APPLICATION OF GAMMA IRRADIATION FOR THE FUNCTIONALIZATION OF TEXTILE MATERIALS

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This work focuses on the synthesis of multiple studies made on the investigation of gamma irradiation effects on textiles. Gamma radiation is used in the research for improved dyeing or to change the mechanical properties of textile and in some cases to reduce the ecological impact of the processing methods. One study researches the effects of gamma irradiation on specific composites such as silk with polypropylene and E-Glass with polypropylene and the changes of their mechanical properties, showing that the mechanical properties of the silk composite increase more compared to the E-Glass composite. The application of gamma irradiation in the process of dyeing polyester textiles can be used to reduce the dyeing temperature. Studies were made even on the effect of gamma irradiation only on dyes and the possibility that it can reduce wastewater production, resulting in the fact that gamma irradiation can result in the degradation and discoloration of dyes in water depending on the dose and dye used. In one study it was researched if gamma preirradiation can affect the growth of microorganism on the textiles for three different fibers. One study was made on reinforcement of synthetic fibers and compared the effect of e-beam radiation and gamma radiation. It resulted that the effects are similar while gamma radiation affects the mechanical properties more than e-beam. The synthesis of the literature review has led to the development of a conceptual application model for gamma irradiation in the field of textiles.

Keywords: gamma irradiation, functionalization, textile.

INTRODUCTION

The textile industry is a major branch of the world's economy, some of its biggest producers and exporters being China, India and Italy. Textiles have been found to originate as early as the Neolithic period from evidence found in excavations, with some indication that weaving was known even in Paleolithic. Over time the materials and techniques evolved and become more sophisticated such as the creation of synthetic textiles.

Gamma radiation is an electromagnetic penetrative ionizing radiation produced during the radioactive decay of the atomic nucleus. One of the main results of gamma irradiation is the excitation of the electron resulting in ionization from which may result bond breaking, the effects being formation of excited states, short life radicals and finally formation of new bonds. Two of the main zones where it is used are industry and research. In industry it can be used for sterilization, DNA alteration in plants and structure and properties material modification. Research in using gamma irradiation for textiles concerns the optimization of textile dyeing, reducing the ecological impact and cultural heritage artifacts biological decontamination (Ahmad Bhatti *et al.*, 2012; Bashar *et al.*, 2018; Blouin and Arthur, 1958; Chirila *et al.*, 2018; Colella *et al.*, 2011; Geba *et al.*, 2014; Machnowski *et al.*, 2012; Millington, 2000; Shubhra and Alam, 2011; Takács *et al.*, 2001; Takács *et al.*, 2000).

This article objective is to review some of the more relevant research made in the usage of gamma radiation for textile functionalization and in the end to propose a conceptual model of the process variants.

Literature Review

In the Table 1 is given the synthesis of the case studies related to the application of gamma treatment to various textile materials.

Table 1. Textile material, irradiation dose and characterization tests performed and conclusions of literature research study

