Effects of Gamma - Irradiation on the Mechanical Properties of Awassi Iraqi Wool

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خلاصة

تم في هذا البحث دراسة تأثير أشعة جاما على الخواص الميكانيكية (قوة القطع والمتانة والإستطالة عند القطع) للصوف العراقي العواسي المصبوغ وغير المصبوغ، لمدى واسع من الجرعات تراوحت من 5 كيلوغري ولحد واحد ميجاغري. تبين أن هذه الخواص تتزايد بزيادة الجرع إلى قيمة قصوى (عند الجرعة 10 كيلو غري) ثم تأخذ بالتناقص بحدة إلى قيم نهائية (63٪، 53٪ و15٪، من قيمها لغير المشعع) لقوة القطع والمتانة والإستطالة عند القطع على التوالي. أما بالنسبة لألياف الصوف المصبوغة فقد لوحظ نفس السلوك مع تغير الجرع الممتصة لهذه الأعلومات سوى أن القيم القصوى عند 10 كيلوغري كانت أعلى والقيم النهائية لهذه الأعلومات الثلاث كانت (75٪، 60٪ و 35٪) من القيم الأصلية. أوضح سلوك الخواص الميكانيكية أن الترابطات العرضية هي المتغلبة في الجرع القليلة بينما في الجرع العالية تكون عمليات التحطم هي المتغلبة

Abstract

The effect of α - irradiation (5-1000 kGy) on the tensile properties (breaking strength, breaking tenacity and elongation at break) of undyed and dyed Awassi Iraqi wool was investigated, it was found that these properties increased to their maximum values (at 10 kGy) before decreasing sharply as the dose increased reaching values of 63%, 53%, 15% of the

initial values of unirradiated undyed fibers, respectively . Behaviour of these parameters with doses observed in case of dyed wool fibers was the same except they were found to have higher values at 10kGy, and the limiting values of those three parameters were 75%, 60%, 35% of that of the initial values . It was noticed that the mechanical behaviour is dominated by the effect of crosslinking process at low doses . At higher doses, the process was dominated by degradation .

1- Introduction

Development in the field of nuclear technology and the steadily larger application of radioactive isotopes and ionizing radiation, have made radiation techniques available to different branches of polymer science . Extensive work has been done on the effects of ionizing radiation on synthetic polymers and polymeric fibers . Radiation effects on textile fibers have been recently reviewed by Mahmood [1] . In recent years physical and chemical modifications of the native fibers to impart new properties or to improve them have become major factors in wool industry and utilization . A new approach to modify the properties of wool is by exposing its fibres in the presence or absence of chemical reagents to ionizing radiation . γ-irradiation is found to have a potential interest for processes aimed at improving wool properties such as shrink and wrinkle resistance and crease retention . Most textile fibers (except wool, polyacrylonitrils and polyethylene terephthalate) show a large decrease in breaking stress and extensibility with doses of about 100 kGy [2,3]. Although the general view is that the physical properties of wool are relatively unaffected by γ-irradiation doses of this order, there are differences in the effects of radiation on wool, as reported by various workers . Thus McGrath and Johnson [5] reported that doses of 5-74 kGy produced a slight increase in the mechanical strength of wool . A slight improvement in tensile properties was also observed [6] at 20 kGy . However, Doncean et al. [7] obtained improvements in wool properties treated with inorganic salt and organic substance exposed to 10 and 7.5 kGy γ-irradiation respectively . These behaviours were ascribed to the formation of crosslinking [7] or rebuilding [6] of some linkages at low doses before bond breakage predominant at high doses . other workers [8,9,10] reported that mechanical strength properties of wool were slightly affected by doses of up to 50-100 kGy, and it was concluded [9]that irradiation did not produce any new crosslinks in the wool .On the other hand, Zahn et al. [11] found that a gamma dose of 100 kGy reduced the breaking strength and extensibility of wool by 12-13% .

High doses of γ- rays (≥100 kGy) caused destruction of wool fibers as revealed by decreasing in tensile properties [8,9]. Destruction at high doses was attributed to gleavage of amide link [11,12] ,cleavage of disulphide bonds [11,13,14] or breakage of secondary hydrogen bonds [15] .

