Dyeing properties of cotton fabric using un-irradiated and gamma irradiated extracts of *Eucalyptus camaldulensis* bark powder

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Eucalyptus (*Eucalyptus camaldulensis*) bark powder (un-irradiated and irradiated) has been used as natural colourant for dyeing un-irradiated and irradiated cotton fabric using different absorbed doses of Co-60 gamma irradiation to study the effect of radiation treatment on the colour strength of dyed fabrics. The data colour report is used for the evaluation of un-irradiated and irradiated dyed cotton using Spectra Flash (SF- 650) in CIE Lab system. Pre- and post-mordanting has also been carried out using chrome alum, potassium dichromate, copper sulphate, ferrous sulphate and stannous chloride as mordants. It is found that gamma irradiation has a potential to improve the fastness properties such as washing, light and rubbing of cotton dyed with Eucalyptus powder.

**Keywords:** Colour fastness properties, Dyeing, Eucalyptus powder, Fabric, Gamma radiation, Mordanting, Spectra Flash SF- 650

1 Introduction

Various parts of plants and animals are used to obtain various shades of natural dyes. The environmental consequences are the reason for the importance of natural dyes around the globe. Lack of standardized profile for extraction and textile dyeing is also a major constraint to use natural materials for dyeing. In the era of synthetic dyes, the natural dyes have become un-competitive due to their limited and non-reproducible shades as well as their poor fastness properties. Recently due to their ecofriendly nature, world has once again attracted towards natural colourants. Various treatments such as ultraviolet, ultrasonic and gamma radiation are being used to improve the colour strength and fastness properties of fabric dyed with natural dyes. Studies on the possible use of natural dyes in textile dye houses have been carried out in the past to evaluate their high compatibility with environment and straight forward nature.

However, limited study has been performed to observe the effect of radiation treatment on the dyeing characteristics of fabric using natural as well as synthetic colourants. Gamma irradiation also shows advantages in increasing the colour strength of dyed fabric using extract of irradiated dyeing powder. Previous studies have shown that gamma radiation treatment not only has potential to improve the extraction of colourants but also the colour of extract without any adverse changes in their physiological characteristics.

Present study has been focused to evaluate the influence of gamma radiation on the dyeing behavior of the natural dye ‘quercetin’ extracted from the bark of Eucalyptus. The aim of this study is not only to enhance the extraction of dye but also to improve the colour fastness of the dyed fabric using irradiated cotton fabric.

Eucalyptus bark contains colouring materials such as tannins, polyphenols and active colouring substance (quercetin), which has brightest yellow shade. It belongs to flavonoids group, has general formula \( \text{C}_{15}\text{H}_{10}\text{O}_7 \) and is chemically known as 3, 5, 7, 3, 4 pentahydroxy flavone.
2 Materials and Methods

2.1 Sample Preparation and Irradiation
Eucalyptus bark was collected from the botanical gardens of University of Agriculture Faisalabad, Pakistan. The bark was washed with distilled water, dried, ground finely and passed through a sieve of 20 meshes to obtain the bark powder of uniform particle size. Plain weaved bleached and mercerized cotton fabrics were obtained from M.S.C. Textile (Pvt), Faisalabad, Pakistan.

Samples of cotton fabric (10 cm × 10 cm) and bark powder samples were exposed to gamma radiation to the absorbed doses of 100, 300, 500, 700, 900 Gy respectively using Co-60 gamma irradiator at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan.

2.2 Optimization of Extraction and Dyeing Process
Aqueous and ethanolic extracts were obtained from un-irradiated and irradiated bark powder. For extraction of dye in traditional method, 1 g of irradiated and un-irradiated powder was mixed with 20 mL of solvents (water and ethanol) [M: L - 1:20] and boiled for 1 h. After boiling, solutions were filtered using suction funnel in hot condition to obtain dye solution without any remaining particles. The dye solution obtained was reddish brown colour and used for subsequent dyeing experiments. In order to optimize the concentration of exhausting agents, dyeing was carried out using 1, 2, 3, 4 and 5 g/L of sodium chloride and sodium sulphate.

The material-to-liquor ratios of 1:10, 1:20, 1:30, 1:40 and 1:50 was employed separately during dyeing. Different mordants such as chrome alum, potassium dichromate, copper sulphate, ferrous sulphate and stannous chloride [M:L - 1:30] have been tried in both pre- and post- mordants for the improvement of the colour strength and colour fastness properties of the dyed fabrics. For all dyeing and mordanting process, the optimized M:L ratio of 1:30 was used.

2.3 Quality Assessment
Finally, all the dyed patches using un-irradiated and irradiated fabric and bark powder were investigated using Spectra Flash (SF-650) at Quality Assurance and Quality Control Laboratory of Noor Fatima Textile (Pvt), Faisalabad, Pakistan.

