properties

Tensile tests were carried out at atmospheric conditions using the WIRA. Single Fibre Strength Meter Type 678. Measurements were carried out as described by Booth[16] and according to the operation manual[20]. The gauge length was 10 mm. For each fibre a complete load-extension curve was drawn on a chart paper moving at a constant speed (20 cm/min) corresponding to the constant rate extension of the fibre (0.2 cm/sec). About 20-30 individual fibres were selected randomly from each sample (7 dyed and 8 undyed samples) and the mean values for breaking strength and elongation at break were calculated. In order to eliminate the effect of variation in the cross sectional area between fibres as well as along the single fibre axis, the specific strength (i.e. tenacity) was determined by dividing the mean breaking strength (in g) of each sample by its mean fibre diameter or its average linear density (in dtex). The mean stiffness for each sample was obtained as follows :

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* Dtex is the mass in g of 10 km of fibre [19].

$$\text{stiffness} = \frac{\text{tenacity}(g/dtex)}{\text{elongation at break }\%} \quad \ldots\ldots\ldots(1)$$

and is expressed as g/dtex.

3- Optical Properties

Diffuse reflectance spectra for dyed and undyed wool fibres were measured over the wavelength range 380-770 nm, at 10 nm intervals, using a Philips PU 8800 UV/VIS double beam Spectrophotometer[21], fitted with PU 7908/24 Integrating Spheroid [22].

Measurements were usually made relative to a white standard plaque consisting of a polytetraflourethylene powder thickly pressed onto a plastic substrate. It was desirable to have the sample so thick that furthur increase in thickness did not change the measurement[24]. Furthermore, it was mounted on a flat black base. Before each measurement, the zero baseline (approximately 0.3% R) and the 100%R line were recorded using standard black plaque and standard white one placed in the sample position respectively.

The output is in the form of a graphical chart in which the x-axis represents the wavelength (λ), while the y-axis represents the reflectance (%R). Data comprising points of λ and R% values have been read out of the Visible Display Unit for analysis.

The ratios of the extinction to the scattering coefficients (K/S) were calculated from the diffuse reflectance according to Kubelka-Munk Equation [26, 27]:

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

where R is the relative diffuse reflectance.

A computer program written in GWBASIC[28] was used to calculate the CIE tristimulus values X,Y,Z[14, 23] and the chromaticity coordinates x,y,z expressed as follows [14, 23, 24]:

$$x=\frac{X}{X+Y+Z},\ y=\frac{Y}{X+Y+Z},\ z=\frac{Z}{X+Y+Z} \quad \ldots\ldots(3$$

Lightness (L), chroma (C) and hue (H) were calculated by the same program according to the following Equations [29, 30]:

$$L = 116\left(\frac{Y}{Y_0}\right)^{1/3} - 16 \qquad 1 \le Y \le 100$$

$$C = \left(A^2 + B^2\right)^{1/2} \qquad \ldots\ldots\ldots\ldots(4)$$

$$H = \arctan\left(B/A\right)$$

where :

$$A = 500[(\frac{X}{X_0})^{1/3} - (\frac{Y}{Y_0})^{1/3}]$$

$$B = 200[(\frac{Y}{Y_0})^{1/3} - (\frac{Z}{Z_0})^{1/3}]$$

and X_0, Y_0 and Z_0 are the tristimulus values of the appropriate illuminant, for illuminant C, as directed by the manual[22], the values are:

$X_0 = 98.041 \quad Y_0 = 100.000 \quad Z_0 = 118.103$

RESULTS AND DISCUSSION

1- Mechanical Properties

The tensile properties of the fibre influence its behavior in processing and affect the properties of both yarn and the final products. The strength is one of the important properties that characterize the quality of wool, its value for undyed Awassi wool fibres ranged between 20.429 and 27.538g with an average of 24.151g (Table 1), While that of dyed Awassi wool fibres ranged between 22.429 and 25.560g with an average of 24.020g (Table 2) indicating that dyes weaken wool fibres to some extent. Ghoneim et al[6] showed that the Karadi wool has an average fibre strength of 24.8g, while Awad et al.[31] found it as 23.5-26.7g for Egyptain Barki wool (Table 3). However it was stated [32] that the coarse wool fibres on the average are stronger than the fine or medium wool fibres, because of their larger cortex layer. On the other hand, the presence of medulla in the wool fibre decreases its strength, as it affects the thickness of the cortex layer in the fibre.

