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EXPERIMENTAL PAPER

Clitoria ternatea L. as material for dyeing textile products made of protein fibers

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Summary

Introduction: Butterfly pea flower *Clitoria ternatea* L. belongs to family *Fabacea*e. The plant has many applications in various industries. The most important usage is in medicine and as a food dye. In Europe, it is almost unknown as a textile dye, unlike in Asian countries.

Objective: The aim of the study was to assess the dyeing properties of textile materials made from protein fibres (sheep wool and natural silk) by water extract of Butterfly pea.

Methods: Knitted fabric made from sheep wool and silk fabric were selected for testing. The colors of both textile materials using six dyeing methods were compared.

Results: The colour palettes obtained from protein fibres – wool knitted fabric and silk fabric are totally different. The colours of wool knitted fabrics are warm beige, shades of olive, heather and yellow tones. The colours of silk fabric are shades of heather and lavender.

Conclusions: The dyestuff obtained from *Clitoria ternatea* L. flowers is suitable for dyeing protein fibres. Naturally dyed fabrics and knitted fabrics made of protein fibres increase the attractiveness of products made of these materials.

Key words: ***Clitoria ternatea L., wool, silk, natural dyeing, anthocyanin***

Słowa kluczowe: ***Clitoria ternatea L., wełna, jedwab, barwienie naturalne, antocyjany***

INTRODUCTION

Butterfly pea flower *Clitoria ternatea* L. (family *Fabaceae*) is a plant originated from Asia, Australia and some African countries, the South of the United States, Central and South America, West India and several Pacific Islands [1, 2]. Commonly called clitoria, has different nomenclature in various countries: blue-pea, kordofan pea (Sudan), cunha (Brazil), fula criqua (Portugal), lan hu die (Chinese), bunga biru, tembang telang (Indonesia), bunga telang (Malaysia), clitoria azul, (Spanish), dangchan (Thai), kittelbloem (Dutch), blaue Klitorie (German), himmelsärt (Sweden); mavi kelebek sarmaşığı (Turkey). English names are as follows: Butterfly pea, Mazerion and Winged leaved Clitoria [2]. It has several synonyms in ayurvedic scriptures, like Sanskrit names: Aparajita, Girikarnu, Asphota and Vishnukranta [3].

Use of herbal medicines in Asia represents a long history of human interactions with environment. Plants used for traditional medicine contain a wide range of substances that can be used to treat chronic as well as infectious diseases [4, 5]. Butterfly pea is an ornamental plants and worshipping materials in Indonesia. Different varieties of plant have beautiful, colourful flowers including white, mauve, light and dark blue [6-8]. The plant has many applications in various industries like pharmaceuticals, medicine, cosmetic, food and textile [5, 9, 10]. *C. ternatea* petals contain valuable bioactive components such as: anthocyanins, alkaloid, steroid, tannin, substances lowering sugar levels [7] and flavonoids. It is used in Ayurvedic medicine due to its rich healing properties. It was used as a sedative, antidepressant, lowering cholesterol levels, antidiabetic], anti-anxiety and anti-convulsant drug with memory-enhancing properties [8, 9, 11-15].

The pro-health effect of this plant results from the presence of ternatin anthocyanins and phenolic compounds, such as quercetin and derivatives of kaempferol [9].

Anthocyanins are recommended for health prevention due to their antioxidant properties. They remove free oxygen radicals from the human body, generated as a result of metabolic precesses. They also have the ability to reduce the permeability of capillary walls, so they have anti-haemorrhagic and anti-inflammatory effects [16, 17].

In Malaysia and Thailand, Butterfly pea is very popular food colouring agent. Blue rice "nasi kerabu" ice-cream drinks and cookies are coloured blue, purple and pink, depending on pH. When the pH changes to acidic, the blue colour changes to pink. Besides, Butterfly pea flower is used as a pH indicator for food freshness smart packaging based on polymers [10, 18, 19].

In Europe, *C. ternatea* has no special traditions of use as a textile dye. It appeared as a blue tea made from the dried leaves of the plant and also as a purple tea with the addition of lemongrass.

