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Sustainable environment friendly approach for *Psilocybe zapotecorum* colour dyeing integrated with anti-microbial finish.

Enfoque sostenible y respetuoso con el medio ambiente para *Psilocybe zapotecorum* teñido de color integrado con acabado antimicrobiano.

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ABSTRACT

Textile dyeing & functional finishing are two necessary and traditional separated processes employed in textile wet processing. Both these processes not only consume large quantities of water and energy, but they also add to the pollution load because of varieties of dyes, chemicals and auxiliaries used for performing them. Therefore, simultaneous dyeing and finishing, one bath method with single natural dye could be more advantageous to antimicrobial textiles, which can protect from antimicrobial activity. Natural dyes use in this work is Mushroom (*Psilocybe zapotecorum*). This- dye is also known as herbal dye and was used as antimicrobial agent as long as a century ago. This approach of designing sustainable eco-friendly processing of textiles to help environment and world health by reduce effluent load, to industries by reducing cost.

Key Words: *Psilocybe zapotecorum,* Mushroom, Cotton, Antimicrobial, Dyeing

RESUMEN

El teñido de textiles y el acabado funcional son dos procesos separados necesarios y tradicionales empleados en el procesamiento húmedo de textiles. Ambos procesos no solo consumen grandes cantidades de agua y energía, sino que también aumentan la carga de contaminación debido a la variedad de tintes, productos químicos y auxiliares utilizados para realizarlos. Por lo tanto, el teñido y el acabado simultáneos, un método de baño con un solo tinte natural podría ser más ventajoso para los textiles antimicrobianos, que pueden proteger de la actividad antimicrobiana. El colorante natural utilizado en este trabajo es el Hongo (Psilocybe zapotecorum). Este tinte también se conoce como tinte de hierbas y se usó como agente antimicrobiano hace ya un siglo. Este enfoque de diseñar un procesamiento ecológico sostenible de textiles para ayudar al medio ambiente y la salud mundial al reducir la carga de efluentes, a las industrias al reducir los costos.

Palabras clave: Psilocybe zapotecorum, Hongo, Algodón, Antimicrobiano, Teñido

Introduction

In the present day world, most of us are very conscious about our hygiene and cleanliness. N. Sekar (1999) and K. Ramkrishna (1999) noted that Clothing and textile materials are not only the carriers of microorganisms such as pathogenic bacteria, odour generating bacteria and mould fungi, but also good media for the growth of the microorganisms. Microbial infestation poses danger to both living and non-living matters. M. L. Gulrajani (2001) mentioned about the inherent properties of the textile fibres provide room for the growth of micro-organisms. Besides, the structure of the substrates and the chemical processes may induce the growth of microbes. Humid and warm environment still aggravate the problem. A. Sutlovic et. al. (2011) and R. Bhuyan et. al. (2004) suggested that infestation by microbes cause cross infection by pathogens and development odour where the fabric is worn next to skin. In addition, the staining and loss of the performance properties of textile substrates are the results of microbial attack. Basically, with a view to protect the wearer and the textile substrate itself antimicrobial finish is applied to textile materials. The use of natural antimicrobial agent which protect against bacteria and it is also non-polluting and biodegradable (R. Dyal and P. C. Dobhal 2001).

Textile dyeing and functional finishing are two necessary and traditional separated processes employed in textile wet processing, which necessitate repeated washing treatments and energy consumption. Generally in textile industry dyeing and finishing is carried out separately (D. Sarkar et. al. 2006, H.T. Deo & R. Paul 2000). Dyeing consumes large quantities of energy and produces large quantities of waste water and effluents (D. Gupta & A. Haile 2007). Effluents treatment is again problematic because some chemical are not bio-degradable and the process is also costly. In the present work, attempts have been made to combine natural colour dyeing and antimicrobial finishing processes together (with the same natural product) for the designing of hygienic wellness textiles (J. Lin et.al. 2003). The natural product used for the purpose is fungus-based product, mushroom which is responsible for the colouration of cellulosic textiles and also for providing the anti-insecticidal and anti-bacterial properties to the treated material due to its anti-oxidant and anti-microbial behavior (D. T. Seshadri & N .V. Bhatt 2005). Simultaneous dyeing and finishing in one bath could obviously *reduce both the cost of production and consumption of resources*. The combination of two processes will help to save energy, time and labour; while utilization of natural dyes and antimicrobial finishing agents will protect mankind from numerous diseases.

Apart from the natural colour dyeing and antimicrobial finishing with the same natural product, the study was further extended to providing mosquito repellency to the mushroom dyed fabrics.

The present work has been undertaken to explore the continuous dyeing method of padding for the application of natural dyes and natural finishing products. The natural colourant was extracted from a fungus, Mushroom (*Psilocybe zapotecorum*). Dyeing was performed in the presence of natural mordants utilizing pre-, meta-, and post-mordanting techniques. At every stage of experimentation the depth of shade was measured and desirable fastness properties were evaluated. Keeping in line with the objective of utilizing renewable resources, cotton and viscose were selected for use as the textile substrates.

MATERIALS AND METHODS

2.1 Textile substrates

Two categories of cellulosic textiles substrates were selected for the experimental work, namely; cotton (natural cellulosic) and viscose rayon (regenerated cellulosic). They were procured from various textile industries in Gujarat. Cotton fabric was procured from Kiran Threads, Vapi in grey state; whereas viscose rayon was supplied by Birla Cellulose, Kharach. The viscose rayon was in RFD (ready for dyeing) condition; hence a mild scouring was utilized to remove the adhered impurities from the fabric. The specifications of these substrates are mentioned in Table I:

Table I: Specifications of various textile substrates

Material	Weave	Reeds/inch	Picks/inch	GSM (g/m^2)
Cotton	Plain	80	60	142
Viscose rayon	Plain	75	40	132

2.2 Natural mordants

For comparative performance studies, three different natural mordants, namely tea leaves, tannic acid and harde were used and procured from the local market. Various images and characteristics of these mordants are given in Table 2.

