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Recent Development of Sustainable Ecological Flame Retardant Textile Composite Material: A Review

Golam Mahmud Faysal[1], Md. Arefin Kowser[2], Mohammad Abdul Jalil[3]

[1]Department of Textile Engineering, Northern University Bangladesh, Dhaka, Bangladesh
[2]Department of Mechanical Engineering, Dhaka University of Engineering & Technology (DUET), Gazipur, Bangladesh
[3]Department of Textile Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh
Email: faysal.tex@gmail.com

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Abstract

The ecological and sustainable product is the demand of the present world. But it was not possible to produce an ecological and sustainable product for all sectors as the world requires now. The synthetic material is used to produce flame retardant materials due to the unavailable sustainable ecological flame-retardant material. But different researchers are trying to produce sustainable ecological flame-retardant material. This research found that the Spinach leaves Juice, banana pseudostem sap (SAP) and eggshell powder have flame retardant properties. Different literature shows that the ash also has flame retardant properties. So researcher suggested developing the composite material from the above materials with cotton fibres. It may be more effective as fire-retardant composite materials.

Keywords

Sustainability, Ecology, Flame, Retardant, Material

1. Introduction

Environmental pollution and health hazards are the major problems in the present world. So the main focus of the present world is sustainability and eco-friendly production. The depletion of synthetic materials has led away for the development of sustainable, economic, and eco-friendly composite materials [1]. That combining two separate materials with distinct physical and chemical characteristics results in a composite material. It is possible to mix them to form a material that has a specific purpose, such as being stronger, lighter or more resistant to electricity when combined. Strength and stiffness may also be improved by using them [2]. Because they enhance the qualities of their basic materials and may be used in a wide range of applications, they are preferred over conventional materials [3]. A recent market study shows that customers throughout the globe are looking for textiles with new functionality, such as a more pleasing aesthetic feel and enhanced health and hygiene [4]. Functions such as wrinkle resistance, water repellence, antimicrobial, colorfastness, and fire retardant properties have been enhanced in clothing and household textiles [5]. A key characteristic of its use in home furnishings, hospitals, trains, and aeroplanes is flame-retardant cloth. Workers in the oil, gas, and petroleum sectors need flame retardant clothing. Cotton textiles are often utilized in all of these applications because of their comfort, softness, and ability to regulate moisture. Cotton is environmentally benign, biodegradable, and made from a renewable source [6]. Cellulosic in nature, cotton is very flammable and difficult to extinguish, posing significant health dangers and causing extensive damage to textiles [7]. In the past, synthetic compounds have been used to enhance the flame retardant properties of cotton textiles. Commercial products, most of which are synthetic, abound on the market. Borax and the boric acid combination is the simplest and most common chemical [8]. Due to their synergistic impact, phosphorus-based flame retardant and nitrogenous chemicals have been the most effective therapy thus far [9]. A cotton fabric treated with an acidic solution like this one lowers the fabric's tensile strength and requires a lengthy and costly curing procedure, which makes the treatment prohibitively expensive. Despite the potential for antimony and halogen to have strong flame retardant properties, the environmental harm caused by halogen chemicals means that this combination is not yet highly effective [9]. Although the most effective technique created so far is a flame retardant finish based on nitrogen and phosphorus, much of the formulation is not environmentally friendly. Bio-polishing enzymes, aloe Vera extract, and other anti-microbial cellulosic textile finishes are in high demand in R&D because people are becoming more health-conscious and concerned about their cleanliness and health [9].

However, to the best of our knowledge, no use of plant extracts (biomolecules) for flame retardant finishing of any textile or polymeric material has yet been described. Based on the knowledge above, it is possible to increase the flame retardant qualities of cellulosic and non-cellulosic material using plants that contain phosphorous, silicate, and other minerals and mineral salts. Different researchers used different biodegradable materials for flame retardancy of textile material. According to the previous research, various attempts were made to improve the flame-retardant property of cellulosic cotton textile using extracted spinach juice, Chicken Eggshell powder, and banana pseudostem sap with natural lignin [9] [10] [11] [12]. So, their composite material would be better performed as flame retardancy textile.

2. Literature Review

The popular fire retardant materials are produced synthetically the present. But very little research has been reported about fire retardancy ecologically. This paper has discussed the natural fire retardant materials used as fire-retardant materials. Cotton is a 100% cellulosic material [13], which means that it burns quickly and is difficult to put out, posing a considerable health concern and causing significant damage to textiles [7]. Flame retardant properties of cotton textiles have been improved significantly since the sixteenth century by employing different synthetic compounds. Borax and boric acid combination di-ammonium phosphate, urea, etc., are some of the most popular and essential non-durable fire-retardant chemicals available [14] [15]. Different researchers show that Polyurethane foam and antimony-based halogen-containing formulations were also employed as a back coating on cotton textiles to make them fire-resistant. Because of halogen compounds' harmful influence on the environment, antimony in conjunction with halogen was not particularly successful [16]. Researchers have shown that a phosphorus-based and nitrogenous compound-based flame retardant provides the best synergistic effect. Because of this, phosphorous-based flame retardants like Tetrakis phosphonium salts and N-alkyl phospho-propionamides derivatives have taken over the market as commercial flame retardant goods in large quantities [16]. As a result of being exposed to acidic circumstances while wearing cotton clothing, compositions like these lower cotton's rip and tensile strengths. Due to high-volume chemicals and high-temperature curing, treatment is poisonous, dangerous, costly, time-consuming, and lengthy [17]. In addition, a phosphorous and nitrogen bound flame retardant devoid of halogens is being developed to provide a more char-forming cellulose substrate [18]. Recently, a study group employed nano zinc oxide and polycarboxylic acid to establish ecologically safe fire retardant cotton fabric [19]. However, researchers struggle to find inexpensive, effective, and environmentally acceptable fire retardants for cellulosic materials. Natural textile finishes, such as natural dyes for colouring and enzymes for bio-polishing, are in high demand because of growing public concern about human health and cleanliness [20]. The antibacterial properties of neem, aloe vera, and banana peel extract are attracting researchers' interest [21]. Few studies have been done on bio-macromolecules to improve the fire retardancy of cellulosic fibers.

