Electronic Journal of University of Aden for Basic and Applied Sciences
EJUA-BA Vol. 5 No. 3 (2024)
https://doi.org/10.47372/ejua-ba.2024.3.377
ISSN: 2708-0684

RESEARCH ARTICLE

EXPLOITING ECO-FRIENDLY NATURAL DYES FROM PLANT SOURCES: EXTRACTION AND DIVERSE APPLICATIONS

Adel A. M. Saeed[1,*], Mokhtar S. S. Al-Salimi[2], Mohsen T. A. Qashqoosh[3], Gamal A. A. Al-Dahbali[4], Wejdan Sameer Abdulmajeed[1], Thoraia Haleem Anwar Mohammed[1], Sabah Mohammed Abdellah Abdallah[1], Omar Mohammed Omar BA Fadhl[1], Afnan Younis Ahmed Saleh[1], Suhair Hamood Hassan Abdullah[1] and Wafa Ali Saleh Nagi[1]

[1] *Dept. of Chemistry, Faculty of Science, University of Aden, Aden, Yemen.*
[2] *Dept. of Chemistry, Yafea University College, University of Lahej, Yafea, Yemen.*
[3] *Dept. of Chemistry, Faculty of Education, University of Aden, Aden, Yemen.*
[4] *Dept. of Chemistry, Faculty of Lawdar Education University of Abyan, Abyan, Yemen.*

***Corresponding author: Adel A. M. Saeed; E-mail: adel_saeed73@yahoo.com**

Received: 31 August 2024 / Accepted: 09 September 2024 / Published online: 30 September 2024

Abstract

Natural pigments extracted from plant sources offer eco-friendly and sustainable alternatives to synthetic colorants. In this study, pigment samples were obtained through aqueous extraction from beetroot (S1), red cabbage (S2), and turmeric (S3). Their physicochemical properties and potential applications were thoroughly evaluated. The research problem addressed in this study is the need to overcome the limitations of natural dyes, such a slower color fastness, reduced reproducibility, and limited color range, in order to promote their wider adoption in various industries as sustainable alternatives to synthetic colorants. The pigment extracts were assessed for their suitability in textile dyeing, paper pH indicators, food coloring, ink production, and natural stamp pad formulations. Cotton and wool fabrics were dyed by adding traditional mordants, and the pigment-treated textiles exhibited distinctive color changes and varying levels of color fastness. The pigment samples demonstrated the ability to act as effective acid-base indicators, displaying characteristic color transitions in response to varying pH levels. When used as natural food colorants, the extracts imparted attractive hues to rice and cream without altering their flavor profiles. The feasibility of incorporating these plant-derived pigments in ink manufacturing and stamp pad production was also explored. Beetroot pigment exhibited superior color retention and fastness properties, while red cabbage and turmeric extracts displayed effectiveness in selected applications. The findings of this comprehensive study highlight the viability of these plant sources as natural substitutes for synthetic colorants in diverse fields. The observed performance characteristics and the eco-friendly nature of the pigments underscore their potential to serve as sustainable alternatives in various industries.

Keywords: Natural Dyes, Beetroot, Red Cabbage, Turmeric, Eco-friendly Applications, Color Fastness.

Introduction

Synthetic pigments are incredibly prevalent due to their cost-effective mass-production capabilities. However, these man-made colorants come at a significant price - they pose serious threats to the environment and human health. Consequently, the interest in natural plant-based dyes has resurfaced globally, with a growing awareness of the organic value of eco-friendly products[1-5]. However, the use of natural dyes is not without its challenges. Natural dyes often exhibit lower color fastness, reduced reproducibility, and a limited color range compared to their synthetic counterparts [6,7]. The susceptibility of natural dyes to environmental factors, such as light, heat, and pH, can also lead to color changes and reduced stability over time [8,9]. Additionally, the extraction and application processes of natural dyes can be more labor-intensive and time-consuming, making them less cost-effective on a large scale [10,11].

The research problem addressed in this study is the need to overcome the limitations of natural dyes, such as lower color fastness, reduced reproducibility, and limited color range, in order to promote their wider adoption in various industries as sustainable alternatives to synthetic colorants.