Table 2: Images and characterization of Mordants

Mordants	Source	Powder	Chemical structure of main ingredient present

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 12(X), 2024:
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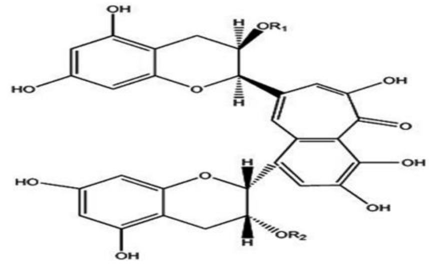
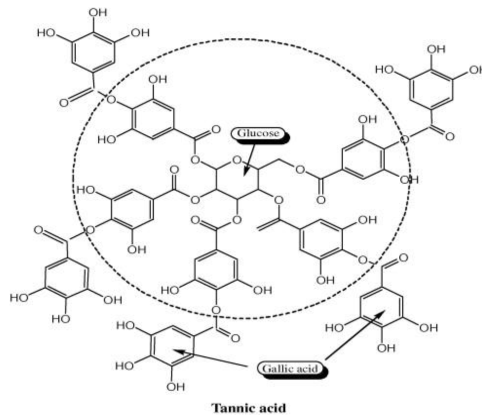
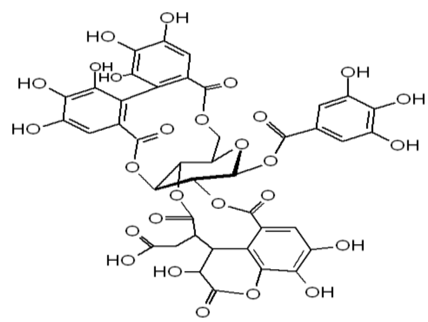
Tea			 Theaflavin
Tannic Acid			
Harde (*Terminalia chebula*)			 Chebulagic acid

2.3 Natural colourant (Mushroom - *Psilocybe zapotecorum*)

For dyeing of textile materials, mushroom was selected as the natural colourant.

2.4 Antimicrobial Finishing Agents

Mushroom itself works as an antimicrobial agent for this study. Therefore, dyeing and antimicrobial finishing has been performed simultaneously during dyeing operations itself.

2.5 Methods

The rising commercial interest in the use of natural dyes encourages research into the use of continuous colouration methods. The process of padding is continuous and very rapid. It depends on the arrangement of the following dye fixation if the total procedure is continuous or semi continuous. Dyeing was carried out on a laboratory-scale pad-dry-cure machine. The machine consist of Two-bowl padding mangle with horizontal squeeze-roller geometry (Figure 1), IR pre dryer and hot air drier for continuous process manufactured by RBE – Machine for Textile Industry. The trough for pad liquor is ahead the nip. Pressure, used to adjust the wet pick up, was controlled using compressed air. The fabric was guided horizontally through the pad liquor and between the squeeze rollers and Laboratory Pad-Dry-Cure machine.

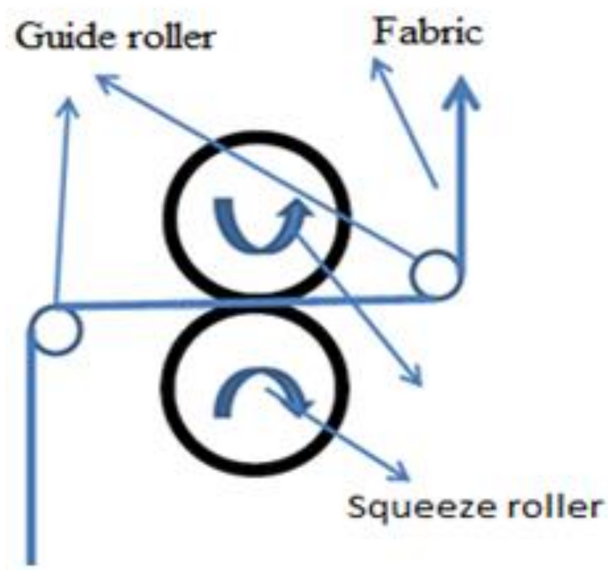


Figure 1: Padding mangle geometry

2.6 Extraction of Coloring component from mushroom (*Psilocybe zapotecorum)*

Mushroom collected from the field during monsoon season had been dried for three days under sunlight, after getting dry product; it had been grinded for converting it into powder. One volume of 95% (v/v) methanol was added to the above powder for extraction of the colouring component and the mixture was kept on a rotary shaker for 30 min at 150 rpm and 35°C. The mixture was then centrifuged at 5000 rpm for 15 min. The same process was repeated for removal of fungal biomass and the filtrate was filtered through a pre-weighed Whatmann filter paper (42 mm). The purified pigments were concentrated in a rotary evaporator and dried to obtain the yellow pigment in a powdered form.

The solution of mushroom was prepared by adding 1 g powder in 100 ml of water (10 gpl) and boiled for 1 hour to extract out the colouring matters. This boiled solution was filtered using Whatmann filter paper 42. The filtrate was used as dye stock solution for comparative studies. The colouring matter and other valuable components are extracted from mushroom by extraction procedure illustrated in Figure II.