The banana tree is very well known and available in Bangladesh, and banana pseudostem sap is considered a waste material. Banana Pseudostem Sap (BPS) extract contains phosphorus, nitrogen, chlorine and other metallic constituents [22]. Various studies have shown that magnesium and potassium nitrate are also found in the BPS [23]. More recently, studies have shown that potassium chloride, sodium chloride, and metal phosphate are the primary components of the salts recovered from BPS [24]. Recent studies show that BPS positively affects fire retardant material with cellulose materials [11].

Spinach is very available in Bangladesh and is used as a nutrient food. Spinach leaf juice (SLJ) contains sodium, magnesium, silicate, iron, proteinous nitrogen, and other metallic constituents [9]. Recent research reported that spinach leaves juice is used as fire-retardant material with cellulosic material [9].

Chicken eggshell is available in Bangladesh and is considered waste material. It contains 95% calcium carbonate in the form of calcites and 5% organic materials. Organic materials like collagen, sulfated polysaccharides, and others like Al_2O_3, SiO_2, S, Cl, P, Cr_2O_3, and MnO [25]. Chicken eggshell is a valuable bio-filler made from chicken eggshell waste in the fire-resistant coating business. It is lightweight and has high thermal stability in bulk, making it a cost-effective and ecologically beneficial choice [10].

Much emphasis has been paid to using lignin to promote fire retardant polymers in recent years [26]. Using lignin as a fire retardant ingredient is a beautiful idea because of its strong heat resistance. In conjunction with other fire retardant chemicals, it may also be employed as a carbon source to develop intumescent systems [12]. The mechanical and thermal characteristics of polymeric materials may be improved by adding lignin or lignin derivatives [27]. Polymer flame retardant additives rely heavily on lignin's heat stability and ability to produce char; hence, their ability is very dependent [12].

3. Materials and Methods

Basak *et al.* (2015) used plain-woven bleach cotton fabric in their study. In this investigation, fresh spinach leaves were removed and utilized. Preparation of cotton cloth was done using Whatman No. 1 filter paper. At 90˚C, with a material-to-liquor ratio of 1:15, bleach cotton textiles were impregnated for 30 minutes with various compositions of SLJ and water, including 1:2, 1:1, and solely SLJ (1:0). Soda ash was used to adjust the pH of all the solutions to a neutral value of 10. After 5 minutes of drying at 110˚C, the cloth was ready to use [9].

Basak *et al.* (2017) used plain-woven bleached cotton fabric for flame retardant finishing by the banana pseudostem sap (BPS). With a material to BPS ratio of 1:10, the fabric was first mordanted with tannic acid (5%) and alum (10%) before being impregnated with various concentrations of the BPS. The cloth was immersed for 30 minutes in each treatment using soda ash to maintain an alkaline pH. Five minutes at 110˚C was all that was needed to dry the cloth samples [11].

Tseghai, Berhe, and Wakjira (2019) used half bleached woven cotton fabric in their study. An acrylic copolymer binder was utilized to adhere the chicken eggshell gel to a cotton cloth. Then, make powder out of chicken eggshells. Washing with a regular laboratory detergent and colouring the collected chicken eggshells was the last step. This was followed by the physical grinding of the dry chicken eggshell into powder. Use an acrylic copolymer binder to make chicken eggshell gel and apply the gel to a piece of cotton. Padding the mangle at one dip, one nip was used to apply the coating. For four and a half minutes at temperatures of 80˚C and 150˚C, we dried and cured the coated cloth [10].

Basak *et al.* (2015) conditioned the treated sample for 48 hrs, at 65% RH and 270˚C temperature [9]. Basak *et al.* (2017) also conditioned the sample at the standard method [11]. Basak *et al.* (2017) and Basak *et al.* (2015) analyzed the treated sample with a different flammability test.

The burning behaviour was tested using established control and treated sample procedures. To determine the limiting oxygen index (LOI), the IS 13501 test technique was employed. According to the FMVSS302N standard, flame time and propagation rate were recorded in horizontal flammability. Various characteristics were measured using the 1871 technique A for vertical flammability. Using a non-contact IR thermometer built by Fisher Scientific (Model No. 15077968 FB61354 225PE, UK), we determined the sample's highest possible temperature while burning [11].

A radiant heat test is used to determine how much heat is emitted through the specimen. The ASTM F1939-08 technique chose the specimen's test value [9].

After undergoing a single wash cycle, the completed samples were tested for their fire retardant activity. It took 40 minutes to wash the constructed textiles in a laundromat using a detergent concentration of 1 g/L in 1 liter of water. Once the cloth had been cleaned and dried at 100˚C for 5 minutes, it was ready to use. The flammability test was carried out after 24 hours in a desiccator [9].

The weathering fastness of treated and untreated cotton fabric samples was tested using the ISO 105-B03-1978 (E) technique. It was raining on and off throughout July and September, but the samples were shielded from the elements for 6 hours every day. The LOI value was used to test the treated and untreated fabrics' fire-retardant properties every 50 hours [9].

