Formulation of sustainable flame retardant from waste egg shell

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Research Article

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Formulation of sustainable flame retardant from waste egg shell

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Abstract:

Egg shell are considered as waste and are generally dumped in the landfills. As the world is moving towards the sustainable way to recycle the waste and hence adding value to the waste produced. The egg shell is consisting of essential amino acids and properties which are still unexploited in various textile processing. The egg shell has proteineous matter which makes it a natural flame retardant. Cotton is the majorly used fibre in the overall textile industry. In the present study the egg shell waste was used to prepare an extract which is further applied on cotton fabric as a flame retardant. The characterization of the above egg shell powder shows it has amine group present at 1072.6 as well as at 873.56cm^{-} C-Cl halo compound is present confirmed through FT-IR analysis. Two peaks were observed in DSC curves at 224.4^{0}C and 254.5 °C. A LoI of cotton has increased to 36 at a lower concentration of 30% while that compared with the conventional cotton fabric.

This is the first attempt, recycling the egg shell and reusing it as a potential textile finishing auxiliary.

Keywords: Green chemistry, Sustainable chemical, Flame retardancy, Waste recycling

Introduction:

India is leading in disposal of waste issue since there are no enough landfills availability in the country. For reaching the goal of sustainability waste disposal is of major concern. From the literature it is been cleared that egg shell contribute 250,000 tons of waste annually worldwide. Egg shell is included as an agricultural waste as it is mainly been used in food processing and manufacturing of plants byproducts. Enormous work has been done for reusing the egg shell waste for production as a biofuel, Bio-effluent treatment, used as bone fillers making its valuable. Egg shell largely consist of amino acids and nitrogenous substance making it to pave its way for its further evaluation. In textile processing finishing is and essential step and is very cost worthy for any manufacturing industry. The mechanical finishing although is not labour intensive but the maintainance and the machines are highly priced. As well as chemical finishing includes quaternary ammonium compounds which are hazardous for the environment making it unsuitable of its usage.

Cotton is used extensively in the overall textile industry due to its properties and ease of availability. Although cotton has good absorption property but it is not resistance towards flame as well as it is not antimicrobial and is easily attacked by the bacteria. There are good finishing agents available in the market to fit this criteria but the cost is generally high. As we know that wool is naturally flame-retardant fabric but due to its bulky nature it is not suitable for home furnishing for example curtains or kitchen wears. Circular fashion is the new progress towards sustainability in which the resources are been reused into a valuable product i.e., the cradle-to-cradle technique in which the end product can further be resued again thereby increasing its shelf life.

In the present study the egg shell waste is been used to add value adding finishing to the textile substrate the egg shell extract prepared is been applied on cotton fabric making is less flammable as well as antimicrobial in nature. This eco-friendly technique in which the waste is been used for developing green clothing with minimal chemicals is been attempted for the first time.

2. Materials and methods:

The Fresh egg shell was used for the study and analysis. 100 % cotton fabric (250gsm) was procured from Bombay dyeing. The chemicals used for preparation of the extract: Methanol, Ethanol and Malonic acid are LR grade.

2.1 Preparation of powder:

The fresh egg shell was used for the study. The egg shell waste of were washed with distilled water so that there is no impurity present in the extract. It is further dried at 105 ^{0}C. The dried egg shells are crushed in motar and pestel and then grinded firmly into fine powder. This powder is used for characterization of the compounds present in the egg shell.

2.2 Preparation of egg shell extract:

The finely grinded egg shell powder is been used for preparation of the extract. The dissolution is been checked in various organic as well as inorganic solvents. The dissolution of egg shell was found to be in formulation of 100% ethanol, 70% methanol in presence of 2M malonic acid and buffer solution of PH (7.2). As amide groups are present the egg shell powder. The powder does not dissolve in single solvent. Hence two solvent were used for the dissolution. At a eutectic temperature the powder dissolves completely in the solvent. The extract prepared is been dialysed and used for its application.

2.3 Method of application (Finishing method):

The 100 % cotton fabric was padded through the above extracted solution using 2 dip-2 nip method having wet pick up of 70-75%. The padded fabric is then dried at 105^{0}C for 120 sec and cured at 140^{0}C for 180 sec in stenter machine.