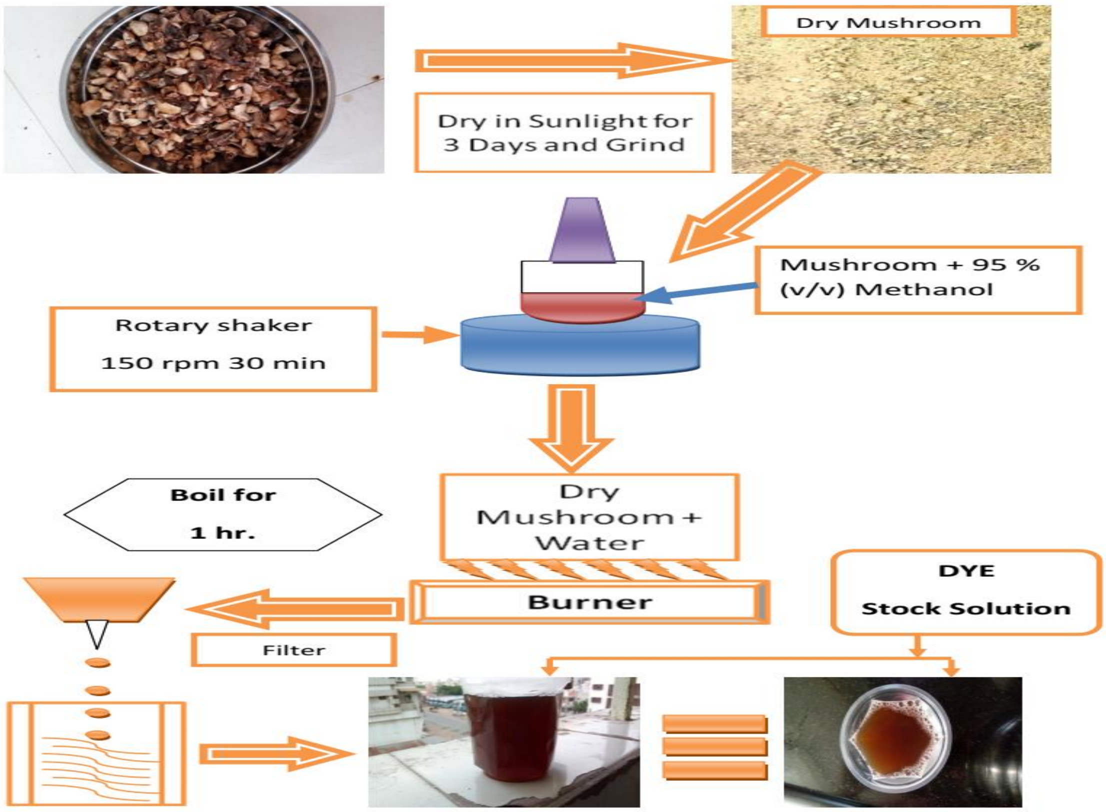


Figure II: Extraction process sequence of mushrooom

2.7 Mordanting Procedures

The process of applying mordants or mordanting is classified into the following three types

1) Pre-mordanting is where the textile material is first treated with the mordant and then dyed. Intermediate drying allows storage of the mordanted material and helps in absorption of the dye liquor.

Mordanting by Exhaust/Padding methods ----- Dry ----- Dyeing by Exhaust/Padding methods ----- Dry ------ Steaming/Curing (in padding method)

2) Meta mordanting involves a dye bath containing both dye and mordant. The fabric is dyed in one step.

Mordanting as well as Dyeing by Exhaust/Padding methods ----- Dry ----- Steaming/Curing (in padding method)

3) Post mordanting method, the mordant is applied after the dye has been applied.

Dyeing by Exhaust/Padding methods ----- Dry ----- Mordanting by Exhaust/Padding methods ----- Dry ------ Steaming/Curing (in padding method)

2.8 Dyeing

Dyeing of both cellulosic textile materials was performed in two steps, i.e. mordanting and dyeing. For present work, three natural mordants were selected and fungal-based natural colourant extracted from mushroom was applied by utilizing four different dyeing methods; batch-wise (exhaust), continuous (pad – dry – cure and pad – dry – steam) and semi-continuous (cold – pad – batch). Mordanting was achieved by pre-mordanting (before dyeing), meta-mordanting (simultaneously dyeing) and post-mordanting (after dyeing) techniques for increasing the dye uptake of mushroom and getting variety of shades. Conditions for mordanting as well as dyeing are suggested in table III and IV.

2.9 Antimicrobial Finish

Mushroom itself works as an antimicrobial agent for this study. Therefore, dyeing and antimicrobial finishing has been performed simultaneously during dyeing operations itself. This particular finish was also applied by four different methods utilized for dyeing, and their optimum conditions are given in Table 3 and 4.

