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Tanuja Kohli
Ph.D. Student, Department of Textiles and Apparel Designing, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Meenu Srivastava
Professor, Department of Textiles and Apparel Designing, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Corresponding Author:
Tanuja Kohli
Ph.D. Student, Department of Textiles and Apparel Designing, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Rhododendron arboreum: An innovative bio-based source of flame retardant finish on cotton textiles

Tanuja Kohli and Meenu Srivastava

Abstract
Cotton is the most abundant polymeric raw material in the world. Over the past few decades, a lot of research has been done on this accessible, biodegradable and renewable material. It has been determined that right now one of the main challenges faced by scientists and technologists is the flammability of cotton products. The need has been aroused to impart cotton fibres and fabrics a useful feature of fire-resistance. Currently, cellulosic materials are given several different types of chemical finishes to impart flame-retardant properties. Nevertheless, these finishing methods have several drawbacks, including numerous undesirable characteristics. To get consistent outcomes, the application procedure uses rigorous control criteria. Furthermore, this technology is far from optimal due to the implementation costs and legal concerns around the use of synthetic fire retardants. In particular, the majority of synthetic fire-retardants have been claimed to be hazardous and need to be used in huge quantities to give flame-retarding properties to textiles, which results in making the technique unacceptable. Moreover, treatment processes are also laborious. Therefore, obtaining an affordable, widely accessible, eco-friendly flame-retardant material is a major difficulty and an unmet requirement. In this regard, an attempt has been made to investigate several plant extracts consisting of capabilities to resist fire and evaluate the appropriate novel and environment-friendly flame-retardant for creating functional textiles. Furthermore, imparting the properties assessed from green flame-retardants to cotton fabrics using non- toxic finishing systems. Therefore, the federal mandatory textile flammability standards can be met by the textile and garment manufacturers and the market share of cotton fibre can be maintained and increased in the future.

Keywords: Bio-based, environment-friendly, fire-retardant, textile finishes

Introduction
Accidents involving fire have been a typical occurrence in India in both the residential and business sectors. This accidental fire damage has long-lasting effects on people's loved ones, personal property, and occasionally even their own lives. India as a nation has experienced fire risks of varied intensities [1]. NCRB gathered information regarding fire accidents as per the places of occurrence for suitable preventive tactics, given the prevalence of fire accidents and the potential damage that such accidents can bring [3]. According to the ADSI data, "Cooking Gas Cylinder/ Stove Burst" is considered to be responsible for the majority of fire mishaps in households throughout the years [3]. Along with this, statistics showed that textile items play a substantial role in fire hazards that endanger human lives. These products include bedsheets, floor coverings, upholstered textiles in seats, bedding, and home furnishings among which clothing (including oversuits, undergarments, work wear, and suiting) is also included. These textile materials are frequently close to people. Natural textile fibres mainly act as a source of ignition for fires since they are flammable or combustible. Actual fire instances have demonstrated that clothing and textiles were the primary causes of human harm and death. Many textile flammability testing methods are already applied under certain conditions and can be used for a range of textile items [4]. But, according to the chemical industry, many chemicals that are being used as fire retardants are dangerous, ineffective, and useless. These flame retardants have been linked to cancer, hormonal disturbance, and neurological impairment. One of the main risks associated with some flame retardants is that they bioaccumulate in people, leading to chronic health issues over time as bodies store ever-increasing amounts of these dangerous chemicals [5]. These chemical flame retardants are frequently categorized based on their chemical composition and characteristics. A few types are Brominated flame retardants (BFRs), Hexabromocyclododecane (HBCD), Organophosphate flame retardants (OPFRs), Polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol A (TBBPA) etc. [6] Since the year 2000, there has been a rise in global

awareness of sustainable eco-friendly green textile chemicals, auxiliaries, and textile products, raising some serious concerns about the environmental friendliness, toxicity, and sustainability of various traditional flame-retardant compounds [7]. People have recently become more conscious of the harmfulness of chemicals and their effects on the environment, as well as the possible risks that may be involved [8].