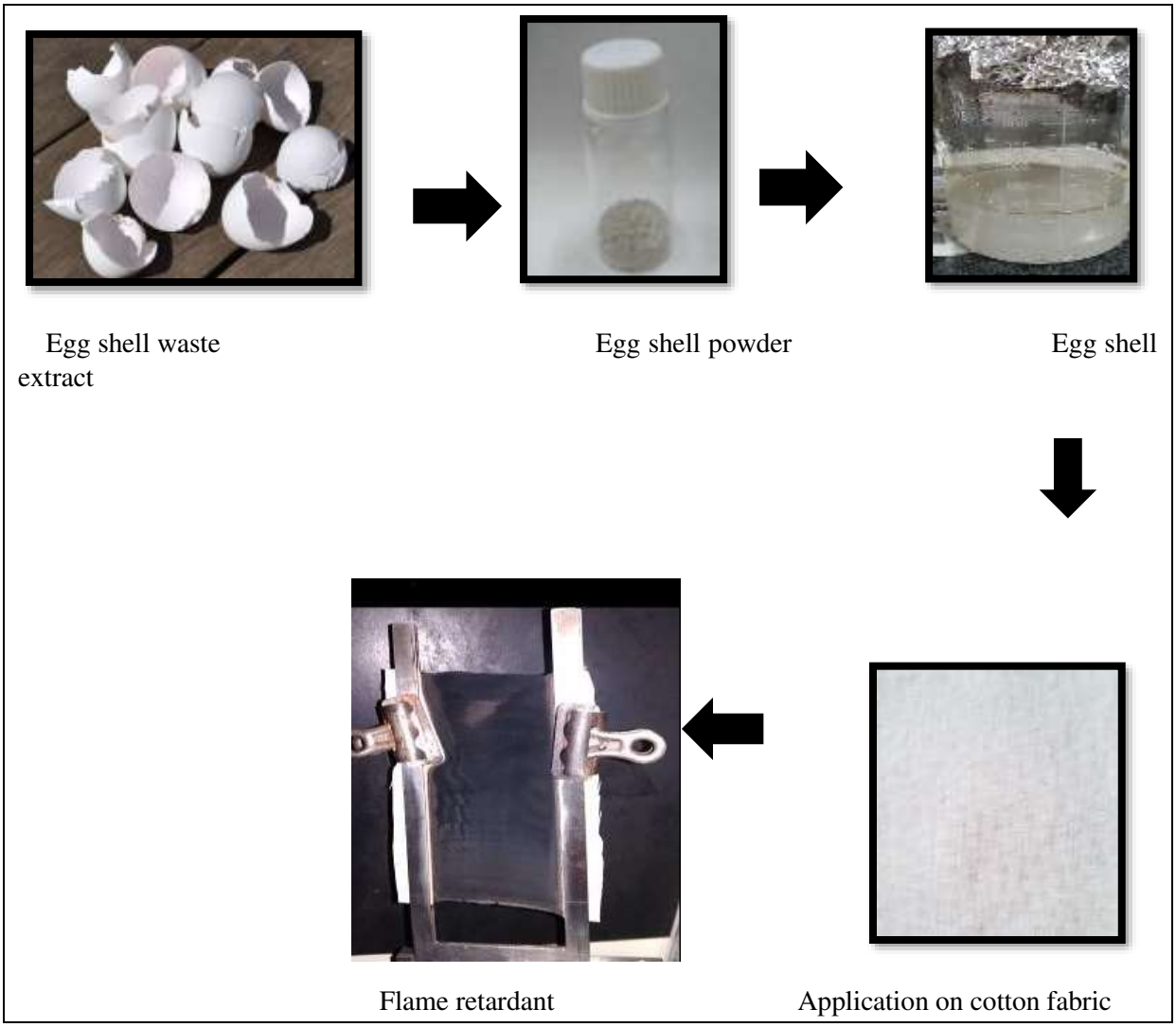

Fig 1: Schematic representation of the Process

3. Results and discussion:

The recycling of egg shell waste for various application like bio-fuels, effluent treatment as well as used as fillers in bone. The components present in the egg shell mainly consist of nitrogen and protein which are essential for an effective flame retardant. The egg shell powder was been characterised for FT-IR using Shimadzu spectrophotometer using ATR mode of operation and scanning of FT-IR spectrophotometer was carried out between 4000 cm^{-1} to 600cm^{-1}. The organic groups present in egg shell are at 17916cm^{-1} acid halide, 1411 cm^{-1} sulfonyl chloride, 1072.6 amine group present,873.56cm^{-1} C-Cl halo compound, 712.23 C-C bending alkene given in fig.2.