The temperature or time-dependent weight loss of a sample is measured using thermogravimetry (TG). The pyrolysis of the polymer substrate is also affected by the addition of a flame retardant [28]. The thermogravimetric analyzer (METTLER TOLEDO TG-50/MT5, Greifensee, Switzerland) was used to establish the TG curves of the control and treated textiles. Both the treated and untreated textiles were tested for tensile strength using an Instron manufacture tensile tester according to ASTM D5035-2006 procedure [9].

The Shimadzu IR Prestige 21 analyzer equipment was used to examine the FTIR curves of the control and treated textiles [11]. To explore the surface of the control and treated samples, we utilized a Philips XL-30 scanning electron microscope (SEM). A field emission gun scanning electron microscope was used to perform EDX examination (FEG-SEM) [9].

4. Results and Discussions

LOI is defined as the quantity of oxygen necessary to promote burning in the combination of oxygen and nitrogen. In the open environment, fibres with an LOI value of 21 or below readily ignite and burn fast. LOI values over 21 cause the sample to ignite, although it takes a long time. The LOI value of textile material may be termed flame retardant if it is equal to or greater than 26 [7]. Basak *et al.* (2015 & 2017) showed in **Table 1** that the control sample LOI value was 18 and caught fire rapidly. They had been bleached and mercerized before to application of SJ and BPS. **Table 1** showed that The LOI value increased when applied to the bleached cotton samples at various concentrations. The LOI value

Table 1. Flammability properties of treated sample [9].

Flammability parameters	Control	1:2		1:1		1:0	
		SJ:Water	BPS:Water	SJ:Water	BPS:Water	SJ:Water	BPS:Water
Add-on (%)	-	3.5	2	5.7	3.5	8	4.5
LOI	18	26	26	28	28	30	30
Horizontal flammability warp way burn rate (mm/min)	90	15.7	14	13.2	8	10	7.5
Vertical flammability occurring of flashing over the surface	Yes	No	No	No	No	No	No
Burning with flame time (s)	60	10	10	Nil	7	Nil	4
Burning with afterglow time (s) after flame stop	0 (as completely burnt with flame)	295	500	345	680	400	900
Total burning time (flame time + afterglow time)	60 s + 0 s	10 s + 295 s	10 s + 500 s	0 s + 345 s	7 s + 680 s	40 s + 400 s	4 s + 900 s
Observed burning rate (mm/min)	250	49.1	29.4	43.5	21.8	37.5	16.6
State of the fabric in contact with flame	Completely Burnt with flame	Burnt with initially flame followed by an afterglow	Burnt with initially flame followed by an afterglow	Burnt with initially flame followed by afterglow	Burnt with initially flame followed by afterglow	Burnt with initially flame followed by afterglow	Burnt with initially flame followed by afterglow

was raised to 26 in bleached cotton fibers treated with a 1:2 SJ solution and also 1:2 BPS solution over 1.3 times the control sample value. The add-on percentages increased from 3.5 to 8 when more concentrated SJ and BPS were applied. Consequently, the LOI went from 26 to 30 as a result. As the LOI value in the SJ and BPS treated samples climbed dramatically, the samples did not catch fire. While the control sample saw flame quickly and completely burned within 60 seconds, the SJ and BPS treated sample (1:2) exhibited just a 10-second burst of flame before combusting and emitting an afterglow for 295 seconds for SJ and 500 seconds for BPS treated sample [9]. The table showed that the Horizontal flammability warp way burn rate (mm/min) was 90 for the control sample, but the BPS (1:0) treated sample was the lowest at 7.5. Burning with flame time (s) for the control sample was the 60s, but the SJ (1:1 and 1:0) treated sample was nil. Burning with afterglow time (s) after flame stop time was higher for BPS (1:0) treated sample. The researcher found from Table 1 that the SJ and BPS treated samples have the fire retardant properties

Figure 1 shows the vertical burning behavior of the control and SJ-treated samples at various time points. There was a fivefold increase in overall burning duration when SJ was used in the (1:2) sample (control sample 60 s).

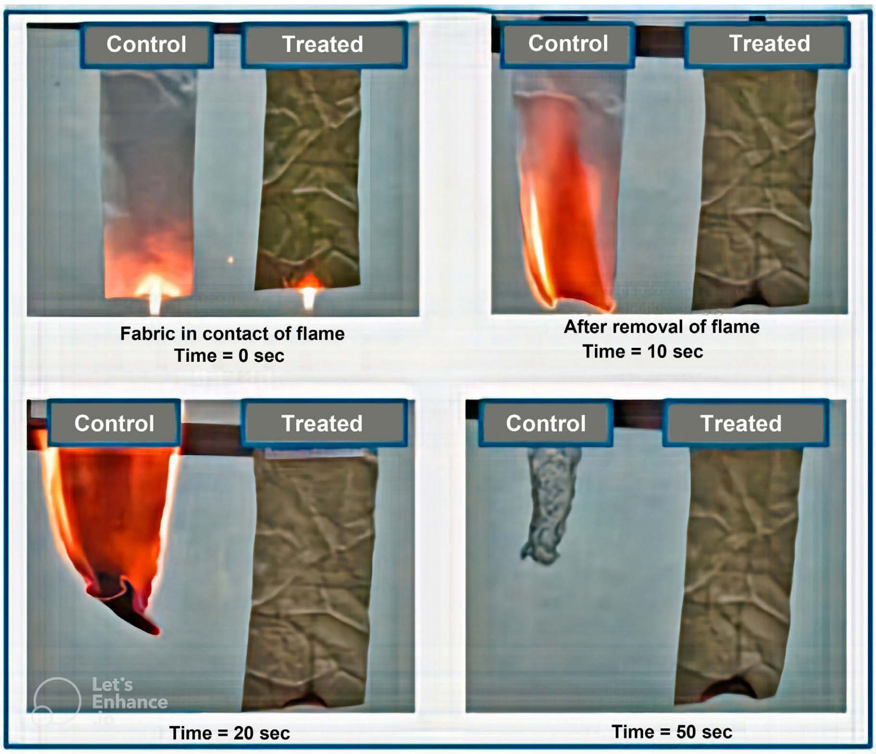

Figure 1. A comparison of the burning behaviour of cotton fibres treated with SJ to untreated controls [9].