Table 3: Optimum Conditions for mordanting

Mordant	Application method	Concentration of mordent	Temperature (°C)	Time (min)
Tea	Exhaust	10 %	Boil	30
	PDC	100 gpl	150 for C & R	5
	PDS	100 gpl	105 for C & R	20 for C & R
	CPB	100 gpl	RT	24 hours
Tannic Acid	Exhaust	10 %	Boil	30
	PDC	100 gpl	150 for C & R	5
	PDS	100 gpl	105 for C & R	20 for C & R
	CPB	100 gpl	RT	24 hours
Harde	Exhaust	20 %	Boil	30
	PDC	200 gpl	150 for C & R	5
	PDS	200 gpl	105 for C & R	20 for C & R
	CPB	200 gpl	RT	24 hours

Table 4: Optimum Conditions for Dyeing

Application method	Dyes and Ingredients	Concentration of mordant	Temperature (°C)	Time (min)
Exhaust	Mushroom	5 %	Boil	90
	Na_2CO_3	3 %		
	$Na_2SO_4.7H_2O$	10 %		
PDC	Mushroom	50 gpl	150 for C & R	5
	Na_2CO_3	5 gpl		
	$Na_2SO_4.7H_2O$	---		
PDS	Mushroom	50 gpl	105 for C & R	20 for C & R
	Na_2CO_3	5 gpl		
	$Na_2SO_4.7H_2O$	---		
CPB	Mushroom	50 gpl	Room Temperature	24 hours
	Na_2CO_3	5 gpl		
	$Na_2SO_4.7H_2O$	---		

2.10 Testing and Analysis

2.10.1 Color value and color parameters

The dyed samples were assessed for the depth of colour by reflectance methods using 10 degree observer. The absorption of printed samples was measured on Premier Spectrascan SS 5100H. The relative colour strengths (K/S values) were computed using Kubelka-Munk expression:

$$K/S = (1 - R)^2/2R \qquad (1)$$

Where, R = decimal fraction of reflectance for the printed material at complete opacity λ_{max} of the dye), K = absorption coefficient, S = scattering coefficient.

Premier Spectrascan SS 5100H was calibrated using white tile for 100 % reflection of light and blank sample for 0 % reflection of light. The light source present in spectrophotometer is Xenon flash lamp. The samples were analysed by folding them in 2×2 sides, and 2 spectral reflections was set at eye of spectrophotometer. The output is recorded using colorscan software supplied with spectrophotometer.

2.10.2 Fastness Testing

The washing fastness test was carried out according to AATCC Test Method – 61 – 2013 using wash wheel or Launder – o – meter. Rubbing fastness test was performed on a Crockmeter according to AATCC Test Method 8 – 2013. The light fastness test was performed according to AATCC Test Method 16–2014 using Fed – O – Meter.

2.10.3 Antimicrobial Activity Test

"Parallel Streak Method" AATCC Test Method 147 -2004 has the aim to determine the antibacterial activity of diffusible antimicrobial agents on treated textile fabric. The average width (*W*) of a inhibition zone, along a streak, on either side of the test specimen is calculated by the following Eq.:

$$W = (TD) / 2 \qquad (2)$$

where, *T* is total diameter of test specimen and clear zone (in mm) and *D* is diameter of the test specimen (in mm).

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RESULTS AND DISCUSSION

3.1 Dyeing performance of mushroom

The colour strength values, in terms of K/S value, suggest ratio of absorption and scattering view of the dyed sample, with reference to reflectance. Strength of shade indicates the shade concentration compare to control one. Table 5 shows that the highest *K/S* value and colour strength achieved in case of pad dray steam method for control sample (dyed without mordanting). When mordanting was done with different mordanting techniques, pad dray steam suggested better *K/S* compare to other dyeing method utilized in studies for pre-mordanting method and post-mordanting method, harde was used as a mordant for cotton fabric. In case of meta-mordanting with harde and mushroom dye pad dry cure gave better *K/S* than other dyeing methods. When harde was used as mordant for mushroom dyeing on viscose rayon, pad dry steam suggested better K/S in the case of control sample, pre-moradanting and post-mordanting, while in meta-mordaning pad dry cure gave excellent *K/S*, also it has been cleared that in pre-mordanting cold pad batch method is more preferable compare to pad dry cure and exhaust (Table 6).

When the mordant was changed by using tannic acid for dyeing of cotton and viscose rayon, post-mordanting gave the better result of *K/S* value as well as strength of shade than other method of mordanting (Table 7 and 8), but pre-mordanting method has shown excellent results in cold pad batch dyeing than other dyeing methods on cotton (Table 8). In case of post-mordanting, exhaust dyeing suggests better result than cold pad batch method for both cotton and viscose rayon.

For the tea as mordant, on cotton and viscose rayon, dyeing shows excellent K/S value in post-mordanting method with pad dry cure for cotton and pad dry steam for viscose rayon (Table 9 and 10). Table 9 also indicates that in pre-mordanting method cold pad batch method gave better colour value and strength than other dyeing methods for cotton, while in exhaust dyeing method, meta-moradanting have better results. For viscose rayon, cold pad batch suggest great *K/S* in pre-mordanting method, while it shows very poor results in meta-mordanting and post-mordanting methods (Table 10).

Table 5: Cotton dyed using Harde mordant

Method of Mordanting ↓ / Method of Dyeing →		Exhaust	Pad Dry Cure	Pad Dry Steam	Cold Pad Batch
Control (Without Mordanting)	K/S	0.873	1.239	1.297	0.883
	Strength(%)	100.00	100.00	100.00	100.00
	L	88.624	87.892	87.690	88.709
	a	1.270	0.496	0.417	1.114
	b	0.710	5.826	6.175	0.944
Pre-mordanting	K/S	3.260	10.337	10.686	10.275
	Strength(%)	373.59	834.38	823.97	1163.21
	L	83.070	73.605	73.111	76.312
	a	-0.122	3.713	3.632	3.227
	b	14.248	24.409	24.263	30.299
Meta-mordanting	K/S	3.362	11.939	11.185	5.567
	Strength(%)	385.24	963.69	862.42	630.22
	L	83.900	70.405	71.187	81.439
	a	-0.863	3.841	3.468	-0.041
	b	16.507	21.348	20.948	23.837
Post-mordanting	K/S	4.190	9.486	9.788	5.297
	Strength(%)	480.09	765.64	754.71	599.66
	L	81.938	74.284	74.185	81.330
	a	0.035	2.764	2.523	-0.858
	b	17.164	21.870	22.247	20.151