Consequently, the development of improved extraction, application, and fixation techniques for natural dyes is crucial to overcome these limitations and promote their wider adoption in various industries. The dyeing process involving natural dyes typically follows three main steps: adsorption, penetration, and fixation[11-15]. During the adsorption step, the dye molecules are attracted to the surface of the textile fibers through physical or chemical interactions. The penetration step involves the diffusion of dye molecules into the interior of the fiber matrix. The fixation step ensures the durable attachment of the dye molecules within the fiber structure, leading to enhanced color fastness and retention. Various compounds, such as NaCl, $KAl(SO_4)_2$, CH_3COOH, $Al_2(SO_4)_3$, and KCl, are utilized to enhance the affinity between the dye and the textile fibers, leading to the formation of strong complexes within the fiber matrix.

In addition to textile dyeing, the versatility of these natural dyes extends to their use as paper pH indicators, food colorants, ink manufacturing, and the production of natural stamp pads. The distinctive color changes observed in response to varying pH levels demonstrate their potential as acid-base indicators[16-18]. The integration of these plant-derived dyes in food coloring applications has also shown promising results, imparting attractive hues to rice and cream without altering their flavor[19-21].

This comprehensive study aims to highlight the viability of beetroot, red cabbage, and turmeric as natural substitutes in diverse fields, showcasing their eco-friendly and sustainable attributes. By exploring the extraction, application, and performance of these plant-based dyes, the growing movement towards more environmentally conscious and healthier alternatives in various industries is being supported.

Materials and Methods

Dye samples were obtained through aqueous extraction from freshly prepared plant materials. The test materials included locally sourced cotton and wool fabrics. Standard mordanting and dyeing protocols were followed, in accordance with established guidelines. pH indicators were created by immersing filter paper strips in the dye solutions. Additionally, rice and cream were dyed to assess their potential as natural food colorants. The feasibility of using these dyes for manufacturing ink and stamp pads was also examined[21-24].

2.1. Dyeing of cotton and woolen fabrics

For the dyeing experiments, cotton fabrics were cut into approximately 10 cm × 10 cm squares, and wool spools were trimmed to lengths of 20 cm. This standardization ensured uniform sample sizes and shapes across the different textile materials.

Both the cotton and wool samples were thoroughly washed with distilled water and air-dried. This pre-treatment step was essential to eliminate impurities or residues on the fabrics, providing a clean surface for the subsequent dye application.

2.2. Preparation of dye fixatives

Potassium aluminum sulfate ($KAl(SO_4)_2$) was ground finely, sieved, and weighed to 18 g. It was then added to 300 ml of distilled water to make a 6×10 ppm solution in a pot. The fabrics to be dyed were placed into this solution and boiled for 10 minutes. Potassium aluminum sulfate is a traditional mordant that helps to enhance the affinity between the natural dyes and the textile fibers. It forms strong complexes within the fiber matrix, leading to improved color fastness and retention.

Sodium chloride (NaCl) and potassium chloride (KCl) were also used in the dyeing process, but they do not function as traditional mordants. These salts can play a role in the dyeing process by influencing the solubility and diffusion of the dye molecules into the textile fibers. They can also affect the ionic interactions between the dye and the fiber, which can impact the depth and evenness of the color.

Acetic acid (CH_3COOH) was prepared by adding 1:4 vinegar to water in a pot, and the fabrics to be dyed were boiled in this solution for 10 minutes. Acetic acid can act as a pH modifier, altering the ionization state of the dye molecules and the textile fibers. This can affect the adsorption and fixation of the dyes, potentially influencing the color outcome and fastness properties.

These compounds can play various roles in the dyeing process, but they do not all serve as traditional mordants in the same way as potassium aluminum sulfate. The strategic use of these additives can help to optimize the performance of the natural dyes and improve their suitability for textile applications.

2.3 Preparing samples for dyeing and method

The plant-based dye samples (S1, S2, and S3) were cut into small pieces, and water was added to fill half of the pot. The samples were then left to boil for 10 minutes.

