DEVELOPMENT AND CHARACTERIZATION OF COTTON FLAME-RETARDANT TEXTILES USING ADDITIVES MADE FROM ANIMAL BONES

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ISSN: (Print) (Online) Journal homepage: https://journals.bdu.edu.et/index.php/ejta

To cite this article: Ahmed Mohammed Nuru, Miftah Aragie Yeshaw (2025) DEVELOPMENT and CHARACTERIZATION of COTTON FLAME-RETARDANT TEXTILES USING ADDITIVES MADE from ANIMAL BONES, Ethiopian Journal of Textile and Apparel, 22-35, DOI: https://journals.bdu.edu.et/index.php/ejta

Development and Characterization of Cotton Flame-Retardant Textiles Using Additives Made from Animal Bones

BY

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ABSTRACT

This study investigates the use of animal bone-derived compounds used as sustainable flame-retardant agents. The study used Kombolcha Meat Industry's automatic machine to grind cleaned bones into a fine powder, then sieved to remove larger particles. Mini tab of Taguchi was used to analyze fabric FR efficiency and durability. Nano bone powder was applied to cotton fabric using the conventional pad-dry-cure method with a dispersion agent (Triton x-100) and a binder (Printofix S New, styrene acrylic copolymer) as a binder. Standardized fire testing procedures, including vertical flammability tests, limiting oxygen index (LOI), and thermal stability analysis, are used to evaluate flame-retardant behaviourof the fabric after they have been chemically treated with components derived from animal bones. To guarantee the usefulness of the treated fabrics in daily applications, their mechanical qualities, softness, and general durability are also assessed. Additional bands were detected in the FTIR spectrum at 1720 cm-1 (C=O str.) and 1258 cm-1 (P=O str.), as well as 1078 cm-1 phosphorus-based polymer produced on cotton fabric. Thermal behaviour in nitrogen atmosphere was also investigated and it was found that at 10%, 15%, and 20% bone powder concentrations, respectively, the char yield increases by 18.78%, 33.78%, and 45.39% at 600ºC and the onset temperature of deterioration of treated cotton fabric falls by 37ºC. The auto flammability test at 45 degrees showed that treated cotton fabric self-extinguishes after 18.2 seconds, contrasting with untreated fabric that burns the entire 15 cm sample length.

Key words: cotton fabric, animal bone, flame retardant, binder

1. INTRODUCTION

Cotton fabric is a popular natural cellulosic raw material in the textile industry due to its biodegradability, strength, water absorbency, moisture content, comfort, non-toxicity, and ease of colour retention [1, 2]. However, it has inherent constraints such as wrinkle formation, shrinkage, microbial deterioration, and high flammability, which limit its potential application. Cotton fabrics are highly combustible due to their low limiting oxygen index (LOI), low onset ignition temperature, and rich source of hydrocarbon fuel during combustion. To ensure human safety, fire-retardant agents are used to reduce the flammability of the material. As a result, the demand for flame retardant fibers and fabrics is increasing to comply with the time-to-time changes in these regulations (Kamath, 2009). Flame-retardant chemicals interfere with combustion components, such as heat, fuel, and oxygen. Melamine fibers act as heat sinks, nitrogen dilutes vapor, and act as a barrier between air and fuel. Bromine forms a protective layer, but toxic after burning. Metal hydroxides quench fires but not in fibers. Phosphorous compounds cause charging and reduce fuel for fire [3, 7].

Researchers have been focusing on developing functional and sustainable textiles to address fire safety concerns. Halogenated flame retardant systems are the most effective and widely used, but some are persistent, bio accumulative, potentially toxic, and environmentally harmful. Green flame-retardant chemicals, such as phosphorus and/or nitrogen, have been the most promising development [5, 8].

Various flame retardants have been developed to modify the flammability of cotton fabrics, including halogen-containing, phosphorus-containing, nitrogen-containing, sulphur-containing, boric-containing, metal hydroxides, and intumescent flame retardants [4, 11]. However, these flame retardants still cannot meet the requirements of halogen-free, formaldehyde-free, efficient, and durable. This research aims to find alternative, non-toxic, non-synthetic, cheap, and indigenous fire-retardant materials. Animal bone powder, an agricultural by-product, is used as a natural fire retardant due to its phosphorus content, which resists high temperatures and is environmentally friendly. This approach reduces environmental pollution and costs associated with waste disposal and imported flame-retardant fabrics. By converting animal bone waste into a fire retardant, this research aims to create a more sustainable and eco-friendly alternative [9].

2. METHODOLOGY

The methodological approach for this study contains two phases. Firstly, develop and characterize biodegradable natural polymer that can be used as a flame retardant agent for cotton fabric. Secondary applied the extracted flame retardant agent on cotton fabric by pad-dry-cure method and evaluated the performance of the extracted flame retardant agent, the physical and mechanical characteristics of the treated fabric.

2.1. MATERIALS AND CHEMICALS

100% cotton fabric which has specification of 46picks/inch, 44ends/inch and 132 GSM was sourced from kombolcha textile Share Company. The chemicals used for these study was Binder, Dispersing agents, Softener UNISIL NLP-W (Polydimethyl Siloxane and Animal bone powder.

