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Extraction of Natural Dye - Chlorophyll and Anthocyanin from Red Banana Leaves, and Red Dacca Banana Peel for Sustainable and Eco-Friendly Textile Applications

Renu Agarwal[1] and Kaviya J*[2]

[1-2] Department of Home Science- Food Science, Nutrition and Dietetics Shrimathi Devkunvar Nanalal Bhatt Vaishnav College for Women, Chennai, Tamil Nadu, India

Abstract

Research on this topic to be focusing on the use of natural dyes for dyeing textile yarns, because of the present environmental and economic sensitivity. This research aims to develop natural dye from Red Banana leaf (Chlorophyll) and Red Dacca banana peel (Anthocyanin) by solvent extraction method, then optimizing the dye extractions (e.g.; pH, Temperature and time) and assess dyeing process on Cotton yarns by Exhaust method in the different concentrations such as 60°C - 110°C in 60 min and characterize its quality stability such as Washing Fastness test and Light fastness test for 0th to 5th day. The results showed that chlorophyll dye was stable at pH 9, Temperature at 40°C - 50°C in 15min and Anthocyanin dye was stable at pH 6, Temperature at 60°C in 60min. Dyeing of cotton yarns was stable in the concentration of 80 °C for 50 min (Chlorophyll) and 70 °C for 40 min (Anthocyanin). Washing fastness test for dyed chlorophyll cotton yarns showed very good grade and Anthocyanin showed Excellent grade. Light fastness test showed Excellent grade for both the Chlorophyll and Anthocyanin dyed Yarns.

Key words: Natural dye, Chlorophyll, Anthocyanin, Cotton yarns, Banana leaves, Red banana peel

Over 3.3 billion metric tonnes of greenhouse gas emissions annually, substantial land and water consumption, soil, air, and water pollution, and rising waste production are all directly related to the global textile industry's grave environmental effects along the entire supply chain [8]. The existing linear system is highly resource-intensive and has detrimental effects on both people and ecosystems. An estimated 98 million tonnes of non-renewable resources are utilized annually, such as chemicals needed in various phases of textile production, oil used to manufacture synthetic fibres, and fertilizers for the growth of natural fibres [1]. After synthetic dyes were discovered in 1856, natural dyes were used much less frequently for textile dyeing. Natural dyes were essentially ignored at the beginning of the 20th century due to a noticeable decline in the cost of synthetic dyestuffs. Today, synthetic dyes are used excessively—an estimated 10,000,000 tons of them are used annually—and their production and application release large amounts of waste and unfixed colorants into the environment, endangering human health and upsetting the natural eco-balance [12].

Extracting natural dye from banana leaves is Eco friendly and Inexpensive [11]. Waste banana leaves were utilized in the current investigation as a source for the natural dye extraction process. Banana leaf natural coloring is cheap and environmentally beneficial. Additionally, acetone works well as a solvent and banana leaf extract exhibits excellent antifungal action [5]. Banana peel is a common agricultural waste, particularly in the food processing industry, but its disposal is a major source of worry. According to recent studies, banana peels are an excellent source of bioactive substances that can be used to create goods with additional value [6].

Banana peels can be recommended as a natural dye source in this situation. The primary chemical components of banana peel and pulp are biogenic amines, phenolic compounds, and carotenoids. Given that those biomasses contain L-dopa and dopamine, they have the potential to be used in the treatment of Parkinson's disease as well as as pro-vitamin A supplements and potential antioxidants due to their phenolic constituents. Plant-based natural chlorophyll pigment extraction can minimize waste and maximize product utilization. It also has a higher medicinal value, is non-allergic, and can be used to make "safe to use" Textiles products. Additionally, it is environmentally friendly, can increase export market share, and has a high level of consumer acceptability [10]. Plants' anthocyanins have several potential uses beyond just being a natural pigment. The colour of anthocyanin changes with pH, demonstrating how adaptable it is to many environmental circumstances in nature. Studies have indicated that they have antimicrobial characteristics. Through further study on anthocyanin and the gene that relates to it, textiles with antimicrobial and self-fluorescent qualities may be developed. It is also known that anthocyanins shield plants from harsh weather. Supercloths could be created with this characteristic. It is also known that anthocyanin doubles a plant's shelf life. A