Tenacity is used for comparing different types of fibres i.e. independently of the direct effect of their dimensions. Values of tenacity for undyed wool fibres appears to be reasonable when compared to typical values obtained by Yousif[8] for the three types of Iraqi wool fibres, i.e. 1.99, 2.13 and 1.72

g/dtex for Awassi, Arabi and Karadi wool fibres respectively (Table 3).

Elongation depends on the ability of wool fibres to stretch without breaking and this character consequently affects the fibre elasticity, which is very important in the spinning and felting processes of wool manufacture. Fibre elongation of undyed Awassi wool ranged from 61.283 to 73.350% with an average of 66.389% (Table 1), while that of dyed one ranged from 46.091 to 55.629% with an average of 51.996% (Table2). Again dyeing appears to decrease wool elasticity and more largely than its strength. Awassi wool seems more elastic than Arabi[7], Merino and Lincoln [33], it is the best in elongation when it is compared with other carpet types of wool such as Karadi[6], Egyptian Barki[31] and Indian Chokla[33] wools. But it is lacking in elongation when compared with Jordanian and New Zealand wools[34] (Table 3).

The stiffness of the fibre in the axial direction was believed[33] to be largely governed by the deformation characteristics of the crystalline helices. The stiffness of undyed Awassi wool fibres ranged between 2.599 and 3.718g/dtex with an average of 165 g/dtex. For dyed wool fibres, values of stiffness were between 3.577 and 4.409 g/dtex with an average of 3.960 g/dtex, which means that dyeing makes the wool fibres more stiffer.

The correlation between the various properties of Awassi wool fibres were compared (Table 4). Positive correlations were found between diameter and strength, diameter and elongation, fibre strength and elongation, tenacity and each of elongation and stiffness, while negative correlation exists between stiffness and elongation, for undyed wool fibres. The presence of the positive correlations is supported by results reported by Ghoneim et al[6]. The present study showed that as diameter increases, both fibre strength and elongation increased too, and there was a correlation between fibre strength, tenacity and both of elongation and stiffness. The negative correlation between stiffness and elongation is clear from Eq.1. For dyed wool fibres, positive correlations were also found between fibre diameter and strength, and between tenacity and stiffness. Negative correlation was found between elongation and stiffness. As a whole the correlations for undyed wool fibres are more significant than those for dyed ones.

2- Optical Properties

Fig. 1 shows the relation between K/S and absorbed energy for dyed and undyed wool samples. Values of K/S were calculated from Eq.2. The estimated values of the optical energy gap ($E_{opt.}$) were obtained from the extrapolation of the linear part of the curves to K/S=0 as explained by Al-Ani et al[25]. Fig.2 shows ln(K/S) as a function of absorbed energy for the same samples, the linear relationship at high photon energies indicated that wool material obeys Urbach's law, but the samples do not show sharp edges, as is consistent with their amorphous nature. The values of Urbach edge (E_e) derived from the slopes of these curves were 0.395 and 0.133eV for undyed and dyed wool samples respectively (Table 5). These results show that the width of the localized states in the band gap region (E_e) for dyed sample is smaller than for undyed one, indicating that significant chemical changes are introduced in the wool as a result of dying. $E_{opt.}$ for dyed sample (2.376 eV) is also less than that for undyed one (2.639 eV) (Table 5) showing that dyeing processes caused structural changes in the wool. This is supported by Bechev et al[36] who concluded that high temperature dyeing of loose wool in acidic medium leads to many changes in the chemical structure and mainly in the supramolecular structure. As far as we are aware, there have been no similar studies of these two parameters for wool samples (both dyed and undyed).