After the initial boiling step, the fabrics (cotton and wool) were treated with various fixatives before being added to the dye solutions. The following fixatives were used:

- Potassium aluminum sulfate ($KAl(SO_4)_2$): The fabrics were placed into a solution of 18 g of potassium aluminum sulfate in 300 ml of distilled water and boiled for 10 minutes.

- Sodium chloride (NaCl) and potassium chloride (KCl): The fabrics were boiled for 10 minutes in a solution made by adding 1:4 vinegar to water.

- Acetic acid (CH_3COOH): The fabrics were boiled for 10 minutes in a solution made by adding 1:4 vinegar to water.

These fixatives were used to enhance the affinity between the natural dyes and the textile fibers, leading to the formation of strong complexes within the fiber matrix and improving the color fastness and retention.

After the fixation step, the pre-treated fabrics were added to the respective dye solutions (S1, S2, and S3) and left for 15 minutes. Following this, the fabrics were washed with distilled water and dried.

2.4. pH reagents paper

2.4.1 Preparation of paper and method

The S1, S2, and S3 samples were cut into small pieces, and 50 ml of distilled water was added. These mixtures were then boiled for 10 minutes in different containers. The filter papers were cut lengthwise and added to the prepared dyes, where they were left to dry. These dried filter papers should be used as soon as possible. Solutions with different acidity grades were prepared and arranged according to the pH gradient, with specific symbols assigned to them. The leaves were then placed in the solutions to observe the color change [25].

2.5. Manufacture Manufacture of ink from plant dyes S1, S2, and S3

The S1, S2, and S3 samples were washed with distilled water, thoroughly ground, and filtered to obtain concentrated dyes. Specific amounts of additives were then incorporated to formulate the inks, as detailed in Table 1.

Table 1. Additives used in manufacturing ink from plant dyes

S1	0.5 g of citric acid*	5 ml of acetone.
S2	0.5 g of potassium aluminum sulfate**	-
S3	10 ml of acetic acid***	0.5 g of citric acid

*The citric acid was added to the beetroot (S1) dye extract to help improve the light fastness and color retention of the ink formulation, as reported in previous studies [21,22].

**Potassium aluminum sulfate was included in the red cabbage (S2) ink to enhance the intensity and stability of the violet color, as it can form complexes with the anthocyanin pigments [23,24].

***Acetic acid was used to aid in the solubilization of the curcumin pigment from turmeric (S3), resulting in a vibrant yellow hue. The citric acid was added to further improve the light fastness of the turmeric-based ink [25].

2.6. Stamp industry from plants dyes S1, S2, and S3

The samples S1, S2, and S3 were washed with distilled water, then ground thoroughly and filtered to obtain concentrated dye extracts. To each dye extract, 0.5 g of Arabic gum powder was added and mixed well to achieve a homogeneous solution. These dye-gum solutions were then added to a box containing cotton, followed by the addition of drops of acetic acid.

The addition of Arabic gum helped to bind the natural dyes and create a suitable ink-like consistency for the stamp pad formulations. The acetic acid was included to further enhance the color properties and fixation of the dyes within the cotton matrix.

2.7. Food coloring

In the previous section (2.3), the plant-based dye samples S1, S2, and S3 were prepared by cutting the plant materials into small pieces, adding water, and boiling the mixtures for 10 minutes. These liquid dye extracts were then utilized as natural food coloring agents for dyeing rice and cream [26].

Additionally, solid dye samples were also prepared by drying the concentrated liquid extracts obtained in section 2.3. These solid dye samples were then rehydrated and used alongside the liquid extracts for the food coloring applications.

The use of both solid and liquid forms of the natural dye extracts allowed for the evaluation of their performance and suitability as food colorants in different physical states. This approach provided a more comprehensive assessment of the dyes' ability to impart attractive hues to the food items (rice and cream) without altering their flavor profiles.

Results and Discussion

3.1. Dyeing of fabrics

Dyeing of fabrics is the process of imparting color to textiles. This can be done using various types of dyes, including natural dyes (derived from plants) and synthetic dyes (manufactured chemically). The dyeing process involves several steps, such as preparation of the fabric, dye selection and application, fixation of the dye to ensure colorfastness, and finally, washing and finishing the fabric to achieve the desired look and feel [27]. Common compounds like $KAl(SO_4)_2$, $Al_2(SO_4)_3$, and alum were examined as traditional mordants in this study. They had an affinity for the dye and the textile fibers, resulting in strong complexes with the dye inside the fiber matrix.