***Correspondence to:** Kaviya J, E-mail: kavyajeeva28@gmail.com; Tel: +91 8270010101

revolution may occur if textile-producing plants were genetically modified to use their anthocyanin qualities [7].

Anthocyanin is among the pigments that can be employed as an organic colouring agent. Anthocyanin pigment is an excellent source for dyes, primarily producing tints ranging from blue to red. An innovative idea for the textile industry is the large-scale manufacture of anthocyanin-dyed textiles. Greek is where the word "anthocyanin" originates. "Kianos" signifies blue, while "anthos" means flower. A class of flavonoids produced by the phenylpropanoid pathway includes anthocyanins. Of the watersoluble natural pigments, they are the largest group [7]. The textile industry can benefit greatly from the use of chlorophyll and anthocyanins not only as dyes but also in the creation of "super cloths." The direction of "Eco-fashion" is currently being taken by the world. The textile industries may undergo a revolution if natural dyes like anthocyanin and chlorophyll are used [7]. More than 250 million people receive their income from the production of cotton, the most significant and widely used natural fiber in the world, which is produced in 75 nations. A major agricultural product utilized mostly for its fibers, which are used to make textiles, cotton is grown all over the world. In terms of clothing, home textiles, and industrial goods, cotton makes up around half of all textile items.

Cotton has been utilized by humans for over 4,000 years, according to archaeological data. At least 3000 years have passed since cotton was first cultivated. Four species of cotton are cultivated: two diploid and two tetraploid varieties. This chapter covered the origins and agricultural history of these four species using both theoretical analysis and archaeological data. A significant advancement in cotton farming was the domestication of wild tetraploid cotton into an annual day-neutral crop. Cotton's Internationalization was aided by its introduction to and extensive cultivation in the United States. The importance of cotton in the global economy was cemented by technological breakthroughs in spinning, ginning, and cultivation [2].

The main objective of this study is:

- To extract chlorophyll and anthocyanin dye from banana plant by-product banana leaf and Red Dacca banana peel.
- To optimize dye extract of chlorophyll and Anthocyanin e.g. pH, Temperature and time.
- To assess dyeing process on cotton yarns
- To characterize the quality stability of cotton yarns by assessment of Washing fastness test and Light fastness test.

MATERIALS AND METHODS

Materials

Banana leaves, Red Dacca banana peel was procured from the Local market Chennai, and cotton yarns were procured from textile shop, Chennai, Tamil Nadu, India.

Methods

Extraction of chlorophyll dye from Banana leaf and Anthocyanin dye from red banana peel by solvent extraction method.

Both the banana leaves and Red Dacca banana peel were ground into powder separately. 500ml of ethanol water (40:60 ratio) was added to a round-bottom flask containing 100g of each powder. The flask was then heated in a water bath at 60°C for 60 minutes. The extract was then obtained by filtering the solution. The crude dyestuff was distilled to obtain one-third of the solution using a Soxhlet apparatus at 70°C for three hours. During this process, ethanol was recovered and concentrated dye was obtained. The solution was then left overnight at room temperature for precipitation. The precipitation in ethanol water was obtained by decanting the solution. The resulting particles were then dried in an oven for one night at 60° Fahrenheit. To enable them to evaporate at lower temperatures, water was introduced to the Soxhlet device [13].

Optimization of chlorophyll and Anthocyanin dye extraction

Effect of pH

Under different pH such as (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13) were selected for optimizing the extraction of Chlorophyll and Anthocyanin dye [1-4].