The tristimulus values X,Y,Z and the chromaticity coordinates x,y,z for both undyed and dyed samples are also shown in Table 5. From this Table we can see clearly that the lightness (which is the fraction of the incident light reflected diffusely by the sample) for dyed sample is less than that for undyed one, while chroma is much greater, chroma gives an indication of the amount of pure chromatic colour present

CONCLUSIONS

The mechanoptical properties of Awassi Iraqi wool fibres were investigated. in the course of the obtained results the following conclusions can be drawn:

1- Dyeing weakens the tensile properties of Awassi wool fibres and makes them more stiff.
2- There are considerable differences between Awassi wool fibres and others from different breeds of sheep, which can be partly related to biological aspects of growth such as follicle type and histological structure of the cortex and partly to fine structure.
3- Awassi Iraqi wool fibre has high strength, high tenacity and stiffness, and good elasticity as compared with other typs of wool.
4- Positive correlations between the different wool characters may possibly increase the efficiency of selection for more than one trait at a time as they give an indication that these characters compiement rather than neutralize each other.
5- Changes that occur in values of Eopt and Urbach edge (Ee) as a result of dyeing indicate that dyeing introduced significant chemical and structural changes in the wool fibres. Such parameters have not been previously reported for wool.

Table 1: Mean value and coefficient of variation (C.V.) of the tensile properties of undyed Awassi Iraqi wool fibres.

Property / Group's No.	No. of Samples	Breaking Strength (g)	C.V. (%)	Mean Fibre Diameter (dtex)	Tenacity (g/dtex)	C.V. (%)	Elongation at Break (%)	C.V. (%)	Stiffness (g/dtex)	C.V. (%)
1	21	20.429 ± 9.557	46.78	11.375	1.796 ± 0.840	46.77	61.600± 33.564	54.49	2.961 ± 2.094	71.81
2	21	23.941± 10.988	45.90	10.975	2.181 ± 1.001	45.90	68.486± 26.479	38.66	3.185 ± 1.911	60.00
3	21	23.357 ± 11.262	48.22	11.275	2.072 ± 0.999	48.21	66.457± 34.165	51.41	3.118 ± 2.198	70.49
4	20	24.788± 11.770	47.48	12.070	2.054 ± 0.975	47.47	73.350± 18.810	25.64	2.800 ± 1.511	53.96
5	20	27.538± 13.135	47.70	12.320	2.235 ± [illegible]	47.70	69.180± 26.70[illegible]	38.60	3.231 ± 1.983	61.37
[illegible]	22	24.886± 13.688	[illegible]	[illegible]	[illegible]	55.02	67.55[illegible] 25.6[illegible]	37.98	3.231 ± 2.1[illegible]	[illegible]
[illegible]	29	21.483 ± 9.572	[illegible]	[illegible]	[illegible]	44.56	61.28[illegible] 20.81[illegible]	[illegible]	[illegible] 1.748	[illegible]
[illegible]	21	26.786± 13.652	[illegible]	[illegible]	[illegible] 1.198	50.98	[illegible] 17.66[illegible]	27.95	[illegible] 2.162	[illegible]
Mean		24.151± 4.175	[illegible]	[illegible]	[illegible]	17.26	66.389 ± 9.241	13.92	3.165 ± 0.701	[illegible]

Table 2: Mean value and coefficient of variation (C.V.) of the tensile properties of dyed Awassi Iraqi wool fibres.

