

Extraction and Application of Natural Pigments from Plant Sources as Sustainable Alternatives to Synthetic Dyes.

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1. ABSTRACT

Colors are necessary and extensively used items. Man has made colors synthetically which are used in different industries world-wide, causing damage to life and environment. Natural dyes are biodegradable and are beneficial as they contain antioxidants, vitamins etc. So, the world is trying hard to shift from chemical dyes towards naturally made.

The aim is to show potential of natural extracts in dyeing of bioplastic, soap, lip balm, and cotton cloth. It promotes the use of natural dyes instead of chemical ones, which cause health problems, persist in environment and release toxic elements. This study shows that natural colors can be used instead of chemicals across multiple applications. Bioplastic is made by gelatinization process, for soap lye solution is made, for lip balm the sample was heated and mixed with different ingredients until it homogenizes, and for dyeing cotton, scouring and mordanting techniques were used. All these products were made under specific lab procedures. Bioplastic was flexible (moldable), and smooth in texture, cotton cloths gained bright colors and did not remove on washing (due to mordanting). The lip balm was smooth, creamy, semi-solid, the soap was firm and smooth in texture. Products were dyed successfully with beetroot, spinach and turmeric extracts. Bright, safe, and biodegradable colorants were yielded and successfully applied. Overall, it proved that by using natural plant-based colors/dyes, it can contribute at large scale to a sustainable world by replacing synthetic-chemical dyes used in industries and at other scales.

Keywords: natural dyes, bioplastic, lip balm, soap, sustainability, natural products

2. INTRODUCTION

World is heading towards a better and modern place but this modernization, sometimes along with ease, brings problems. In ancient times, natural dyes were used by people but after the industrial evolution synthetic dyes became popular. The use of chemicals and chemical-based stuff is facilitating in many ways, but it is known that the use of these materials is costly for health and environment. Today, synthetic dyes are commonly used to dye different materials manufactured in textiles, plastic, rubber, cosmetics and in many more industries (Kant 2011). Many industries are utilizing chemical dyes to color stuff like clothes, cosmetic products, cleaning materials etc. Synthetic dyes have more profound and stable colors, also they are easy to use and store, but for these benefits people must compromise health of both living organisms as well as the environment (Alegbe & Uthman, 2024). Synthetic dyes are cause of many health issues such as respiratory problems, skin allergies, irritation, and carcinogenic effects also they cause pollution as synthetic dyes are non-biodegradable, so they accumulate and cause harm to environment (Islam et al., 2022). They remain in environment for long and release harmful or toxic materials. To address these issues, natural dyes extracted from different natural materials such as turmeric, beetroot, spinach, and rose can be used (Gavit et al., 2024). The natural dyes extracted from natural materials are safe, eco-friendly, and biodegradable (Dey et al., 2025). The use of natural dyes instead of synthetic or chemical-based dyes is the best way towards the world shifting to sustainable future. This study demonstrates the extraction and then the use of natural dyes in making different products (soap, colored cotton, lip balm, and dyed plastic), and paving the way for detergent, textile, cosmetics, and packaging industries to manufacture eco-friendly and safe products (Saxena & Raja, 2014). Apart from safety these dyes are also beneficial as materials from which these dyes are extracted contain antioxidants, vitamins, and other elements. These elements provide different benefits naturally to humans. To give world the stuff that doesn't contribute to pollution and disasters caused due to synthetic materials, is the purpose of this study. This study is beneficial because of growing global demand for eco-friendly textiles, shift of world towards herbal and organic cosmetics, and skin care products. Using plant-based dyes in daily use is a meaningful step towards sustainable and better world (Nambela, 2025).

3. MATERIALS AND METHODS

The plant materials like beetroot, spinach, turmeric, and beeswax, coconut oil, shea butter, and rose essential oil were purchased from a local market in Karachi. Reagents and chemicals were bought from Dae-Jung Korea.

3.1 Dye Extraction

Beetroot (*Beta vulgaris*), spinach (*Spinacia oleracea*), and turmeric (*Curcuma longa*) were processed by washing 50 g samples with distilled water, chopping them finely, and immersing them in 100 mL distilled water within 250 mL beakers. The mixtures were maintained at 60 °C under constant stirring for 30 minutes, cooled, and filtered. The colored extracts red, green, and yellow were stored in amber bottles at 4°C (Saeed et al., 2024).

