

Research Article

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Opportunities of using *Spirulina platensis* as homemade natural dyes for textiles

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Abstract: Some previous studies on *Spirulina platensis* show that this species contains pigments that can be used as natural dyes in textiles. However, research on the usage of spirulina natural pigment in certain types of conventional textile handicraft home industries in Indonesia has not been conducted. The purpose of this study is to utilize the potential of *Spirulina platensis* as homemade natural dyes for the development of designs in textiles. Through an experimental methodology, various experiments starting from the extraction process and dyeing were conducted to find out the right way to produce home dyes using spirulina and techniques of surface textile design to apply them in textiles. This is useful as one of the solutions today, since an increasing number of consumers are consciously seeking sustainable products, with no exception to the types of textile products. Therefore, this will provide an opportunity for business collaboration ideas in agribusiness and craft textiles. Additionally, it can add to the nature of textile natural dyes derived from various plant species in Indonesia.

Keywords: homemade, natural dyes, *Spirulina platensis*, textile

1 Introduction

Before synthetic dyes were as popular as they are today, ancient humans were familiar with various types of plants used as natural dyes in textiles. Previously, the use of natural dyes in textile industry was not as popular as synthetic dyes due to several weaknesses. Approximately only 1% of natural dyes were used in the textile sector. This

happened due to problems such as unavailability of dyes in standard ready-to-use forms, limited and non-reproducible colors, inability to meet huge demands, and prevention of resource overexploitation to get natural resources of natural dyes. Therefore, various research efforts have been carried out around the world to address this problem, given the enormous benefits to the environment and its prospects for the future economic sector [1].

In fact several studies of the potential of these natural dyes are slowly starting to increase again because they are considered important [2]. This is driven by an increase in human concern over the decline in environmental quality due to the high number of pollution and waste generated from the remnants of the production in the textile industry which adversely affect human survival itself [3]. The impact caused by the use of synthetic dyestuffs on life is very bad. The presence of naphthol, vat dyestuffs, nitrates, acetic acid, soaping chemicals, enzymatic substrates, chromium-based materials, and heavy metals has clearly become a very dangerous water waste [4].

Therefore, to overcome this problem, many have began to return to the use of eco-friendly materials and safe production processes to maintain environmental and natural sustainability. In addition to conducting a brief review of natural colorants from plant sources and their classification, technically, experiments were also carried out on technical procedures for the natural dyeing process [5], including the use of natural mordant and fixation to determine the effect on the resulted color, that is the strength of color against fading, brightness as well as new color variations created [6,7].

The search for potentials of natural dyes for textiles is continuously carried out on various types of natural resources in animals, plants, and minerals that contain strong color pigments that can be applied to fabrics. It is implemented not only by discovering new natural sources but also by experimenting on various types of natural sources that have been found a long time ago and by developing them to get new color references in textiles [7,8]. One of them is *Spirulina platensis* which is a planktonic organism that is autotrophic. It does not have a true cell nucleus (prokaryotic), and is shaped like a

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spiral-like filament with blue-green color. This spirulina is widely cultured and sold commercially in both fresh and dried form as a food supplement [9]. In addition, this spirulina has been known to contain biopigments, including chlorophyll, carotene, xanthophyll, and phycocyanin, and is also known to have many benefits for humans [10,11], especially, phycocyanin biopigments that contain blue pigments which are known to be very potential for natural dyes have been developed into a variety of food and cosmetic products [12,13].

Meanwhile, in the textile sector, Blond & Bieber, a design studio in Germany, has recently developed research results by utilizing the potential of various types of microalgae, including *Spirulina platensis* as a natural dye to be applied to motifs on fabric and subsequently made into various fashion products. The spirulina pigment extraction process was carried out in a laboratory by applying various measured variables to get the optimal color [14].

The great potential of spirulina to become one of the promising alternatives to be developed in Indonesia as a natural dye, certainly, needs to be linked to the condition of the industry itself. As explained by Ciptandi [15], efforts to implement an innovation into a community group or community-based industry need to consider the suitability of conditions in the community. The goal is not to force certain innovation, but to offer appropriate technology. In Indonesia, the industrial model engaged in the textile sector is not only in the form of small to large scale industries, but there are also types of home industries that still produce textiles and textile crafts in a conventional way [16].