Bio-based flame retardants are substances that may be made from biomass, which is referred to as the biological stuff that can be found on earth. It consists of biomolecule-containing plants, animals, and microbes, some of which have essential properties like flame retardancy. By using chemical or biological processes, these compounds can either be employed as-is or transformed into derivatives [9]. According to a research, fire retardants must not be persistent, bio-accumulative, or hazardous to people, other animals, or the ecosystem as a whole to be considered ecologically benign. The chemical must easily degrade in the environment; this is a crucial criterion. Therefore, natural materials are valuable because of their inherent biodegradability and low toxicity [10]. In this direction, present research has been carried out to develop an eco-friendly, non-toxic flame-retardant finish for textile material.

2. Materials and Methods

This study focused on the synthesis of bio-based FR agents using plant-derived tannins and lignin. A plain woven organic cellulosic (cotton) fabric of 0.325 mm thickness with 180 GSM was used in the study. The natural source *Rhododendron Arboreum* was procured from the forest of Uttarakhand in raw/natural form after a thorough study regarding the phytochemical constitution of the plant. It was found from the study that it contained high amounts of tannins (47.98%) and lignin (24.88%) [7]. Which are the compounds found to be responsible for having flame-retardant properties.

2.1 Extraction of FR agent

The grey fabric was first mordanted with 20% alum. Extraction was done by keeping M:L = 1:10 containing solvent-aqueous medium in the ratio 70:30. Prepared solution was then treated at 60 °C for 20 hours Then it was impregnated with different concentrations of *R. arboreum* solution such as 20, 30, 40 and 50 percent. The fabric was then treated for 30 min at 90 °C.

2.2 Determination of percent add-on

The treated fabric samples and control fabric samples were conditioned at 65% RH and 27 °C temperature for 1 hour before conducting any physical and chemical characterization tests. After the application of *R. arboreum* on organic cotton fabric samples, the add-on, i.e. increases in the sample weight was determined using the gravimetric principle from the bone dry weights of the sample before and after the treatments. The per cent add-on of *R. arboreum* was calculated as follows:

Percent add-on = [*M2 – M1 / M1*] x 100,

Where, *M1* and *M2* are the oven-dried weight of the control and *R. arboreum* treated samples respectively. The reported results are the average of five readings.

3. Results and discussion

Cotton fabric without any treatment could not pass the flammability test and was completely burnt, suggesting on cotton poor fire retardancy. *R. arboreum* treatment to the cotton fabric imparted good flame retardancy and the burning of the fabric was stopped after removing the burning source. To enhance the performance of fire retardant, the extracted compound is used with a cross-liner to enhance the washing durability of the fire-retardant finish.

3.1 Thermal characterization

The vertical flammability test method was used to evaluate the behaviour of control and treated fabric samples. In this test, different parameters were measured according to ISO 900 method. The unmodified cotton fabric easily caught fire during the vertical burning test with a robust flame on the specimen; the fabric sample was destroyed and fully consumed within 12 s (the ignition time) leaving only traces of residue on the sides. Fig 1 shows the photographs of the modified cotton fabric samples after the vertical burning test. The modified cotton fabrics stopped the flame propagation after the removal of the flame source and self-extinguished, showing no after-flame or after-glow activity.