Horio et al. [10] stated that two types of parallel effects occured in wool during γ-irradiation, the first effect, as manifested by an evident decrease in dye accessibility at lower doses (0.01-1 kGy), was thought to be due to the formation of crosslinking, the remarkable decrease in the mechanical properties and increase in dye uptake at higher doses (≥100kGy) was attributed to the second effect i.e. a strong structure damage of the fibre . The same effect was suggested by Al-Alawi [16] who reported that two physical changes to irradiated human hairs might occur, one of them was the crosslinking tending to strengthen keratin fibre at lower doses, and the other was the possibility of degradation at high doses tending to break the chains and to some extent to destroy the crosslinking formed by irradiation and to weaken the fibre .

The discrepance between results reported by different authors, concerning effects of low doses of γ - rays on wool, need a more extensive examination .

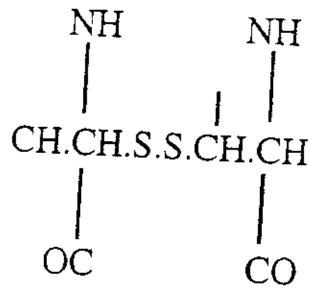
As there are no previously reported measurements available in the literature concerning Iraqi wool irradiation, save one single report by Al-Ani etal [17] dealing with killing the moth grubs, which attacked Iraqi wool fibres, by irradiation, the present work is intended to investigate the effects on some mechanical properties of undyed and dyed Iraqi Awassi wool fibers subjected to γ-irradiation from 5 to 10^3 kGy, the most interesting range, in attempt to determine the optimum value of doses that may impart improved properties that will prove useful in the processing of wool, and to estimate the highest tolerable radiation , without damage, needed in some applications of ionizing radiation as in graft polymerization of wool fibres . The results presented here also give new information about radiation effect on wool at low radiation dose levels .

2- Structure and the Chemistry of Wool

Wool is one of the most important fibers ,it has a very complicated structure. Furthermore ,it is a protein fibre [18], and the chemistry of protein is immensely complicated .Further complications arise from the well known fact that the structure of the tip is different from that of the root for the same fiber .

condensation ... amino acids of general formula H2N.CHR.COOH to give different long polypeptide chains .

Almost half the total weight of the keartin is in the backbone,and the other half is in the side - chains . Some of the side -chains terminate in amino groups and others in carboxyl groups which could easily form crosslinks [18,19] .Wool contains cystine which forms covalent crosslinks of the disulphide type in keratin [18-20]



This type of crosslinking highly affects the physical and mechanical properties. A third type of linking occurs through hydrogen bonding [18 ,19] . In addition to their occurance between separate polypeptide chains (inter-chain), these bonds can also occur between different parts of the same chain (intra-chain) [19] .

3- Experimental

3.1 Materials

Scoured Iraqi (Awassi) [21-23] wool was obtained from the General Establishement for Woolen Industries . Random samples underwent a prolonged treatment with ethanol, followed by a long rinse in distilled water (24 hr), after which they were dried at room temperature and moisture .

Before irradiation ,some wool fibers were dyed with Lanasyn yellow 2 GLN 250%, this dye is a 1 :2 metal complex dye [18] . Metal complex dyes are chemically colsely related to chrome dyes, but from the dyer s point of view they are acidic dyes . Standered dyeing processes were conducted as that being followed in the General Establishement for woolen Industries, and according to that recommended for Lanasyn [24] .

The mean fibre diameters, measured by the air flow method [25-27], were (34.00 ± 1.46) and (34.11 ± 1.16) μ m for undyed and dyed wool fibres respectively .

3.2 Irradiation

Irradiation was carried out in Candian gamma- cell- 220 ^{60}Co irradiation facility located at the Agricultural and Biological Research Center / Iraqi Atomic organization - Baghdad .

Batches of undyed and dyed wool fibres were packaged in small separate plastic containers made of polyethylene, and irradiated in the dry state at room temperature and atmospheric pressure to different doses ranging from 5 kGy up to 1 MGy in air ,at dose rate around 5kGy / hr .

3.3 Measurements

Tensile tests were carried out at atmospheric conditions using the W.I.R.A. Single Fibre Strength Meter Type 678. Measurements were carried out as described by booth [27], and according to the instruction manual [28], the gage 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) .