Materials	Dose (kGy)	Tests	Objective	Observations	References
Cotton+H ₂ O ₂	5, 10, 15, 20	SEM	Exploitation of gamma radiation for the processing of cotton textiles	No impurities and smooth	Ahmad Bhatti <i>et al.</i> , 2012
Grey Cotton	100		Effect of gamma irradiation on the mechanical properties and surface morphology	Longitudinal crack in the second cellular wall	Bashar <i>et al.</i> , 2018
Cotton + Itodye Nat Pomegranate+ Iron alum	5, 10, 15, 20, 45		To improve the dyeing behavior of Itodye Nat Pomegranate	No observed structural changes	Blouin and Arthur, 1958
Cotton + NaOH	Unspecified directly		Effects of gamma irradiation and alkaline treatment on the structure of cotton cellulose	Changes in fibrils structure starts to be observed after irradiation with 300 kGy and treatment with 14% NaOH	Chirila <i>et al.</i> , 2018
Grey Cotton	5, 10, 15, 20	FTIR	Exploitation of gamma radiation for the processing of cotton textiles	Peaks at 2918 and 2849 cm ⁻¹ are responsible for the presence of waxes	Ahmad Bhatti <i>et al.</i> , 2012
Colored Cotton				Showed many peaks in 1100-1400 cm ⁻¹ region	
Colored Cotton	1000		Radiation induced deterioration of textile fibers and the potential impact of radiation damaged fibers on the results of the forensic analysis	Nothing different observed in FTIR	Colella <i>et al.</i> , 2011
Cotton +NaOH/TMAH	Up to 300		The comparison of two types of alkalies on the crystalline structure of irradiated cotton	It was observed the transformation of cellulose I in cellulose II depending on the radiation dose and alkali treatment	Geba <i>et al.</i> , 2014
Cotton	0.877, 8.77, 43.85, 87.7, 438.5, 877		Effects of gamma radiation on the physical and chemical properties of purified cotton in oxygen and nitrogen atmosphere	Relative unchanged FTIR spectra	Machnowski <i>et al.</i> , 2012
	5, 10, 15, 20, 45		To improve the dyeing behavior of Itodye Nat Pomegranate	No important differences	Blouin and Arthur, 1958

	Up to 500		Effects of gamma irradiation and alkaline treatment on the structure of cotton cellulose	Increase absorbance at 1740 cm ⁻¹ as consequence of radiation degradation	Chirila <i>et al.</i> , 2018
Cotton+H ₂ O ₂	100	Mechanical tests	Exploitation of gamma radiation for the processing of cotton textiles	The bursting strength decreases with the H ₂ O ₂ concentration	Ahmad Bhatti <i>et al.</i> , 2012
Cotton	5, 10, 25, 100		Effect of gamma irradiation on the mechanical properties and surface morphology	Irradiation causes a decrease of the breaking force and elongation at break depending on the dose. Irradiation with doses between 5-25 kGy does not cause statistically significant differences	Bashar <i>et al.</i> , 2018
	0.877, 8.77, 43.85, 87.7, 438.5, 877		Effects of gamma radiation on the physical and chemical properties of purified cotton in oxygen and nitrogen atmosphere	Decrease in tensile strength of the fibers	Machnowski <i>et al.</i> , 2012
Cotton + Itodye Nat Pomegranate+ Iron alum	5, 10, 15, 20, 45		To improve the dyeing behavior of Itodye Nat Pomegranate	Lower tensile strength, pre-treatment with gamma radiation does not negatively influence elongation at break.	Blouin and Arthur, 1958
Cotton +NaOH/TMAH	Up to 300	XRD	The comparison of two types of alkaline on the crystalline structure of irradiated cotton	It was observed the transformation of cellulose I in cellulose II	Geba <i>et al.</i> , 2014
Cotton +NaOH	Up to 500		Effects of gamma irradiation and alkaline treatment on the structure of cotton cellulose		Chirila <i>et al.</i> , 2018
Cotton + Reactive Black-5	0.1, 0.2, 0.3, 0.4, 0.5, 0.6	Color strength	The improvement of color strength and fastness for Reactive Black-5 using high energy radiation	Color strength increases with radiation dose and temperature up to 60°C	Millington, 2000
Cotton + Itodye Nat Pomegranate	5, 10, 15, 20, 45		To improve the dyeing behavior of Itodye Nat Pomegranate	It's observed an increase in color strength with the dose	Blouin and Arthur, 1958
Colored Wool	1000		Radiation induced deterioration of textile fibers and the potential impact of radiation damaged fibers on the results of the forensic analysis	Nothing different observed in FTIR	Colella <i>et al.</i> , 2011
Wool + Artificial ageing	10, 25	FTIR-ATR Mechani	To demonstrate that gamma irradiation does not destroy too much	Modification in the Amide I and II ratio Reduced breaking force and	Shubhra and Alam, 2011

