



Non-medical Application of Bacteria in Dyeing Textile

Lusia Sri Sunarti ^{a*}

^a Department of Microbiology, Faculty of Medicine, Universitas Kristen Indonesia, Jakarta, Indonesia.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: to revisited new method of producing dyes which is safer for the human health using new unusual source of natural based dyes produce by live cell of bacteria which is engineered biotechnologically.

Discussion: due to the importance of textile to human life and along with the post modern era, textile products play a vital role in meeting not just man's basic needs, but far beyond. Textile dyeing process need certain dye to make it looks better, comfortable and give certain self-confident to their user. Unfortunately, classic synthetic dyes use for a traditional dyeing techniques. These substances are known to be toxic and can cause various health issues. Hence, biotechnology improvement in using dye from bioengineered bacteria offer a breakthrough in a safer and eco-friendly textile industry. The challenges include the lack of awareness due to not much knowledge about this breakthrough and moreover how to push this approach, which is currently still on a limited lab scale, into a massive and widespread industrial existence.

Conclusion: Environmental and health issues regarding the use of conventional dyes leading to increased awareness of good practice of textile industry. Biotechnology offers alternative approach of safer and responsible dyeing with genetically engineered bacteria. This become the most recent

*Corresponding author: Email: lusia.sunarti@uki.ac.id;

achievement in textile industry. This approach is promising, but still needs a lot of effort from all stakeholder to push it from only limited laboratory scale onto a more massive industrial scale.

Keywords: Pigment; biotechnology; safe; non-toxic; biodegradable; synthetic dye; toxic; eco-friendly.

1. INTRODUCTION

Textiles are a fundamental need for modern human's self-actualization, which accommodates multiple purposes such as protection, comfort, and hygiene; all in style and can affect its user's performance, self-esteem, mood enhancer and even mental health [1-5]. Textile and clothing provide specific and sufficient protection against internal or external distress and maintain the constant regulates of body temperature, e.g. exercise apparel. From all of previously mentioned perspective, human body is in permanent contact with textile materials [6-8].

Throughout history of human civilization, it reflects the materials available to a culture combined civilization as well as the traditional local wisdom technologies to produce it, including its dyeing [9]. In dyeing, color is obtained in textiles and other materials by the use of colorants (dyes and pigments) [10]. Dyes, natural or synthetic, always react chemically with the correct materials, e.g., textile, they are administered to. Using the correct technique and dyes, it maintains the initial color from being wiped away [11,12].

Dyes constitutes of natural materials are often called natural dyes [10,11]. Historically, people dyed yarn, fabric and even their clothing directly using what the nature or in more specific the environment provide them [13]. This included extract from plants (e.g., fragments dyed red from roots of an old world species of madder (*Rubia tinctoria*), animals (e.g., insects such as Kermes and Cochineal were used to produce shades of red, lichens, and even from shellfish which the Murex created Tyrian purple, the world's most expensive dye.) and minerals (the dyes obtained from natural earth pigments which already been used since ancient times, which achieved their tinctorial properties due to the presence of oxides or the hydrated oxides of manganese, with example of mineral dyes are chrome yellow, iron buff, Prussian blue, nankin yellow and manganese brown etc.) [14-16]. The effort to produce natural dyes is very hard because time consuming, costly and need specific handling [17-20].

Nowadays, almost all available dyes in the popular market which used to color clothing are artificial or synthetic [21]. Artificial/synthetic dyes are widely applicable because it offers some positive aspects, including (1) assemble interesting colors, (2) light-resistant, in condition which the dyes do not fade easily in or under bright light (3) economically and technologically inexpensive to produce- compared to natural dyes, (4) the textile able to retain its original color and will not wash out, (5) can color synthetic fabrics like polyester and nylon, unlike natural dyes which limited in their application. The use of heavy metals such as cadmium, mercury, lead, chromium and arsenic are necessary in the production of textile dyes, but their colored effluents are toxic and can damage cells. It is also responsible for causing permanent problem with human's immune systems and various diseases including kidney disease and cancer [22-23].