Preliminary test showed that there were large differences between various wool fibres . Furthermore, big variation was observed between the load extension curve of the tip portion and the base portion of the same fibre, due to irregular cross - section, but by dividing the middle portion of the fibre into two parts (each of 3- 3.5 cm) they behaved approximately the same . So each individual fibre was divided into two portions, one was retained without treatment and designated as a control, while the otherwas irradiated to the required dose .After irradiation , the two portions were tested at the same time where measurements were performed at the ends of the single fibre where originally connected (before cutting), and the relative values rather than absolute ones were calculated. This ensured the constancy of the working conditions and enabled observation and recording of the variation in tensile properties resulting from different doses. Between 10 and 20 fibres that have apparantly uniform diameters, were chosen from each batch .

In order to eliminate the effect of variation that might exist in the cross - section between the two portions of the individual fibre, the specific strength [26] (i.e. tenacity) should be determined . Therefore, before the tensile tests, the diameter in dtex was measured over the actual test length using the vibroscope (Zweigle S 151) [29] and according to ASTM method [30] .

4- Results and Discussion

Figures 1 and 2 show the relative values (irradiated / unirradiated) of the tensile properties i.e. strength, tenacity and elongation at break of undyed and dyed wool fibers respectively, exposed to different doses . Each value is an average of ten measurements with a standard deviation not more than ± 0.01 . As shown in Fig.1 a, b, and c the relative values of the three parameters increased with doses reaching a maximum value at 10 kGy then commence decreasing attaining values of about 0.63, 0.53 and 0.15 of that of the control at 1, 0.75 and 1 Mgy, for breaking strength, tenacity and elongation at break respectively . For dyed wool fibres the relative values of these parameters exhibited a similar behaviour except the maximum values at 10 kGy were higher as shown in fig. 2 a, b , and c . Also the limiting values are higher, i.e. 0.75, 0.60 and 0.35 of that of the control at 1, 0.75 and,1 Mgy ,for breaking strength, tenacity and elongation at break respectively .

Irradiation with low doses, between 5-10 kGy, showed to strengthen wool fibers in terms of increasing tensile properties, this may be explained in terms of crosslinking as it was suggested earlier [16], or as explained previously [6] in terms of a competition between breaking and rebuilding of disulphide bridges as crosslinks ; the rebuilding may be dominated at low doses . Higher doses up to 1 MGy cause a gradual reduction in the tensile strength and tenacity, but in contrast, it causes a rapid decrease in elongation at break . These results may be attributed to the cleavage of the dislphide bonds [11,15,16], or breakage of the peptide bonds [11,12] .

Other studies [1] of the effects of γ - ray on different properties of Iraqi wool fibres supported the formation of crosslinking at low doses as revealed by a decrease in dyeability, alkali solubility and an increase in hydrophilicity in the range (10-20 kGy) . The cleavage of the disulphide bonds and that of peptide bonds at higher doses were also confirmed [1] by the increase in the first and second of these two parameters and decrease in the third one, as well as by DSC investigation .

Our results at low doses are in agreement with the slight increase in tensile properties of wool observed by McGrath and Johnson [5] at doses (5-74 kGy) and Beevers and McLaren [6] at 20 kGy and with that observed by Tusukada et al [31] for silk (20-30 kGy) , and by Al-Alawi [16] for hair at doses in the range (20-120 kGy), and for cotton yarns in the range (0.44-0.88 kGy) [4] .

In contrast, O Connel and Walden [9] concluded that irradiation did not produce new crosslinks in wool at low doses, and that doses greater than 100 kGy were required to rupture covalent bonds .

At 100 kGy the 6% and 3% reduction in the strength and extensibility respectively, of the present results can be compared with the 12-13% decrease in these parameters observed by Zahn et al. [11] for Crossbred wool at the same dose, these differences can be ascribed to differences in breeds . At higher doses (>100 kGy) our results are parallel to those obtained by other investigators for wool [6,10,14], human hair [16] silk [31], cotton [38], acetate and triacetate yarns [33] .

The improvement in the tensile properties of the dyed wool fibers (fig.2) may be attributed to the presence of dye molecules (which contain aromatic groups) that might promote crosslinking at low doses and protect the protein fibres against radiation at higher doses. It was found [11,34] that aromatic groups introduced into wool fibres, imparted stabilization to radiation as an energy transfering systems.