Table 6: Viscose Rayon dyed using Harde mordant

Method of Mordanting	Method of Dyeing →	Exhaust	Pad Dry Cure	Pad Dry Steam	Cold Pad Batch
Control (Without Mordanting)	K/S	2.630	3.364	3.980	1.572
	Strength(%)	100.00	100.00	100.00	100.00
	L	81.867	82.583	81.201	86.530
	a	0.357	2.153	2.702	0.856
	b	4.764	15.044	15.924	7.256
Pre-mordanting	K/S	5.073	21.993	27.735	27.140
	Strength(%)	192.89	653.75	696.83	1726.63
	L	81.108	64.445	61.391	65.475
	a	-0.792	4.766	5.317	6.113
	b	20.128	27.445	28.188	36.281
Meta-mordanting	K/S	5.149	13.432	13.175	6.137
	Strength(%)	195.78	399.27	331.01	390.41
	L	81.632	68.927	69.166	81.152
	a	-0.808	3.617	3.570	3.900
	b	21.499	21.713	21.623	26.496
Post-mordanting	K/S	5.160	9.070	9.621	5.041
	Strength(%)	196.17	269.61	241.72	320.68
	L	80.781	74.783	74.070	82.185
	a	0.107	2.6264	2.491	-1.164
	b	19.784	22.239	22.187	21.6201

Table 7: Cotton dyed using Tannic Acid mordant

Method of Dyeing → / Method of Mordanting ↓		Exhaust	Pad Dry Cure	Pad Dry Steam	Cold Pad Batch
Control (Without Mordanting)	K/S	0.873	1.239	1.297	0.883
	Strength(%)	100.00	100.00	100.00	100.00
	L	88.624	87.892	87.690	88.709
	a	1.270	0.496	0.417	1.114
	b	0.710	5.826	6.175	0.944
Pre-mordanting	K/S	2.882	4.504	4.093	5.551
	Strength(%)	330.26	363.56	315.60	628.40
	L	83.171	80.564	81.303	79.889
	a	0.441	2.229	2.041	1.565
	b	11.711	16.928	16.346	21.012
Meta-mordanting	K/S	3.067	6.587	7.398	3.528
	Strength(%)	351.45	531.64	570.44	399.43
	L	83.641	76.925	75.625	83.290
	a	0.250	3.165	3.094	0.725
	b	14.142	18.982	19.146	17.327
Post-mordanting	K/S	6.389	8.586	7.398	3.832
	Strength(%)	732.14	693.02	570.44	433.85
	L	77.193	74.425	75.916	82.722
	a	1.970	3.577	3.421	0.587
	b	17.968	20.850	19.972	17.862

Table 8: Viscose Rayon dyed using Tannic Acid mordant

Method of Dyeing → / Method of Mordanting ↓		Exhaust	Pad Dry Cure	Pad Dry Steam	Cold Pad Batch
Control (Without Mordanting)	K/S	2.630	3.364	3.980	1.572
	Strength(%)	100.00	100.00	100.00	100.00
	L	81.867	82.583	81.201	86.530
	a	0.357	2.153	2.702	0.856
	b	4.764	15.044	15.924	7.256
Pre-mordanting	K/S	4.461	7.013	7.267	5.938
	Strength(%)	169.61	208.45	182.57	377.77
	L	80.401	76.745	76.303	79.855
	a	0.800	3.814	3.897	4.441
	b	15.596	20.609	20.640	24.001
Meta-mordanting	K/S	4.931	7.574	8.944	6.400
	Strength(%)	187.47	225.14	224.72	407.17
	L	80.755	76.036	73.972	79.178
	a	0.862	3.637	4.006	3.471
	b	19.395	21.033	21.170	24.049
Post-mordanting	K/S	8.422	11.616	10.519	7.566
	Strength(%)	320.21	345.28	264.29	481.34
	L	74.991	71.644	72.729	76.794
	a	2.500	5.485	5.289	3.848
	b	20.909	24.151	23.538	23.260

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Table 9: Cotton dyed using Tea mordant

Method of Dyeing → / Method of Mordanting ↓		Exhaust	Pad Dry Cure	Pad Dry Steam	Cold Pad Batch
Control (Without Mordanting)	K/S	0.873	1.239	1.297	0.883
	Strength(%)	100.00	100.00	100.00	100.00
	L	88.624	87.892	87.690	88.709
	a	1.270	0.496	0.417	1.114
	b	0.710	5.826	6.175	0.944
Pre-mordanting	K/S	3.331	7.521	10.415	11.036
	Strength(%)	381.71	607.09	803.06	1249.33
	L	81.424	75.165	71.794	70.566
	a	1.723	5.145	6.370	6.060
	b	10.754	18.968	21.113	19.863
Meta-mordanting	K/S	6.901	6.220	6.360	4.886
	Strength(%)	790.86	502.04	490.39	553.13
	L	74.973	76.845	76.531	79.532
	a	4.993	4.635	4.596	3.184
	b	15.710	17.317	17.186	16.893
Post-mordanting	K/S	9.844	15.615	15.349	9.843
	Strength(%)	1128.09	1260.36	1183.55	1114.27
	L	71.199	64.878	65.421	71.661
	a	6.882	6.976	7.071	6.412
	b	17.706	17.481	18.317	18.756