Sodium chloride (NaCl), potassium chloride (KCl), and acetic acid (CH_3COOH) were also used in the dyeing process. While they do not function as traditional mordants, these compounds can play a role in the dyeing process by influencing the solubility, diffusion, and ionization of the dye molecules, as well as the interactions between the dye and the textile fibers. The use of these additives can impact the depth, evenness, and fastness properties of the dyed fabrics.

From Tables 2, 3, and 4, it can be seen that the cotton fabric was dyed by the extract in all three cases, and the color depth on the fabrics differed based on the additive used. Comparing the color strength of the fabrics, it was observed that fabrics dyed with only the dye extract (without any additives) had a deeper/stronger color shade than fabrics dyed with the addition of NaCl, KCl, or CH_3COOH.

Yellow color dye is the most common color found in nature dye turmeric. They are known to produce pale shades, less light fastness and fairly good wash fastness e.g., turmeric Table 4. Yellow from safflower color dye turmeric gives excellent fastness to light and washing.

Table 2. S1 pigment effect of selected stabilizers on cotton fabric and wool fabric after dyeing and washing

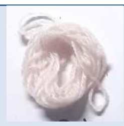
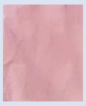
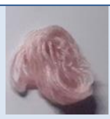
Type of stabilizers	S1 Dye		S1 Dye	
	Cotton Fabric		**Wool Fabric**	
	After Dyeing	After Washing	After Dyeing	**After Washing**
	Image and Color		**Image and Color**	
Without stabilizer	 Ruby	 Bordeaux	 Ruby	 **Cloud**
NaCl	 Gamet	 Searlest	 Opal purple	 **Coin**
$KAl(SO_3)_2$	 Rubine	 Magenta	 Thistle purple	 **Champagne**
CH_3COOH	 Cool red	 Fantasy rose	 Raisin purple	 **Carnation**
$Al_2(SO_4)_3$	 Bordeaux	 Strawberry	 Amethyst	 **Blush**
KCl	 Muted red	 Pink	 Pearly	 **Lilac**

Table 3. S2 pigment effect of selected stabilizers on cotton fabric and wool fabric after dyeing and washing

Type of stabilizers	S2 Dye		S2 Dye	
	Cotton Fabric		**Wool Fabric**	
	After Dyeing	After Washing	After Dyeing	**After Washing**
	Image and Color		**Image and Color**	
Without stabilizer	 Slivery	 Corn blue	 Lris	 **Lilac mist**
NaCl	 Flint	 Deep lilac	 Lavender	 **Carolina**

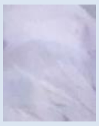
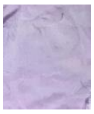
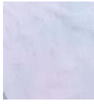
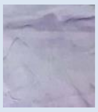
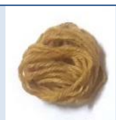
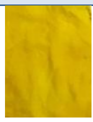
$KAl(SO_3)_2$	 Soft purple	 Purple	 Orchid	 **Pearl**
CH_3COOH	 Jasmine	 Gray	 Floral	 **Rhino**
$Al_2(SO_4)_3$	 Aloof grapy	 Rocks	 Wisteria	 **Steel**
KCl	 Dark gray	 Pewter	 Mouve	 **Olympic**

Table 4. S3 pigment effect of selected stabilizers on cotton fabric and wool fabric after dyeing and washing

Type of stabilizers	S3 Dye		S3 Dye	
	Cotton Fabric		**Wool Fabric**	
	After Dyeing	After Washing	After Dyeing	**After Washing**
	Image and Color		**Image and Color**	
Without stabilizer	 Medallion	 Dijon	 Sunflower	 **Mustard**
NaCl	 Canary	 Dark honey	 Honey	 **Fawn**
$KAl(SO_3)_2$	 Honey	 Yolk	 Yellow	 **Hazelnut**
CH_3COOH	 Cyber	 Corn	 Butter	 **Dijon**
$Al_2(SO_4)_3$	 Pineapple	 Lemon	 Marigold	 **Gold**
KCl	 Tuscan sun	 Butter	 Blonde	 **Corn**