2.2. EQUIPMENT'S AND MACHINERY

Equipment's used for the study were Stoves, Scissor, Electronic Balancing, Beakers, PH meters, Pipettes, TGA instrument, sample padding machine, oven dryer, 45^{o}flammability test instrument, scissors, Mini Dryer and FITR.

2.3. PREPARATION OF BONE-BASED ADDITIVES

The animal bones were cleaned, ground, and subjected to a chemical extraction process to obtain flame-retardant compounds. The extraction processes were performed by the following experimental methods.

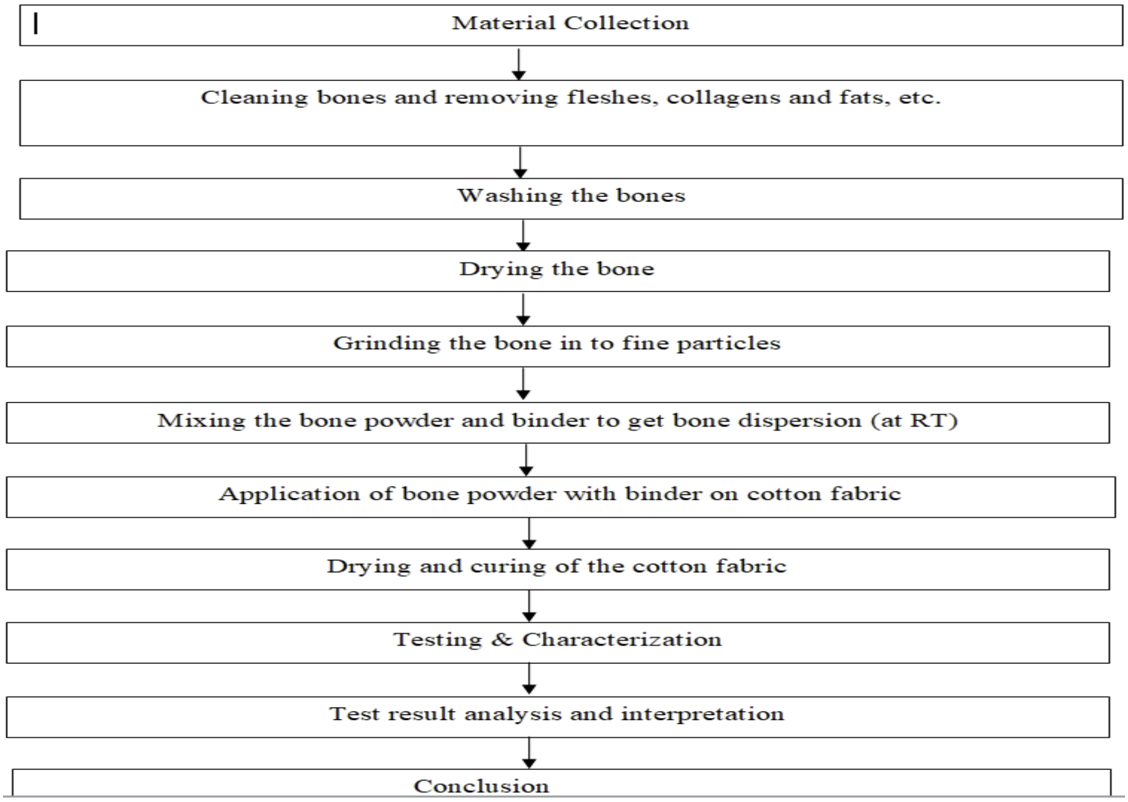

Fig.1: Experimental flow chart

2.3.1. BONE COLLECTION

The cattle bones were obtained from Kombolcha meat industry found in South Wollo, Kombolcha city administration to get cattle bone powder from the pure bones.

2.3.2. CLEANING OF BONE

After collection of cattle bones, bones were sliced by stainless steel knife. Then sliced bones were washed with hot water containing little amount of standard laboratory detergent in order to remove the fleshes, collagens, bloods, bone marrows and fats. After thorough cleaning of bones, they were dried/ sterilized by using UV radiations and in autoclave at 122^{o}C for about 2 hours to obtain pure dried bones free from any bacteria, fungi and germs.

2.3.3. GRINDING OF BONE

The cleaned and dried bone samples were in the form of larger particles that cannot be applied to fabric. Therefore, cleaned and dried bones were grinded in automatic bone grinding machine available in Kombolcha Meat Industry. Further, to get very fine bone powder again the coarser bone powder was grinded using mechanical seed and coffee grinding machine. Finally, the fine bone powder was sieved using required mesh sized sieve.

2.3.4.INVESTIGATION OF PARTICLE SIZE

The particle sizes were investigated through re -grinding the solid particle size obtained above by using automatic bone grinding machine and mechanical seed grinding machine and fine powder were obtained in different particle sizes by using sieve analyzer in Wollo university chemical engineering department.