3.2 Use of Extracted Dye in Different Products.

3.2.1 Bioplastic

Corn starch (10 g) was dissolved in 100 mL distilled water in a 500 mL beaker made of borosilicate. The solution was heated with continuous stirring at 90 °C until translucent gel is not formed (gelatinization). Then glycerol (3 mL) was added, 10 mL of any dye extracts which are extracted from different sources (for natural coloration). The pH was adjusted to approx. using glacial acetic acid. The viscous mixture was poured into Petri dishes made up of silicon and spread evenly on the petri dish. Drying was done in an oven at 45°C for 24 hours. The dried films were peeled off and conditioned at 25°C for 48 hours before further use (Li et al., 2015).

3.2.2 Dyed Cotton Cloth

Cotton cloth squares (10 × 10 cm) were first scoured by boiling in 100 mL of distilled water with 2g sodium carbonate and a mild detergent (1 mL) for 20 minutes to remove waxes, oils, and impurities. The fabric was then washed and dried in the air. The textile was then mordant by immersion in a 100 mL solution of alum (2g) at 70 °C for 30 minutes and then rinsed and dried (Hosen et al., 2021). The mordant fabric was subsequently dyed: two individual dye baths (50 mL each) of beetroot extract and turmeric extract were prepared, and each sample of the fabric was dipped into each respective bath, which was at 80°C, and left for 45 minutes, with occasional stirring. The fabrics were then cooled, washed until the water ran clear, and then dried in air at room temperature (Gooding et al., 1996). This gave pinkish red (beetroot) and yellow (turmeric) dyed fabrics.

3.2.3 Herbal Lip Ointment

Beeswax pellets (5g), coconut oil (5mL), and shea butter (2g) were mixed in a 100 mL beaker and then melted by using a water bath maintained at around 70 °C until homogenizes (Ahnert, 2015). The mixture was removed from heat and allowed to cool to about 50 °C, then beetroot extract (3 mL) for coloring, rose essential oil (0.1 mL) for fragrance, and vitamin E oil (0.1 mL) for its antioxidant activity were added. The mixture was transferred into sterilized lip balm container immediately and allowed to set at room temperature.

3.2.4 Herbal Soap

A lye solution was made by dissolving 10 g of sodium hydroxide in about 25 mL of distilled water and then cooling it down to about 40 °C. Coconut oil (50 mL) and olive oil (20 mL) were heated to about 40 °C in the meantime (Beetseh & Godwin, 2015).

4. RESULTS

The natural color from beetroot, spinach, and turmeric were isolated successfully (Summoogum-Utchanah & Joyram, 2015). These colors were good shades, and they are non-toxic to environment and easily degradable in soil and different products were prepared by using this color. Decorative bioplastic flower, colorful cotton fabric, herbal lip balm and herbal soap.

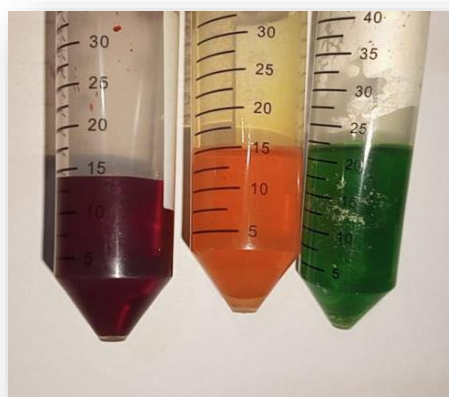


Figure 1: Extracted dyes, the dyes were extracted from natural source. Each extracted dye was 13 to 17 ml from 10g different natural sources.

4.1 Dye Extraction

The dye from the beetroot, spinach and turmeric was isolated successfully (Sengupta et al., 2015). Natural dyes have diverse applications Sk et al., 2021). Across at least five major categories: primarily textiles (fibers and fabrics), but also in the food industry (safe coloring for confectionery and beverages), cosmetics (lip balm, soap), pharmaceuticals (coloring pills), and coloring various craft and industrial materials (leather, wood, and paper).

4.2 Use of Extracted Dye in Different Products.

4.2.1 Bioplastic

First bioplastic sheets were prepared by using corn starch and glycerol with colored dye. These sheets were smooth texture, pliable and flexible plastic like polymer, which can be transformed into any shape. Decorative piece (rose) was also prepared from bioplastic, where red color of petals in flower is from beet root and green color in leave is from spinach as shown in figure 2(a).

4.2.2 Dyed Cotton Fabric

The cotton fabric was dyed by using natural pigments. These fabrics were colored easily and did not remove by washing. This natural dye behaved like a normal chemical dye and colored the fabric by heating at 70°C as shown in figure 2(b).

