UV-protection property of Eri silk fabric dyed with natural dyes for eco-friendly textiles

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Abstract. Eri silk (Samia ricini) is a wild silkworm which has been promoted and supported to culture for textile industry in Thailand. Especially for the recent decade, textile industry was interested to develop eri silk for casual eco-friendly textile style with functional properties. This research aims to study on UV protection property of eri silk fabric dyed with natural dyes from plant extracts and their washing fastness property. The processes included extracting the colorants from Thai plants i.e. natural indigo, Burma padauk bark, Neem bark, etc., mordanting the eri silk yarn with potassium aluminum sulphate, iron (II) sulfate and dyeing with their natural dyes to increase the washing fastness property. Eri silk fabrics were woven by the dyed eri yarn providing an excellent protection (UPF 50+) with a proper shade for making 3 prototype clothing products. The result shows that UPF property of eri silk fabric dyed with Burma padauk bark, Gloden shower seed, Neem bark, Andaman satinwood leave and mordanted with iron (II) sulfate presented highest UPF (>100) with good washing fastness. Three prototype products were designed with color matching with natural dyes and fabricated which were hat, scarf and dress. The first product, hat, made from the hand-weave fabric comprised of Ne 20/2 eri spun silk yarn as a warp yarn and Ne 20/2 eri spun silk yarn that dyed from Burma padauk bark as weft yarns. Second product was scarf which made from Ne 20/2 eri spun silk yarn as a warp yarn and Ne1.2 eri hand-reel silk yarn dyed from natural indigo and Burma padauk bark as weft yarns. The last product was dress which made from Ne 30/2 eri spun silk yarn that dyed from sappen as a warp yarn and Ne 30/2 eri spun silk yarn that dyed from indigo as weft yarns. These eco-friendly eri silk products exhibited excellent functional UV-protection property.

1. Introduction
Eri silk (Samia ricini) is a wild silkworm which has a number of benefits and it is cultivated with the complete life cycle. The characteristic of eri silk are smooth, shiny and white. However, with its crimp characteristic, the spun yarns are often blended with other fibers such as cotton fiber [1]. The eri silk has...
the unique characteristic of lightness, soft-smooth feel, thermal property and additionally, it can easily absorb sweat and it is well ventilated. Dyeing and physical properties of the eri and cotton fiber blended yarns at different blend ratios were found differently depending on physical nature of eri silk and cotton fibers [2]. Moreover, there are large amount of cassava plantations in Thailand, accounting for 1,600 million square meters and the cassava leaves are wasted and do not create a value. Since cassava and castor leaves were feed for eri silk worm then production of eri silk can generate subsidiary income to farmers.

Natural dyes extracted from plants are non-toxic, non-hazardous, and environmentally friendly. Dyeing fiber with natural dyes not only adds further elegance to clothing but it also has special properties including bacteria [3] and UV protection [4]. However, the level of UV protective property depends on the plant and materials used in the process of production. Moreover, in these days, people are more concerned about functional properties of product like sun protection. This affected on purchasing fabric goods such as coats, scarves, hats and dresses of customers. As a result, an increasing trend on health and environmental awareness, together with consumer needs of UV protection goods, made our research group interested in the studies of the improvement on UV protection property of eri silk. Study of different natural dyes extracted from Thai plants in order to enhance its ability of UV protection for design the dyed eri silk products to be more appropriate use.

2. Experimental

2.1. Materials
Eri silk fabrics, used for the study of natural dye on UV protection, were woven by Ne 30/2 spun eri silk yarns as warp and weft yarns. Natural dyes were extracted at boiled condition from Gloden shower pods, Neem bark, Andaman satinwood leave, Burma padauk bark, Sappan and Acacia bark. Concerning for any eri silk products in this study, different yarns count of eri spun silk yarn and hand eri spun yarns were chosen to design diversity of woven fabrics.

2.2. Dyeing method
The eri spun silk yarns were dyed with extracted solution of these natural dyes at 100°C at L:R of 1:20 for 1 hr. Then post mordant process was prepared by soaking these dyed eri fabrics at room temperature in AlK(SO₄)₃ and FeSO₄ solution (5 g/L). Finally, these dyed eri spun silk yarns were hand woven in plain weaving pattern by community enterprise group at Khonkan province based on matching color trends.