Due to those issues, scientists began to develop new method of producing dyes which is safer for the human health. A new and unusual source of dyes is bacteria which is engineered biotechnologically and this become the aim of this simple mini-review.

2. APPLICATION OF BACTERIA FOR DYEING TEXTILE

Most living organisms actually contain certain cells that can produce specific color or pigments, e.g., melanin in human [23]. Beside contributes for color, melanin also acts as photo-protector, e.g., epidermal melanin or retinal melanin protects its host from harmful UV radiation [24]. In a lower level organism, microorganism such as bacteria able to generate sufficient substance which act like pigments that can facilitate its survivability [25]. The pigments of bacteria facilitate its existence in the nature, even in harsh and dangerous environments marked with minimum food source [26], extreme temperatures [27], unstable pH [28] and radiation levels [29]. The benefit of using bacterial pigment as textile dyeing: (1) brilliant color, (2) can be applied to many types of fabrics, (3) non-toxic, (4) eco-friendly, (5) high values product, (6) additional

Table 1. List of some pigments produced by bacteria

Pigment	color	Species	Properties	Habitat	Role in bacteria	Miscellaneous
Violacein	Blue-purple	<i>Chromobacterium violaceum</i>	Gram-negative β -proteobacteria	Freshwater and marine habitats	Defending against other microorganisms	It was used to dye fibrous materials and nylon cloth after being manufactured by culturing <i>Chromobacterium</i> and <i>Janthinobacterium</i> in a specific media [31].
Violacein	Dark Violet	<i>Janthinobacterium lividum</i>	Gram-negative bacteria	various environments, including Antarctica	As an antioxidant, and also has anti-fungal and anti-bacterial effects.	tinging and produced excellent color tone on silk, cotton, wool, nylon, and vinylon. <i>J. lividum</i> cultures can be successfully used for violacein production and for simultaneous dyeing of fabrics resulting in dyed fabrics with antimicrobial properties without utilization of organic solvents [32].
Indigoidine	Blue-green	<i>Streptomyces aureofaciens</i>	Gram-positive, filamentous, spore-forming bacteria that are members of the phylum Actinobacteria	present in almost all environments from deep sea to high mountains	/	Great reproductive capacity, eco-friendly, biotechnologically valuable, producing specialized metabolites with a broad spectrum of bioactivities, such as antioxidant, anticancer, antibiofilm, antifouling, and antibiotic activities, as well as pigments, among others [33].
Carotenoids	Yellow & orange	<i>Serratia marcescens</i>	an opportunistic, gram negative, nosocomial pathogen which belongs to family, Enterobacteriaceae	Soil and water	Surviving in areas with high levels of radiation	The pigment was largely effectual and exhibited utmost zones of inhibition, thus demonstrating the finest antimicrobial effect against the microbes tested. The textile yarn materials soaked with this intrinsic dye pigment also exhibited antimicrobial action [34].
Prodigiosin	Red	<i>Serratia marcescens</i> , <i>The marine Serratia rubidaea</i>	an opportunistic, gram negative, nosocomial pathogen which belongs to family, Enterobacteriaceae	Soil, human digestive system, sea	Defending against other bacteria	Prodigiosin could be better used to dye acrylic; Dyed cotton possesses good rubbing, washing and perspiration color fastness. Prodigiosins endow dyed cotton with antibacterial property against <i>S. aureus</i> and <i>E. coli</i> [35].

Pigment	color	Species	Properties	Habitat	Role in bacteria	Miscellaneous
Prodigiosin	Red	<i>Streptomyces coelicolor</i> (Actinobacteria)	Gram-positive microorganism often used as a model of physiological and morphological differentiation in streptomycetes	Soil	Defending against other bacteria, helping cells use iron	Applied as antibacterial silk dyeing [36].
Pyocyanin	Greenish-blue	<i>Streptomyces coelicolor</i> (Actinobacteria)	Gram-positive microorganism often used as a model of physiological and morphological differentiation in streptomycetes	Soil	Defending against other bacteria, helping cells use iron	Used by designer named Chieza NA [37].
Pyocyanin	Greenish-blue	<i>Pseudomonas aeruginosa</i>	a gram-negative, aerobic, non-spore forming rod	Inside plants and animals	Helping cells use iron, changing to reddish-pink at lower pH levels	Antibacterial, antioxidant, and anticancer properties [38].

functionalities, (7) has anti-microbial, anti-cancer, anti-oxidative properties and so on.