4.2.3 Herbal Lip Balm

The herbal lip balm was produced have the pinkish-red color of beetroot. Cosmetic products provide a subtle, non-synthetic tint and color to the lips, and as a functional moisturizer to hydrate and protect the lips from chapping and dryness. Additionally, the natural extracts often lend antioxidants or therapeutic benefits beyond simple hydration. The texture of the naturally colored lip balm is typically smooth, creamy, and semi-solid as shown in figure 2(c).

4.2.4 Herbal Soap

The herbal soap was prepared by using natural ingredients like natural oils of coconut oil and olive oil. The pink color of soap is because of beetroot extract. The texture of naturally produced soap is typically firm but smooth and creamy, often with dense, rich leather as shown in figure 2(d).

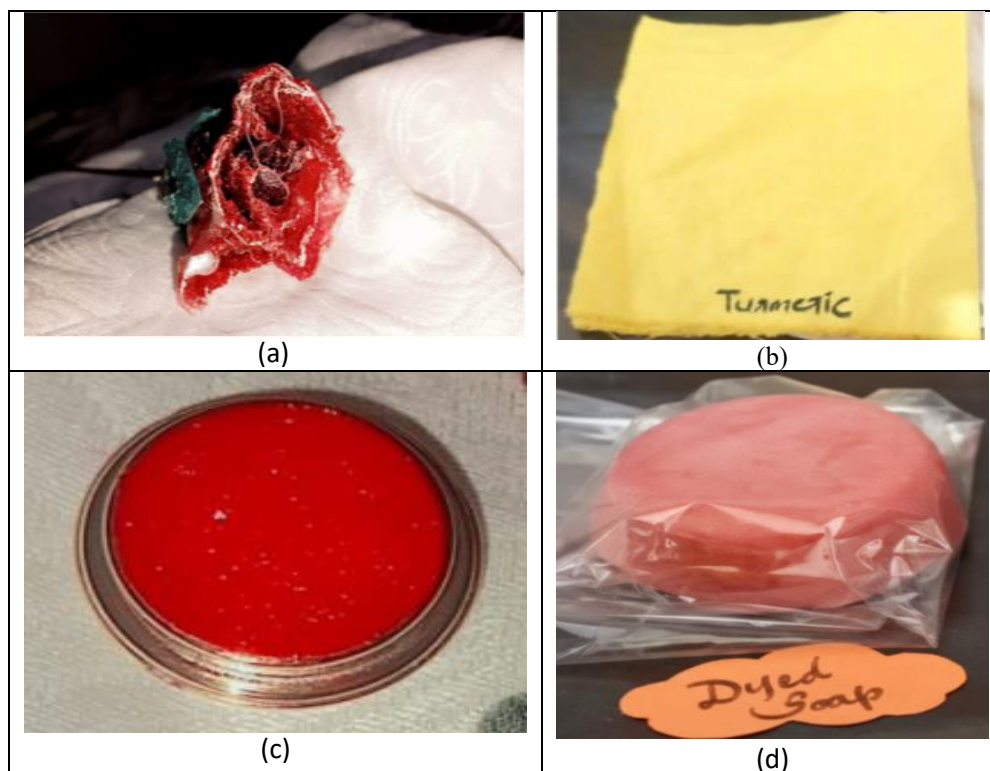


Figure 2: (a) Bioplastic rose was shaped from bioplastic sheets based on corn-based biomaterial, (b) The cotton fabric colored with turmeric shows the yellow color appears when boiling the fabric with extracted turmeric, (c) The herbal lip balm based on bee's wax and the natural color of beetroot (d) The herbal soap was prepared natural oils and the natural color of beetroot.

5. DISCUSSION

In textiles, the key process was alum mordant, which greatly improved brightness and hue of the pinkish red (beetroot), green (spinach) and yellow (turmeric) tones on the cotton material. In beauty products, the lip moisturizer, the stability of the formulation was attained by incorporating the sensitive beetroot extract and essential oils following the beeswax/oil base was liquefied and cooled, while the cold-process soap effectively blended extracts at the trace phase for consistency coloration prior to the 10–15 day curing duration. These naturally dyed materials proved that it could make visually appealing, safe materials by using locally sourced, renewable dyes which are harmless and biodegradable. Thereby, use of natural dyes in textile, cosmetic, and packaging sectors is supported by this study.

5. CONCLUSION

So, basically the study suggests strongly that replacing conventional chemical dyes with natural extracts could be an effective way to minimize harm to our environment and to living beings. It could also reduce the use of chemicals and instead will use renewable sources which are recyclable as well as biodegradable. This study is evidence that natural extracts could work similarly as chemical dyes. Little more work and effort in this study could replace these chemical dyes industrially. This is the step towards sustainable and secure future.

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