Effect of temperature and time

Under different temperature ranging from 30°C, 40°C, 50°C, 60°C and time with 0^{th} to 60min of absorbance @510nm, optimization of chlorophyll and anthocyanin dye extraction was carried out [3-4].

Dyeing process of the chlorophyll and anthocyanin dye in cotton yarns with different concentrations

Dyeing had carried out using a dyeing machine set to 60°C, 70°C, 80°C, 90°C, 100°C, 110°C were identified as S1, S2, S3, S4, S5, S6 (S denotes sample) for 60 minutes, using the Exhaust method. Following a 40-degree Celsius cooling of the dye bath, samples were cleaned at room temperature. Samples were air dried in a flat dryer machine after being squeezed. The fabric surface was soaped to remove unmixed dye using a 0.5 g/l ISO standard soaping method for 10 minutes at 80°C. A 1:20 liquor ratio was maintained for both the dyeing and soaping processes [9].

Stability test of cotton yarns

The sample that had the highest level of dye extraction on the cotton yarn was then subjected to colour fastness tests, such as the washing and light fastness tests, and was graded on a 5-point scale (5- Excellent, 4- Very Good, 3- Fair, 2- Poor, 1- Very Poor) [3-4].

Washing fastness test is analyzed for 0^{th} to 5^{th} day

Yarns dyed with chlorophyll and anthocyanin will be immersed in soapy water during the first five days. After that, the yarn was removed, cleaned, dried, and its colour fastness was examined [3-4].

Light fastness test is analyzed for 0^{th} to 5^{th} day

Yarns dyed with chlorophyll and anthocyanin dye will be exposed to a xenon lamp for the first five days, after which the colour fastness will be assessed [3-4].

RESULTS AND DISCUSSION

Optimization of the Chlorophyll and Anthocyanin dye extraction

Extraction of dye was optimized using different parameters like pH, temperature and time. Leaves of banana and peel of red banana were used for the dye extraction. The dye extracts were absorbed in UV- visible spectrophotometer to obtain the absorbance @ 510nm.

Effect of pH

Chlorophyll and Anthocyanin dye were analyzed with 12 different pH. e.g. (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13) of absorbance @ 510nm. Chlorophyll dye are remains stable in green colour at pH 9 (Alkaline circumstances). The colour of chlorophyll dye changed from green-to-green olive (yellowish green) at acidic pH 2–5. Decrease in pH of the dye decreases the dye stability of chlorophyll. Anthocyanin dye is red and stable under pH 6 (acidic circumstances), when pH values increased, anthocyanin stability decreased and color changed from red to brownish black.

Effect of temperature and time

Chlorophyll and anthocyanin dye were analyzed for temperature with 30°C, 40°C, 50°C, 60°C and time with 0th to 60min of absorbance @510nm. For chlorophyll, the maximum dye extraction from banana leaves was achieved at temperature 40°C in 30min (Table 1) with stable green color (Fig 1), while in a higher temperature after 60°C and time, above 20min, the dye colour was decreased from green to light green. For Anthocyanin the maximum dye extraction from red banana peel was achieved at temperature 60°C in 60min as depicted in (Table 1**)** with stable red colour (Fig 2), while in a higher temperature after 70°C and time above 70 min, the dye colour was changed from red to brownish colour and the dye stability was affected.

Table 1 Effect of Temperature and time in dye extraction Absorbance @510nm.

