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Producing Fire Retardant Cotton Fabric Using Chicken Eggshell

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Abstract

Cotton has poor fire retardance characteristics. As a result, the textile material is not recommended in areas of fire risks though it has high comfort factor that make preferable for wearing purpose; therefore, imparting fire retardance is must to cotton. This research focuses on producing fire retardant cotton fabric using chicken eggshell to replace synthetic fire-retardant chemicals. Chicken eggshell contains fire-retardant mineral such as calcium carbonate, phosphorous, nitrous, potassium and zinc. Imparting fire retardance using synthetic chemicals has many limitations; toxicity, environmental hazards, non-biodegradable, non-renewable source and cost. On the other side chicken eggshell being bio-product has not any side effects since it occurs in nature abundantly. In most cases the chicken eggshell is removed after usage or hatching causing a big environmental pollution in appearance as well as in odour. Conversion of such wastes to treasure has a dual benefit in preventing cotton from burning extension and using the eggshell wastes for valuable treatment process. Treated fabric using chicken eggshell showed low flammability than untreated. In addition, the treated fabric formed ash and char, whereas untreated fabric produced only ash and got totally burn. The fire propagations were 40 and 1.4 mm per second for untreated and treated fabrics respectively.

Keywords: Bio-product; Chicken eggshell; Cotton; Fire retardant; Waste

Introduction

Initially, flame-retardant materials were created around 400 BC. But the need of them does not increase drastically until the 17th century in 1632 the idea of reducing the risk of the fire in threat red came about in Paris. The process of increasing flame retardant materials such as fire proofed plaster and clay began [1].

If human's intervened with chemistry to treat naturally flammable fibers, they could present potential harm from them on the process of making things flame retardant snow balled in the 18th century Alum and Ammonium were used to make fabrics flame resistant. The first serious experiments took place in 1820. A chemist named Gay Lussac determined that two types of salt make fabrics flame resistant the first salt was low melting and formed glassy layer on fabrics and the second salt broken down into 2 flammable vapours when it was heated up [2-4]. This was yet another step toward making today's textiles flame resistant. By the 20th century, other scientists perfected the same method by incorporating Stannic Oxide into fabric to make them flame retardant. Stannic Oxide is also known as tin oxide is an off white powdery product that's produced thermally from high-grade tin metal [2]. These techniques were used to make natural fibers fire resistant once synthetic materials started dominating the cotton market. However cotton producers needed to come up with a better way to promote their products or they have to call it quits. Advanced technologies of the 20th century scientists start the process of chemical modifying of the cellulose molecules on both the surfaces and within cotton fibers [3]. To keep these special process commercially available scientists needed to work hard to find a chemical combination that still kept the cotton's strength and durability without being too expensive. The discovery of Tetra (hydroxyl methyl) Phosphonium Chloride (THPC) advanced the process of making fabric resistant to flames THPC could be applied to cotton, a paper, plaster paint furniture and often building materials [4]. Over time research continued to improve the way THPC was utilized [5]. The flammable fabrics act of 1953 changed how clothes were manufactured and sold. Clothing could not be made from dangerously flammable textiles anymore and before they could even be sold [6]. The articles of clothing needed to pass consumer products safety.

The eggshell fire retardant study was carried out to develop intumescent flame retardant coating that incorporate Chicken Eggshell (CES) waste as novel eco-friendly bio-fillers. Three flame retardant additives ammonium polyphosphate Pentaerythritol and Melamine were mixed with flame retardant fillers and acrylic binder to synthesize the intumescent coatings [7]. The fire performance of the coatings was evaluated in accordance with fire propagation and surface speed of flame test standards was found that 4 out of 5 of the coats specimens neither showed surface spread of flame nor any afterglow composition up on fire exposure addition of 5.0wt. % and 2wt% eggshell bio-filler in to formulation of improved fire protection due to char formation with better morphology, and strength of the protecting shield. The chicken eggshell applied at a thickness of 1.5 ± 0.2 mm achieved the lowest fire propagation index with value of 4.5 and 5.0 respectively materials which indicates excellent fire stopping properties [8]. Chicken eggshell has proved to be efficient in the protection of plywood against fire.

