Properties of woolen woven coated with melanin of yak hair

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ABSTRACT
The melanin of yak hair is a biomaterial with unique features and functions. We investigated the properties of woolen woven when coated with yak hair melanin. Natural melanin was extracted from yak hair by the method of acid hydrolysis. The woolen woven was coated with 5%-10% owt melanin, 0.8 g/l sodium hydroxide (NaOH), and acetic acid (CH3COOH), at a liquor ratio of 1:40 at 96°C for 30 min. Melanin, extracted from yak hair, has the potential to become a natural dye. But converting it into leuco form with the help of a reducing agent makes it dyeing ability. From the UV/Vis spectrophotometer, SEM, and EDS analysis results, it can be seen that the melanin is completely absorbed into the wool fibers. Also, woolen woven is coated with melanin, the good 3/5-4/5 color fastness, the tensile strength of the fabric has improved by warp 53.53%, weft 45.87% but the elongation has reduced by warp 10.79%, weft 18.3%, and the thermal properties of woolen textiles are improved by 23%. It is a step towards developing future clothing materials that reduce environmental stress.

Keywords: *natural pigment, functional textile, dyeing ability, color fastness*

1. INTRODUCTION

In the Future, we need smart and functional textiles, that are protected from environmental stress, due to changes in the climate. Various methods to develop smart and functional textiles start right from the fiber stage and end in the dyeing and finishing stage. Among these methods, the application of smart and functional dyes is considered the most affordable method to develop smart and functional textiles [1].

The yak is an animal adapted to the harsh climate of high mountains, and the yak hair with natural melanin is a valuable raw material to protect against environmental stress. Natural melanin is highly contained in yak hair, that compassion to other animal fibers. Melanin is a natural biopolymer that contributes to various biological processes and protects the organism from the negative effects of the environment [2]. Physico-chemical properties of natural melanin are antitumor, free radical scavenger, UV protection, heat resistance, metal ion absorption, mechanical-chemical strength, nanoparticle synthesizer, radioactive residue remover, paramagnetic, and electron transfers. The complex polymer of melanin is insoluble in organic solvents, amorphous and heterogeneous, which has limited the study of its structure. Recently, scientists have extracted melanin from fungi, bacteria, and animals to discover biomaterials with unique properties that can be used in physics, chemistry, and materials science in many fields, from electric batteries to new treatments and cosmetics [3]. For example, an advanced functional material extracted from yak hair melanin and synthesized with titanium oxide has been shown to remove heavy metals from wastewater from a dyeing industry [4], and melanin-based composites from alpaca wool have been shown to provide UV protection [5,6]. Based on this, it is possible to develop user-friendly and future-functional textile materials using the properties of melanin in the internal microstructure of yak hair.

A case in which natural melanin has been used as a dye in textile materials is research work on dyeing wool and cotton fabric with sepia melanin from an ink sack of squid [7]. In particular, no research is done on dyeing textiles with the melanin of yak hair. Therefore, we investigated the dyeability and properties of woolen woven when coated with yak hair melanin. In this way, it

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is possible to develop woolen textiles for the future-functional textile materials.

2. EXPERIMENTAL

2.1 Materials and chemicals

The black-brown yak hair was used as a natural melanin source and provided by Jinst Murun LLC Khovsgol Province, Mongolia. The 100 % woolen woven with white color was prepared for the experimental work by weaving it on the weaving machine of the Research and Development Institute of Light Industry(RDILI) belonging to the Mongolian University of Science and Technology. Hydrochloric acid (HCI, 32%), acetone, sodium hydroxide (NaOH), acetic acid (CH3COOH), and other additional chemicals were purchased from Green Chemistry Ltd.

2.2 Extraction of natural melanin

The natural melanin was extracted from yak hair [5]. Prepared extract melanin, 20 g of yak hair was washed with acetone and dried at 60°C for 12 hours. For the 20 g yak hair added 600 mL of 32% HCI (Liquor ratio 1:30) in a 1000 mL flask and heat with stirring at 96°C for 3 hours in a water bath. The precipitates are centrifuged at 4000 rpm for 20 minutes. The supernatant is neutralized with distilled water and dried at room temperature in the dark Fig. 1.

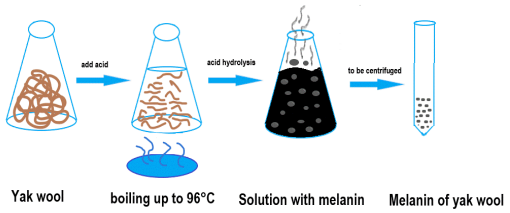

Figure 1. Extraction melanin of from yak hair

2.3 Developing coating on woolen woven

The woolen woven was scoured in an aqueous solution with 0.8 g/l nonionic detergents, Listrill WWW, with a liquid ratio of 1:45 at 38°C for 10 min. The woven was then raised with water, and air dried in the room.