Sheep wool and silk belong to the group of natural protein fibres [20]. Due to their valuable properties are used in almost every field of the economy, and above all, they are an irreplaceable raw material for the production of fully ecological products. Current trends in textile industry are towards a broader and more conscious use of natural raw materials. The reason for increasing interest in natural fibres is their undeniable timelessness and universality of applications. Moreover, textiles made of natural fibres are a suitable product for those who value a healthy lifestyle and a fashionable and elegant appearance. Domestic sheep wool is usually creamy in colour, while natural silk is white. Subjecting wool and silk to natural dyeing processes, which allows obtaining different colours, increases the attractiveness of products made of these materials [21-24].

The aim of the study was to assess the dyeing properties of knitted fabric made from sheep wool and silk fabric by water extract of *Clitoria ternatea* flowers.

Ethical approval: The conducted research is not related to either human or animal use.

MATERIALS AND METHODS

Materials

The plant material

Research material consist of dried dark blue flowers of the plant *Clitoria ternatea* L., obtained from India. Dried flowers and dye obtained from the plant are presented in figures 1-2.

Textile materials made of protein fibres

Research material consisted of knitted fabric from sheep wool and silk fabric. Knitted fabric was produced in Poland of Polish Merino wool. Silk fabric was imported from China. Knitted fabric was characterized by mass per unit area of 300 g/m^2, number of stitches per unit length – course: 100/10 cm, wale – 85/10 cm. Silk fabric was characterized by mass

Figure 1.

Dried flowers of the plant *C. ternatea* L.

Figure 2.

Dye obtained from dried flowers of the plant *C. ternatea* L.

per unit area – 56 g/m^2, number or threads per unit length: warp – 700/10 cm weft – 430/10 cm. Textile materials made of wool and silk are presented in fig. 3, 4.

Methods

Washing

Knitted wool fabric and silk fabric were washed separately to soften and remove chemical additives from fabric processing. Samples were immersed in aqueous solution of non-ionic detergent (5 ml/l) for 30 minutes. The samples were dried at room temperature.

Pre-mordanting

The pre-mordanting process helps the dyes bind to the fibre. The obtained colours are in many cases more intense and resistant to external conditions.

The same pre-mordanting process was used for wool and silk.

- 3000 ml H_2O,
- 25 g of alum (Aluminum potassium sulphate: $Al_2K_2(SO_4)_4 \times 24H_20$)
- 100 g of fabric

Alum was dissolved in a small amount of warm aqueous solution (temp. 40°C). After this, wet fabrics were placed in water. The solution was heated to 60°C for 90 minutes. After cooling the solution down, the fabric was squeezed but not washed. After drying, it was used to dyeing processes.

Dyeing

In this experiment, eco-friendly natural dye extracted from *C. ternatea* was used. The dyeing process was conducted in the Ugoloni apparatus [21, 22]. Six dye cups were used in this process. For knitted wool fabric, the solution of 500 ml H_2O containing water extraction of the *Clitoria ternatea* L. was

Figure 3.

Knitted wool fabric

Figure 4.

Silk fabric

poured into each cup. For silk fabric the dyeing solution was 333 ml H_2O (tab. 1 and 2).
Cup 1 – no mordants
Cup 2 – aluminium potassium sulphate: $Al_2K_2(SO_4)_4 \times 24H_20$
Cup 3 – sodium carbonate: Na_2CO_3
Cup 4 – citric acid: $C_6H_80_7$
Cup 5 – copper sulphate: $CuSO_4 \times 5H_20$
Cup 6 – iron sulphate: $FeSO_4 \times 7H_20$

Table 1.

Methods of dyeing of wool knitted fabrics by *Clitoria ternatea* L.

Sample	Mordant [g]	Dye [g]	H_2O [ml]	Wool knitted fabric [g]
W1 W1a	–	10	500	12
W2 W2a	Alum 1 g	10	500	12
W3 W3a	Sodium carbonate 1 g	10	500	12
W4 W4a	Citric acid 0,7 g	10	500	12
W5 W5a	Copper sulphate 1 g	10	500	12
W6 W6a	Iron sulphate 0.7 g	10	500	12

Samples
W1 – raw knitted wool fabric, W2 – raw knitted wool fabric +alum, W3 – raw knitted wool fabric + sodium carbonate, W4 – raw knitted wool fabric +citric acid, W5 – raw knitted wool fabric +copper sulphate, W6 – raw knitted wool fabric +iron sulphate; W1a – pre-treated wool knitted fabric, W2a – pre-treated wool knitted fabric + alum, W3a – pre-treated wool knitted fabric + sodium carbonate, W4a – pre-treated wool knitted fabric +citric acid, W5a – pre-treated wool knitted fabric + copper sulphate, W6a – pre-treated wool knitted fabric + iron sulphate.