2.3. Characteristic
UV spectrophotometer was used to measure L, a*, b* values of the dyed eri silk with different natural dyes. Ultraviolet (UV) transmission and the ultraviolet protection factor (UPF) of dyed eri silk spun yarns were determined according to AATCC138:2000 test method. Also, the color fastness to washing was characterized according to ISO 105-C01 A1S: 2012 standard test method.

2.4. Product development
Three prototype products of eri silk fabrics developed in this research were hat, scarf and dress depending on color and weaving structure.

3. Results and discussion

3.1. Effect of dyeing properties and UPF values of dyed eri silk fabrics
The color value (L, a*, b*) results were presented in Table 1. Eri spun silk yarns dyed with natural dyes which were Andaman satinwood leave, Golden shower pods, Neem bark, Sappan, Acacia bark and Burma padauk bark with an efficiency enhancement of post-mordanting by AlK(SO₄)₃ and FeSO₄. It was found that dyeing eri silk with Andaman satinwood leave was resulted in greenish-brown color. In addition, eri spun silk yarns dyed with Golden shower pods resulted in brown. With Neem bark, Sappan, Acacia bark and Burma padauk bark, the post-mordanted samples produced a reddish-brown color. After mordanting with both AlK(SO₄)₃ and FeSO₄, it gives the contrast results. The consequent color of mordanting with AlK(SO₄)₃ was shown with bright color which gave increasing value of a* or b*, while mordanting it with FeSO₄ resulted in decreasing value of L, a* or b* making color darken.
The Ultraviolet Protection Factor value (UPF) was used to determine the ability of UV protection of the fabric. It was found that without natural dyes and mordant, the UPF value of evaluated eri silk fabric was 35.08. Mordanting undyed eri silk with AlK(SO₄)₂ and FeSO₄ gave the UPF values of 49.9 and 65.3, respectively. It can be obviously observed that eri silk with natural dyes from Burma padauk bark, Andaman satinwood leave, Neem Bark and non-mordanting gave the results of UPF values of 201.94, 184.42 and 157.78, respectively ranking from the highest ability of protection. Since tannins from plant has an advantage on protecting against UV radiation, dyeing eri spun silk yarn with natural dyes enhances the ability of UV protection regarding an increase in tested value of UPF. The UPF value of samples shown in table 2 appeared to be more than 50 which indicated that the resistance of dyed eri silk was very strong giving the highest UV protection. Furthermore, the dyed eri silk with mordanting by AlK(SO₄)₂ and FeSO₄ gave higher UV protection property towards eri silk. However, mordanting with FeSO₄ tended to be more effective on UV protection property due to darken color shade.

### 3.2. Color fastness to washing test

According to Table 3, the results indicated that the color fastness to washing of eri silk fabrics with Sappan and Burma padauk bark extract was very good with rating of 4-5. In the same way, the fastness property to washing of those plants extract fabric with mordants (AlK(SO₄)₂ and FeSO₄) was also ranked as 4-5 which was considered as very good fastness property.

| Table 1. Color values (L a* b*) of dyed eri silk fabrics by post-mordanting technique |
|------------------------------------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|
| Type of plants                           | Type of mordants | a*     | b*    | Color obtained |
|------------------------------------------|----------|--------|-------|----------------|
| Without                                  | Without  | 87.45  | -0.00 | 9.86           |
|                                          | AlK(SO₄)₂ | 87.63  | 0.02  | 10.27          |
|                                          | FeSO₄    | 67.88  | 2.34  | 11.67          |
| Andaman satinwood leave                   | Without  | 78.40  | 1.60  | 19.36          |
|                                          | AlK(SO₄)₂ | 70.95  | 1.24  | 24.25          |
|                                          | FeSO₄    | 58.52  | 2.61  | 16.41          |
| Golden shower pods                       | Without  | 43.31  | 4.40  | 16.78          |
|                                          | AlK(SO₄)₂ | 35.96  | 4.23  | 14.98          |
|                                          | FeSO₄    | 32.80  | 2.09  | 9.92           |
| Neem bark                                | Without  | 52.93  | 12.89 | 13.40          |
|                                          | AlK(SO₄)₂ | 47.68  | 12.23 | 12.58          |
|                                          | FeSO₄    | 35.68  | 4.16  | 5.91           |