Property / Group's No.	No. of Samples	Breaking Strength (g)	C.V (%)	Mean Fibre Diameter (dtex)	Tenacity (g/dtex)	C.V (%)	Elongation at Break (%)	C.V. (%)	Stiffness (g/dtex)	C.V (%)
1	22	23.671±1 0.416	44.09	11.65[illegible]	2.032 ± 0.894	44.00	46.091± 25.782	55.94	4.409 ± 3.138	71.17
2	21	22.786± 10.644	46.72	[illegible]	2.072 ± [illegible]	46.72	52.406± 24.807	47.24	3.954 ± 2.630	[illegible]
3	21	24.298± 10.258	42.22	[illegible]	2.077 ± 0.877	42.22	55.629± 25.154	45.22	3.734 ± 2.310	61.86
[illegible]	21	25.560± 9.946	38.91	12.025	2.126 ± 0.827	38.90	50.971± 25.125	[illegible]	4.171 ± 2.619	62.79
5	21	24.00± 11.435	47.70	12.54[illegible]	1.914 ± 0.912	47.65	53.514± 24.543	45.86	3.577 ± 2.366	[illegible]
[illegible]	22	25.398± 12.252	48.24	[illegible]	2.182 ± 1.053	48.26	52.282± 30.302	57.97	4.174 ± 3.148	75.42
7	21	22.429± 13.308	59.33	[illegible]	1.966 ± 1.166	59.33	53.086± 29.357	55.30	3.703 ± 3.003	81.1[illegible]
Mean		24.020 ± 4.247	17.68	[illegible] ± [illegible].482	2.053 ± 0.364	17.73	51.996± 10.027	19.28	3.960 ± 1.042	26.3[illegible]

Table 3: Tensile properties of Iraqi Awassi wool (dyed and undyed) compared along with the corresponding literature

Type of Wool	Investigators	Strength (g)		Tenacity (g/dtex)		Elongation (%)		Stiffness (g/dtex)		Mean Fibre Diameter (μm)	
		Mean ± σ	Range	Mean± σ	Range	Mean ± σ	Range	Mean ± σ	Range	Mean ± σ	Range
Awassi (Dyed)	Present Work	24.020± 4.247	22.43-25.56	2.053±0.364	1.914-2.182	52.00±10.027	46.09-55.63	3.960±1.045	3.577-4.409	33.552±0.789	32.38-34.91
Awassi (Undyed)	Present Work	24.151±4.175	20.43-27.54	2.098±0.362	1.796-2.235	66.389±9.241	51.28-73.35	3.165±0.701	2.599-3.718	33.220±0.742	32.34-34.55
Awassi	Yousif[8]			1.99							
Awassi (Non-Medulla)	Al-Roubaiey[1]	37.090				32.850					25-30
Arabi	Yousif[8]			2.13							
Arabi	Yousif[7]				1.5-2.9		45-65				28-32
Karadi	Yousif[8]			1.72							
Karadi	Goneim etal.[6]	24.8± 0.45	22.5-28.8			31.8±0.55	29.9-35.0			48.1±0.56	44.8-54.1
Hamadani* (Continous-Medulla)	Al-Roubaiey[1]	38.66				32.94					25-31
Jordanian	Ramal et al.[14]					87.6				55±5	
NewZealand	Ramal et al.[34]					85.5				37±3	
Egyptain (Barki)	Awad et.al.[31]		23.5-26.7			41.8					31.1-37.1[35]
Indian (Chokla)	Rao and Gupta[33]					33**				35	
Lincoln	Rao and Gupta[33]					32**				40	
Merino	Rao and Gupta[33]					32**				24	

* Hamadani is one of sub-type of Karadi sheep[3]

** Ak RH=0%

Table 4 : Correlations between properties of undyed and dyed Awassi wool fibres.

a - Undyed

Character	Strength	Tenacity	Elongation	Stiffness
Diameter	0.543	0.182	0.554	-0.201
Strength	-	0.918	0.529	0.561
Tenacity	-	-	0.372	0.754
Elongation	-	-	-	-0.327

b - Dyed

Character	Strength	Tenacity	Elongation	Stiffness
Diameter	0.506	-0.33	0.073	-0.059
Strength	-	0.645	-0.036	0.379
Tenacity	-	-	-0.077	0.620
Elongation	-	-	-	-0.829

Table 5 : Some optical properties of undyed and dyed Awassi wool fibres.