Table 2 shows the flammability of egg shell-treated cloth, according to Tseghai, Berhe, and Wakjira (2019). The treated sample fabric shows reduced flammability than the untreated sample utilizing three samples with varied eggshell powder concentrations. 8 cm of treated fabric may be kept without burning coat Sample 2 with medium solution concentration. This sample fabric is less flammable than material treated with less eggshell, which reduces fire spread. Untreated sample fabric isn't fireproof. Save **Table 3**'s 13 cm sample cloth. Sample 3 had a decreased rate of fire propagation and fabric flammability than samples treated with low and medium eggshell concentrations. Three sample tests show the untreated cloth's flammability. This test saves 18cm of fabric [10].

Table 3 illustrates that more powder reduces flame propagation. Low and medium quantities generate eggshell ash and char. High powder-liquid ratio coatings create char. Fire-retardant cotton fabric is constructed with eggshells, which slows fire spread. **Table 3** shows how changing chicken eggshell powder-to-liquid ratios affect fabric fire resistance. Powder liquid ratio reduces cloth's flammability. **Table 3** shows that 2 cm of a 20 cm cloth length burns in 5 seconds, whereas 18 cm is preserved at a high concentration. **Table 3** demonstrates that a 20-cm fabric with a medium coating thickness reduces flammability by a medium amount. 5 seconds of burning reduces a 7-cm fabric to 13cm. Low-thickness coatings may reduce flammability [10].

Basak *et al.* (2014) investigate fabric heat radiation. It measured: the fabric's heat radiation. This approach sent 20 kW/m^2 heat through control and treated

Table 2. Fire retardancy performance test results [10].

Sample Name	Eggshell Powder	Binder	Sample Length	Fire Propagation
Untreated	-	-		4 cm per second
Sample 1	70 mg	20 ml.	20 cm	2.4 cm per second
Sample 2	80 mg			1.4 cm per second
Sample 3	100 mg			0.4 cm per second

Table 3. Flame retardant performance analysis [10].

Sample name	Flame propagation	Residue
Sample-1	Reduced fire	Ash and char
Sample-2	Slow fire	Ash and char
Sample-3	Prolonged fire	Char
Untreated sample	Rapid-fire	Ash

textiles. Both fabrics needed 12 and 24 hours to reach 12˚C: 14.28% and 12.1% for treated textiles. Treated cloth radiates 9% less heat than control fabric. The SJ-treated sample generated less heat and warmed with time (total burning time). The treated fabric's TF was 20% lower than the control's. This proves the fabric's LOI and thermal stability [9].

Basak *et al.* (2014) also analyze the thermogravimetry (TG) of the sample. The effects of SMSN on fabric heat deterioration and charring were studied using TG analysis [14]. N2 atmosphere and 10˚C/min heating rate were used for TG curves of dried spinach juice powder (A), control cotton fabric (B), and bleached cotton fabric treated with the SJ (1:0) composition (C) shown in **Figure 2** Dry spinach powder's TG curve demonstrates a loss of mass at temperatures ranging from 50 to 100 degrees Celsius. Unbound and bonded water molecules are likely to have been lost in distinct ways causing these symptoms [29].

At 200˚C - 360˚C, the second weight loss zone appeared, with a peak at 250˚C. This happened after 100˚C. Only a 30% decrease in mass was seen at this point. Dehydration and char formation ushered in the third stage of weight loss at temperatures over 600˚C. Control (B) cotton fabric's three-stage TG curves were evident in the early stage, which occurred below 100˚C. The mass loss, in this case, was mainly owing to the polymer's loss of absorbed liquid [28]. Around this time, the significant pyrolysis stage began, with the peak in principal loss occurring at 300˚C. Cellulose pyrolysis products might be generated with this fast mass loss (78%) [30]. It was shown that dehydration and char formation occurred at temperatures higher than 380˚C. Here, CO_2 may be generated during the dehydration of non-oxidizable water [28].

B decomposes rapidly at 300˚C, according to its TG curve, and loses 98% of its mass by 500˚C. Cotton fabric (C) treated with spinach juice lost 15% of its weight initially, whereas cotton fabric (C) lost 5%. Spinach juice's inorganic salt may generate excess moisture in treated cloth, causing shrinkage. Curve C commenced