The mordanted fabrics dyed with different dye concentrations were tested through ISO standards methods to evaluate the effect of gamma radiation on colour fastness properties such as light, washing and rubbing. Standard methods such as ISO 105-CO3 for wash fastness, ISO 105 X-12 for rub fastness and ISO 105-BO2 for light fastness were applied for the investigation of the effect of gamma radiation on the colour strength of the dyed fabric using natural dye extracted from irradiated Eucalyptus bark powder.

3 Results and Discussion
The colour strength values change remarkably in ethanolic media than in aqueous media, which shows the high colour strengths and dark brown shades of the fabrics dyed in ethanolic extract as compared to that dyed in aqueous extract. The low colour strength and unevenness in shade in aqueous extract is due to the presence of insoluble impurities that might come on the fabric along with colourant. The results shown in Fig. 1 demonstrate that irradiated fabric dyed using alcoholic extract gives more colour strength than un-irradiated fabric. Previous studies showed that gamma irradiation causes dislocation and fragmentation of fibres, however only soluble colourant gets...
maximum chances to sorb on the fabric and not the colourant with impurities. Hence, un-irradiated fabric absorbs less dye and yields greener shade.

Optimization of radiation dose for the dyeing process has also been evaluated by studying the absorbed gamma radiation doses of the range 100-900 Gy (Fig. 2). Extraction and dyeing performed using Eucalyptus powder irradiated to the absorbed doses of 500 Gy shows maximum colour strength with dark brown shade. At higher radiation absorbed doses, low colour strength was obtained because of the degradation of fibres that may sorb impurities on the fabric instead of colourants.

Results shows in Fig. 3 reveal that the colour strength of the dyed fabric increases with the increase in M: L ratio up to 1:30 and then decreases on further

**Fig. 2—Effect of absorbed doses on dyeing of irradiated cotton fabric with aqueous extract of irradiated Eucalyptus powder**

**Fig. 3—Effect of M: L ratio on dyeing of irradiated cotton using extract of irradiated Eucalyptus powder**

**Fig. 4—Effect of salt concentration on dyeing of irradiated cotton using extract of irradiated Eucalyptus powder**

**Fig. 5—Effect of alum, chrome, copper, iron and tin as pre- and post-mordants on the dyeing of irradiated cotton using extract of irradiated Eucalyptus powder**
increases in M: L ratio, most probably due to the presence of insoluble impurities in large amount comparatively and low concentration of actual colourant in the extract. Figure 4 shows that the dyeing using sodium chloride as an exhausting agent gives better results as compared to sodium sulphate. It is found that fabric samples dyed by using sodium chloride (3 g/L) are dark redder brown in shades and show higher colour strength.

Pre-mordanting and post-mordanting were also carried out using various concentrations of different mordants (Fig. 5). In case of pre-mordanting, iron shows maximum colour strength, because of the oxidation of Fe$^{2+}$ ions and the formation of complexes of these ions with the carboxylic groups of the cellulose and phenolic group of the natural colourant. Due to low reduction power of the iron than that of other metals present in mordant, it gives rise to hue and shade$^{13}$. Low colour strength values in post-mordanting condition are due to accumulation of the metal dye complex in the form of clusters which upon investigation in Spectra Flash spectrometer show dull reddish brown shades. Pre-mordanting and post-mordanting results show that pre-mordanting using 10% iron gives comparatively dark reddish brown shades. Mordanting results of Eucalyptus bark powder are comparable with the results obtained using turmeric powder$^4$.

The rating results of colour fastness properties (Table 1) also show that gamma irradiation to an absorbed dose of 500Gy has enhanced the fastness properties such as light, washing and rubbing of the dyed fabric$^4$.

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<th>Parameter</th>
<th>Mordant conc., %</th>
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<th>Rub fastness</th>
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4 Conclusion

The role of gamma radiation on the colour strength of the fabric dyed with the extracts of eucalyptus bark powder and its colour fastness properties is found to be prominent.

4.1 The irradiated fabrics dyed with the extracts of irradiated eucalyptus bark powder show better colour strength than that of un-irradiated fabric dyed with the extracts of un-irradiated bark powder.

4.2 The best results are obtained at the optimum dyeing conditions: absorbed gamma radiation doses 500 Gv, material: liquor ratio 1:30, salt conc. 3 g/L sodium chloride (exhausting agent), and conc. of pre-mordant 10% ferrous sulphate. Under these conditions, not only good colour strength is obtained, but also good colour fastness properties are also observed.

4.3 The study shows that the gamma radiation improves the colour fastness properties of the cotton fabric dyed with the ethanolic extract of Eucalyptus bark powder. The colour fastness of the fabric improves when extract obtained from irradiated powder of eucalyptus bark is applied on to the irradiated cotton fabric under the optimized dyeing conditions.

4.4 In ordinary application of dyes under the influence of modern techniques such as gamma radiation, the dyer can achieve better results (colour depth/strength and shades) by the selection of plant material, the amount of dyestuff and the amount of mordant used.

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