Table 2.

Methods of dyeing of silk fabric by *Clitoria ternatea* L.

Sample	Mordant [g]	Dye [g]	H_2O [ml]	Silk fabric [g]
S1 S1a	–	6.67	333	7.56
S2 S2a	Alum 0.6 g	6.67	333	7.56
S3 S3a	Sodium carbonate 0.6 g	6.67	333	7.56
S4 S4a	Citric acid 0.5g	6.67	333	7.56
S5 S5a	Copper sulphate 0.6 g	6.67	333	7.56
S6 S6a	Iron sulphate 0.6 g	6.67	333	7.56

Samples
S1 – raw silk fabric, S2 – raw silk fabric + alum, S3 – raw silk fabric + sodium carbonate, S4 –raw silk fabric + citric acid, S5 – raw silk fabric +copper sulphate, W6 – raw silk fabric + iron sulphate; S1a – pre-treated raw silk fabric, S2a – pre-treated raw silk fabric + alum, S3a – pre-treatedt +sodium carbonate, S4a – pre-treated raw silk fabric + citric acid, S5a – pre-treated raw silk fabric + copper sulphate, S6a – pre-treated raw silk fabric +iron sulphate.

The dyeing liquid was heated to a temperature of 60°C (gradient 1°C/1 min.), maintained for 60 min.

Colour determination – Pantone®

The colours of the samples were compared with the standards of the colour identification system developed by Pantone according to the sampler – Pantone (Colour) Matching System (PMS). The catalogue contains 2100 textile colours (including 2011 update) and is an excellent tool for quick colour selection and specification.

RESULTS AND DISCUSSION

Photographs of knitted wool fabric and silk fabric dyed with *C. ternatea,* both without mordant and with mordants: alum, sodium carbonate, citric acid, copper sulphate and iron sulphate are presented in Figures 5 and 6. Pantone® colour measurement results are presented in Tables 3, 4.

In dyeing processes, the colours obtained from this plant depended on the presence of anthocyanins in flower petals and the technologies used [25].

The water extract from the plant flowers is very sensitive to pH changes. After extraction of the dye in deionized water, the solution is blue. In the process of change of the environment from acidic to alkaline, the colour of the solution changes from red to purple [2, 19, 26]. The colours obtained in fabrics do not correspond with the colour of the dyeing solutions – dark blue (Figure 2, 4, 6).

The colour palettes obtained on protein fibres – wool knitted fabric and silk fabric are totally

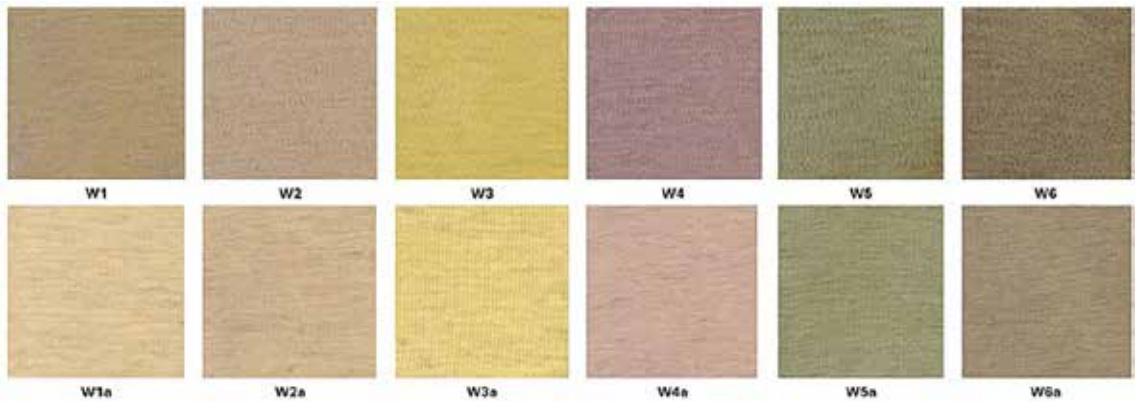

Figure 5.