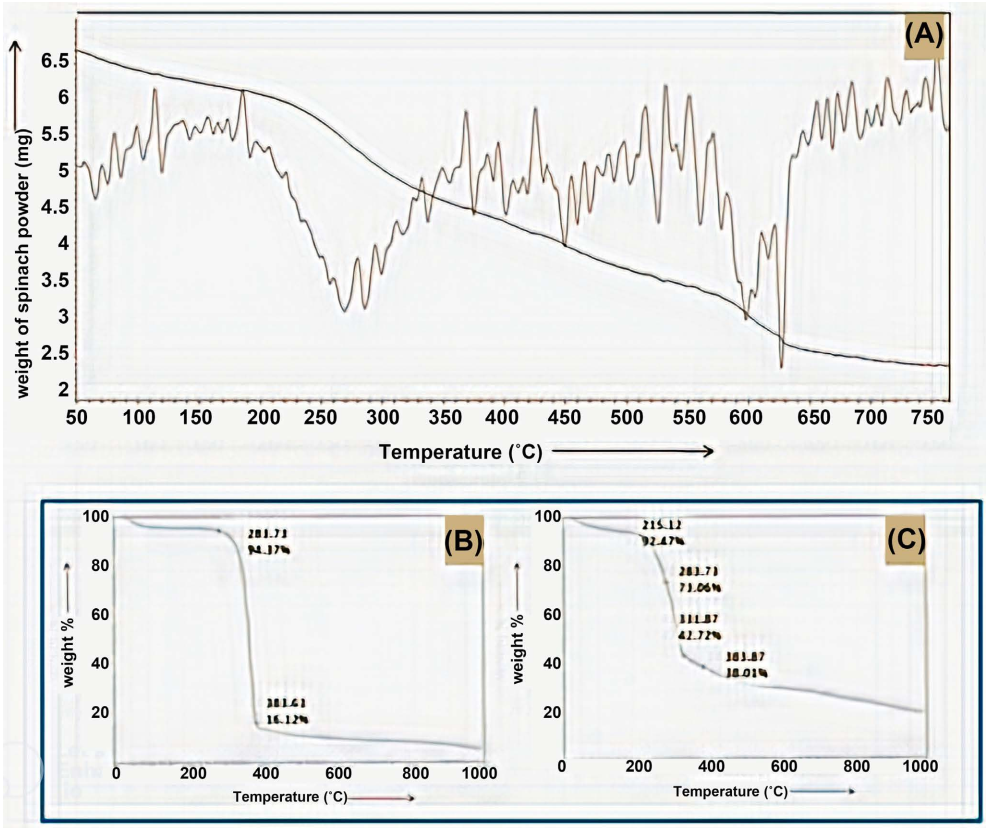

Figure 2. Graphs depicting the thermal analysis of dry spinach powder (A), cotton fabric (B), and cotton fabric treated with spinach juice (1:0; C) [9].

pyrolysis at 215˚C, 65˚C lower than the control's temperature. Peak significant loss was reduced from 330˚C to 265˚C (65˚C). This pyrolysis phase removed 54% of the bulk. This mass loss is between A (30%) and B (10%) (78% loss). Spinach juice improves the pyrolysis range by 50˚C, resulting in less mass loss. The formation of non-oxidizable CO_2 and H_2O at lower temperatures reduces cellulose substrate combustion temperature. In the third stage, the treated fabric burned more slowly than the control fabric and left more char residue. 330˚C was 20 - 30 degrees hotter than the control cotton fabric. The quantity of char residue that remains at 500˚C rises from 13% to 30%. The findings showed that spinach juice affected early dehydration and char formation. The treated sample kept more mass at higher temperatures because spinach juice (A) deteriorated less across a broader temperature range. Vertical flammability tests were comparable. The spinach juice-treated sample is stable at 50˚C - 600˚C. Reduced gas production and increased char formation enhanced flammability in treated samples. Spinach juice improves the thermal stability of treated cotton and lowers cellulose loss.

Basak *et al.* (2014) also analyzed the FTIR analysis and found that Samples' FTIR spectra are shown in Figure 3. The difference between curves A and C may be easily seen. The dried SJ's curve B revealed a broad water band between 2600 and 3600 cm^{-1}. Inorganic salts in SJ are the primary cause of the peaks between

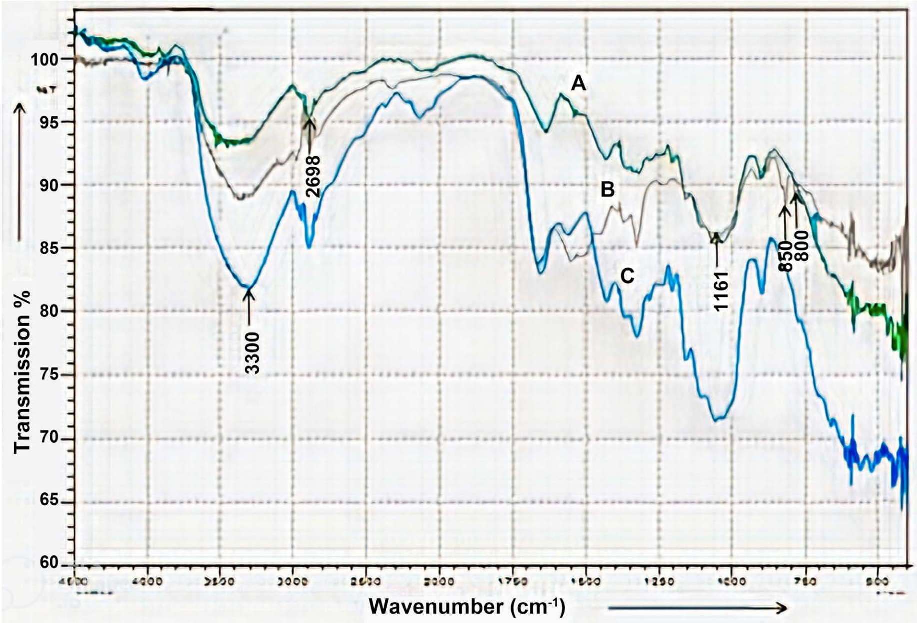

Figure 3. FTIR analysis of control fabric (A), dried spinach juice (B) and SJ-treated (1:0) fabric (C) [9].