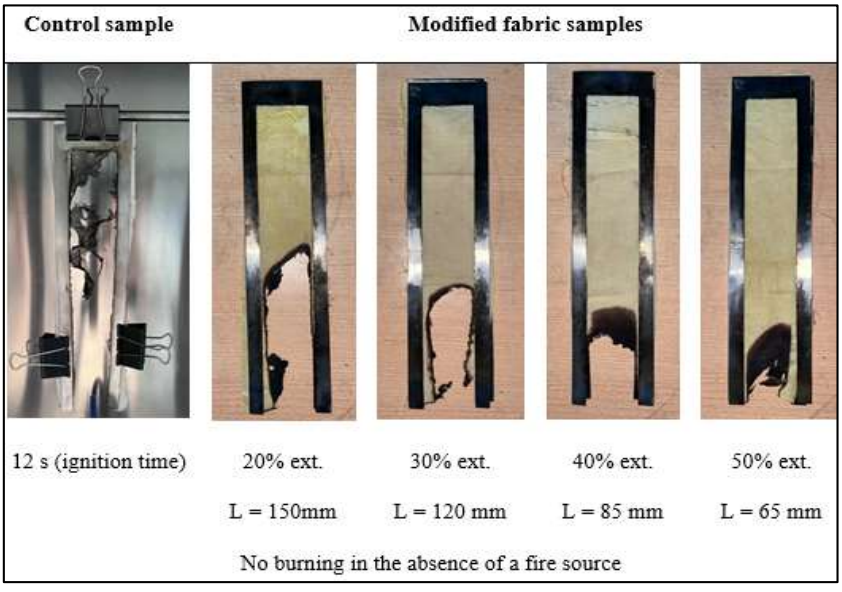

Fig 1: Vertical burning test values of fabric samples modified with *R. arboreum*

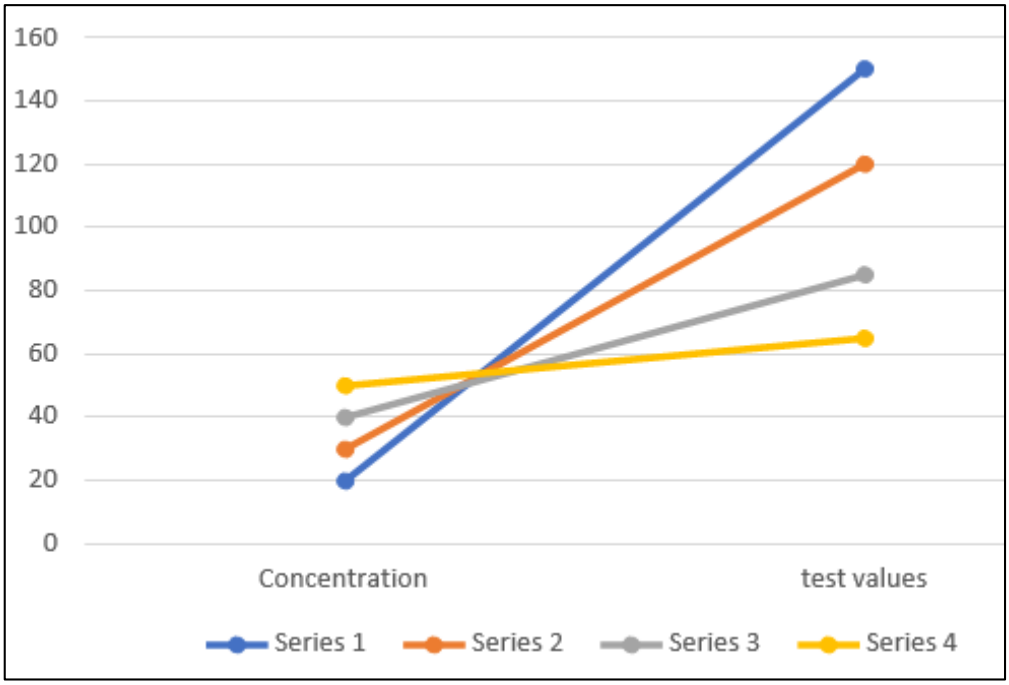

Fig 2: Test values of different extract concentration

As shown in fig 2, the test values decrease with an increase in the concentration of the extract. The fabric sample modified with 50% of extract concentration shows the best flame-retardant property among all the treated samples.

3.2 Wash durability of the finish

The flame-retardant activity of the finished samples was evaluated after washing them using standard detergent of 5 g/l at 40 °C for 40 min. the fabric was then rinsed in fresh water for 5 min, followed by drying at 100 °C for another 5 min. The changes in burning rate are presented in Table 1 and fig-3.