| Table 2. UPF values and protection class of eri silk fabrics by post-mordanting technique |
|------------------------------------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|
| Type of plants                           | Type of mordants | UPF    | Protection class |
|------------------------------------------|----------|--------|------------------|
| Without                                  | Without  | 35.08  | Very good        |
|                                          | AlK(SO₄)₂ | 46.69  | Excellent        |
|                                          | FeSO₄    | 65.13  | Excellent        |
| Andaman satinwood leaf                   | Without  | 184.42 | Excellent        |
|                                          | AlK(SO₄)₂ | 292.81 | Excellent        |
|                                          | FeSO₄    | 331.63 | Excellent        |
| Golden shower pods                       | Without  | 147.28 | Excellent        |
|                                          | AlK(SO₄)₂ | 441.71 | Excellent        |
|                                          | FeSO₄    | 843.01 | Excellent        |
| Neem bark                                | Without  | 157.78 | Excellent        |
|                                          | AlK(SO₄)₂ | 204.57 | Excellent        |
|                                          | FeSO₄    | 262.82 | Excellent        |

| Table 3. Color fastness to washing test at 40.℃ ISO 105-C01 A1S: 2012 |
|------------------------------------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|
| Type of plants                           | Color change | Acetate | Cotton | Nylon | Polyester | Acrylic | Wool |
|------------------------------------------|-------------|---------|--------|-------|-----------|---------|------|
| Sappan                                   | 4/5         | 5       | 4      | 4/5   | 4/5       | 4/5     | 4/5  |
| Sappan + AlK(SO₄)₂                       | 4/5         | 5       | 4      | 4/5   | 4/5       | 4/5     | 4/5  |
| Sappan + FeSO₄                           | 4/5         | 5       | 4/5    | 4/5   | 4/5       | 4/5     | 4/5  |
3.3. Development of three prototype products (hat, scarf and dress) with natural UV-protected dyes

The result was concluded that all UPF value tests of dyed eri silk from natural extract were above 50 indicating that natural dyes had the highest efficiency on UV protection. Accordingly, our research group selected the complement colors which were reddish-brown color from Sappan and Burma padauk bark and blue color in order to combine them and to create natural indigo dyed eri silk for prototype products with natural UV-protected dyes (Table 4). The natural indigo dye not only has high demand in the market but it also has an excellent ability on UV protection. As previous research, indigo dyeing in fabric provided significant efficiency on UV protection and moreover, its property raised after washing [5].

Table 4. Development of three prototype products with natural UV-protected dyes

| Products                                           | Descriptions                                                                                   | Pictures |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------|----------|
| Hat: the entire face, ears, and neck UV protection hat | Plain weave fabric made from the hand-weave fabric comprised of Ne 20/2 eri spun silk yarn as a warp yarn and Ne 20/2 eri spun silk yarn that dyed from Burma padauk bark as weft yarns (71x28 yarn per square inch). Ikat pattern was made from 20/22Dx4 mulberry silk filament yarn as weft yarn (71x41 yarn per square inch). | ![Hat Picture](image1.png) |
| Scarf                                              | Plain weave fabric comprised of Ne 20/2 eri spun silk yarn as a warp yarn and Ne 2.1 eri hand-reel silk yarn dyed from natural indigo and Burma padauk bark as weft yarns. | ![Scarf Picture](image2.png) |
| Dress with jacket: suitable pattern and texture for dress (casual dress for officers) | Plain weave fabric comprised of Ne 30/2 eri spun silk yarn that dyed from sappen as a warp yarn and Ne 30/2 eri spun silk yarn that dyed from indigo as weft yarns (20x107 yarn per square inch) | ![Dress Picture](image3.png) |

4. Conclusions

Eri silk yarns dyed with Andaman satinwood leaves, Golden shower pods, Neem bark, Sappan, Acacia bark and Burma padauk bark had an excellent level on UV protection. Moreover, with post-mordanting by AlK(SO₄): and FeSO₄, the UV protection property was observed in the UPF value. As a result, natural dyes together with post-mordanting were applied in order to UV protection for eri products which were hat, scarf and dress. The color of a reddish-brown color from Sappan and Burma padauk bark was matched with natural indigo in order to develop the products with a trendy stylish color and a greater quality on UV protection.

5. References

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