800 and 900 cm^{-1} [31]. At 800 and 850 cm^{-1}, small peaks that potentially represent sodium chloride and magnesium chloride salts can be identified [32]. EDX research has also shown the presence of these salts. The peak of the control cotton fabric's curve A, which corresponds to intramolecular –OH stretching and hydrogen bonding, was 3445 cm^{-1}. The C–O–C asymmetric stretching of the B-glucosidic bond of cellulose may be responsible for a peak at 1161 cm^{-1}. Indicated by 2898 cm^{-1} the stretching of CH and CH_2 [33]. When it comes to curve C, the water peak at 3300 cm^{-1} is much larger and more powerful. The area given by the curves A and B in the same location must be multiplied together to calculate the peak's size. According to a study, a greater number of bound and unbound water molecules in the treated cloth were shown to aid in its fire retardant properties.

Basak *et al.* (2014) also examine SEM and EDX. **Figure 4** shows control and SJ-treated cotton SEM images (1:0). **Figure 4(A)** shows a control sample without coatings or deposits. **Figure 4** shows the SJ coating after treatment (1:0). **Figure 4(B)**, SJ is equally distributed globally. **Figure 5** shows the energy-dispersive X-ray of the control and SJ-treated fabric, and **Table 4** shows the findings. The control sample only included carbon and oxygen since this method cannot distinguish hydrogen. **Figure 5** shows that SJ-treated (1:0) sample has several atomic peaks. They symbolise sodium, magnesium, silica, and chlorine. Sodium is more abundant in SJ-treated cotton than magnesium. SJ-treated models had far less carbon than controls (27.2%). However, blood oxygen jumped 7.5%. Except for sodium, all other elements are metal chlorides or metal phosphates. Soda ash and SJ are sodium sources. SJ-treated textile contains silicon silicates (SiO_2 or Na_2SiO_3).

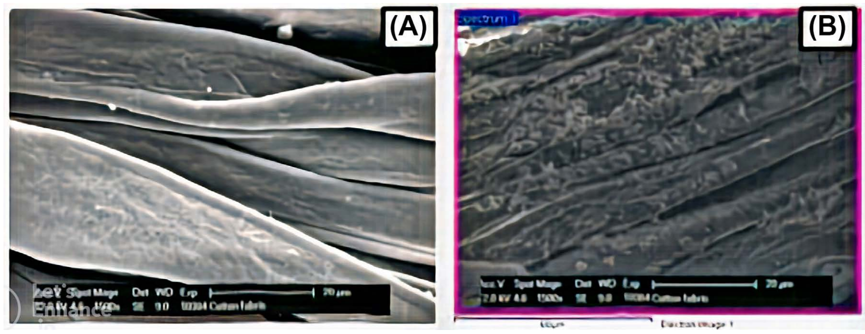

Figure 4. SEM images of Control fabric (A), SJ-treated (1:0) fabric (B) [9].

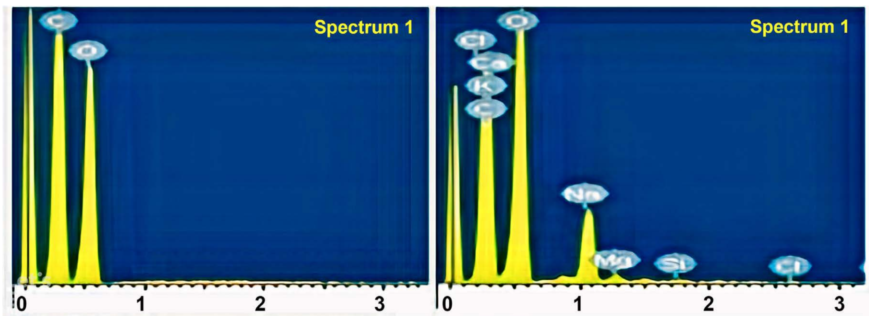

Figure 5. EDX images of control (A) and SJ-treated (1:0) (B) cotton fabrics [9].

Table 4. Atomic percentage of control (A) and SJ-treated (1:0) cotton fabric measured using EDX [9].

Elements	Control		SJ treated (1:0)	
	Weight (%)	Atomic (%)	Weight (%)	Atomic (%)
C	46.1	53.2	33.54	41.59
O	53.9	46.8	57.28	52.86
Na	0	0	7.78	5.00
Mg	0	0	0.46	0.28
Si	0	0	0.21	0.11
Cl	0	0	0.14	0.06
K	0	0	0.13	0.05
Ca	0	0	0.16	0.06

Basak *et al.* (2017) treated pre-mordanted, bleached, and mercerized cotton with banana pseudostem sap (BPS). Limiting oxygen index (LOI), horizontal flammability, and vertical flammability of treated and control fabrics were considered. Non-diluted BPS-treated textiles exhibited an LOI of 30 compared to 18 for the control fabric, a 1.6-fold improvement. In the vertical flammability test, BPS-treated fabric briefly caught fire before extinguishing. There was no visible flame in the horizontal flammability test, but an afterglow propagated at 7.5 mm/s, nearly 10 times slower than the control fabric. Pure BPS was assessed by EDX and mass spectrometry and thermal degradation and pyrolysis of fabric samples (TGA). The fabric's original khaki colour and mechanical strength were unchanged by treatment. The results propose that BPS impart flame retardancy to cellulosic fabrics and provide natural colour [11].