The development of this natural *Spirulina platensis* dye also needs to be developed in home industries in Indonesia by looking at the readiness of the industry which still carries out all its production processes conventionally. This objective is carried out by means of experiments with

conditions adapted to the conditions of the industry with a homemade approach through the dye extraction stages and surface textile design. Therefore, in this way, the right homemade method for extracting natural *Spirulina platensis* dyes and textile design techniques for making motifs on fabrics can be found.

2 Research methods

This study used a *Spirulina platensis*, and the methodology was carried out in three stages, namely, the experimental stage of dyeing cloth, the experimental stage of surface textile design, and testing stage of dyeing fastness to domestic laundering.

2.1 Fabric dyeing experiment stage

This stage began with the extraction of dye and paste making which was done simply by removing the water content in the spirulina using an oven, then grinding it into a powder. Furthermore, the fabric was dyed using the hot and cold methods. This method followed the standard process of dyeing natural dyes in general which was carried out conventionally, as shown in Table 1.

The process was continued with an experimental stage as shown in Table 2, that is making natural dye paste as an alternative to be able to apply the spirulina color pigment to fabrics. The paste making was done by mixing ingredients that can be obtained easily, including spirulina powder, alginate powder dissolved in water as a gelling agent which functioned as a thickener [17], and

Table 1: Experimental variables of cold and hot dyeing on fabrics using *Spirulina platensis* powder

Techniques	Dyeing process
Cold dyeing	<p>Tools and materials: 5 g spirulina powder, 2 L of water, 15 mL of $\text{Al}_2(\text{SO}_4)_3$ as a color generator, 100% cotton cloth, and dyeing container</p> <p>Process:</p> <ol style="list-style-type: none"> 1. Mixing spirulina powder into aqueous solution and aluminum sulfate 2. Soaking 100% cotton cloth in the solution for 8 h 3. Lifting the cloth that has been soaked in the dye solution
Hot dyeing	<p>Tools and materials: 5 g spirulina powder, 15 mL of $\text{Al}_2(\text{SO}_4)_3$ as a color generator, 2 L of water, 100% cotton cloth, and dyeing container</p> <p>Process:</p> <ol style="list-style-type: none"> 1. Mixing spirulina powder into aqueous solution and aluminum sulfate 2. Soaking 100% cotton cloth into the dye solution under hot conditions while the stove is on 3. Lifting the cloth after 15, 30, and 60 min

Table 2: Experimental variables of making *Spirulina platensis* natural dye paste

No.	Constants	Variables
1	Spirulina powder + water	5% Alginate + 5% glycerin
2	Spirulina powder + water	5% Alginate + 10% glycerin
3	Spirulina powder + water	10% Alginate + 5% glycerin
4	Spirulina powder + water	15% Alginate + 5% glycerin
5	Spirulina powder + water	15% Alginate + 10% glycerin
6	Spirulina powder + water	20% Alginate + 5% glycerin
7	Spirulina powder + water	20% Alginate + 10% glycerin
8	Spirulina powder + water	20% Alginate + 15% glycerin

glycerin which functioned as a moisture guard for the paste so that it does not dry out easily [18]. All these ingredients were mixed and dissolved in water.

This experiment aimed to find the most appropriate concentration of paste to be applied to the surface of the fabric by varying the composition of alginate and glycerin and keeping spirulina powder and water as constants.

The resulted paste was tested on fabrics to identify the characteristics of each potential paste concentration.

2.2 Experiments on surface textile design with *Spirulina platensis* natural dyes

The next experiment was the application of natural spirulina dye paste on fabrics by carrying out three stages of the process as shown in Figure 1. This experimental stage was carried out to identify the potentials of spirulina natural dye application using surface textile design techniques, namely screen printing, to produce motifs on textiles.