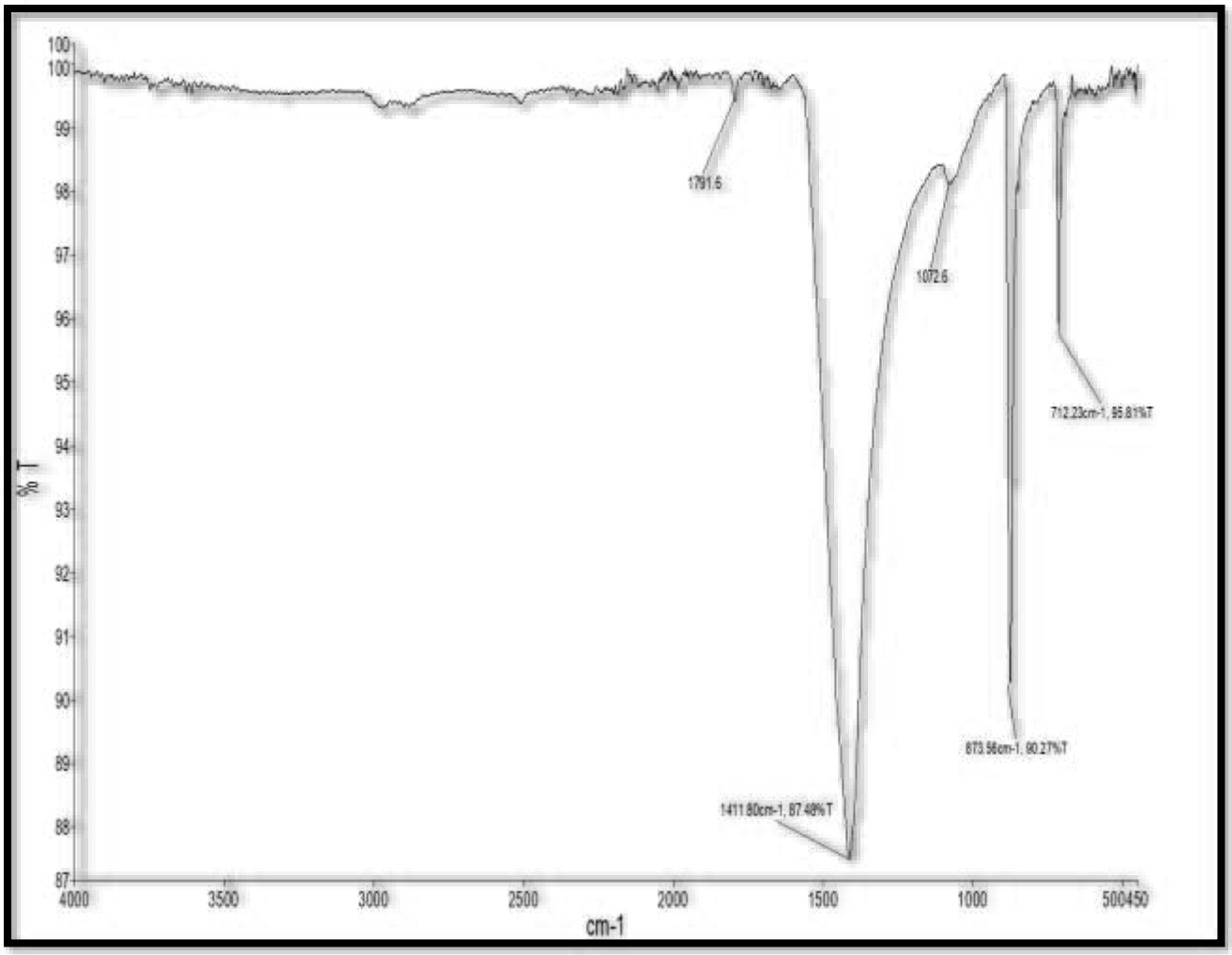

Fig 2: IR Characterization of functional group of egg shell powder

Table 1 represents the optimization of cotton fabric with egg shell extract. It shows that the LoI for 30% concentration of cotton has a good resistance towards the flame having An LOI of 36. Which is equivalent the normal wool LOI value. There is no dripping observed after flaming. The fig. 3 shows the set up for LOI and flame retardancy of cotton fabric.

Differential scanning Calorimetric analysis:

Two peaks were observed in DSC curves of standard samples. The first peak appeared at 29.0 °C was due to the removal of physically adsorbed moisture. The second endothermic peak for the decomposition of organic substances like shell membranes and matrix protein were at 224.4^{0}C and 254.5 °C.