Basak *et al.* (2014) discovered that spinach juice (SJ), an ecologically acceptable natural ingredient, gave cellulosic fabrics flame-resistant qualities. Alkaline fluid was used to condition and bleach newly bleached and mercerized cotton clothing. Control and treated materials were tested for LOI, horizontal and vertical flammability, and radiant heat (RHT). Researchers discovered treated fabrics were more flame-resistant than untreated ones. SJ raised LOI by 1.6 times. The fabric won't catch fire. The treated fabric's afterglow (without flame) was nine times lower than the control's at 10 mm/min. TGA was used to study heat degradation and pyrolysis. FTIR, SEM, and EDX were used to analyse cellulosic fabrics treated and untreated with SJ. The soap-cleaning and weathering resilience of flame retardant characteristics was also examined. SJ treatment turns cellulosic fabric green. One attribute changed significantly [9].

Tseghai, Berhe, and Wakjira (2019) observed that this study aims to replace synthetic fire retardants with chicken eggshells in fire-resistant cotton fabric. Eggshells include calcium, phosphorus, nitrogen, potassium, and zinc. Synthetic fire retardants are poisonous, environmentally hazardous, non-biodegradable, and non-renewable. As a bio-product, chicken eggshell has no adverse effects. Eggshell removal after usage or hatching causes environmental pollution. Eggshells may be transformed into treasure, saving cotton from burning and aiding in treatment. Eggshell treatment reduced the flammability of textiles. Untreated and treated textiles performed differently. Untreated and treated fabrics burn at 40 and 1.4 mm per second [10].

5. Conclusion and Future Perspectives

Basak *et al.* (2014) used spinach leaves juice (SJ) to impart flame retardancy in cotton fabric [9]. Basak *et al.* (2017) also used banana pseudostem sap (SAP) for producing fire retardancy fabrics in their study [11]. Another researcher, Tseghai, Berhe, and Wakjira (2019) used eggshell powder to produce flame retardancy fabric [10]. The previous researchers proved that the materials mentioned above have flame retardant properties. The researcher suggests making a fibre-reinforced composite material from the combination of spinach leaves juice (SJ), banana pseudostem sap (SAP), cotton ash and cotton fibre. Any natural binder may be used as the binding agent for this composite material due to global sustainable requirements.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Lee, J.C. and Pandey, B.D. (2012) Bio-Processing of Solid Wastes and Secondary Resources for Metal Extraction—A Review. *Waste Management*, **32**, 3-38. https://doi.org/10.1016/j.wasman.2011.08.010

[2] Chowdhury, N., Islam, T., Rahman, H. and Farjana, Y. (2020) A Study on Mechanical Properties of Carbon Fiber Reinforced Polymer Composite. *International Conference on Materials, Energy, Environment and Engineering*, Dhaka, 29-30 November 2020, Paper ID: ICMEEE-509.

[3] Chawla, K.K. (2012) Composite Materials: Science and Engineering, 1st Edition, Springer Science & Business Media, Berlin.

[4] Chowdhury, N., Al Rakib Shikder, A. and Moula, A.G. (2021) A Study on Sustainable Fashion Supply Chain of Zara. Shahjalal University of Science and Technology, Dhaka.

[5] Gulrajani, M.L. and Gupta, D. (2011) Emerging Techniques for Functional Finishing of Textiles. *Indian Journal of Fibre and Textile Research*, **36**, 388-397.

[6] Dutta, R. (2008) Ecofriendly, Biodegradable, Trendy, Handicrafted Jute Products for the Leisure and Hospitality Sector. The independent bd, Dhaka.

[7] Petrilli, T. (2008) Technology and Development Programme. USDA, Missoula.

[8] Patil, V.M. and Desmukh, A. (2012) Some Studies of Temporary and Permanent Flame Retardants on 100% Cotton Fabric. In: *Textile and Fashion in Proceedings*, SAGE, India, 272-278.

[9] Basak, S., Samanta, K.K. and Chattopadhyay, S.K. (2015) Fire Retardant Property of Cotton Fabric Treated with Herbal Extract. *The Journal of the Textile Institute*, **106**, 1338-1347. https://doi.org/10.1080/00405000.2014.995456

[10] Tseghai, G.B., Berhe, B.T. and Wakjira, Y.T. (2019) Producing Fire Retardant Cotton Fabric Using Chicken Eggshell. *Journal of Textile Science & Engineering*, **9**, Article No. 396.

[11] Basak, S., Samanta, K.K., Saxena, S., Chattopadhyay, S.K., Narkar, R., Mahangade, R., *et al.* (2017) Flame Resistant Cellulosic Substrate Using *Banana pseudostem* sap. *Polish Journal of Chemical Technology*, **17**, 123-133. https://doi.org/10.1515/pjct-2015-0018

[12] Mandlekar, N., Cayla, A., Rault, F., Giraud, S., Salaün, F., Malucelli, G., *et al.* (2018) An Overview on the Use of Lignin and Its Derivatives in Fire Retardant Polymer Systems. In: Poletto, M., Ed., *Lignin: Trends and Applications*, IntechOpen, London, 207-231. https://doi.org/10.5772/intechopen.72963

[13] Khandaker, S., Hasan, J., Hossain, M.T. and Saha, G.C. (2021) Cotton Spinning Waste as Useful Compost for Organic Indian Spinach (*Basella alba*) Production in Bangladesh. *International Journal of Recycling of Organic Waste in Agriculture*, vol. 10.

[14] Kandola, B.K., Horrocks, A.R., Price, D. and Coleman, G.V. (2006) Flame Retardant Treatments of Cellulose and Their Influence on the Mechanism of Cellulose Pyrolysis. *Journal of Macromolecular Science*, **36**, 721-794. https://doi.org/10.1080/15321799608014859

[15] Charuchinda, S., Srikulkit, K. and Mowattana, T. (2005) Co-Application of Sodium Polyphosphate and Chitosan to Improve Flame Retardancy of Cotton Fabric. *Journal of Scientific Research, Chulalongkorn University*, **30**, 97-110.