2.4.PREPARATION OF BONE POWDER DISPERSION AND APPLICATION TO COTTON FABRIC

2.4.1.PREPARATION OF BONE POWDER DISPERSION

The bone powder dispersion is created by processing animal bones to produce fine particles that can be suspended in a liquid medium for easy application onto fabrics. The preparation steps and components are listed as follows.

Table1: Preparation of bone powder dispersion

Material	unit	Amount	
Fabric length	Cm	20	
Distilled water	ml	69.8 , 64.8, 59.8	Preparation of bone powder dispersion
Animal bone powder	g	10 , 15 , 20	Used as flame retardant chemical (agent)
Binder Printofix S New (styrene	ml	15 ,20 ,25	Binding FR material to the fabric
Dispersing agent (Triton x-100)	ml	0.2	Used to uniformly disperse FR chemical in to the water/to develop separation of particles and to prevent bone powder from clumping or settling.
Standard Detergent	ml		For washing
Curing Temperature	ºC	150 ºC	For fixation
Time of drying	min	4	To remove water content
Time of curing	min	10	
M:L		1:10	To determine the solution

The bone powder was dispersed in water in the presence of dispersing agent (Triton X-100) and binding agent (binder) by thoroughly agitating or mixing each components in the beaker for about 5-10 minutes. The dispersion should be mixed thoroughly using a homogenizer or ultrasonic processor to break down agglomerates and ensure that the particles are well distributed in the liquid. This helps to prevent clumping of the bone particles and ensures an even distribution in the liquid medium.

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2.4.2.APPLICATION BONE POWDER DISPERSION TO COTTON FABRIC

The cotton fabric was passed through the bone powder dispersion in a padding machine, slowly at 0.5m/min to get sufficient residence time to imbibe chemicals into the fiber and then passed through press rolls at 0.5 bar pressure then dried at 80^{o}C for 4 min to remove the water content and cured at 150^{o}C for 10 minutes in the mini oven dryer.

2.5. SOFTENING TREATMENT

Flame retardant treatments can make fabric feel stiff, crisp, or rough, which can reduce the overall comfort of the material. Thus, to improve its handle and to give pleasing touch the FR treated fabrics were further treated by using silicon softener (Polydimethyl siloxane).

The softening treatment was given using pad-dry- cure method. The concentrations of softener were used 20 gpl. The pH of the solution was maintained at 5.5 using acetic acid. The treated samples were padded at constant pressure. The curing temperature was maintained at 150ºC for 60 Sec [6].

2.6.EXPERIMENTAL DESIGN

Mini tab of Taguchi was used to decide the number of runs, level of design and number of factors and achieve optimum tests and the significance of all tested samples. There are two independent factors that affect the FR efficiency and durability. These are amount of binder and bone powder concentration each with three levels and three replications. The response is FR tests and fabric physical test results.

Table2: Experimental design for testing

Taguchi Design

Design Summary

Taguchi Array L9(3^2)
Factors: 2
Runs: 9

Columns of L9(3^4) array: 1 2

+	C1 Bone concentration (g)	C2 Binder amount (ml)	C3 Tensile strength (N)	C4 Bending length (cm)	C5 Shrinkage %
1	10	15			
2	10	20			
3	10	25			
4	15	15			
5	15	20			
6	15	25			
7	20	15			
8	20	20			
9	20	25			

In this research the level of design were 3 and the number of factors were 2 (cattle bone powder concentration and amount of Binder).

Based on the above experimental design, after padding the fabric through pad bath containing required additives, fabrics were dried and cured. The cross laying or fixing of animal bone dispersion was carried out by the binder to produce the flame-retardant cotton fabric samples. The feed speed and number of dips of the padding were arranged 0.5m/min and 3 dip 3 nips respectively to get the required add-on and fixing levels accordingly. The individual and interaction effects of the major parameters such as concentration ratios of animal bone powder and binder amount on the flame-retardant properties of the cotton fabric were analyzed by using ANOVA in the design of experiment.

2.7. CHARACTERIZATION AND EVALUATION PARAMETERS

Treated and Untreated cotton fabrics were evaluated with respect to Flame Retardancy and Mechanical Properties of the fabric. Vertical flame spread test (ASTM D1230), Limiting Oxygen Index (LOI), and thermal degradation analysis (TGA) were conducted to evaluate the flame-retardant properties. On the other category bending length, Tensile strength and tear resistance tests (ASTM D5034) were carried out to assess the effect of the treatment on the physical properties of fabric. All testing parameters were performed at standard atmospheric conditions.

2.7.1.TENSILE STRENGTH TEST

This test measures the mechanical properties of fabric by using dynamometer based on the strip test method of ASTM D751. Strip test is a tensile test in which the full width of the test specimen is gripped in the tensile grip jaws of testing machine. Rectangular specimens of dimension 50 mm × 650 mm were cut from sample, three specimens were cut with the length parallel to the warp and three more with length parallel to weft and then gripped the specimen between the two jaws then, tensile force is applied on the fabric specimen until it ruptures and Finally, the maximum force at break in newton and elongation were recorded.