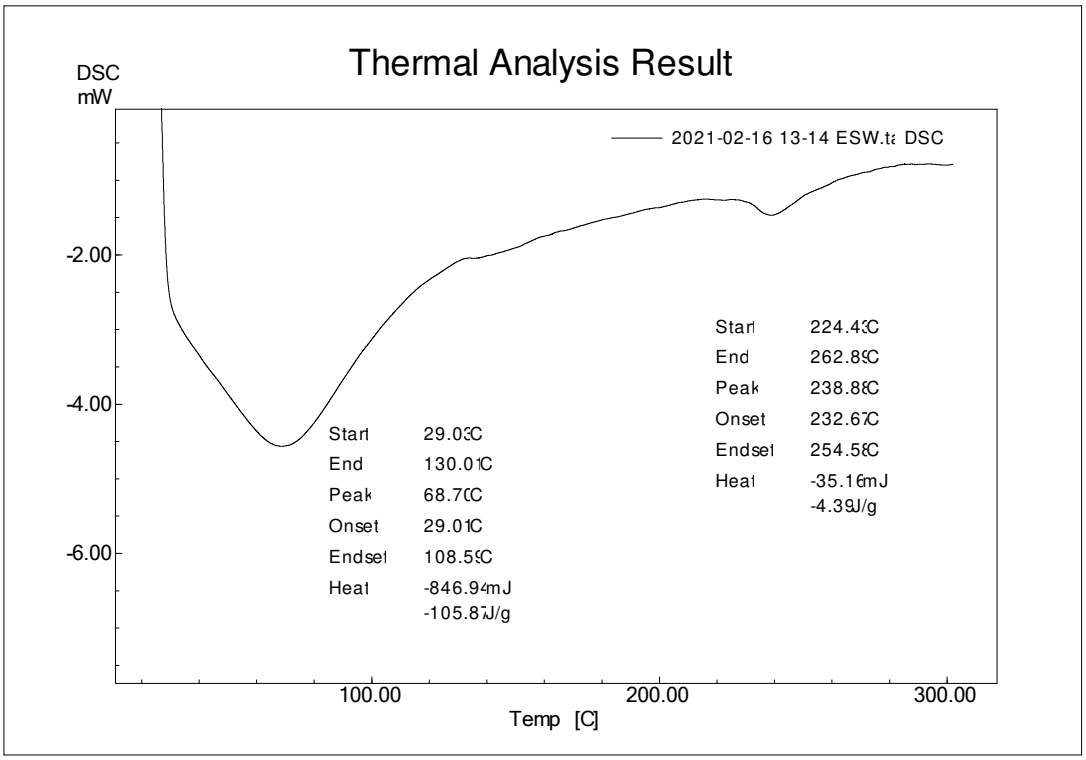

Fig. 3: DSc Graph of Egg shell extract

TGA Analysis:

A thermogravimetric analyser was used to determine the thermal decomposition behaviour of the composites. 6.753[mg]of the sample was considered for the testing, using a platinum pan. The flow rate 100[ml/min] at heating rate was 10 °C min− in aluminium pan 1 with a temperature range of 30 to 600 °C. The nitrogen atmosphere is used for the melting behaviour. The graph below in the fig. 4 shows the TGA results of the egg shell powder. The weight loss observed through the TGA analysis is -6.338%.

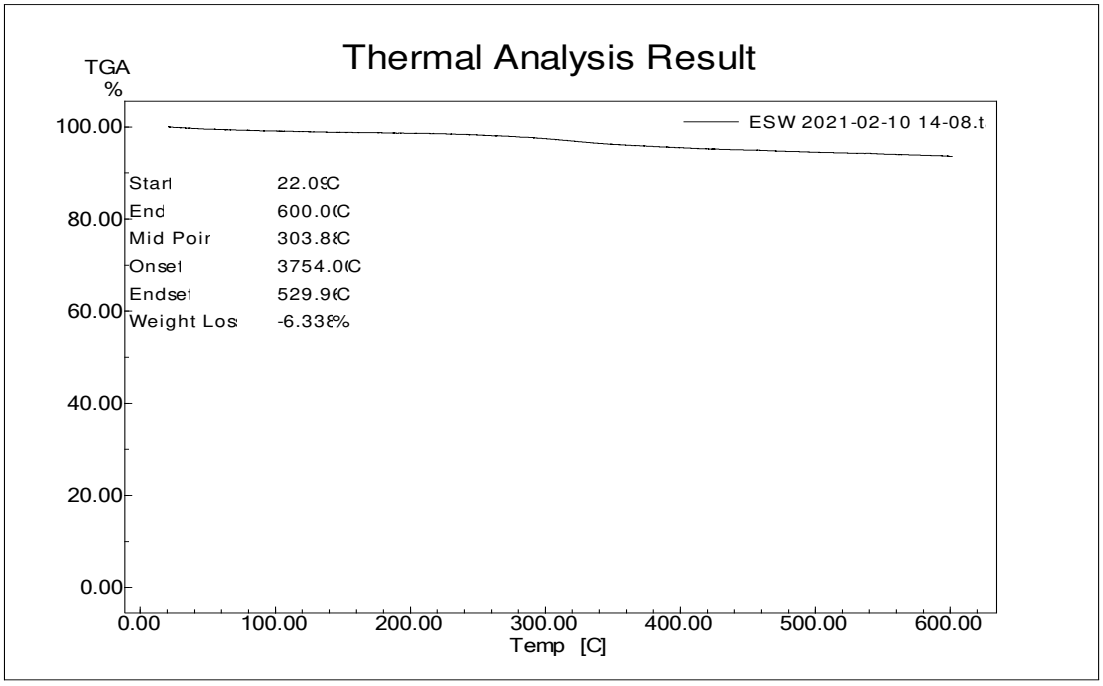

Fig 4: TGA graph of egg shell extract

The finishing of the cotton fabric through the prepared egg shell flame retardant at various concentration is been assessed. The limiting oxygen index is been evaluated for the finished fabric. Even at the 30% concentration of egg shell extract it is showing LOI of 36 which is comparatively better than the conventional untreated sample of cotton which is 23. The table 1 shows the optimization of the treated cotton fabric and their respective LOI results. Fig 5 shows the pictorial representation of the LOI of treated sample.