Wool knitted fabric after dyeing process

Samples
W1 – raw knitted wool fabric, W2 – raw knitted wool fabric +alum, W3 – raw knitted wool fabric + sodium carbonate, W4 – raw knitted wool fabric +citric acid, W5 – raw knitted wool fabric +copper sulphate, W6 – raw knitted wool fabric +iron sulphate; W1a – pre-treated wool knitted fabric, W2a – pre-treated wool knitted fabric + alum, W3a – pre-treated wool knitted fabric + sodium carbonate, W4a – pre-treated wool knitted fabric +citric acid, W5a – pre-treated wool knitted fabric + copper sulphate, W6a – pre-treated wool knitted fabric + iron sulphate.

Figure 6.

Silk fabric after dyeing process

Samples
S1 – raw silk fabric, S2 – raw silk fabric + alum, S3 – raw silk fabric + sodium carbonate, S4 –raw silk fabric + citric acid, S5 – raw silk fabric +copper sulphate, W6 – raw silk fabric + iron sulphate; S1a – pre-treated raw silk fabric, S2a – pre-treated raw silk fabric + alum, S3a – pre-treatedt +sodium carbonate, S4a – pre-treated raw silk fabric + citric acid, S5a – pre-treated raw silk fabric + copper sulphate, S6a – pre-treated raw silk fabric +iron sulphate.

Table 3.

Results of Pantone® colour measurement of knitted wool fabric

Sample	Color	Pantone TCX
W1	Pea colour	17–0525
W1a	Cream	11–0817
W2	Pistachio	16–0421
W2a	Darker cream	12–0619
W3	Lemon gray	14–0836
W3a	Beige	13–0824
W4	Heather gray	16–380
W4a	Pastel yellow	13–0824
W5	Sage colour	16–0421
W5a	Light olive	14–4501
W6	Olive	17–0525
W6a	Light sage	16–0518

Samples
W1 – raw knitted wool fabric, W2 – raw knitted wool fabric +alum, W3 – raw knitted wool fabric + sodium carbonate, W4 – raw knitted wool fabric +citric acid, W5 – raw knitted wool fabric +copper sulphate, W6 – raw knitted wool fabric +iron sulphate; W1a – pre-treated wool knitted fabric, W2a – pre-treated wool knitted fabric + alum, W3a – pre-treated wool knitted fabric + sodium carbonate, W4a – pre-treated wool knitted fabric +citric acid, W5a – pre-treated wool knitted fabric + copper sulphate, W6a – pre-treated wool knitted fabric + iron sulphate.

Table 4.

Results of Pantone® colour measurement of silk fabric

Sample	Colour	Pantone TCX
S1	Gray lilac	17–3817
S1a	Gray	17–5102
S2	Lilak	18–3834
S2a	Lilak	18–3834
S3	White	11–1001
S3a	Icle	12–5201
S4	Lavender	18–3737
S4a	Dark lavender	17–3730
S5	Dark lilac	18–3828
S5a	Dark lilac	18–3828
S6	Gray lavender	18–3812
S6a	Gray lavender	18–3812

Samples
S1 – raw silk fabric, S2 – raw silk fabric + alum, S3 – raw silk fabric + sodium carbonate, S4 –raw silk fabric + citric acid, S5 – raw silk fabric +copper sulphate, W6 – raw silk fabric + iron sulphate; S1a – pre-treated raw silk fabric, S2a – pre-treated raw silk fabric + alum, S3a – pre-treatedt +sodium carbonate, S4a – pre-treated raw silk fabric + citric acid, S5a – pre-treated raw silk fabric + copper sulphate, S6a – pre-treated raw silk fabric +iron sulphate.

different. The colours of wool knitted fabrics have warm beige, shades of olive, heather and yellow tones. The colours of silk fabric are shades of heather and lavender.

CONCLUSIONS

Natural dyes have better biodegradability and, in general, have higher environmental compatibility than synthetic dyes. The dyestuff obtained from *Clitoria ternatea* L. flowers is suitable for dyeing protein fibres. In the experiment, a wide range of colours was obtained. In the case of knitted wool fabrics, treated and untreated samples, various shades were obtained, such as warm beige, shades of olive, heather and shades of yellow. In the case of silk fabric, similar tones were obtained for both treated and untreated samples, like shades of heather, lilac and lavender.

Naturally dyed fabrics and knitted fabrics made of protein fibres increase the attractiveness of products made of these materials. The colours obtained in the experiment harmonize perfectly, which is an encouragement for designers who can combine differently coloured materials dyed with *Clitoria ternatea* L. flowers.

This products are addressed to selected, conscious group of customers who value ecology, a healthy lifestyle and unique aesthetics.

Conflict of interest: Authors declare no conflict of interest.

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