2.7.2.SHRINKAGE TEST

This taste was done by plotting 10 cm × 10 cm rectangle on the fabric before treatment. Then this rectangle was measured again after treatment is given based on ASTM D7983-17 standards. The area difference was calculated and the shrinkage was expressed in percentage. Untreated fabric samples were prepared with the dimension 15 cm × 15 cm. 10 cm × 10 cm box was plotted on each sample. The flame-retardant finish was applied on all the samples by pad-batch- dry method. Then the previously plotted box dimension was measured again. Finally, the shrinkage was calculated by area difference in percentage.

2.7.3. FABRIC BENDING LENGTH TEST

This test measures the bending stiffness of a fabric by allowing a narrow strip of the fabric to bend to a fixed angle under its own weight based on ASTM D1388-08 Standards. Rectangular specimens of dimension 25 mm × 200 mm were cut from sample; three specimens were cut with the length parallel to the warp and three more with length parallel to weft. The specimens were placed on the platform with one end coincident with the front upper edge of the platform. The slide was placed on the specimen so that the zero of the scale is in line with the notch. The slidewas pushed forward at a uniform rate, carrying the specimen with it, until by looking in the mirror it is seen that the end edge of the specimen is in line with the two scribed lines at 41.50 to the horizontal. The procedure was repeated with the other side up and again at the other end of the specimen. The same procedure was done for samples in the weft way.

2.7.4.FTIR ANALYSIS

Fourier transform infrared spectroscopy (FTIR) was used to identify and characterize the important functional groups present in untreated and flame retardant treated cotton fabrics. FTIR spectra were carried out using the KBr pellet testing techniques on Shimadzu IR affinity-I 8000 FTIR spectrometer in the range 4000-400 cm-1 for 15 scans with a resolution of 4 cm-1.

2.7.5. THERMOGRAVIMETRICANALYSIS

The thermogravimetry (TG) of untreated cotton fabric (UCF), treated cotton fabric (TCF10%), treated cotton fabric (TCF15%) and treated cotton fabric (TCF20%) were performed using TA instruments DSCQ10 (Differential Calorimeter Thermal Analyzer) by taking about 10 mg of samples in alumina crucibles under continuous nitrogen flow of 100 ml min-1 from ambient temperature to 700°C at a heating rate of 10ºC min-1.

2.7.6.FLAMMABILITY TEST

The burning behavior of cotton fabric samples was studied using the 45° automatic flammability tester according to Standard Test Method for Flammability of Apparel Textiles, ASTM D1230-94. In this study, the ignition time was set at 10 s. The experiments were carried out at the ambient temperature of 30°C. The fabric sample was dried at 105°C in an oven for 30 min, cooled down in a desiccator for 15 min and then mounted in a frame and held at an angle of 45°. This test measures the time required for flame to propagate through the length of the fabric and ease of ignition. The specimen (15 cm × 5 cm) was then exposed to flame and then burning time and burning characteristics were recorded.

3. RESULTS AND DISCUSSION

3.1. FLAMERETARDANCY PERFORMANCE

The flame retardant performance of treated fabric involves testing its ability to resist ignition, slow down flame spread, and reduce the risk of burning. The treated cotton fabrics demonstrated significant improvements in flame retardancy. The results showed that different fire propagation resistance or it reduces fire flammability than untreated sample fabric. From this test a maximum of 14.1 cm fabric can be saved from 15cm fabric without burning after treatment.

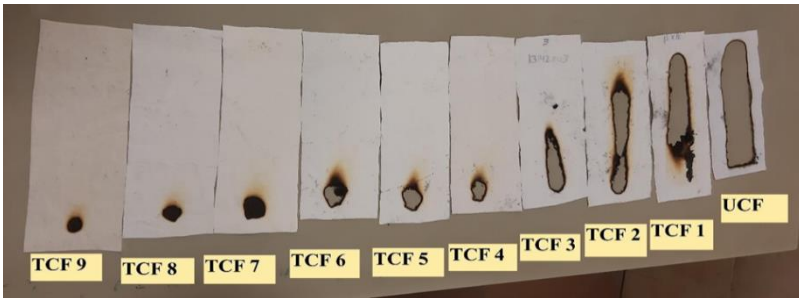

Fig 2: Burning Behavior of Untreated and Treated Cotton Fabric

The above fig. showed that there was a reduction of flammability by using 45^0 flammability tests from untreated cotton fabric (UCF) up to treated cotton fabric code 9 (TCF 9).

Table 3: Fire retardancy performance test results of UCF and TCF

Sample Code	Bone powder concentration (g)	Binder amount (ml)	Sample Length	Flame spread time (s)	Char length (cm)
UCF	-	-	15 cm	18.2	BL

TCF1	10	15	15 cm	60.5	BL
TCF2	10	20	15 cm	73.8	BL
TCF3	10	25	15 cm	99	BL
TCF4	15	15	15 cm	DNI	2.5cm
TCF5	15	20	15 cm	DNI	2.2cm
TCF6	15	25	15 cm	DNI	2cm
TCF7	20	15	15 cm	DNI	1.2cm
TCF8	20	20	15 cm	DNI	1.5cm
TCF9	20	25	15 cm	DNI	0.9cm

DNI-Did not ignite, BL-Burn the entire length

As shown fig.1 sample code TCF 4-6 was treated with medium solution concentration. These treated sample fabrics have low fire propagation or it reduces fire flammability as compared to the fabric which was treated at low concentration of bone powder (sample code TCF 1-3).