Table 1: Optimization of cotton finished with egg shell extract

Sr. No	Fabric	Conc. Of Egg Extract	Add On %	LOI
1	Cotton	10	30.2	23
2	Cotton	20	47.5	30
3	**Cotton**	**30**	**54.8**	**36**
4	Cotton	40	49.2	44
5	Cotton	50	48.4	46

Fig 5: LOI of cotton

Table 2: UV-protection factor values of finished fabric different concentrations of Egg shell Extract.

Sr. No.	**Treated Samples**	**UPF value**	**P.C**
1	Control sample	9.41	Moderate
2	10	20.05	very good
3	20	31.20	very good
4	30	34.25	Excellent
5.	40	39.97	Excellent
6.	50	40.45	Excellent

From table 2 it is evident that the UPF values are increasing with increase in concentration as compared to the untreated control sample of cotton fabric. Excellent U.V protection can hence make the treated fabric be used in various home textile products as a good UV protective finish.

The egg shell waste has its enormous value. Not only it provides flame retardancy but as it enhances the antimicrobial properties to the cotton fabric. The treated fabric was hence further tested for Antimicrobial testing by AATCC 100 method

Table 3: Antimicrobial activity of different fabric finished with egg shell extract					
Fabric	Sample Identification	Test Culture	No. of colonies recovered at '0' hr [B]	No. of colonies recovered at	Reduction of Microorganisms

				‘24’ hrs [A]	[R]
COTTON	30% Conc.	*S. aureus*	2.00 X 10^5	1.6 X 10^4	94%
		K. pneumoniae	2.04 X 10^5	1.9 X 10^4	92.38%
	50% Conc	*S. aureus*	1.88 X 10^5	9 X 10^4	96.21%
		K. pneumoniae	1.96 X 10^5	1.1 X 10^4	93.45%
	Washed	*S.aureus*	2.04 X 10^5	1.8X 10^4	92.87%
		K. pneumoniae	2.08 X 10^5	2.1 X 10^4	84.45%

Table 3 shows the quantitative analysis of the cotton substrate treated with egg shell extract it shows that with 30% conc of egg shell extract the reduction in antimicrobial activity is 94% with S.aureus and 92.3% in presence of K.pneumoniae. while with 50 % conc it shows 93.45% reduction as well as the after laundering sample shows 84.45% reduction towards microbial attack.

Fig 4: Represents the Antimicrobial resistance of the extract in present of S.aureus and K.pneumoniae.

Conclusion :

The sustainable approach through circular fashion is regulated by making use of egg shell waste and developing a functional property to the textile substrate. The flame retardancy of with LoI value of 36 at 30% concentration shows that how this process is viable even at the lowest concentration of the egg shell extract. The antimicrobial nature of the egg shell shows a positive factor for its usage in medical wears. It shows excellent functional properties. An eco-friendly and cost-effective product having functional properties possessing flame retardancy as well as antimicrobial properties and is easily compostable. The future scope of this extract will be in making scaffolds for medical textile due to its excellent antimicrobial properties.

Commercial opportunities for such products which solves all the above problem will be high in the near future.

Declaration:

Availability of data and material:

The article submitted is an original work and has neither been published in any other peer-reviewed journal nor is under consideration for publication by any other journal.

Competing interest:

All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
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The following authors have affiliations with organizations with direct or indirect financial interest in the subject matter discussed in the manuscript.

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Author's contribution:

Both the author's have contributed for the research work. The idea and experimentation were carried out by the first author. While the help for writing of the paper and data interpretation was contributed by the second author.