2.3 Testing

The final stage was the testing of dyeing fastness to domestic laundering in accordance with the Indonesian

National Standard, ISO 105-C06: 2010 with the test conditions according to Table 3.

3 Results and discussion

All stages of the experiments in this study were conducted by considering the readiness of the home textile industry which still conducts the entire production process conventionally.

3.1 Results of dyeing the fabric and applying *Spirulina platensis* dye paste

The first stage began with extracting spirulina and dyeing the fabric by hot and cold methods. This method followed the standard process of dyeing natural dyes in general which was done conventionally according to Table 1. After the dyeing process, the results are as shown in Figure 2.

Based on the extraction and fabric dye experiments, it was known that the colors did not stick well. Although the dyeing time had been adjusted to see whether the time variable affects the absorption of the color in the fabric, it was known that the results were not significant. So it could be concluded to be a failure. Therefore, the experimental stage of making a natural coloring paste was then proceeded as an alternative to make it possible to apply spirulina color pigments to the fabric. The process is shown in Table 2, and the results are shown in Table 4.

Based on Table 4, several successful variables of spirulina dye paste were obtained. The consideration in deciding the paste being successful was that the condition of the paste in the form of both liquid and thick concentrations can be adjusted and shaped according to the purpose, as well as the moisture of the paste before it finally dried. This was important for the next stage when the

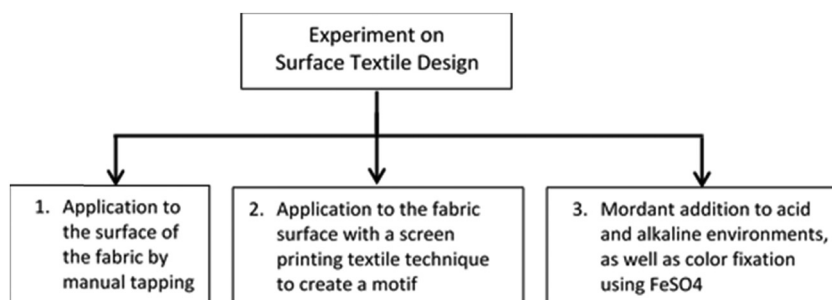
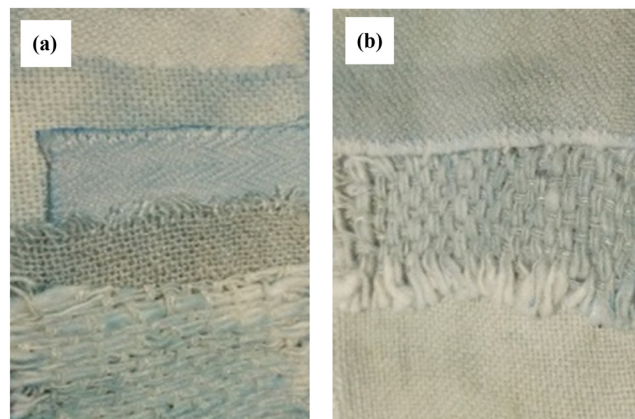
**Figure 1:** The experimental process stage of applying color to fabrics with surface textile design techniques.

Table 3: Test condition of color fastness to domestic laundering

Temperature (°C)	Liquor volume (mL)	Available chlorine (%)	Sodium perborate (g/L)	Time (min)	Number of steel balls	Adjust pH to
40	150	None	1	30	10	Not adjusted

**Figure 2:** Results of dyeing experiments on fabric using spirulina powder: cold dye (a) and hot dye (b).

paste would be applied on the fabric to form a motif. The paste should be adjustable in order to form the desired motif, and not dried out quickly when the process of making the motif was being carried out. As shown in Table 5, it was decided to choose 2 recipes for ingredients that were considered the best, i.e. paste of variable 5 and 7. Then, the paste would be tested to be applied on the fabric surface.