Table 10: Viscose Rayon dyed using Tea mordant

Method of Mordanting / Method of Dyeing		Exhaust	Pad Dry Cure	Pad Dry Steam	Cold Pad Batch
Control (Without Mordanting)	K/S	2.630	3.364	3.980	1.572
	Strength(%)	100.00	100.00	100.00	100.00
	L	81.867	82.583	81.201	86.530
	a	0.357	2.153	2.702	0.856
	b	4.764	15.044	15.924	7.256
Pre-mordanting	K/S	8.705	22.750	21.404	26.884
	Strength(%)	330.99	676.24	537.76	1710.31
	L	71.855	61.163	62.004	58.732
	a	3.829	7.609	7.368	8.180
	b	14.485	22.023	21.856	22.216
Meta-mordanting	K/S	12.502	11.643	11.924	10.336
	Strength(%)	475.35	346.10	299.58	657.54
	L	68.138	69.605	68.939	71.706
	a	6.252	6.123	6.031	5.557
	b	17.907	19.294	18.376	20.531
Post-mordanting	K/S	13.606	19.121	19.577	10.715
	Strength(%)	517.32	568.38	491.85	681.70
	L	67.872	61.737	61.187	70.953
	a	8.674	6.992	6.677	6.900
	b	20.603	16.926	16.234	19.984

3.2 Shades of mushroom natural dye on cellulosic substrate

The utilization of a suitable mordant during application of natural dyes is quite benficial in obtaining a variety of shades on various textile material. In the present study also, three natural mordants, viz. tea, tannic acid and harde have been used for getting different shades on cotton and viscose rayon fabrics. The fastness characterisitcs of the dyed samples is also increase due to mordant utilization. Figures 3, 5 and 7 demonstrates the shades on cotton substrate dyed with mushroom dye and mordanted with tea, tannic acid and harde mordants respectively using pre-, meta- and post mordanting techniques. Similarly, Figures 4, 6 and 8 represents the shades on viscose rayon fabric dyed with mushroom dye and mordanted with tea, tannic acid and harde mordants respectively using pre-, meta- and post mordanting techniques. The shades range from creamish yellow to greenish yellow and light brown to dark brown, as well as different tones of green, brown and grey.

Figure 3: Various shades on cotton fabric dyed with mushroom dye in absence and presence of Tea mordant using various mordanting techniques

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Figure 4: Various shades on viscose rayon fabrric dyed with mushroom dye in absence and presence of Tea mordant using various mordanting techniques

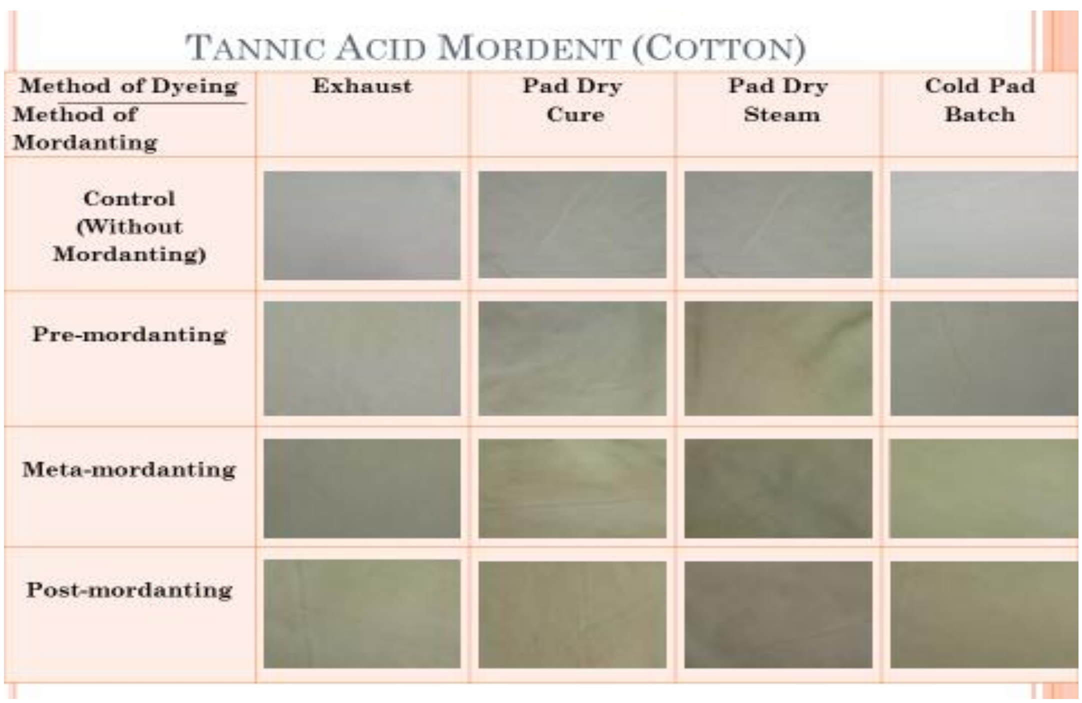

Figure 5: Various shades on cotton fabrric dyed with mushroom dye in absence and presence of Tannic acid mordant using various mordanting techniques

Figure 6: Various shades on viscose fabrric dyed with mushroom dye in absence and presence of Tannic acid mordant using various mordanting techniques

Figure 7: Various shades on cotton fabrric dyed with mushroom dye in absence and presence of Harde mordant using various mordanting techniques

Figure 8: Various shades on viscose fabrric dyed with mushroom dye in absence and presence of Harde mordant using various mordanting techniques

3.3 Fastness characteristics

3.3.1 Washing Fastness

Washing fastness results of mushroom with harde mordant on cotton are better in the case of pad dry cure dyeing method than other dyeing methods (table 11). Table also suggests that exceptional washing fastness was achieved for cold pad batch compare to pad dry steam. The washing fastness results of dyeing with tannic acid as mordant on cotton also gave better result in pad dry cure dyeing method, but in case of pad dry steam dyeing method, washing fastness is very unfortunate. When dyeing of cotton is done using tea as a mordant, washing fastness suggest excellent and same results with exhaust, pad dry cure and cold pad batch dyeing method, while pad dry steam shows poor result. Table 12 clearly indicating for washing fastness of mushroom dyeing on viscose rayon fabric with harde as a mordant gave better performance for pad dry cure dyeing method. It has been also seen that the mordant tannic acid also gave better result in pad dry cure method compare to other dyeing methods. For mordanting with tea, also gave poor results in cold pad batch and exhaust dyeing method on viscose rayon.