Sample code TCF 7-9 has very low fire propagation or expansion and low flammability. The fabric sample treated with high concentration of bone powder showed higher flame-retardant property than the fabric treated at low and medium concentrations of bone powder. Untreated sample fabric has no any fire retardance; its flammability is more from the nine sample tests.

Table 4: Flame retardant performance observations

Sample code	**Bone concentration (g)**	**Binder amount (ml)**	**Flame Propagation**	**Residue**
UCF	-	-	Rapid fire	Ash
TCF1	10	15	Slow fire	Ash and char
TCF2	10	20	Slow fire	Ash and char
TCF3	10	25	Slow fire	Ash and char
TCF4	15	15	Very slow fire	Char
TCF5	15	20	Very slow fire	Char
TCF6	15	25	Very slow fire	Char
TCF7	20	15	Reduced fire	Char
TCF8	20	20	Reduced fire	Char
TCF9	20	25	Reduced fire	Char

The study reveals that the amount of bone powder used in fire-retardant cotton fabric reduces flame propagation, producing ash and char at low concentrations. Char is produced at medium and high concentrations. The fabric treated with different concentrations of bone powder showed different fire-propagation resistance. High concentrations resulted in more reduction of fire flammability, while medium concentrations reduced flammability. Low concentrations also reduced fire flammability. The fabric's flammability is reduced when bone powder is mixed with organic binder, ensuring good durability.

Table 5: Fire Retardance Performance Before and after washing

Sample Name	Bone powder concentration (g)	Binder conc. (g)	Sample Length	TCF before hand laundering		TCF After hand laundering	
				Flame spread time (s)	Char length (cm)	Flame spread time (s)	Char length (cm)
TCF1	10	15	15 cm	60.5	BL	28.9	BL
TCF2	10	20	15 cm	73.8	BL	31.7	BL
TCF3	10	25	15 cm	99	BL	32.3	BL
TCF4	15	15	15 cm	DNI	2.5cm	63.8	BL
TCF5	15	20	15 cm	DNI	2.2cm	71.9	BL
TCF6	15	25	15 cm	DNI	2cm	DNI	4.1
TCF7	20	15	15 cm	DNI	1.2cm	DNI	4.7
TCF8	20	20	15 cm	DNI	1.5cm	DNI	3.3
TCF9	20	25	15 cm	DNI	0.9cm	DNI	2.6

From the test result in Table5, it was observed that flame spread time of the treated cotton fabric before washing were higher and treated cotton fabric after hand laundering exhibited the lower flame spread time. The reason of showing lower flame spread time of TCF after hand laundering was due to the removal of flame-retardant chemicals (animal bone powder) during washing.

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3.2. THERMO GRAVIMETRIC ANALYSIS

Thermogravimetric Analysis (TGA) is a powerful technique used to assess the thermal stability and decomposition behaviour of materials, including flame-retardant treated fabrics. In this test, the fabric is subjected to a controlled temperature program, and its weight loss is monitored as a function of temperature. TGA can provide valuable insights into the degradation behaviour of flame retardant-treated fabrics and the effectiveness of the flame retardant treatment

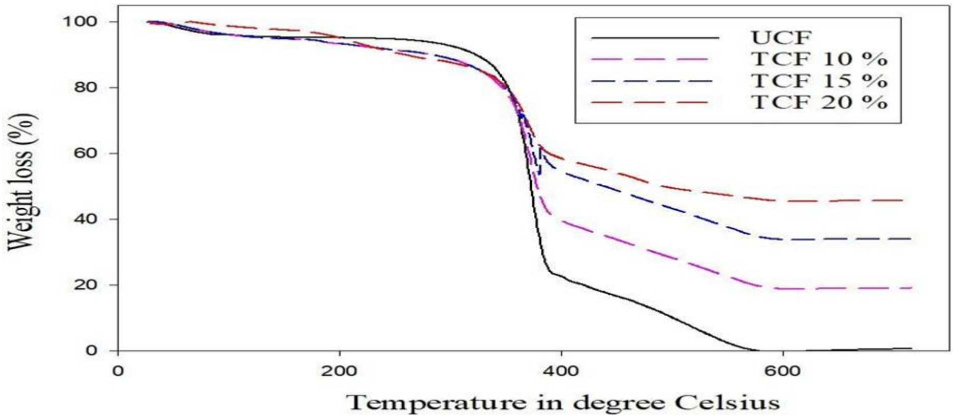

Fig.3: Thermo gravimetric Analysis result

The study investigates the thermal degradation of untreated cotton fabric (UCF) and treated cotton fabric at different concentrations of bone powder. UCF undergoes a single stage of thermal degradation, resulting in weight loss and the formation of volatile products like levoglucosan. TCF undergoes two phases of thermal degradation at different concentrations, with initial weight loss occurring at different temperatures. The study also found that phosphoric acid releases acid-catalyzed dehydration, lowering the onset temperature of TCF.