Synthetic derivatives are currently used instead of pigments in many applicative fields, from food to feed, from pharmaceutical to diagnostic, from agronomy to industry [30]. Progress in organic chemistry allowed to obtain rather cheap compounds covering the whole color spectrum [25,30].

3. BASIC STEPS OF BACTERIAL DYEING

The application of bacterial dyes in textiles has been brought to massive commercial industry scale [39]. It has revolutionized the fashion industry with eco-friendly issue and even health related antibacterial product of garment [39-41]. These natural pigments offer good aspiration to better humanity for restoring the contamination that conventional toxic dyes have done to the environment, including affect human health [42].

In the past years, Biotechnology has again delivered us a golden solution to bring life to the dryland, dead waters pollution and so on [43-44]. Biotechnology has change the world for good and even further, including how Biotech textile labs are changing the fashion business forever, and along comes the bright prospective of applying Bacterial textile dyeing [45-46].

Basic steps of bacterial dyeing are as follows:

1. Choose specific strain of bacteria that produce specific pigment and augment its number massively,
2. Carefully sterilize the chosen fabric in certain temperature oven to discard of potential contaminant from unwanted bacteria,
3. Bacteria addition with its nutrition media to produce best color,
4. Grow more bacteria on fabric to induce more production of pigment,
5. Sterilization to kill bacteria.

The advantage with this "live dyeing" approach is that in each batch of fabric is distinctive and unique [37]. Their patterns cogitate on how the bacterial colonies grow on selective or non-selective condition [47]. The other advantage of live dyeing is that the fabric does not need any harmful chemicals or pre-treating [48]. In addition to the previously mentioned advantages, it also water-saver and energy-saver because it happens to uses only a small amount of water and energy [49,50]. Dyeing with bacteria

basically is a fermentation [35,46] refine where chosen bacteria metabolize a nutrient and produce their own unique pigment [51-54]. The dyeing process is artisanal. They cultivate the bacteria directly onto the textiles [49,51,52], leaving visible growth patterns that create a new and unique aesthetic with unique one-of-a-kind print, no dyeing achieve is the same.

Up to the present, this approach of live dyeing has only been used in laboratories scale [51]. Concern related to health issues, especially with the handling of bacteria, still prevent the wider application of this technique [52]. Live dyeing also needs to be done carefully and as *lege artis* as possible in a way that does not unintentionally bring in other types of unwanted microorganisms onto the fabric [53]. It would be challenging to use this method on a larger and bigger scale [55,56].

In spite of the previously mention concern, the future of bacterial dyeing is promising, with increasing market value and with additional health and sociological benefit. A number of companies are getting involved in genetically engineering bacteria to produce pigments, e.g. Algalife, Ginkgo Bioworks and Colorifix.

As the world becomes more aware and concern about ecology and sustainability, the future of dyes and pigments may come from this microscopic but vigorous bacteria. With the help of new and trustful biotechnology engineering, improvement in dyeing fabrics and textile using live cell can be optimized into large industrial scale.

4. CONCLUSION

In conventional dyes, harsh chemicals, heavy metals and salts are used to fix the color in the textile fiber. This bring consequences to the health status of textile industry worker and also pollution to the environment. Biotechnology offers alternative approach to produce color by dyeing clothes with genetically engineered bacteria is the most recent achievement in textile and fabrics industry. This approach is promising, but still needs a lot of effort from all stakeholder to push it from only laboratory scale onto a more massive industrial scale.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image

generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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