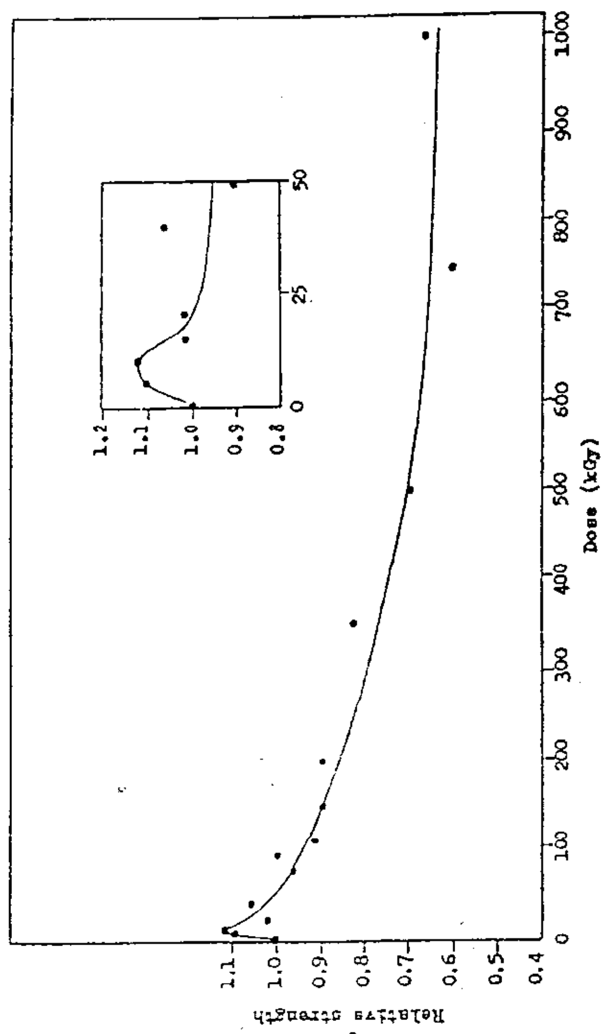


Figure (1 a) : Relative strength (irradiated / control) of undyed wool fibres vs. dose.

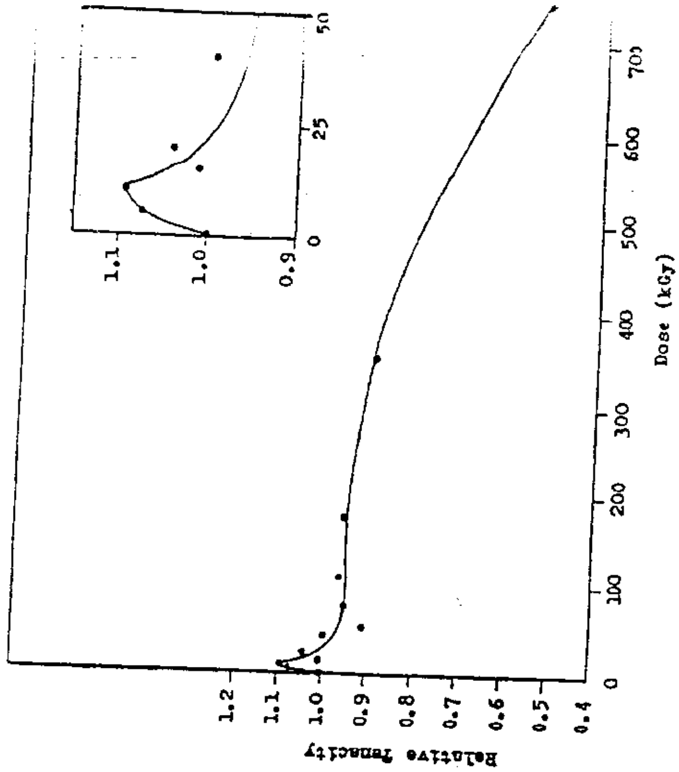


Figure (1 b) : Relative tenacity (irradiated / control) of undyed wool fibres vs. dose.