The woolen woven was coated with 5%-10% owt melanin, 0.8 g/l sodium hydroxide (NaOH), and acetic acid (CH3COOH), at a liquor ratio of 1:40 at 96°C for 30 min. Mordants (Ferric sulfate Fe2(SO4)3, Copper (II) sulfate pentahydrate CuSO4*5H2O, Potassium hexacyanoferrate K3[Fe(CN)6], Sodium hydrosulfite Na2S2O4) was used same-time dyeing.

2.4 The characterization techniques

Scanning electron microscopy (SEM) and EDS analysis were using a JEOL JCM-6000 plus Benchtop SEM. Transmission and absorption wavelength was determined by a Genesys 10S UV/Vis spectrophotometer.

The properties of woolen woven were determined according to the textile national standards MNS and international standard methods: ISO, AATCC, and IWTO. The colorfastness to washing and rubbing of dyed woven were carried out with a washing machine and crock meter according to ISO. All experiments and tests were performed by accredited laboratories RDILI.

3. RESULTS AND DISCUSSION

3.1 Dyeing ability melanin of yak hair

Melanin is not soluble in water, so attaching it directly to the wool fibers was impossible. Therefore, the method of dissolving in water with the help of a reducing agent was chosen [7]. It was converted to Leuco-compounds by dissolving it using a reducing agent (NaOH) and in this form, they are introduced into the fiber Fig. 2.

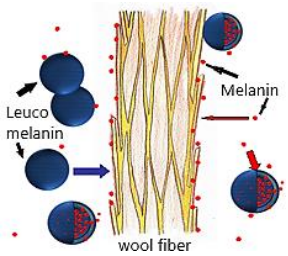

Figure 2. Processing dyeing leuco-melanin for wool fiber

When the white fabric is coated with melanin, it is dyed brownish-gray (Fig.3)

In order to coat woolen fibers with melanin, it is necessary to create an alkaline solution with an amount of sodium hydroxide of more than 0.5-0.75 g/l, but it is necessary to pay attention to the damage to the fibers. Therefore, adjusting the pH with acetic acid, which is commonly used in keratin fiber dyeing technology, will not only prevent fiber damage but also intensify color input. Good dyeability of wool fibers in the acidity of a solution. The melanin molecule diffuses well in the wool fibers in a strongly acidic solution with a pH of 3-4.

Figure 3. Before and after woolen woven coated with melanin of yak hair

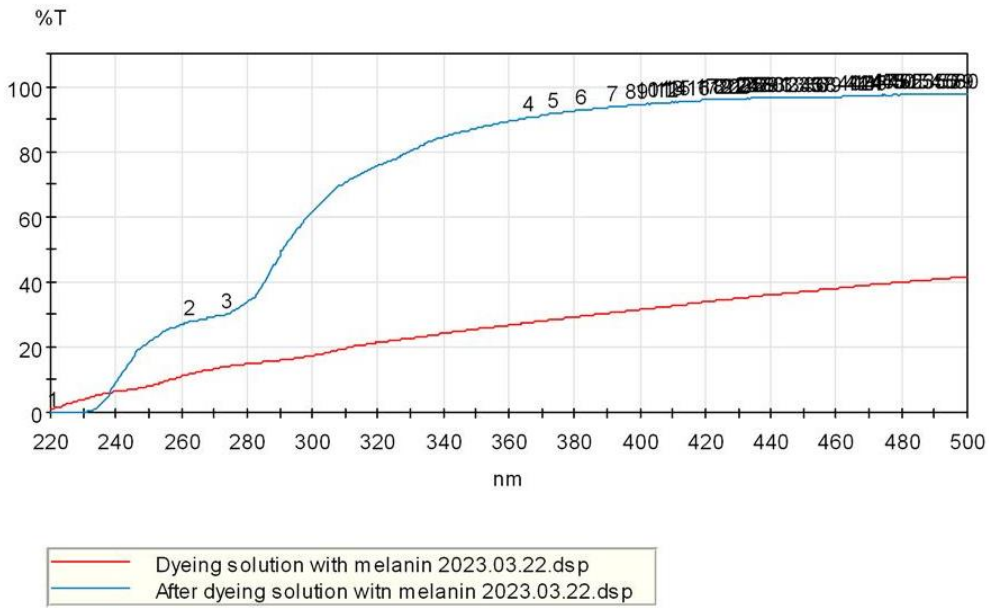

Figure 4. Spectral transmission of solution before and after woolen woven coated with melanin of yak hair