3.3.FTIRANALYSIS

The flame retardant finishing of cotton fabric samples were determined by an FTIR analysis. Like a fingerprint no two unique molecular structures produce the same infrared spectrum.

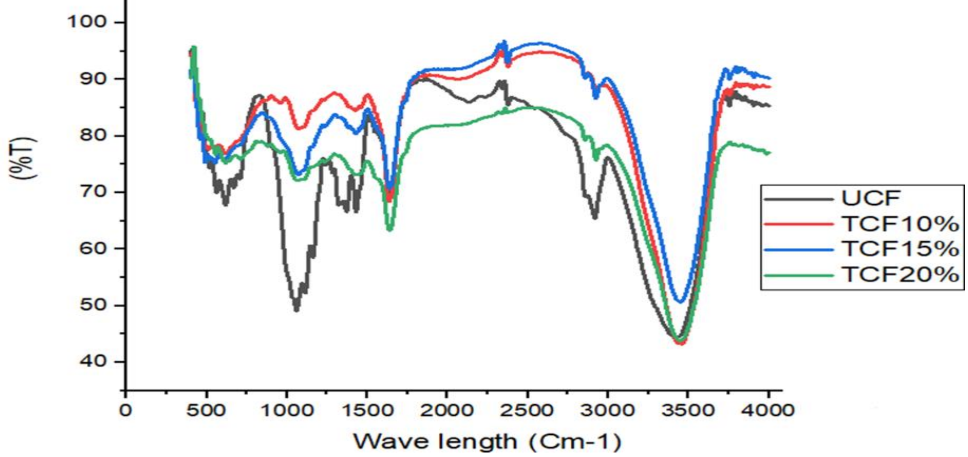

Fig.4: FTIR Curves of important functional groups

Both untreated (UCF) and treated cotton fabric (TCF) have been described using FTIR spectra. UCF's spectrum includes the following bands: O-H str. (3422 cm-1), C-H str. (2902 cm-1), CH2 symmetrical bending (1434 cm-1), C-H and O-H bending (1319 cm-1), C-O-C antisymm. str. (1157 cm-1), and C-O str. (1035 cm-1). These are characteristics band of cellulose (Olsson & Salmén, 2004). In TCF, additional bands at 1720 cm-1 (C=O str.), 1258 cm-1 (P=O str.) and 1078 cm-1 (P – – O – – C str.) are seen. These additional bands indicate that a layer of phosphorus-based compound is formed on cotton fabric.

3.4. EVALUATE THE PHYSICAL PROPERTIES OF TREATED FABRIC

3.4.1.SHRINKAGE TEST

Shrinkage testing of flame retardant-treated cotton fabric is important to assess how much the fabric will reduce in size when subjected to flame. This is critical for flame-retardant treated fabrics, as the treatment may affect the fabric’s dimensional stability. Shrinkage can be caused by the mechanical stress of washing, temperature, or chemical treatments.

Table6: Shrinkage test results

Sample code	Original area (cm^2)	Area After Treatment (cm^2)	Shrinkage (%)
TCF1	100	97.08	2.92
TCF2	100	97.01	2.99
TCF3	100	96.90	3.1
TCF4	100	96.81	3.19
TCF5	100	96.63	3.37
TCF6	100	96.45	3.55
TCF7	100	95.5	4.5
TCF8	100	95.04	4.96
TCF9	100	95.06	4.94

As showed on the table a slight shrinkage is observed on the samples after treatment. But this is the most noticeable effect on many other finishes and chemical treatments of cotton.

3.4.2.FABRIC BENDING LENGTH TEST

Bending length is a measure of the flexibility or stiffness of a fabric. It quantifies how easily a fabric bends when subjected to a force and is an important characteristic to evaluate, particularly for flame retardant (FR) treated fabrics, as the treatment can affect the fabric's flexibility. A fabric with higher bending length tends to be stiffer, while a fabric with a lower bending length is more flexible.

Table7: Effect of flame retardant treatment on bending length of the fabric

Sample code	Bending Length (cm)			
	Before FR treatment		After FR treatment	
	Warp	Weft	Warp	Weft
TCF1	3	2.7	3.2	2.9
TCF2	3	2.8	3.3	3.1
TCF3	2.8	2.6	3.3	2.9
TCF4	3.1	2.5	3.6	3.2
TCF5	2.9	2.6	3.5	3
TCF6	3	2.9	3.7	3.1
TCF7	3.2	2.7	4	3.2
TCF8	3	2.8	4.1	3.3
TCF9	3	2.6	4.4	3.5