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Table 11: Various Fastnesses of dyed on Cotton

Mordant		Harde				Tannic Acid				Tea			
Dyeing Method		I	II	III	IV	I	II	III	IV	I	II	III	IV
Washing		3-4	4-5	3-4	5	4	4	3-4	4	4-5	4-5	3-4	4-5
Rubbing	Dry	3-5	3-5	3-4	5	4-5	4-5	3-4	4-5	4	4	3-4	5
	Wet	3	3-4	3	4	3	4-5	3-4	4-5	4	4	3	4-5
Light		4	4-5	3-5	4-5	4	5	3-4	5	3-5	5	3-5	5

Table 12: Various Fastnesses of dyed on Viscose Rayon

Mordant		Harde				Tannic Acid				Tea			
Dyeing Method		I	II	III	IV	I	II	III	IV	I	II	III	IV
Washing		3	3-5	4	4-5	4	4	4-5	5	3-5	3-4	4	4-5
Rubbing	Dry	4	4	4-5	5	3-4	4-5	4	4-5	4	4	4-5	5
	Wet	3-4	3	3-5	4	3-4	4-5	4-5	4	3-5	4-5	4	4-5
Light		3	3-4	3-4	4	4	4	4-5	5	3-4	4-5	4	5

I = Exhaust, II = Cold Pad Batch, III = Pad Dry Steam, IV = Pad Dry Cure

3.3.2 Rubbing Fastness

Both dry and wet rubbing fastnesses of mushroom dyeing using mordant harde on cotton have an outstanding fastness when dyed with pad dry cure method, rubbing fastness is normal with pad dry steam method and; exhaust and cold pad batch dyeing method has pitiable fastness (table XI). In both the mordant tannic acid and tea, shows excellent fastness, while other dyeing methods show usual fastness compare to it. When viscose rayon is dyed with mushroom using various mordant, harde suggests excellent rubbing fastness, both dry and wet, with pad dry cure method (table XII), but with pad dry steam method, it suggest better dry fastness compare to wet rubbing fastness. For tannic acid as a mordant for dyeing with mushroom, gave comparable fastness compare to exhaust and cold pad batch dyeing method, while pad dry cure and pad dry steam method has excellent dry and wet rubbing fastness on viscose rayon. Same excellent rubbing fastness (dry and wet) for mushroom dyed with application of tea as mordant, but table also indicates fastness is good in cold pad batch and exhaust method. For tea as mordant dry rubbing fastness is better in pad dry steam dyeing method compare to exhaust dyeing method. It has been also seen that for tea as mordant gave better wet rubbing fastness in case of cold pad batch dyeing method than pad dry steam method.

3.3.3 Light Fastness

Light fastness is the measurement of the dye fading by continuous exposure of light on the printed fabric under specific conditions and determines the dye strength till some extent towards light. In case of dyeing with mushroom on cotton using harde as mordant indicated tremendous light fastness when dyed using pad dry cure and cold pad batch methods (table 11). The fastness results were below average for pad dry steam method than any other dyeing methods utilized in present work. In case of tannic acid as mordant, has better fastness in pad dry cure and cold pad batch methods than pad dry steam and exhaust dyeing method, but pad dry steam shows very poor light fastness for tannic acid. The results of table 12 also indicate that equal and excellent light fastness has been achieved in case of mordanting with tea for cotton in pad dry cure and cold pad batch dyeing methods. In the case of, pad dry steam and exhaust dyeing method, light fastness has average and equal results. Pad dry cure dyeing method gave better result for light fastness on viscose rayon with harde mordanting, while pad dry steam and cold pad batch method has average result, and exhaust dyeing method shows poor light fastness (table 13). Tannic acid mordating, exhaust, pad dry steam and exhaust dyeing methods have equal and good result for light fastness, while pad dry cure dyeing method shows excellent fastness compare to other dyeing methods. Table also suggests, for tea application as mordant, dyeing is giving better fastness in cold pad batch method, while pad dry cure has excellent fastness, and exhaust as well pad dra steam shows poor result than above two methods.

3.4 Performance study of Natural Finishing agent (Mushroom)

The antibacterial properties of materials can be studied by qualitative (AATCC-147) as well as quantitative (AATCC-100) test methods. However, it has been found the qualitative test is good for testing the main agent or the treated fabrics, provided the antibacterial agents used are capable of leaching out. On the other hand, quantitative test is the proper indicator of degree of antibacterial activity when the antibacterial agents are fixed on to the textile material or are unable to leach out. The different tests carried out in this study are based on such consideration.