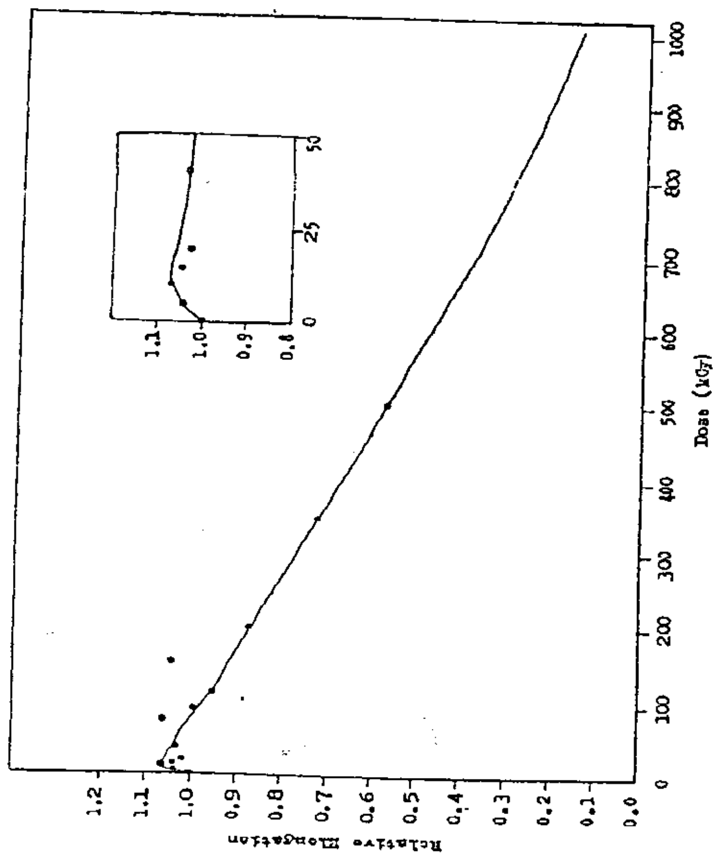


Figure (1 c) : Relative elongation (irradiated / control) of undyed wool fibres vs. dose.

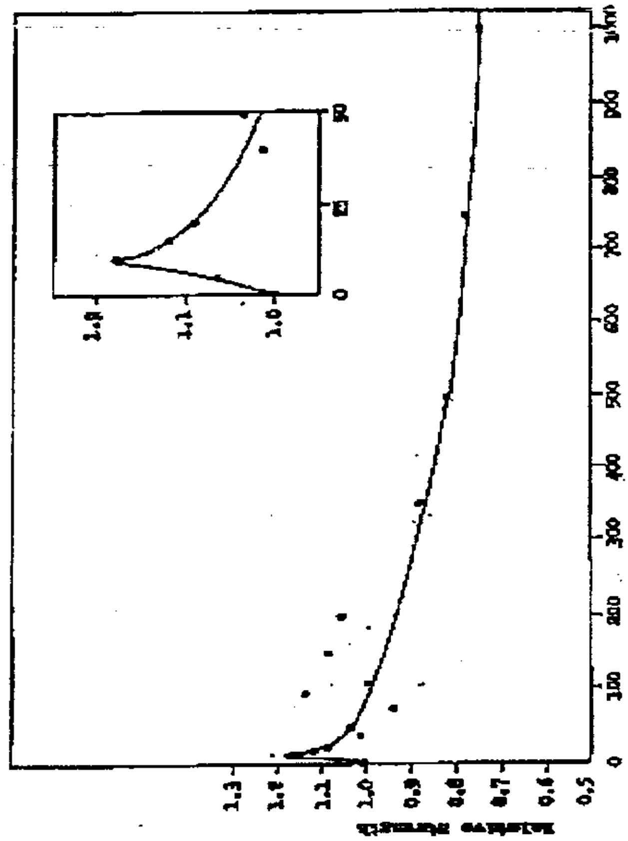


Figure (2 a) : Relative strength (irradiated / control) of dyed wool fibres vs. dose.