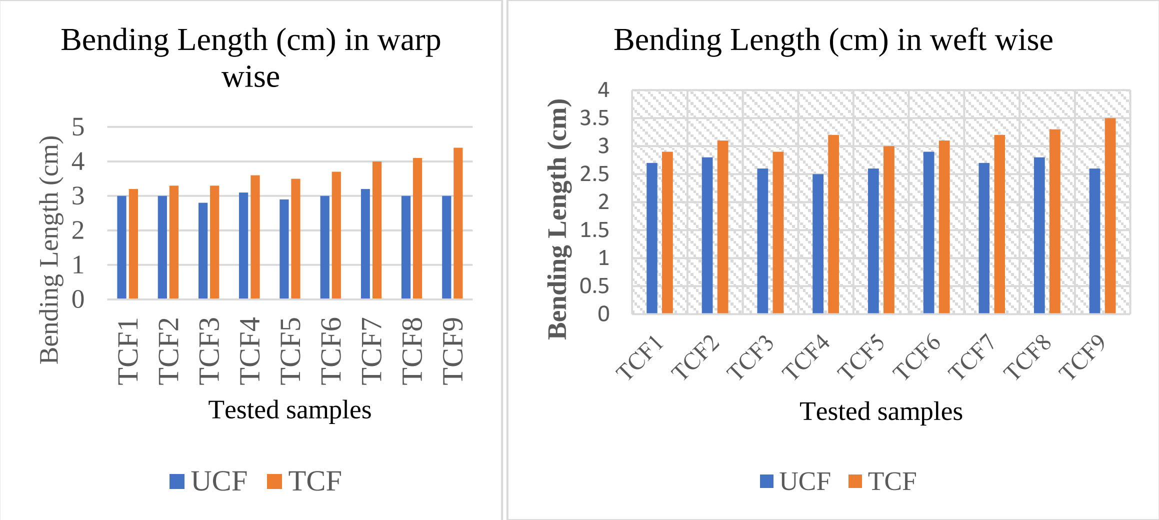

Fig.5: Bending length (cm) results of both untreated and flame treated cotton fabrics

From fig.5, it is observed that the bending length (Stiffness) of FR treated samples significantly increased as compared to untreated cotton fabric stiffness in both warp and weft wise directions respectively. These results revealed that the mechanical properties change as a result of flame retardant treatments. Also, results from table and figures above indicated that the stiffness of FR treated samples increases as the bone and binder concentration percentage increases.

Table 8: Fabric stiffness test result of TCF before and after hand laundering (HL)

Sample code	**Bending Length (cm)**			
	TCF before HL		TCF after HL	
	Warp	Weft	Warp	Weft
TCF1	3.2	2.9	3.2	2.9
TCF2	3.3	3.1	3.2	3.0
TCF3	3.3	2.9	3.1	2.8
TCF4	3.6	3.2	3.5	2.9
TCF5	3.5	3	3.3	3.0
TCF6	3.7	3.1	3.4	3.0
TCF7	4	3.2	3.7	3.1
TCF8	4.1	3.3	3.8	3.2
TCF9	4.4	3.5	4.1	3.3

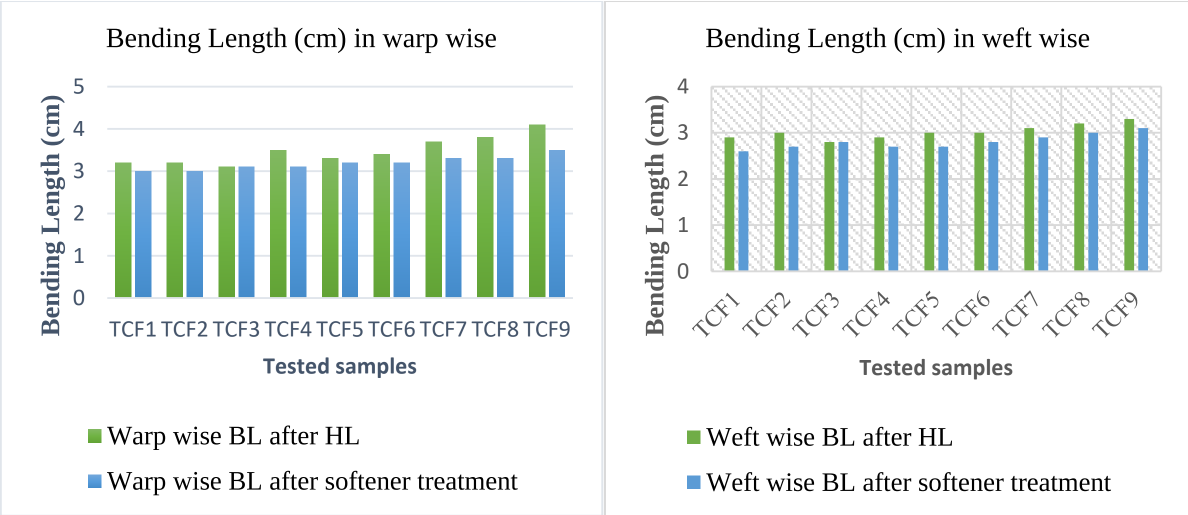

Fig6: Bending Length (cm) of TCF after hand laundering and after softener treatment

It is observed from fig 6, even after softener treatment, FR treated fabrics had higher bending length compared to untreated samples but when compared to bending length of treated cotton fabrics before softener treatments, it had lower bending lengths in both warp and weft wise directions and this showed that treatment of flame treated cotton fabrics with softener reduces the stiffness of the fabrics and improved its handle and gave pleasing touch in both warp and weft wise directions.