3.2 Paper indicators

The results exhibited distinctive color changes for all surveyed plant species in both acidic and alkaline solutions. Specifically, beetroot (S1) exhibited color changes from pink to light red when shifting from an acidic to an alkaline solution. On the other hand, red cabbage (S2) displayed unique color red changes in solutions acid and changes to green and greenish blue in base solutions. Turmeric (S3) showed a yellow color; in citric and acetic acids solutions and it turned dark red and light red in backing soda and detergent bases. The specific color changes of the indicators in solutions with different solutions are shown in Table 5. The changes in the colors of these indicator paper strips were found in studies [28,29].

Table 5. The specific color changes of the indicators in solutions in different acids and bases

Dye	Citric acid	CH_3COOH	Water	Backing soda	Detergents
S1 Paper	Pink	Pink	Light pink	Light Red	**Light Red**
S2 Paper	Red	Light Red	Purple	Green	**Greenish blue**
S3 Paper	yellow	Light yellow	yellow	Dark Red	**Light Red**

3.3 Food coloring

Food coloring refers to substances added to food or drink to change its color. It is commonly used in baking, confectionery, and other food preparations to enhance visual appeal or achieve a desired appearance. Food colorings can be natural (derived from plants, minerals, or insects) or synthetic (produced in a laboratory). They come in various forms including liquids, powders, gels, and pastes, and are regulated by food safety authorities to ensure they are safe for consumption . Attractive hues were imparted without flavor alterations. Beetroot imparted an intense pink shade while red cabbage and turmeric yielded lilac and yellow shades respectively. Figures 1 and 2 show the variance of the colors with different food items. Beetroot, derived from the roots of the Beta vulgaris plant, are known for their deep red pigments. The extracted pigments can then be concentrated and used to achieve vibrant shades of red in foods and drinks. Natural red food colorings extracted from red beetroot provide an opportunity to enhance the visual appearance of foods without compromising on the clean and healthy nature of the ingredients [26]. Red cabbage is famous for its deep purple pigments. These pigments, called anthocyanins (cyaniclin) are extracted from red cabbage through various methods, such as juicing it or grinding it into a paste. The extracted pigments can then be concentrated and used to achieve vibrant lilac shades in foods and beverages [25]. Turmeric, a spice commonly used in culinary traditions, has a vibrant yellow pigment known as curcumin. Curcumin extraction involves grinding the turmeric root into a fine powder, followed by a solvent-based extraction method to obtain the desired colorant. Turmeric coloring finds its way into many food products such as curries, baked goods, beverages, snacks, and condiments. The concept of natural yellow colorants has emerged as a powerful alternative to synthetic options, offering vibrant colors [30, 31].