			Tristimuluse Values			Chromaticity Coordinates					
	E_{opt} (eV)	Urbach Edge (E_e) (eV)	X	Y	Z	x	y	z	Lightness (CIELAB)	Chroma (CIELAB)	Hue (Degree)
Undyed	2.639	0.395	60.869	62.623	57.868	0.336	0.345	0.319	83.244	13.494	95.22
Dyed	2.376	0.133	33.741	32.374	5.484	0.471	0.452	0.077	63.651	65.824	83.835

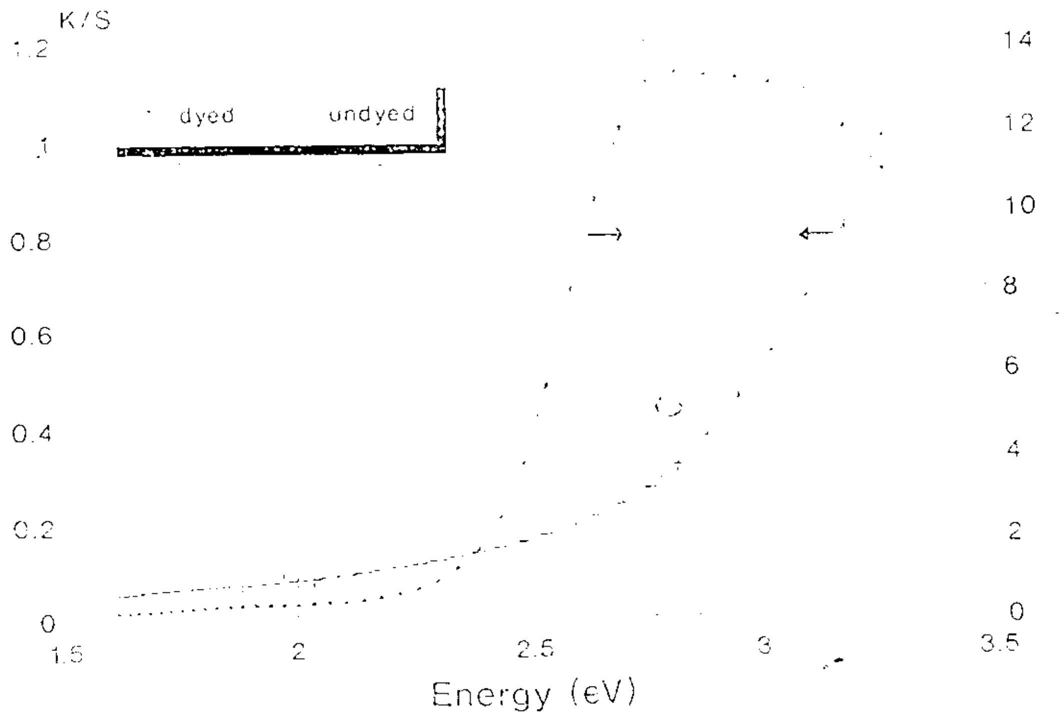

Fig. 1 : K/S as a function of photon energy of dyed and undyed wool fibers .

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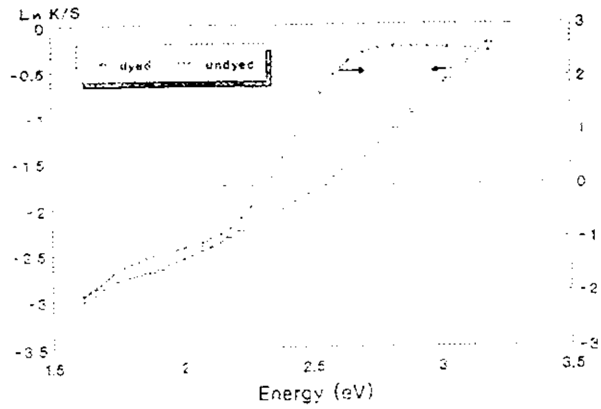

Fig. 2: Ln (K/S) as a function of photon energy of dyed and undyed wool fibres.

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