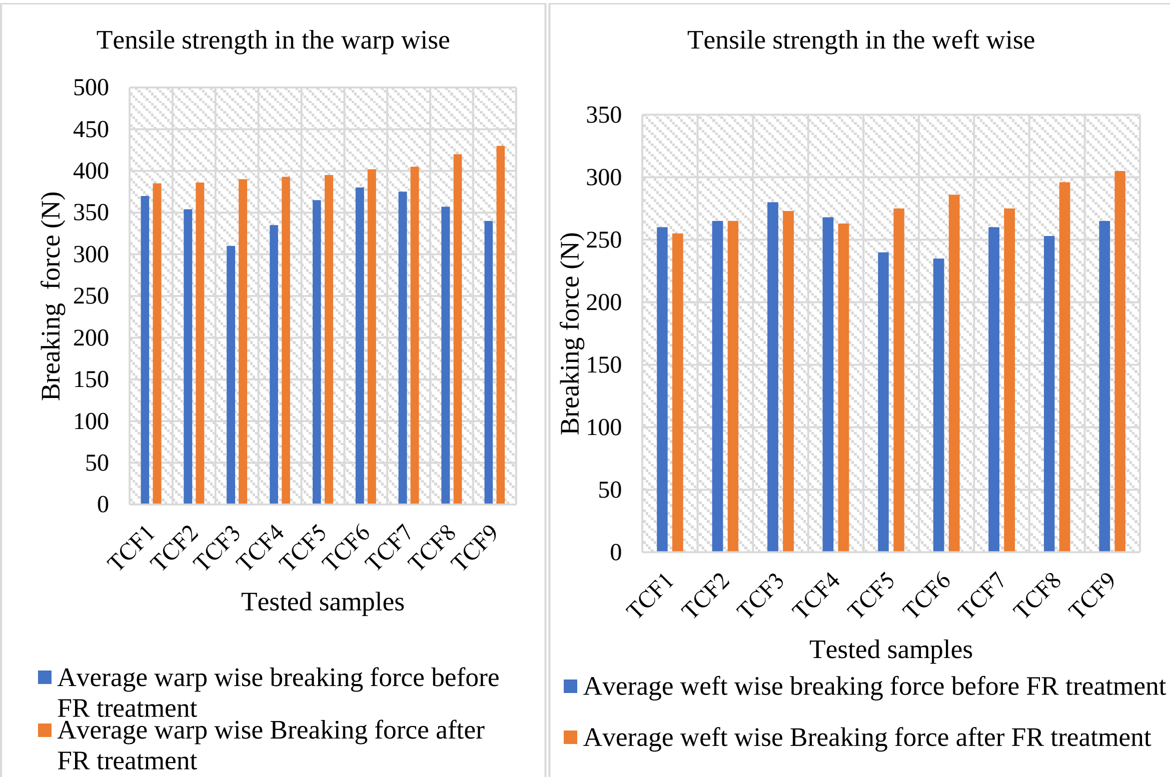

Fig7: Warp and weft Wise tensile strength of cotton fabric before and after FR treatment

As fig7 showed that the treated cotton fabric tensile strength increases as compared to untreated cotton fabric in both warp and weft sides of the fabrics, this indicates that there is little alteration in tensile strength after FR treatment besides the flame retardancy due to the binding effects of binders along the warp and weft sides of the fabric.

4. Conclusion

This study investigated the potential of using animal bone powder as a flame retardant for cotton fabric, with a view to understand if it can be a better alternative to the existing synthetic chemical based flame retardants. It can be concluded that it is definitely possible to produce flame retardant cotton fabric by using animal bone powder. By using animal bone powder, it is possible to produce fire retardant fabric for different applications with different concentrations. Different bone powder concentration showed different fire or flame retardant results. The higher concentration of bone powder showed better flame retardant properties. While burning animal bone powder treated fabric forms ash and char, but untreated fabric forms only ash.

FTIR indicate the presence of phosphorous based polymer layer on cotton fabric. In TG study, the onset temperature of degradation of treated cotton fabric is decreased by 37 ºC in comparison to untreated cotton fabric due to acid catalyzed dehydration by phosphoric acid released from decomposition of phosphorous based flame retardant. The char yield was increased by 18.78%, 33.78% and 45.39% at 600 ºC in inert atmosphere for treated cotton fabric at 10%, 15% and 20% bone concentrations, respectively as compared to untreated cotton fabric. The 45o auto flammability test showed that treated cotton fabric with animal bone concentration of 15% and 20% found self-extinguishes and also durable up to two hand laundering.

The amount of flame retardant required depends primarily on fabric type and application conditions. For different application we can use different concentrations of bone powder. The results of tensile strength of treated fabric showed there was no degradation of the fabric. The treated fabric gave slight shrinkage of the fabric, but this is the most noticeable effect on many other finishes and chemical treatments of cotton. The stiffness property of the fabric was increased. Generally animal bone treated cotton fabric used as flame retardant material for different application such as ceiling (roofing), carpet, tents and aprons for people who wear working in the welding and kitchen areas, etc.

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