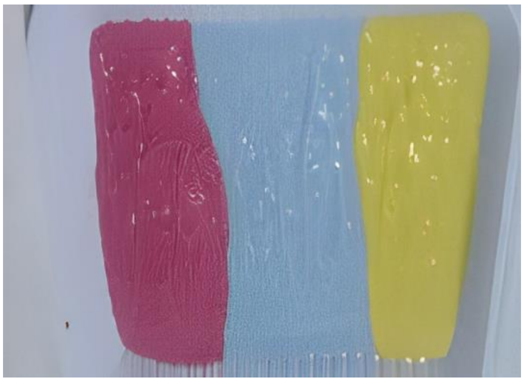


Fig. 1. Dyeing of creams by S1, S2, and S3 plant dyes

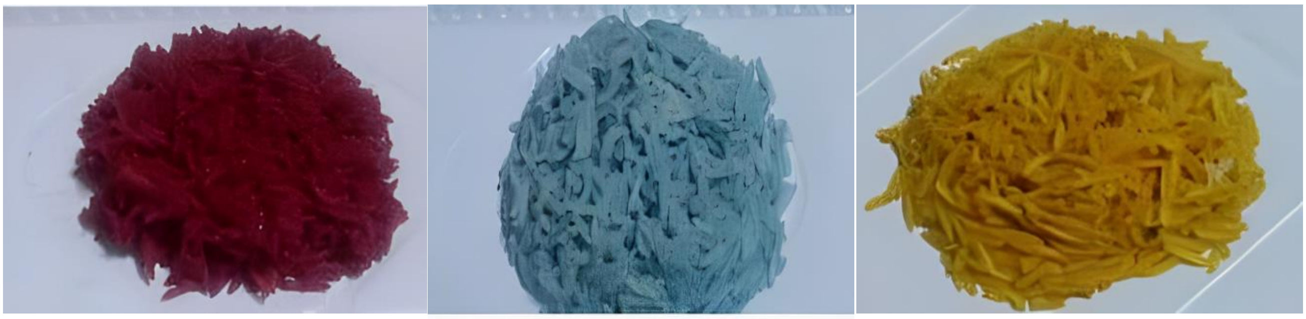


Fig. 2. Dyeing of rice by S1, S2, and S3 eco-friendly dyes

Table 6. Result of S1, S2 and S3 ink samples

Compression	Whiteboard ink		
	S1	**S2**	**S3**
Color writing	Light Red	Violet	Yellow
Dry time	5 sec	1min	10 sec
Ease erase	Very ease	Ease	not ease
Image			
Compression	**Paper ink**		
	S1	**S2**	**S3**
Color writing	Pink	Violet	Yellow
Dry time	3 sec	3 sec	3 sec
Image			

3.4 Ink manufacturing

Ink manufacturing involves blending various components to create a substance used for writing, printing, or drawing. The main components of ink typically include pigments or dyes (for color), binders (to hold the pigment particles together), solvents (to adjust viscosity and aid in drying), and additives (for specific properties like drying time or durability).

The results of incorporating the natural dye extracts S1, S2, and S3 into ink formulations are presented in Table 6.

As shown in Table 6, the beetroot pigment extract (S1) produced a light red colored ink with a very fast drying time of 5 seconds and was easily erasable. This can be attributed to the addition of citric acid, which facilitated higher light fastness and improved pigment retention in the ink formulation.

The red cabbage extract (S2) yielded a vibrant violet colored ink that dried within 1 minute and 10 seconds. The inclusion of potassium aluminum sulfate helped to intensify the color of the red cabbage ink.

The turmeric extract (S3) imparted a brilliant yellow color to the ink. The addition of acetic acid aided in the solubilization of the curcumin pigment, resulting in the vivid yellow hue. However, the turmeric ink was not as easily erasable as the beetroot and red cabbage inks.

The performance characteristics of these natural dye-based inks highlight their potential as sustainable alternatives to synthetic inks. The ability to formulate inks with distinct colors, fast drying times, and varying degrees of eras ability demonstrates the versatility of these plant-derived pigments. The strategic use of additives, such as citric acid and potassium aluminum sulfate, further enhanced the desired properties of the inks, showcasing the importance of optimizing the ink formulations to maximize the benefits of natural colorants.

3.5 Stamp pads

Stamp pads, also known as ink pads or stamp ink pads, are small containers filled with ink that are used in conjunction with rubber stamps or other types of stamps to transfer ink onto surfaces such as paper or fabric. The feasibility of utilizing the natural dye extracts S1, S2, and S3 in the production of stamp pads was also explored in this study.

The results of the stamp pad formulations are presented in Table 7.

Table 7. Results of stamp samples

Compression	Samples of Stamps		
	S1	**S2**	**S3**
Color of stamp	Light pink	Light violet	Light yellow
Time of dry	1min	3sec	5sec
Image			

As shown in Table 7, the beetroot pigment extract (S1) and the turmeric extract (S3) provided long-lasting and vibrant stamp impressions. The beetroot dye produced a light pink stamp, while the turmeric extract yielded a light yellow stamp.

In contrast, the red cabbage extract (S2) exhibited a light violet stamp color, but the dye tended to disappear rapidly from the stamp pad due to dilution. It was observed that the cotton material inside the stamp pad remained white, indicating the lack of durable color retention for the red cabbage extract.

The drying times for the stamp pad formulations also varied. The beetroot (S1) stamp took the longest to dry, requiring approximately 1 minute and 3 seconds. The red cabbage (S2) and turmeric (S3) stamps, on the other hand, dried more quickly, within 5 seconds.