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Figures

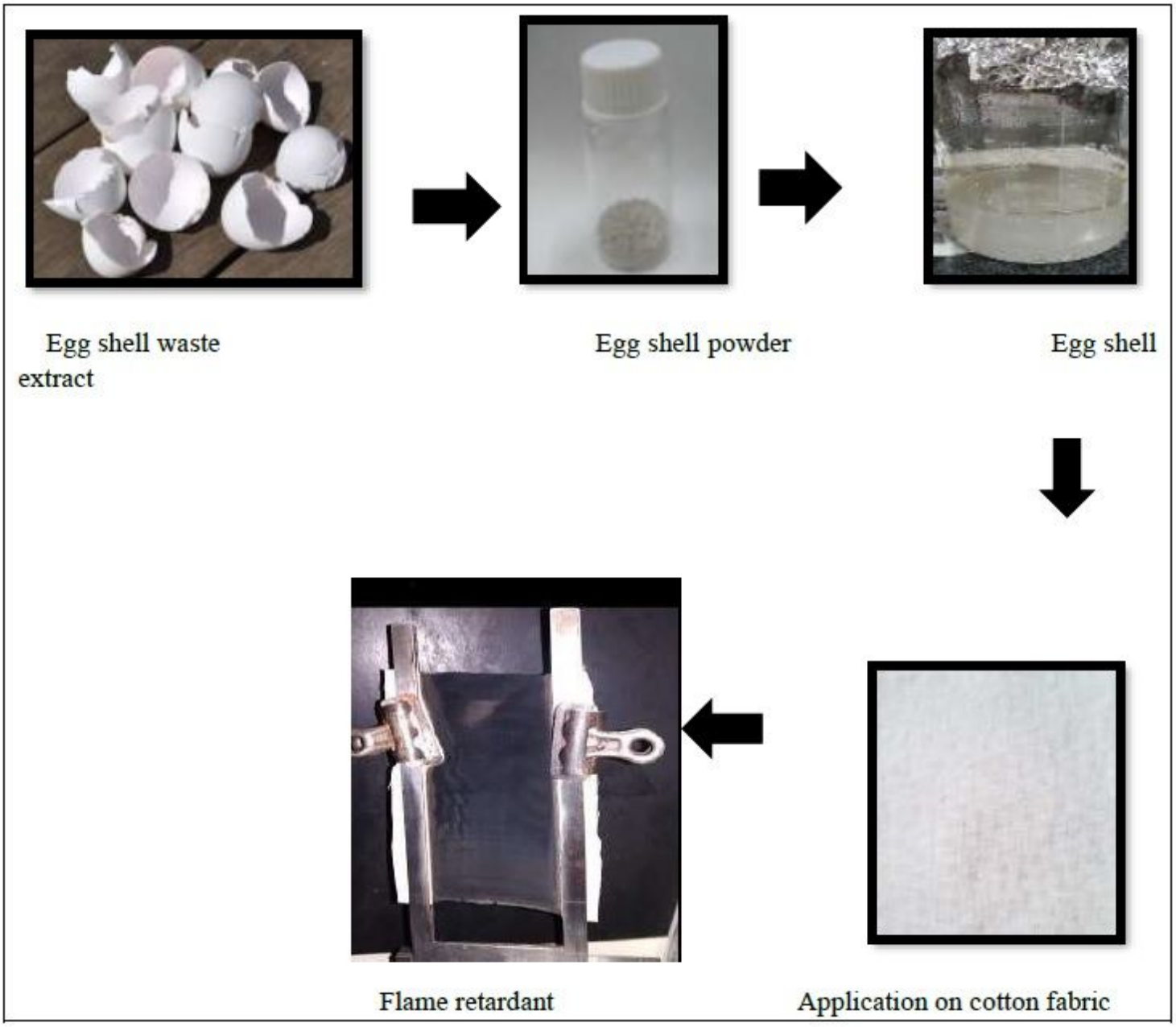

Figure 1

Schematic representation of the Process

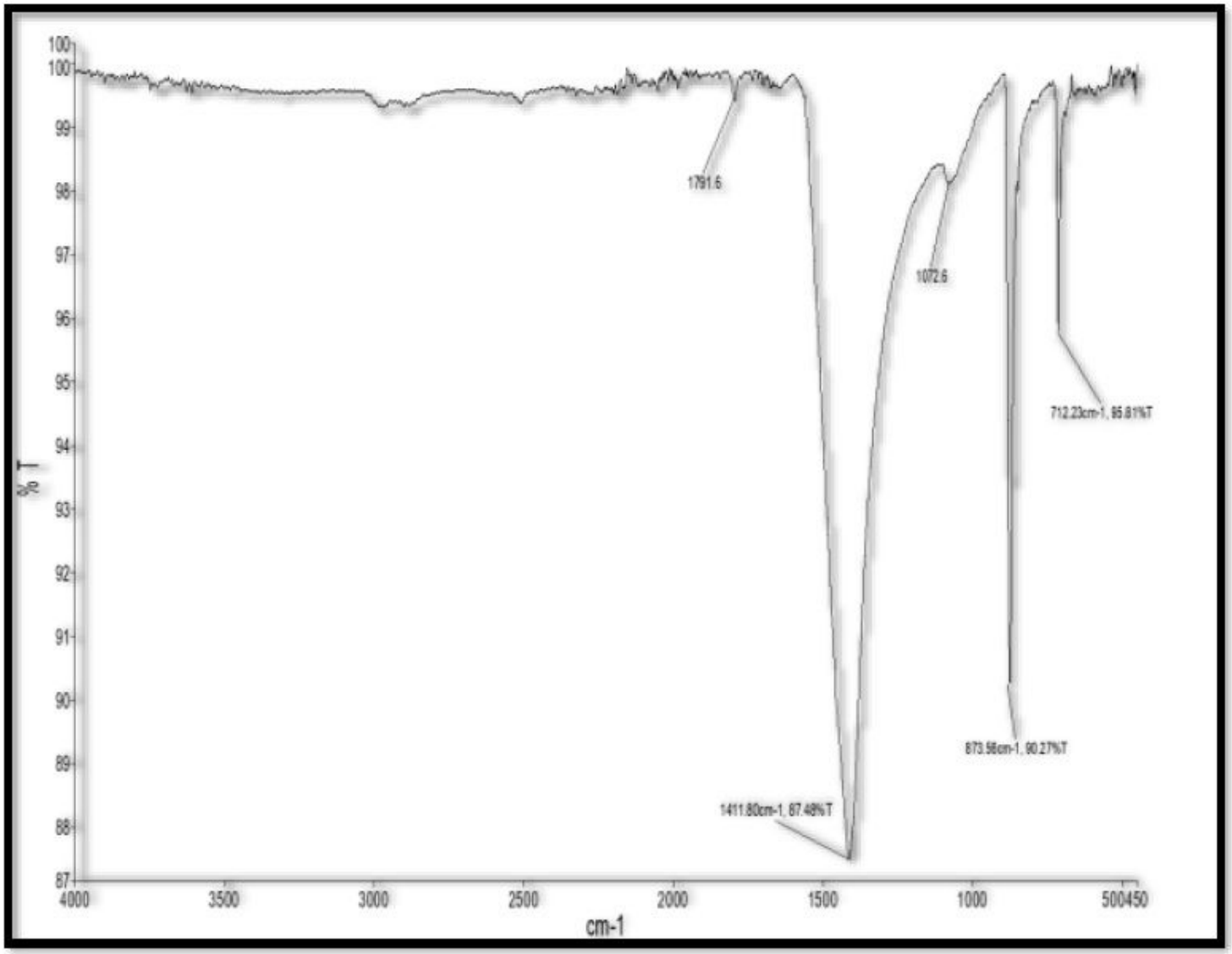

Figure 2