Chemical fire retardants help delay or prevent composition, but there is potential health and environment toxicity, and human health related problems such as allergic, skin irritation etc. During these chemicals applied on fabrics as fire retardant material and worn by human being. In addition to this production of those chemicals are expensive and increase costs to use them as fire retardant and also chemicals such as Urea and DAP are used as land fertilizer [9]. Because of these problems harms of chemical fire retardants need to be weight up against the benefits. There is concern that the production of synthetic

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chemical fire retardants can results in risk to human health and the environment studies shows that some toxic chemicals have been found in human tissue and in the environment where the chemicals are produced. Their concern is about human contact during the production of the chemicals and over the disposal of waste products [10]. Some of the chemicals are: Aziridinlyphosphate Oxide (APO), UREA, DAP, Hydroxyl Phosphonium and other synthetic fire retardant chemicals.

Therefore it is important to see alternative natural or non-synthetic fire retardant materials. Chicken eggshell was used as natural fire retardant because it contains most minerals such as calcium carbonate phosphorous, potassium, and others that can impart retardance. Many studies have proved that chicken eggshell is an agriculture by-product that has been listed worldwide as one of worst environmental problems, especially in those countries where the egg product industry is well developed [11]. Converting such wastes to treasure reduces also the environmental pollution from the eggshell which takes place a long period of time for complete decomposition giving foul odour to the nearby community.

Chicken eggshell

Chicken eggshell is a biomaterial containing (Table 1) 95% by weight of calcium carbonate in the form of calcites and 5% by weight of organic materials, organic materials such as collagen, sulfated polysaccharides, and others like (AL_2O_3), SiO_2, S, Cl, P, Cr_2O_3, MnO) [12,13].

This research study has pointed out a useful bio filler derived from chicken eggshell waste and its potential role in the fire protective coating industry. The other advantage of using chicken eggshell is that it is available in bulk quantity, lightweight, high thermal stability and being an inexpensive and environmentally friendly.

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Methodology

Materials and chemicals

Half bleached woven cotton fabric (140 GSM) was used. Chicken eggshell was collected from Kombolcha Institute of technology (Figure 1). To fix the chicken eggshell gel on cotton fabric, acrylic copolymer binder was used.

Experiments: The experiment has been conducted into the following steps.

Step 1: Converting chicken eggshell in to powder (Figure 2).

The collected chicken eggshell was washed using standard laboratory detergent and subjected to complete dying. Then, the dried chicken eggshell was manually grinded to fine particles.

Step 2: Preparing chicken eggshell gel using acrylic copolymer binder (Figure 3).

Step 3: Coating the gel on cotton fabric (Figure 4).

The coating was carried out by padding mangle at 1 dip 1 nip.

Step 4: Drying and curing of coated fabric at 80° and 150°C for 4 and 5 minutes respectively.

Figure 1: Chicken eggshell collected from kombolcha institute of technology.

Figure 2: Manually grinded Chicken Eggshell fine powder.

Figure 3: Chicken Eggshell powder mixed with Acrylic copolymer binder (Gel).

Test and test analyzing

Three samples were produced by using different amount of eggshell powder to liquid ratio to analyse the fire retardance eggshell powder at different solution concentrations (Table 2).

Table 2 describes performance of fire retardant was checked

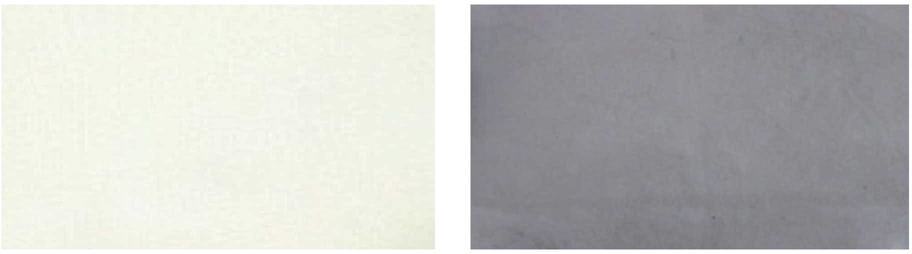

Figure 4: Untreated cotton fabric (left) and cotton fabric coated using chicken eggshell gel (right).

at different concentration of chicken eggshell powder. Finally the performance was tested by approaching flame lighter vertically to the treated samples the time in which untreated sample and treated sample was burned based on ASTM D6413 is the Standard Test Method for Flame Resistance of Textiles (vertical test). Then, the time in which coated sample stop burning and formation of ash and char were observed and recorded.