The use of the stamp pads made with these natural dye extracts clearly showed the fingerprint lines, demonstrating their potential for various applications that require clear and distinct impressions, such as in security or identification systems.

The differences in the performance characteristics of the stamp pads can be attributed to the inherent properties of the individual plant-based pigments. The superior color retention and fastness exhibited by the beetroot and turmeric dyes suggest their suitability for long-lasting stamp pad formulations. The relatively poor performance of the red cabbage extract may be due to its susceptibility to dilution and reduced color stability over time.

These findings highlight the importance of considering the specific characteristics of each natural dye when formulating stamp pads or other ink-based products. The strategic selection and optimization of the natural colorants can lead to the development of eco-friendly and high-performance stamp pad solutions that can serve various industries and applications.

Conclusion

This comprehensive study demonstrated the viability of natural dye extracts from beetroot, red cabbage, and turmeric as eco-friendly and sustainable alternatives in diverse applications. The findings highlight the potential of these plant-based resources to serve as substitutes for synthetic colorants across various industries.

In textile dyeing, the natural dyes exhibited distinctive color outcomes and variable fastness properties depending on the specific plant source and the mordants used. Beetroot dye imparted superior color depth and wash fastness on both cotton and wool fabrics, while red cabbage and turmeric extracts displayed fair to good performance in selected applications. The traditional mordants, such as alum and metal salts, were found to be more effective in enhancing the color fastness properties of the natural dyes compared to the use of sodium chloride, potassium chloride, and acetic acid, which do not function as mordants in the traditional sense.

The natural dye samples also showed promising potential as acid-base indicators, exhibiting characteristic color changes in response to varying pH levels. This attribute underscores their suitability for manufacturing pH test papers, a valuable tool in various analytical and monitoring applications.

Furthermore, the integration of these plant-derived colorants in food coloring, ink production, and stamp pad manufacturing proved successful. Beetroot, red cabbage, and turmeric dyes were able to impart attractive hues to food substrates, create high-quality inks, and produce long-lasting stamp impressions, demonstrating their versatility and adaptability.

The findings of this study highlight the significant advantages of natural dyes over their synthetic counterparts. These plant-based colorants offer eco-friendly, sustainable, and often safer alternatives that can meet the growing demand for environmentally conscious and health-conscious products. With further optimization of extraction and application techniques, the scope for utilizing these natural resources in diverse industries can be further expanded.

In conclusion, this research underscores the immense potential of beetroot, red cabbage, and turmeric as viable natural dye sources, paving the way for their wider adoption and integration across various fields. The successful demonstration of their performance in textile dyeing, paper indicators, food coloring, ink manufacturing, and stamp pads reinforces the feasibility of these plant-based alternatives as sustainable and environmentally friendly solutions.

Acknowledgments

We would like to express our sincere gratitude to Aden Refinery Company and their laboratory team for their invaluable support and assistance throughout our research. Special thanks to Dr. Safa Gamal for her expert guidance and contributions, which were instrumental in the successful completion of this work.

Authors' Declaration

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: All ethical guidelines have been adhered to.

Sample availability: Samples of the compounds are available from the author.

Authors' Contribution Statement

Conceptualization: Adel A. M. Saeed, Mokhtar S. S. Al-Salimi; Mohsen T. A. Qashqoosh; Gamal A. A. Al-Dahbali; Methodology: Adel A. M. Saeed, Mokhtar S. S. Al-Salimi, Wejdan Sameer Abdulmajeed; Software: Wejdan Sameer Abdulmajeed, Thoraia Haleem Anwar Mohammed; Validation: Adel A. M. Saeed, Mokhtar S. S. Al-Salimi; Investigation: Thoraia Haleem Anwar