IR Characterization of functional group of egg shell powder

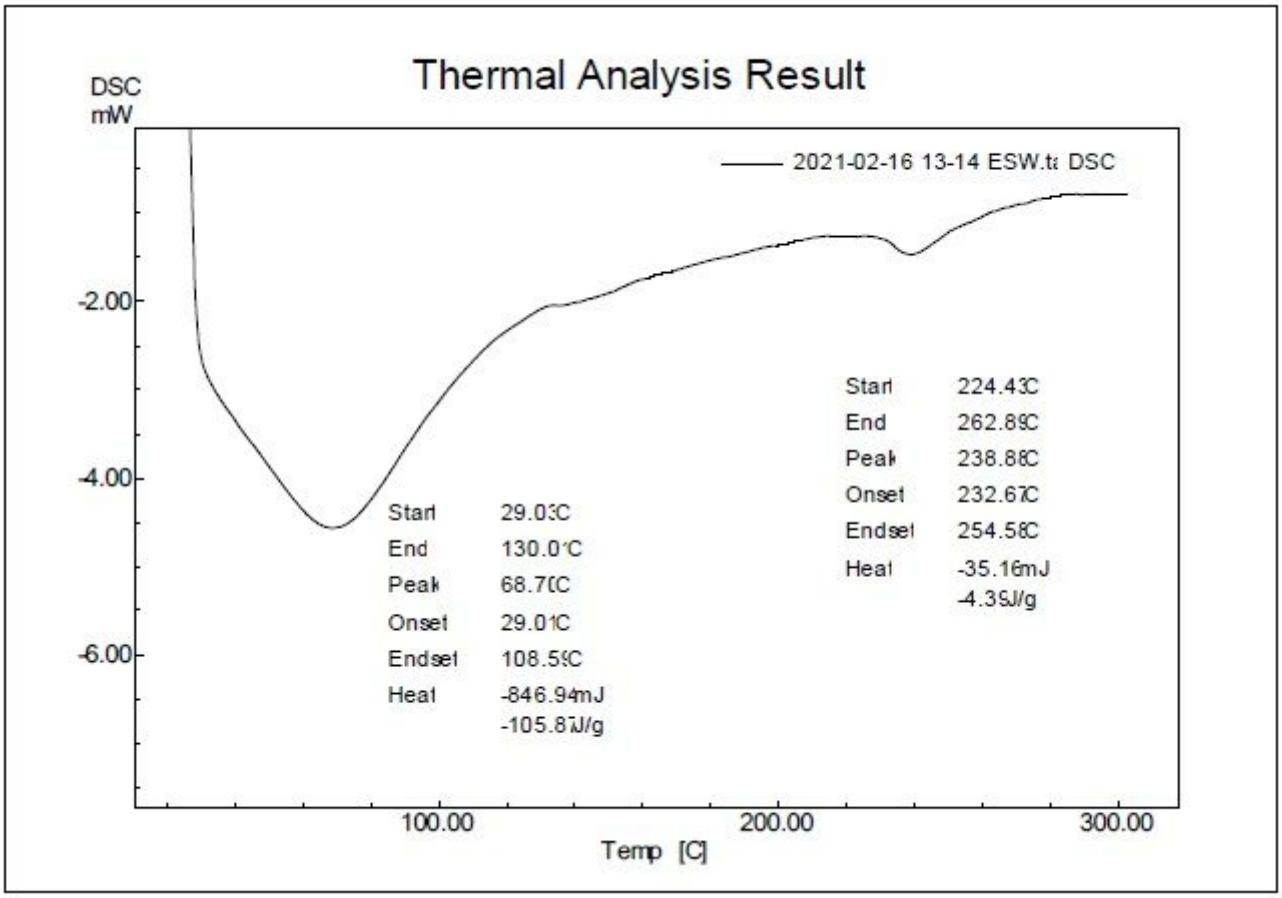

Figure 3

DSc Graph of Egg shell extract

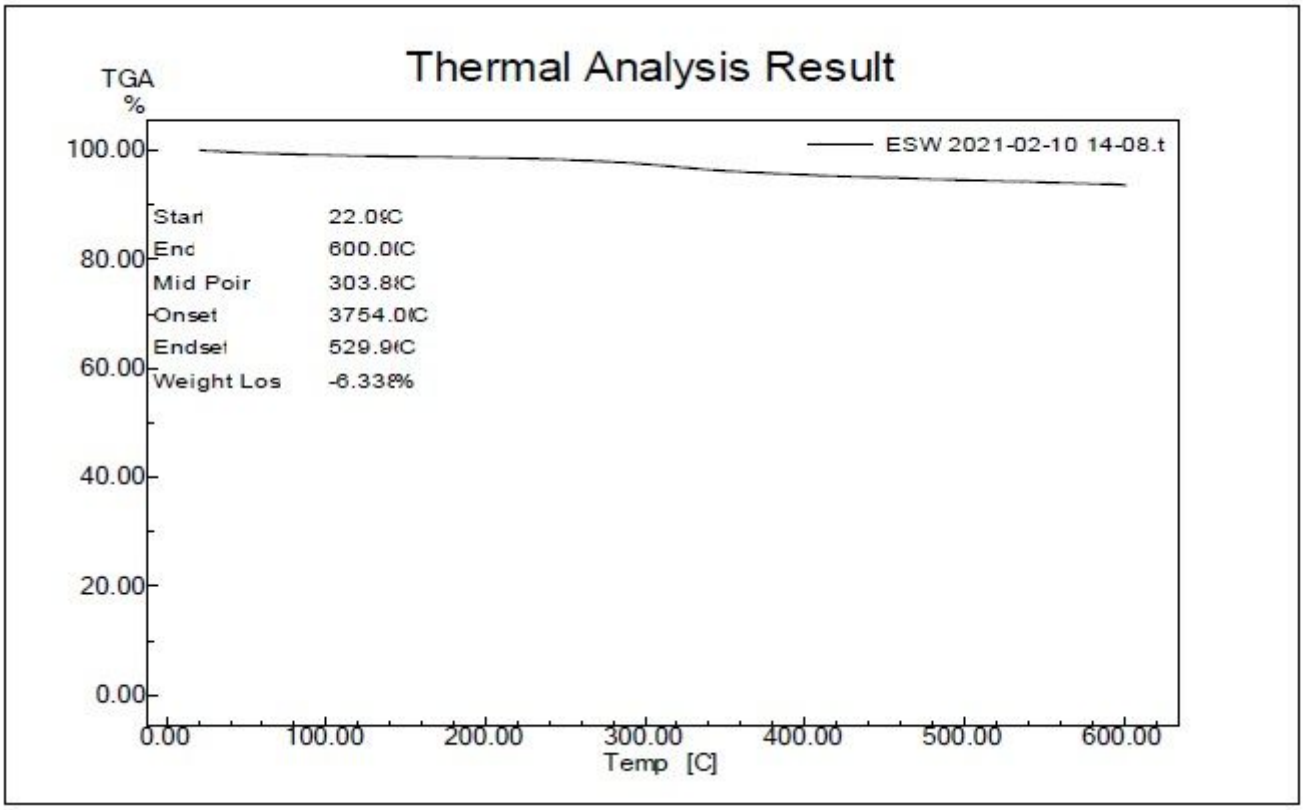

Figure 4

TGA graph of egg shell extract

Figure 5

LOI of cotton

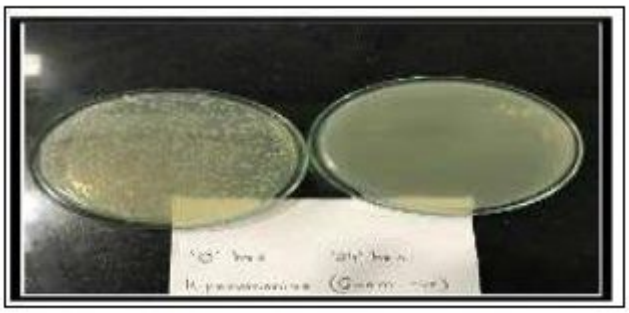

Figure 6

Represents the Antimicrobial resistance of the extract in present of S.aureus and K.pneumoniae.