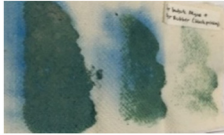

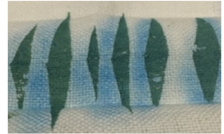
3.2 Results of surface textile design experiment with *Spirulina platensis* natural dyes

The next stage of the experiment as shown in Table 6 was to apply the paste on the surface of two types of fabric, namely cotton and linen, and then to see the final result

Table 4: Result of experiment of making *Spirulina platensis* natural coloring paste

Variables	Composition	Analysis	Decision
1	3 g Powdered spirulina + 40 mL of water + 2 mL of alginate + 2 mL of glycerin	The mixture was too liquid and difficult to adjust	Damaged
2	3 g Powdered spirulina + 40 mL of water + 2 mL of alginate + 4 mL of glycerin	The mixture was too liquid and could not be adjusted	Damaged
3	3 g Powdered spirulina + 40 mL of water + 4 mL of alginate + 2 mL of glycerin	The mixture thickened well so it was easy to manage, but the paste only stayed moist for less than 3 min before it dried	Successful
4	3 g Powdered spirulina + 40 mL of water + 6 mL of alginate + 2 mL of glycerin	The mixture tended to thicken with a concentration tending to be liquid but was still easy to adjust and the moisture of the paste could last up to 3 min before it dried	Successful
5	3 g Powdered spirulina + 40 mL of water + 6 mL of alginate + 4 mL of glycerin	The mixture thickened well and was still adjustable with the moisture of the paste which could last up to 5 min before it dried	Successful
6	3 g Powdered spirulina + 40 mL of water + 8 mL of alginate + 2 mL of glycerin	The mixture was too thick that it was difficult to adjust and the paste would stay moist only for less than 3 min before it dried	Damaged
7	3 g Powdered spirulina + 40 mL of water + 8 mL of alginate + 4 mL of glycerin	The mixture thickened well so it was easy to manage and the paste's moisture could last up to 5 min before it dried	Successful
8	3 g Powdered spirulina + 40 mL of water + 8 mL of alginate + 6 mL of glycerin	The mixture thickened with thickening concentration and was still easy to adjust with the moisture of the paste that could last up to 10 min before it dried	Successful

Table 5: Concentration variable of selected *Spirulina platensis* color paste

Composition	Images	Notes	Result of application on fabrics
3 g Spirulina powder + 40 mL of water + 6 mL of alginate + 4 mL of glycerin		Deep green color paste; however, when applied to the fabric, bluish color appeared from the phycocyanin biopigment	
3 g Spirulina powder + 40 mL of water + 8 mL of alginate + 4 mL of glycerin		Thick green color paste; however, when applied to the fabric, bluish color appeared from the phycocyanin biopigment	

after rinsing without previously adding the mordant process. Meanwhile, as shown in Table 7, the next stage was to apply a paste on textiles by applying one of the surface textile design techniques, namely screen printing, on cotton and to add mordant $Al_2(SO_4)_3$ as a color binder on the fabric [19]. In addition, the motif exploration process was also carried out to measure the ability of the paste to print the motif on the fabric.

Based on Table 7, the results of the experiments on spirulina paste application on fabric with screen printing and fixation were as follows:

1. The shape and composition of the motif could be formed properly. This showed that the concentration of the paste used was good, so there were no obstacles in the incision process on the fabric.
2. The addition of fixation helped the color that had been etched on the fabric to stick well.

3. The addition of the dyeing process to the mordant solution and fixation showed a change in the resulted color.

3.3 Test results of color fastness to domestic laundering

The test results are presented below in Table 8. The test results showed that the color change was related to the fastness resistance, all in the range of 1–2, which was low. This showed that the motif produced by applying the spirulina paste after going through the washing process had great potential to wear off. Similarly, the test on staining of other materials showed that it was in the range of 4–5, which was high. This showed that

Table 6: Experiments on *Spirulina platensis* paste application on fabric





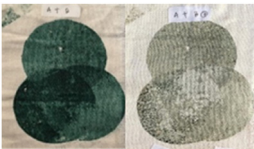
Paste type/cloth	Before rinsing	Notes
Paste variable 5		<ul style="list-style-type: none">– The final color produced was greenish, not significant both in cotton and linen– The shape of the motif could be printed well– Had strong characteristic results of handmade and differed from color characteristics of digital printing techniques
		