Physical property tests

Tensile strength test: Since the fabric strength tester was not functional in the place where this research has been conducted the test was done on yarn form with the following procedure based on ASTM D 2256 Tensile properties of yarn single strand method. 10 warp and weft yarns each were taken out from the treated fabric. Similarly 10 warp and weft yarns each were taken out from the untreated fabric samples.

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. 10 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.

Fabric bending length: 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 slide was 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.

Result and Discussion

Fire retardance performance: Table 3 shows that the result of three different samples with different powder concentration gives that different fire propagation resistance or it reduces fire flammability than untreated sample fabric. 8 cm fabric can be saved without burning after treatment.

Protein	1.44%
Crude fat	0.100.20%
Ash	80.991.1%
calcium carbonate	Total of Ca 90.9%
Phosphorus	0.12%
Sodium	0.150.17%
Magnesium	0.370.40%
Potassium	0.100.13%
Sulphur	0.090.19%
Alanine	0.45%
Arginine	0.560.57%
Asparctic acid	0.830.87%
Cysteine	0.370.41%
Glutamic acid	1.221.26%
Glycine	0.480.51%
Histidene	0.250.30%
Isoleucine	0.34%
Leusine	0.57%
Methionine	0.280.29%
Lysine	0.37%
Pchickenylalanine	0.380.46%
Proline	0.540.62%
Serine	0.640.65%
Threonine	0.450.47%
Tyrosine	0.25.26%
Valine	0.540.55%
Calcium	35.136.4%

(Source;-www.serve.com/BatonRouge nutrition sairaj)

Table 1: Composition of chicken eggshell.

Material	Sample I	Sample II	Sample III
Fabric	10 g	10 g	10 g
Water	10 ml	10 ml	10 ml
Eggshell powder	70 mg	80 mg	100 mg
Binder	20 ml	20 ml	20 ml
Temperature	150 ˚C	150 ºC	150 ˚C
Time	5 minutes	5 minutes	5 minutes
Fabric length	20 cm	20 cm	20 cm

Table 2: Material and parameter used for sample one.

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

Table 3: Fire retardance performance test results.

Sample 2 is coated with medium solution concentration. This treated sample fabric has low fire propagation or it reduces fire flammability than fabric which is treated at low concentration of eggshell. Untreated sample fabric has no any fire retardance. From Table 3, 13 cm sample fabric can be saved.

Sample 3 has very low fire propagation or expansion and fire flammability of fabric is reduced than sample which is treated at low and medium concentration of eggshell due to treated with high concentration of eggshell. Untreated sample fabric has no any fire retardance; its flammability is more from the three sample tests. At this test 18 cm sample fabric is saved.

From Table 4 the flame propagation reduces as the amount of powder increases. In addition to this ash and char produced at low and medium thickness of concentration of eggshell usage. Char is produced when sample is coated at high thickness powder liquid ratio.

Fire-retardant sample cotton fabric is produced by using eggshell that has low fire-propagation when compare with untreated cotton fabric. From Table 4 Fabric with different coating thickness that prepared by different chicken eggshell powder liquid ratio shows different fire-propagation resistance with different powder liquid ratio. When fabric is coated with high thickness of powder liquid ratio more reduction of fire flammability is occurred.

As explained on Table 4 from 20 cm length fabric 2 cm length of fabric is burned in 5 sec and 18 cm length of fabric is saved at high concentration. And also medium reduction of flammability occurs when use medium coating thickness method as shown in Table 4 from 20 cm length of fabric 7 cm fabric length is burned in 5 sec and 13 cm length is saved. Low thickness coatings have also ability to reduce flammability of fire.

As shown in Table 5 from 20 cm length of fabric 12 cm burned in 5 sec and 8 cm length of fabric is saved and also get different flame-resistance results by using different chicken eggshell powder fineness. More fine powder shows better resistance to fire-propagation speed and moderate finer powder shows relatively less resistance to fire-propagation speed.

Eggshell fire-retardant powder mixed with organic binder in case of fixation. Without binder chicken eggshell powder cannot fixed effectively with the cotton fabric. It shed down simply after drying. Since the eggshell powder is fixed with this coated fabric it is not washed off if this coated fabric is washed by water and soap. So it has good durability.

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

Table 4: Flame retardant performance observations.

No of sample	Liquid to powder ratio	Fire propagation speed	Coating thickness	Water to binder ratio
Sample 1	30ml/70mg	12cm/5se	50mg	10/20(ml)
Sample 2	30ml/80mg	7cm/5se	65mg	10/20(ml)
Sample3	30ml/100mg	2cm/se	83mg	10/20(ml)
Untreated fabric	-	20cm/5e	Not coated	-

Table 5: General information about result.