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		cal tests		elongation at break	
Wool	9.1, 25, 50, 100, 250, 500		To determine if gamma radiation can be used in the wool processing chain	At doses above 100 kGy the burst strength is reduced by 15%	Takács <i>et al.</i> , 2001
Wool + Artificial ageing	10, 25	TG and DTG	To demonstrate that gamma irradiation does not destroy too much	Degradation starts at 230-234 °C with minor changes caused by radiation or ageing, irradiation up to 10 kGy does not have great influence on thermal stability	Shubhra and Alam, 2011
Wool	9.1, 25, 50, 100, 250, 500	Color changes	To determine if gamma radiation can be used in the wool processing chain	Color changes to pink-red for 25-250 kGy and yellow at 500 kGy	Takács <i>et al.</i> , 2001
Silk	100	SEM	Effect of gamma irradiation on the mechanical properties and surface morphology	No visible difference compared to the control sample	Bashar <i>et al.</i> , 2018
Silk	10, 25	FTIR	Determination of the optimal radiation dose for heritage textile decontamination	Modification in the Amide I and II ratio	Shubhra and Alam, 2011
Silk	5, 10, 25, 100	Mechanical Tests	Effect of gamma irradiation on the mechanical properties and surface morphology	Irradiation causes a decrease of the breaking force and elongation at break depending on the dose. Irradiation with doses between 5-25 kGy does not cause statistically significant differences	Bashar <i>et al.</i> , 2018
Silk+Polyp ropylene	2.5, 5, 10		The comparison of gamma radiation effect on silk/PP and E-Glass/PP composites	Improved tensile, bending and impact properties, hardness unchanged until 5 kGy but changes at 10kGy	Takács <i>et al.</i> , 2000
Silk	10, 25		Determination of the optimal radiation dose for heritage textile decontamination	Reduced breaking force and elongation at break	Shubhra and Alam, 2011
Silk	10, 25	TG and DTG		Both in air and nitrogen atmosphere thermal stability is lower, endothermic peak temperature slightly increased with dose, insignificant changes in thermal stability with dose	
Flax	100	SEM	Effect of gamma irradiation on the mechanical properties and surface morphology	No visible difference compared to the control sample	Bashar <i>et al.</i> , 2018
Flax+ Itodye Nat Pomegrana te+ Iron	5, 10, 15, 20, 45		To improve the dyeing behavior of Itodye Nat Pomegranate	Changes dependent on the dose can be observed	Blouin and Arthur, 1958

alum Flax	5, 10, 25, 100	Mechani cal Tests	Effect of gamma irradiation on the mechanical properties and surface morphology	Irradiation causes a decrease of the breaking force and elongation at break depending on the dose. Irradiation with doses between 5-25 kGy does not cause statistically significant differences	Bashar <i>et al.</i> , 2018
Flax+ Itodye Nat Pomegrana te+ Iron alum	5, 10, 15, 20, 45		To improve the dyeing behavior of Itodye Nat Pomegranate	Lower tensile strength, pre- treatment with gamma radiation does not negatively influence elongation at break. No important differences but the crystallinity indices present an irregular variation It's observed an increase in color strength with the dose	Blouin and Arthur, 1958
	5, 10, 15, 20, 45	FTIR			
	5, 10, 15, 20, 45	Color Strength			

As can be seen there are few studies and more research need to be done in the domain to create a real functional model for the treatment of textiles using gamma radiation. Nevertheless a simplified model is proposed in Fig. 1:

Figure 1. Conceptual model of textile materials functionalization by irradiation

Irradiation may be performed in dry or wet state at various dose ratios and at total absorbed doses in order to obtain the desired properties.

CONCLUSIONS

Our study revealed that the majority of the studies focus on the effect of gamma irradiation on natural textiles, the majority of experiments being done in air atmosphere. The main effect observed was that the mechanical properties slightly diminished while if there are dyes used the color strength is increased. Gamma irradiation can be used to increase mechanical properties if the textile is used in combination with various compounds. Research and development in the application of gamma irradiation to

textile materials is in the laboratory phase a lot of technological development needs to be done in order to be able to apply this green treatment method in industry.

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