Temperature (°C)	Dye	Absorbance @ 510nm				
		0th min	15th min	30th min	45th min	60th min
30	Chlorophyll	1.601±0.001	0.275±0.004	0.733±0.01	1.928±0.008	0.605±0.008
	Anthocyanin	0.257±0.005	1.327±0.001	1.339±0.001	0.257±0.01	1.28±0.004
40	Chlorophyll	0.41±0.001	0.498 ±0.008	2.726±0.011	1.304±0.004	0.454±0.01
	Anthocyanin	1.159±0.003	0.354±0.008	1.355±0.01	0.349±0.008	0.395±0.002
50	Chlorophyll	0.408±0.008	1.241±0.004	0.412±0.008	0.450±0.005	1.571±0.008
	Anthocyanin	1.408±0.008	1.196±0.008	0.484±0.01	1.287±0.005	1.532±0.008
60	Chlorophyll	0.234±0.001	1.357±0.006	1.448±0.006	0.341±0.008	1.231±0.01
	Anthocyanin	1.174±0.001	1.349±0.001	0.455±0.008	1.165±0.01	2.2873±0.011

Fig 1 Chlorophyll dye

Fig 2 Anthocyanin dye

Analysis of chlorophyll and anthocyanin dyeing concentration in cotton yarns

Dyeing of cotton yarns Chlorophyll and Anthocyanin were optimized using different temperatures and samples of 60°C- S1, 70°C- S2, 80°C- S3, 90°C- S4, 100°C – S5, 110°C – S6, (S denotes sample) under the different duration of 10, 20, 30, 40, 50 and 60 min.

Concentration of chlorophyll dye: In cotton yarn, the maximum percentage of dye exhaustion in chlorophyll was obtained in S3 at 80 °C for 50 min showed stable green color dye (Fig 3)**.** In S1 and S2 at temperature 60°C -70°C shows the olive green in color and S4, S5, S6, shows greenish black color and stability of dye were decreased when temperature was increased above 90°C.

Concentration of anthocyanin dye: In cotton yarn, the maximum percentage of dye exhaustion in Anthocyanin was obtained in S2 at 70 °C for 40 min showed stable red color dye (Fig 4). In S1 at temperature 60°C shows the light red in color and S3, S4, S5, S6, shows reddish brown color and stability of dye were decreased when temperature was increased above 80°C.

Analysis of the stability test for cotton yarns

A color fastness test indicates how resistant a textile's color is to particular environmental factors. The two main tests for color fastness are the washing and light fastness tests. Color fastness properties of the cotton yarns were analyzed with the parameters of washing and light fastness test for 0th to 5th day.

Fig 3 Chlorophyll dyed yarn

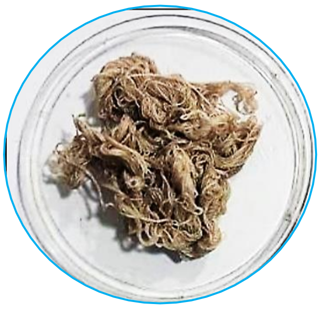

Fig 4 Anthocyanin dyed yarn

Fig 5 Dyed chlorophyll and anthocyanin yarns were kept soaked in detergent water

Washing fastness test

The ability of a cloth to maintain its original color when washed is referred to as the fabric's color fastness. The dyed cotton yarns were kept soaked in detergent for a duration of 5 days (Fig 5) and monitored for color fastness.

Even after five days of constant soaking in detergent water, anthocyanin dye remained remarkably stable and did not cause any colour fading or changes in the cotton yarns (Fig 6).

Chlorophyll dye was very stable till 3rd day and slightly color fading was found on 4th and 5th day of continuous soaking in detergent (Fig 7). The dyed cotton yarns were evaluate using 5-point rating scale. This was summarized in (Table 2).