Paste variable 7		<ul style="list-style-type: none">– The final color produced was greenish, not significant both in cotton and linen– The shape of the motif could be printed, but color was not evenly distributed, there were certain parts that looked thinner than other parts. However, this actually gave transparent-like color effect– Had strong characteristic results of handmade and differed from color characteristics of digital printing techniques
		
Mixture of paste on cotton		The shape was printed well, greenish and uneven. The result of mixture of paste was not significant

Table 7: Experiments on *Spirulina platensis* paste application on cotton with screen printing and fixation

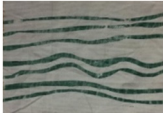
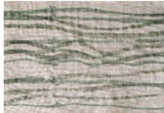



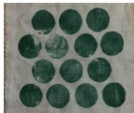
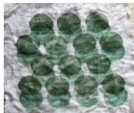
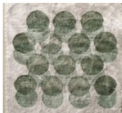

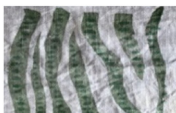

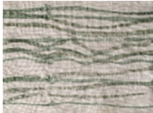

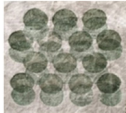

Materials	Screen printing stage 1	Screen printing stage 2	Final result
100% Cotton, paste variable 7 + mordant solution $\text{Al}_2(\text{SO}_4)_3$ without fixation			
100% Cotton, paste variable 7 + mordant solution stages 1 and 2 $\text{Al}_2(\text{SO}_4)_3$			
100% Cotton, paste variable 7 + mordant solution stages 1 and 2 CH_3COOH (acetic acid)			
100% Cotton, paste variable 7 + mordant solution/stage 1 $\text{Al}_2(\text{SO}_4)_3$, and fixation/stage 2 FeSO_4			

Table 8: Test results of color fastness to domestic laundering

Types of testing				
Color changes	1–2	1–2	1–2	1–2
Acetate staining	4–5	4–5	4–5	4–5
Staining on cotton	4–5	4–5	4–5	4–5
Staining on polyamide	4–5	4–5	4–5	4–5
Staining on polyester	4–5	4–5	4–5	4–5
Staining on acrylate	4–5	4–5	4–5	4–5
Staining on wool	4–5	4–5	4–5	4–5

the washing residue had no impact on staining the other fabrics.

4 Conclusion and recommendations

Based on the results of the experiments carried out, it can be concluded that the use of *Spirulina platensis* as homemade natural dyes in textiles has potentials and weaknesses to be applied to home industries in Indonesia which are still running the entire production process conventionally. Potentials and weaknesses found include:

1. These homemade natural dyes with spirulina paste match the characteristics of the conventional handicraft industry

in Indonesia, because in the process it follows the existing running production pattern, which is handmade. It has been proven that spirulina can dye fabrics by conventional ways as follows:

- a. Unlike natural dyes derived from other plants that can be extracted using hot media, spirulina does not show optimal results. However, it can be done by making a coloring paste using a mixture of ingredients consisting of crushed spirulina, water, alginate, and glycerin.
- b. Application of paste on two types of fabrics with different textures, namely cotton and linen, was successful. But it is still recommended to use only fabrics with natural fibers because they have the ability to bind color pigments more optimally than synthetic fabrics.
- c. The consistency of paste using the technique of applying motifs in the form of screen printing

succeeded in printing the shape of the motif well, so that in the future, the development of motifs has considerable potential.

- d. *Spirulina* shows that, with mordant dyeing and fixation process, it can produce different colors, so that in the future, the potential to develop color variations is quite large.
2. Final result, in the form of imperfect motifs and colors, is actually one of the strengths of handicraft products that must be able to expose the imperfect character of handwork.
3. With a low level of fastness resistance, it is concluded that spirulina as a natural dye applied to textiles using the method in this study has no affinity. Therefore, it is not suitable as a product that requires several washes. Unless the coating process is carried out afterwards so that the color will be protected.

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