Table 1: Changes in the burning rate of modified fabric after washing

Flammability parameters		After washing	Fabric parameters Before washing
Vertical flammability (mm/min)	20%	300 mm	150 mm
	30%	300 mm	120 mm
	40%	285 mm	85 mm
	50%	260 mm	65 mm

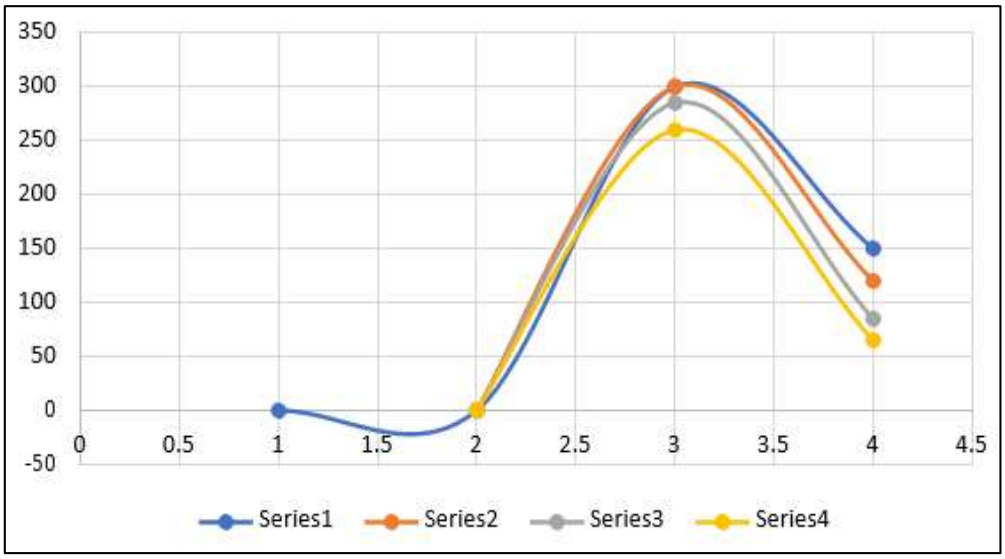

Fig 3: Changes in burning rate of modified fabric after washing

It can be seen that the test value of washed fabric increases from 150 for the unwashed fabric to 300 in the washed fabric sample modified with 20% of extract concentration, which is, significantly higher. Similarly, it was noticed that after washing the samples, as the test value increased its burning rate also increased.

3.3 Mechanical strength

The two most important properties of any textile i.e. tensile strength was evaluated according to standards ASTM D461 (Computerized fabric strength tester). The effect of *R. arboreum* on the mechanical properties of treated samples was studied after comparing the results between control fabric

samples and treated fabric samples.

Table 2: Effect of *R. arboreum* on tensile strength of fabric

Control fabric	Conc.	Tensile strength
Tensile strength: Load = 3.90 kg	20%	30.32 mm
	30%	29.08 mm
Ext. = 31.76 mm	40%	29.07 mm
	50%	28.90 mm

It can be seen from Table 2 that the application of flame-retardant finish has no significant adverse effect on the tensile strength of *R. arboreum* treated sample.

4. Conclusions

The present study focuses on the extraction of bio-based, sustainable and reactive tannin and lignin-containing FR agent from *R. arboreum*. The vertical flammability test method was used to evaluate the behaviour of control and treated cotton fabric samples. Thermal characterization showed very encouraging results as clearly depicted in various tables and graphs by way of vertical burning test values of fabric samples modified with *R. arboretum*, Changes in the burning rate of modified fabric after washing and the Effect of *R. arboreum* on tensile strength of fabric. The material was synthesized by extracting the compounds in the lab. The modified cotton fabrics depicted a reduction in the flammable behaviour and displayed self- extinguishing properties due to the shielding action of the generated intumescent char. The after-wash test values showed a significant loss in the flame-retardant property of the treated fabric. Whereas, there was no significant change in the tensile and tear strength of *R. arboreum*- modified fabric samples. The findings pave the path for more researches on the extraction and use of different plant molecules and other biomolecules for the flame-retardant finishing of textiles that would aid in the development of environmentally friendly green textile goods.

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