The post-treatment solution was analyzed by UV/Vis spectrophotometer. (Fig. 4.) As can be seen from the curve in the spectrum above, the wave transmission increased by 40 %T after treatment, confirming that the melanin was absorbed into the wool fibres. From the SEM image, it can be seen that melanin granules are sitting on the surface of the wool fibres. (Fig.5)

The quantitative analysis before and after woolen woven coated with melanin of yak hair by EDS was shown in the following Table 1.

The average of the three measurement results shows that the amount of sulphur has decreased and the carbon, nitrogen, and oxygen content improved.

The following Table 2. shows the changes in the physical and mechanical properties of woolen woven coated with melanin. As can be seen from this table, when the woolen textile is coated with melanin, the air volume is reduced by 14.4% and the size air is reduced by 14.7%, which means that the air permeability is reduced.

The thickness of the fabric became thinner by 8.4%, but the thermal resistance increased by 16.96% and the thermal conductivity decreased by 23.9%, which improved the thermal properties.

The tensile strength of the fabric has improved by warp 53.53%, weft 45.87% but the elongation has reduced by warp 10.79%, weft 18.3%. 10 cm of shrinkage along the dense base direction of the fabric showed almost no change. In results, it appears that melanin coating of woolen textiles can improve their properties.

3.2 Coating melanin of yak hair with mordant

Mordants (Ferric sulphate Fe2(SO4)3, Copper (II) sulphate pentahydrate CuSO4*5H2O, Potassium hexacyanoferrate K3[Fe(CN)6], Sodium hydrosulphite Na2S2O4) was used same-time dyeing. Then the color changes due to the effect of salt. After processing, the colorfastness to rubbing and washing was checked by ISO standard. The colour fastness of the coated woollen woven to washing and rubbing was shown in the following Table 3 and 4.