Chicken eggshell powder can be coated by mixing with coloring or dye stuffs and pigment for decoration purpose with no significant effect to reduce fire-resistance properties of chicken eggshell powder. So, chicken eggshell can be used as fire-retardant material and for different purpose with different coating thickness and with different powder fines. It will be functional wearing for special fire dangerous area, for carpenter, ceiling.

General properties of treated fabric observed

Following are the general properties which are observed of Treated fabrics:-

Surface burning flame resistance between a certain time intervals without flame propagation on the treated fabric:

For low concentration of solution coating i.e. when coating thickness is low: Here we have taken 20 cm sample length for all samples. When burn the treated sample as well as untreated fabric, at the same time interval which was 0.08 sec. There is a great difference flammability of the two fabrics. That is the treated sample fabric stopped burning after 1.9 cm height only within a given time. But untreated fabric burned 9 cm in the given time (0.08 sec).

For high concentration of coating i.e. when coating thickness is thick: The same sample fabric length also prepared with the above sample. The treated sample fabric (sample 3) shows very small flammability. And it forms char. The place burned is negligible whereas grey fabric run out in the same time.

Duration and washing fastness of fire-retardant material: Washing fastness of eggshell treated fabric depends on the amount of binder and heat setting .The more binder (without water) and high heated sample fabric have good washing fastness than concentration of binder and water and less heat setting sample cotton fabric.

Percentage weight of coated fire-retardant on the original fabric weight: Percent weight of coated fabric depends on the viscosity of the solution and eggshell particle size. When low viscosity and large particle size are used, the weight become low and vice versa. As viscosity becomes more and small particle size, the weight of sample fabric will be larger and larger.

Physical properties of treated fabric

Table 6 showed 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.

Table 7 showed the stiffness property of the fabric was increased as the treatment acts like coating material.

Table 8 showed that the treatment there is no much alteration in tensile strength after treatment besides the retardancy.

No.	Original area (cm^2)	Area after treatment (cm^2)	Shrinkage (%)
1	100	97.02	2.98
2	100	95.04	4.96
3	100	95.06	4.94
Average	100	95.70	4.30

Table 6: Shrinkage test result.

No.	Bending Length (cm)			
	Unreated		Treated	
	warp	Weft	Warp	Weft
1	3.25	2.75	3.75	3.15
2	3.15	3.05	3.55	3.15
3	3.45	2.60	3.40	3.20
Average	**3.28**	**2.80**	**3.57**	**3.17**

Table 7: Fabric stiffness test result.

	Sample No.		**1**	**2**	**3**	**Average**
Breaking Force (N)	Treated	Warp	1.72	1.90	1.77	1.80
		Weft	1.65	1.47	1.83	1.65
	Untreated	Warp	1.73	2.01	1.91	1.88
		Weft	1.88	1.55	1.94	1.79

Table 8: Tensile strength test result.

Recommendation and Future Work

Chicken eggshell can be used as fire retardant material for variety of application area. But up to now it used only limited application area of material, so textile manufacturer and textile engineering department must be give more attention to increase uses of eggshell as fire retardant material and consideration of its environmental friendly material and to reduce synthetic chemicals effects of environmentally hazard and production cost reduction. This thesis deals producing fire-retardant cotton fabrics by using chicken eggshell and application of the fabrics are for ceiling, carpet, for people that work at fire danger area such as kitchen room. But for the future the study tries to produce fabrics which are used for any fire retardant applications by increasing fineness of the chicken's eggshell powder, by using standard milling machine and coating methods

Conclusion

The following conclusions have been drawn from this work. Fire-retardant cotton fabric can be produced by using chicken eggshell powder as flame retardant material. By using chicken eggshell powder we can produce fire retardant fabric or different application with different coating thickness and powder liquid ratio. Different coating thickness shows different fire or flame resistance result. More coating thickness and more powder fineness have better flame resistance. While burning treated by eggshell fabric which is forms ash and char, but untreated fabric forms only ash. Chicken eggshell powder can be used with coloring or pigment for decorative flame retardant fabric. For different application we can use different coating thickness. The strength of the treated fabric was not altered much therefore the finish doesn't degrade the fabric. The finish results slight shrinkage on 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 Chicken eggshell coated fabric used as flame retardant material for different application such as ceiling, carpe for people who wear in military and kitchen area.

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