[16] Horrocks, A.R. (2011) Flame Retardant Challanges for Textiles and Fibres. *Polymer Degradation and Stability*, **93**, 377-392.

https://doi.org/10.1016/j.polymdegradstab.2010.03.036

[17] Kei, S.C.H. (2010) The Effect of Atmospheric Pressure Plasma on Flame Retardant Property of Cotton. Hong Kong Polytechnic University, Hong Kong (China).

[18] Nguyen, T.M.D., Chang, S., Condon, B., Uchimiya, M. and Fortier, C. (2012) Development of an Environmentally Friendly Halogen Free Phosphorous Nitrogen Bond Flame Retardants for Cotton Fabrics. *Polymers for Advanced Technologies*, **23**, 1555-1563. https://doi.org/10.1002/pat.3029

[19] Hady, A.A.E., Farouk, A. and Sharaf, S. (2013) Flame Retardancy and UV Protection of Cotton Based Fabrics Using Nano ZnO and Polycarboxylic Acids. *Carbohydrate Polymers*, **92**, 400-406. https://doi.org/10.1016/j.carbpol.2012.08.085

[20] Sarvanan, D., Lakshmi, S.N.S., Raja, K.S. and Vasahi, N.S. (2013) Biopolishing of Cotton Fabric with Fungal Cellulose and Its Effect on the Morphology of Cotton Fibres. *Indian Journal of Fibre & Textile Research*, **38**, 156-160.

[21] Salah, S.M. (2012) Antibacterial Activity and UV Protective Property of Some Egyptian Cotton Fabrics Treated with Aquous Extract of Banana Peel. *African Journal of Agricultural*, **6**, 3994-4000.

[22] Kolambe, B.N., Patel, K.K., Pawar, S.L., Patel, J.M., and Prajapati, D.R. (2013) A Novel Organic Fertilizer of Banana Pseudostem. WIPO Patent No. WO 2013/001478 A1.

[23] El-Sayed, M., Mansour, O.Y., Selim, I.Z. and Ibrahim, M.M. (2001) Identifi Cation and Utilisation of Banana Plant Juice and Its Pulping Liquors as Anti-Corrosive Materials. *Journal of Scientific and Industrial Research*, **60**, 738-747.

[24] Neog, S.R. and Deka, C.D. (2013) Salt Substitute from Banana Plant (*Musa Balbiciana colla*). *Journal of Chemical and Pharmaceutical Research*, **5**, 155-159.

[25] Dittrich, B., Wartig, K.-A., Mülhaupt, R. and Schartel, B. (2014) Flame-Retardancy Properties of Intumescent Ammonium Poly(Phosphate) and Mineral Filler Magnesium Hydroxide in Combination with Graphene. *Polymers*, **6**, 2875-2895. https://doi.org/10.3390/polym6112875

[26] Liu, S.M., Huang, J.Y., Jiang, Z.J., Zhang, C., Zhao, J.Q. and Chen, J. (2010) Flame retardance and Mechanical Properties of a Polyamide 6/Polyethylene/Surface-Modified Metal Hydroxide Ternary Composite via a Master-Batch Method. *Journal of Applied Polymer Science*, **117**, 3370-3378. https://doi.org/10.1002/app.32086

[27] Kubo, S. and Kadla, J.F. (2003) The Formation of Strong Intermolecular Interactions in Immiscible Blends of Poly(vinyl alcohol) (PVA) and Lignin. *Biomacromolecules*, **4**, 561-567. https://doi.org/10.1021/bm025727p

[28] Mostashari, S.M. and Mostashari, S.Z. (2009) Thermogravimetry of Deposited Ammonium Aluminium Sulphate Dodecahydrate Used as Flame Retardant for Cotton Fabrics. *Cellulose Chemistry and Technology*, **43**, 455-460.

[29] Shen, Y.M., Kuan, C.-F., Kuan, H.-C., Chen, C.-H., Wang, J.-H., Yip, M.-C., *et al.* (2013) Preparation, Characterization, Thermal, and Flame Retardant Properties of Green Silicon Containing Epoxy Functionalized Grapheme Nanosheets Composites. *Journal of Nanomaterials*, **2013**, Article ID: 747963. https://doi.org/10.1155/2013/747963

[30] Xing, T.L., Liu, J., Li, S.W. and Chen, G.Q. (2012) Thermal Properties of Flame Retardant Cotton Fabric Grafted by Dimethyl Methacryloyloxyethyl Phosphate. *Thermal Science*, **16**, 1472-1475. https://doi.org/10.2298/TSCI1205472X

[31] Karastergiou, P.S. and Philippou, J.L. (2000) Thermogravimetric Analysis of Fire Retardant Treated Particle Boards. *Wood and Fire Safety*, Thessaloniki, 385-394.

[32] Miller, A.F. and Wilkins, H.C. (1952) Infrared Spectra and Characteristic Frequencies of Inorganic Ions. *Analytical Chemistry*, **24**, 1253-1294. https://doi.org/10.1021/ac60068a007

[33] Cilurzo, F., Selmin, F., Minghetti, P. and Montanari, L. (2005) The Effects of Bivalent Inorganic Salts on the Mucoadhesive Performance of a Polymethylmethacrylate Sodium Salt. *International Journal of Pharmaceutics*, **301**, 62-70. https://doi.org/10.1016/j.ijpharm.2005.05.029