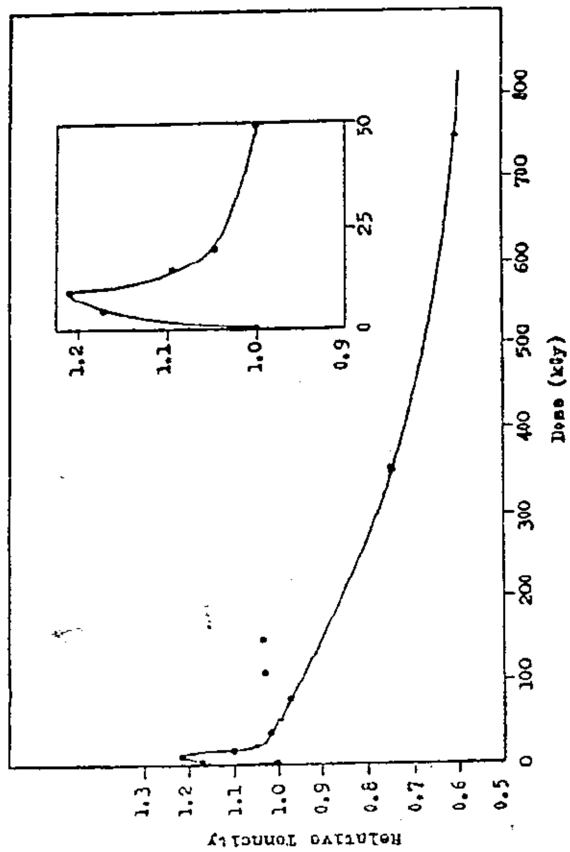


Figure (2 b) : Relative tenacity (irradiated / control) of dyed wool fibres vs. dose.

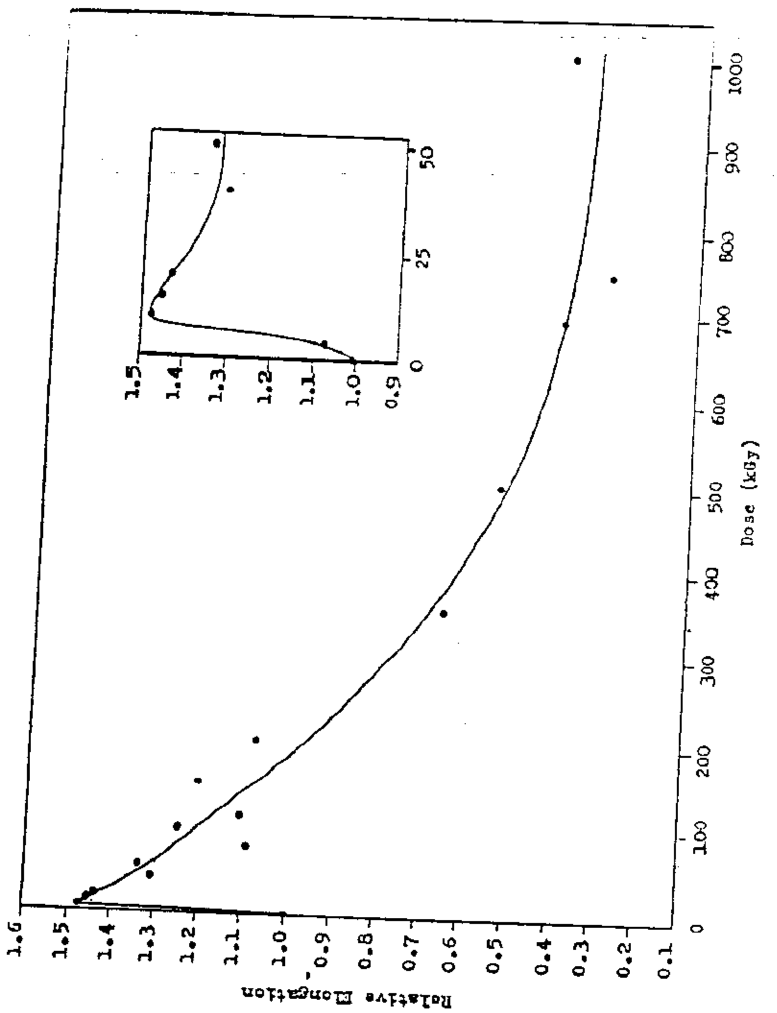


Figure (2 c) : Relative elongation (irradiated / control) of dyed wool fibres vs. dose.

5- Conclusions

In the course of the obtained results, it can be concluded that irradiation at low doses (5-10 kGy), strengthen wool fibers in terms of increasing tensile properties, especially for dyed fibers, while at high doses, a decrease in tensile properties was observed with increasing doses . Irradiation with 10 kGy can be considered as the optimum condition that improves the tensile properties of Iraqi wool fibres, these improvements are desirable in carpet manufacturing .

From the point view of industrial applications, e.g. for radiation induced graft copolymerization of vinyle monomers, sterilization, control static charges in processing , and destruction of bacteria and other microorganisms, a treatment not exceeding 50 kGy of the absorbed dose can be recommended as sufficiently safe for maintaining almost intact wool fibres .

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