Table 13: Qualitative Studies of Mushroom Extract Treated Fabric

Fabric	Growth under fabric	Zone of inhibition, mm	
		Sa	Ec
Untreated (Cotton)	Present	NIL	NIL
Finish Cotton (Exhaust Method)	Absent	10.2	5.4
Finish Cotton (CPB)	Absent	9.9	4.9
Finish Cotton (PDS)	Absent	10.1	5.8
Finish Cotton (PDC)	Absent	12.5	6.6
Untreated (VR)	Present	NIL	NIL
Finish VR (Exhaust Method)	Absent	10.1	8.0
Finish VR (CPB)	Absent	8.0	5.9
Finish VR (PDS)	Absent	12.6	7.1
Finish VR (PDC)	Absent	13.5	6.5

VR = Viscose Rayon, CPB = Cold Pad Batch, PDS = Pad Dry Steam, PDC = Pad Dry Cure, Sa = *Staphylococcus aureus,* Ec = *Escherichia Coli*

Table 14: Quantitative Studies of Mushroom Extract Treated Fabric

Fabric	Growth under fabric	Bacterial Reduction, %	
		Sa	Ec
Untreated (Cotton)	Present	0	0
Finish Cotton (Exhaust Method)	Absent	99.2	94.2
Finish Cotton (CPB)	Absent	99.8	94.5
Finish Cotton (PDS)	Absent	99.9	92.6
Finish Cotton (PDC)	Absent	99.9	95.3
Untreated (VR)	Present	0	0
Finish VR (Exhaust Method)	Absent	99.8	85.2
Finish VR (CPB)	Absent	98.2	89.1
Finish VR (PDS)	Absent	99.7	87.1
Finish VR (PDC)	Absent	99.9	90.8

VR = Viscose Rayon, CPB = Cold Pad Batch, PDS = Pad Dry Steam, PDC = Pad Dry Cure, Sa = *Staphylococcus aureus,* Ec = *Escherichia Coli*

Antibacterial activities of mushroom extract treated fabrics using qualitative and quantitative methods are given in Tables 13 and 14. Parallel streak method results clearly show that all treated fabrics are having very good antibacterial properties to both Gram positive and Gram negative micro-organisms. The treated fabrics do not allow the growth of bacteria under the test specimens. All the treated fabrics show a zone of inhibition ranging from 9.9 mm to 12.5 mm for Gram positive and from 4.9 mm to 6.6 mm for Gram negative bacteria (Table XIII). The untreated fabric (control) shows bacterial growth under the test specimen. It is also indicated by quantitative results that irrespective of method and methodology adopted for application, the % reduction value to both the microorganism (*S. aureus* and *E.coli*) are found to be > 90% for muhroom extract treated fabrics (Table XIV). The untreated fabric shows zero % reduction to both the micro-organisms. The zone of inhibition values indicate that mushroom extracts not only prevent the growth of bacteria under the fabric, but also leaches out and kills the bacteria (bactericides). This is in agreement with the test results of % reduction value as shown in Table XIII.

CONCLUSION

- Various dyeing methods and mordanting techniques have been used for the application of mushroom natural dye on the cellulosic fibres; among these dyeing methods, pad-dry-cure technique has given excellent result as compared to exhaust, cold pad batch and pad dry steam dyeing techniques. Among pre-, meta- and post-mordanting procedures used for the application of mordants, it has been noticed that meta-mordanting has performed well with harde and tannic acid mordants, while tea has given best dyeing result in post- and pre-mordanting methods on cotton and viscose rayon.
- The anti-oxidant and anti-microbial behaviour of mushroom has given an additional anti-bacterial finish during dyeing operations. The analysis of antimicrobial activity confirms about bacteria repellency with gram positive and gram negative bacteria.
- Dyeing of cotton in presence of natural mordants possess enhanced colour strength (*K/S*) values as compared to the dyeing of cotton in the absence of mordants. When tannic acid mordant is used for mordanting, highest value is achieved in the case of pad dry cure dyeing method. Similarly, for mordanting cotton with tea and harde mordants, excellent colour strength values are obtained for pad dry cure method of dyeing. Both harde and tannic acid have given best performance when applied by meta-mordanting technique and the mordanting and dyeing conducted by pad dry cure process, tannic acid suggest meta-mordanting pad dry cure process, while in case of tea mordant, post-mordanting technique and pad dry cure process of mordanting and dyeing responsible for best dyeing performance.
- Dyed viscose rayon in presence of mordant, using natural mordant for mordanting, is responsible for better dyeing compared to the dyeing of viscose rayon without mordanting. When tannic acid mordant is used for mordanting, highest K/S value is achieved in the case of pad dry steam dyeing method. Similarly, application of tea

and harde mordants on viscose rayon gave excellent good colour strength values for pad dry steam and pad dry cure method of dyeing respectively. From the results, it may be recommended that mordanting with harde mordant for meta-mordanting and pad dry steam processes, tannic acid mordant for meta-mordanting and pad dry steam processes, while tea mordant for meta-mordanting and pad dry cure process should be utilized commercially for achieving enhanced dyeing performance.

- The imparting of antimicrobial finish along with dyeing operation improves the antibacterial resistance of the dyed fabric and does not allow the growth of bacteria under the test conditions. Also, the zone of inhibition values indicates that mushroom extracts not only prevent the growth of bacteria under the fabric, but also leaches out and kills the bacteria (bactericides).
- The utilization of simultaneous dyeing and finishing with natural resources will lead to reduction in the effluent load and also considerable saving to energy, time, labour, cost, etc. Thus, the designed natural colour dyeing and finishing procedure may be commercialized in coming future.

In brief, the extracted mushroom can perform well as dye and antimicrobial agent for textile substrates. The proposed research will be highly beneficial to the society not only in giving protection to the human being against harmful bacteria but also for the preservation of the environment.

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