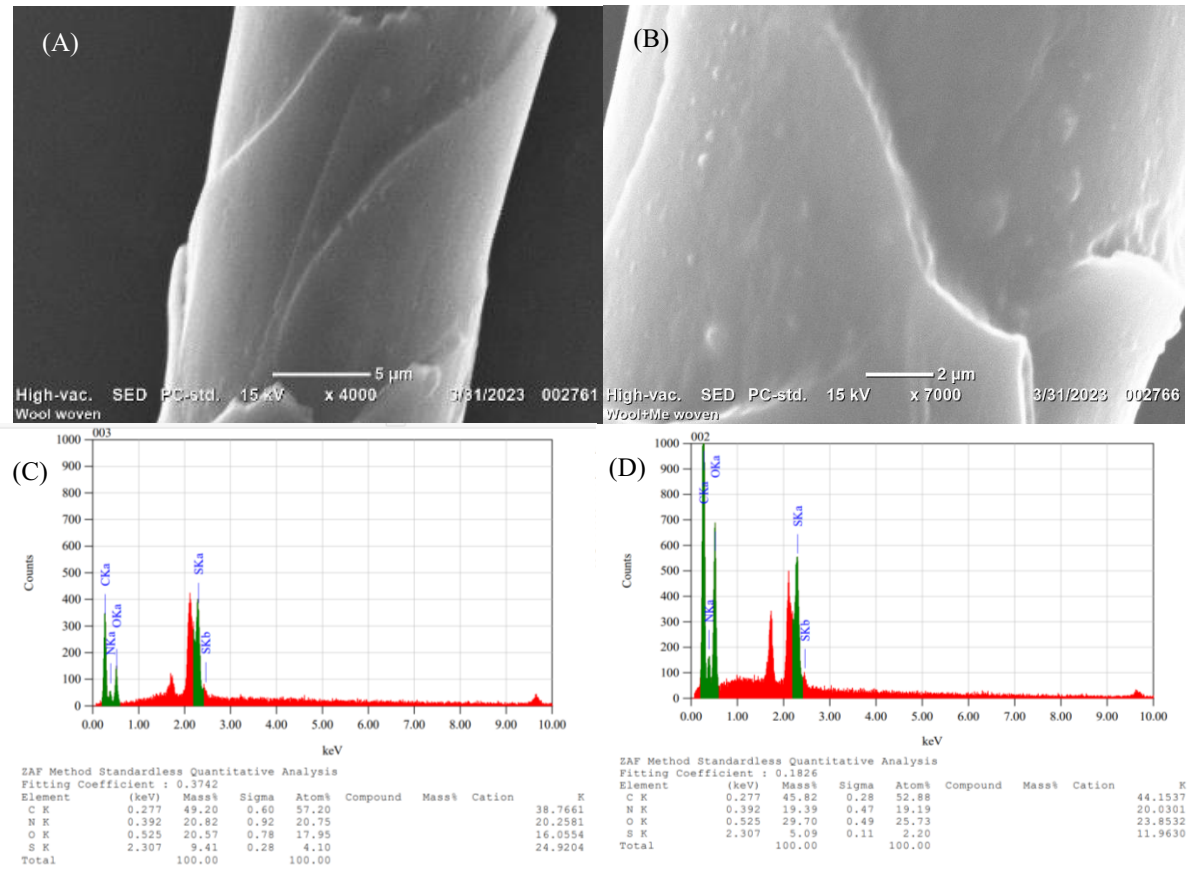

Figure 5. (A) wool fiber, (B) wool fiber coated with yak melanin and before (C) and after (D) EDS spectrum woolen woven coated with melanin of yak hair

Table 1. Quantitative analysis before and after woolen woven coated with melanin of yak hair by EDS

Element	Before		After	
	Mass, %	Atom, %	Mass, %	Atom, %
C	49.20	57.2	44.62	51.07
N	20.82	20.75	24.29	23.83
O	20.57	17.95	27.25	23.43
S	9.42	4.1	3.83	1.67

According to the colorfastness to rubbing, the dye stability is good even when the mordant is used for melanin treatment.

According to the colorfastness to washing, the dye stability is good even when the mordant is used for melanin treatment.

CONCLUSION

Melanin, extracted from yak hair, has the potential to become a natural dye. But converting it into leuco form with the help of a reducing agent makes it dyeing ability. From the UV/Vis spectrophotometer, SEM, and EDS analysis results, it can be seen that the melanin is completely absorbed into the wool fibers. Also when woolen woven are coated with melanin, the physical-mechanical properties and colorfastness are improved. It is a step towards developing future clothing materials that reduce environmental stress.

AUTHORS' CONTRIBUTIONS

Batchimeg Ganbaatar: Conceptualization, Methodology, Investigation, Writing-original draft, Data curation, Resources, **Oyunchuluun Lkhagvasuren:** Investigation, **Dagvasuren Erdene:** Resources **Batsuren Choijamts:** Resources, **Nadmid Gongor:** Supervision, Writing-review & editing is a step towards developing future clothing materials that reduce environmental stress.

Table 2. Properties woolen woven coated with melanin

Properties		Before	After	Deference,%
Air permeability	The volume of air, l/ hours cm2	1077.8	922.5	14.4
	The size of air, mm/sec	400.8	341.8	14.7
Thickness, mm		0.83	0.76	8.4
Thermal resistance, m2*K/W		0.01023	0.01232	16.96
Thermal conductivity, W/(m*K)		0.08156	0.06204	23.9
Strength, kg f	warp	9.69	14.88	53.5
	weft	11.16	16.28	45.87
Extension, %	warp	27.82	17.03	10.79
	weft	42.25	24.22	18.03
The density of the weave, cm	warp	140	145	3.5
	weft	162	162	0

Table 3. Test for colour fastness- Part X12: Colour fastness to rubbing, ISO 105-X12:2001

Type mordant	Download force (N) 9 Testing conditions 65% 22°C			
	dry		wet	
	warp	weft	warp	weft
Without mordant	3/4	3/4	4/5	4/5
Fe2(SO)3	3/4	3/4	4/5	4/5
CuSO4*5H2O	3/4	3/4	4/5	4/5
K3[Fe(CN)6]	2/3	2/3	3/4	3/4
Na2S2O4	3/4	3/4	4/5	4/5

Table 4. Tests for colour fastness - Colour fastness to domestic and commercial laundering, ISO 105-C06:2010

Type mordant	Testing condition ECE Phosphates Detergent 40°C 30 min					
	WO	PA	PES	PAN	CO	AC
Without mordant	4/5	4/5	4/5	4/5	4/5	4/5
Fe2(SO)3	4/5	4/5	4/5	4/5	3/4	4/5
CuSO4*5H2O	4/5	4/5	4/5	4/5	4/5	4/5
K3[Fe(CN)6]	3/4	3/4	3/4	3/4	3/4	4/5
Na2S2O4	4/5	4/5	4/5	3/4	3/4	4/5

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