Table 2 Washing fastness properties of dyed cotton yarn (chlorophyll and anthocyanin)

Dye	Days				
	Day 1	Day 2	Day 3	Day 4	Day 5
Anthocyanin	5	5	5	5	5
Chlorophyll	5	5	5	4	4

5- Excellent, 4- Good, 3- Fair, 2- Poor, 1- Very poor

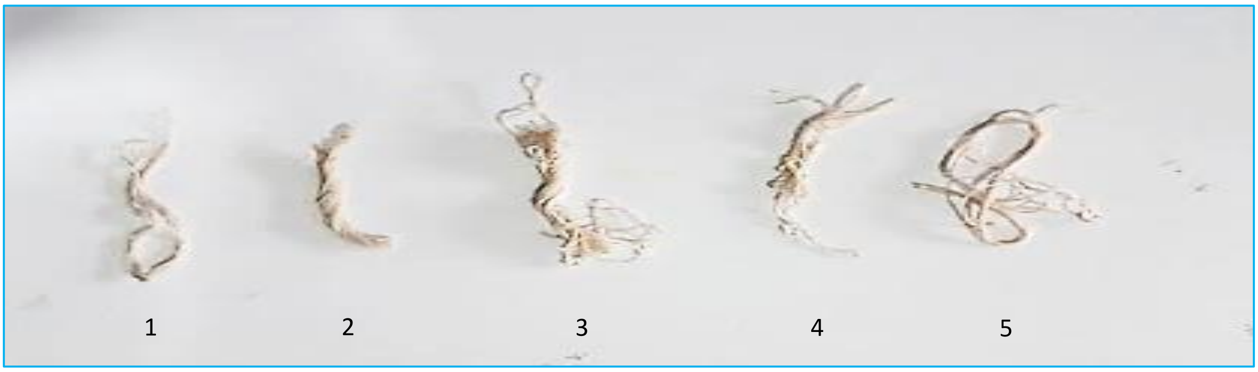

Fig 6 Anthocyanin dyed yarns soaked in detergents for 0th to 5th day

Fig 7 Chlorophyll dyed yarns soaked in detergents for 0th to 5th day

Light fastness test

The term "colour fastness to light" or "light fastness test" describes how resistant printed or pigmented materials are to fading or changing colour when exposed to artificial or solar light. The dyed cotton yarn Anthocyanin and Chlorophyll was kept exposed to xenon lamp for a duration of 5 days and monitored for color fading. When exposed to light, the dyed cotton yarns containing anthocyanin and chlorophyll dye exhibited very good stability and no color fading (Fig 8-9). The dyed cotton yarns were evaluate using 5-point rating scale. This was summarized in (Table 3).

Fig 8 Anthocyanin yarn exposure to Xenon light

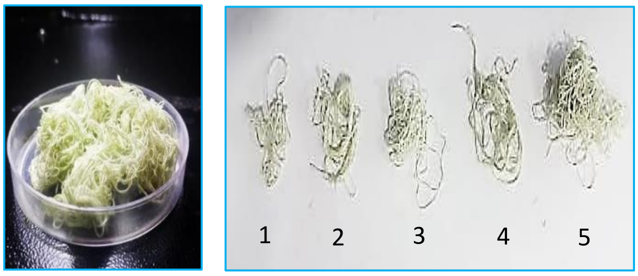

Fig 9 Chlorophyll yarn exposure to Xenon light

Table 3 Light fastness properties of dyed cotton yarn anthocyanin and chlorophyll

Dye	Days				
	Day 1	Day 2	Day 3	Day 4	Day 5
Anthocyanin	5	5	5	5	5
Chlorophyll	5	5	5	5	5

5- Excellent, 4- Good, 3- Fair, 2- Poor, 1- Very poor

CONCLUSION

From the present research, it can be showed that natural dye - Chlorophyll and Anthocyanin can be efficiently extracted from Banana leaves and Red Dacca banana peel. The extracted Chlorophyll and Anthocyanin dye could be successfully applied to Cotton yarns. It shows the best Temperature and time for dyeing cotton yarns in chlorophyll dye was 80°C for 50min and Anthocyanin dye was 70°C for 40min in dyeing machine. Stability test shows that Chlorophyll and Anthocyanin dyed yarns were stable in washing and Light fastness test. Result of the study conclude that banana leaves (chlorophyll) and red Dacca banana peel (anthocyanin) have the potential to be developed as natural dye for textiles.

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