Mohammed, Sabah Mohammed Abdellah Abdallah, Omar Mohammed Omar BA Fadhl, Afnan Younis Ahmed Saleh, Suhair Hamood Hassan Abdullah, Wafa Ali Saleh Nagi; Resources: Adel A. M. Saeed, Mokhtar S. S. Al-Salimi; Data Curation: Wejdan Sameer Abdulmajeed, Thoraia Haleem Anwar Mohammed; Writing - Original Draft: Thoraia Haleem Anwar Mohammed, Sabah Mohammed Abdellah Abdallah, Omar Mohammed Omar BA Fadhl, Afnan Younis Ahmed Saleh, Suhair Hamood Hassan Abdullah, Wafa Ali Saleh Nagi; Writing-Review and Editing: Adel A. M. Saeed, Mokhtar S. S. Al-Salimi, Wejdan Sameer Abdulmajeed; Visualization: Wejdan Sameer Abdulmajeed, Thoraia Haleem Anwar Mohammed; Supervision: Adel A. M. Saeed; Project Administration: Adel A. M. Saeed.

References

[1] K. K. Gaikwad and L. Hakim, "Natural dyes from plants for smart packaging and printing applications," Journal of Advance Chemistry Engineering, vol. 12, no. 9, pp. 1–8, 2022.

[2] S. M. Alam, S. Islam, and S. Akter, "Reviewing the sustainability of natural dyes," Advance Research in Textile Engineering, vol. 5, no. 2, pp. 1–6, 2020.

[3] S. A. Ebrahim, H. A. Othman, M. M. Mosaad, and A. G. Hassabo, "Eco-friendly natural thickener (pectin) extracted from fruit peels for valuable utilization in textile printing as a thickening agent," Textiles, vol. 3, no. 1, pp. 26–49, 2023.

[4] J. Mussarat, T. Kainat, R. Atiya, A. Noreen, M. Z. Ansa, and S. U. Hussain, "Evaluation of Improvised and Eco-Friendly Natural pH-Paper Indicators," Frontiers in Chemical Sciences (FCS), vol. 3, no. 2, pp. 22–31, 2022.

[5] A. A. M. Saeed, M. S. S. Al-Salimi, Y. K. Manea, W. Abdulmajeed, T. H. A. Mohammed, S. M. A. Abdallah, O. M. O. BA Fadhl, A. Y. A. Saleh, S. H. H. Abdullah, and W. A. S. Al Asahb, "Towards Greener Analysis: Evaluating Plant-Derived Natural Dyes as pH Indicators," Mor. J. Chem., vol. 12, no. 4, pp. 1511–1530, 2024.

[6] I. Čorak, I. Brlek, A. Sutlović, and A. Tarbuk, "Natural dyeing of modified cotton fabric with cochineal dye," Molecules, vol. 27, no. 3, pp. 1–13, 2022.

[7] F. Nwafulugo, F. Samuel, T. Nyam, S. Omale, and P. O. Nwosibe, "Marker ink production from berry seed extract," Int. J. Sci. Eng. Res., vol. 10, pp. 698–704, 2019.

[8] M. C. Heller, S. E. Selke, and G. A. Keoleian, "Mapping the influence of food waste in food packaging environmental performance assessments," J Ind Ecol., vol. 23, no. 2, pp. 480–495, 2019.

[9] M. M. Ragab, A. G. Hassabo, and H. A. Othman, "An overview of natural dye extraction techniques for valuable utilization on textile fabrics," Journal of Textiles Coloration and Polymer Science, vol. 19, no. 2, pp. 137–153, 2022.

[10] H. Cao, L. Ai, Z. Yang, and Y. Zhu, "Application of xanthan gum as a pre-treatment and sharpness evaluation for inkjet printing on polyester," Polymers, vol. 11, no. 9, pp. 1–12, 2019.

[11] M. Diaa, H. Othman, and A. G. Hassabo, "Printing wool fabrics with natural dyes curcuma and alkanet (a critique)," Journal of Textiles, Coloration and Polymer Science, vol. 19, no. 1, pp. 11–16, 2022.

[12] A. L. Mohamed, S. Shaarawy, N. Elshemy, A. Hebeish, and A. G. Hassabo, "Treatment of cotton fabrics using polyamines for improved coloration with natural dyes extracted from plant and insect sources," Egyptian Journal Chemistry, vol. 66, no. 3, pp. 1–19, 2023.

[13] S. Voon, J. An, G. Wong, Y. Zhang, and C. K. Chua, "3D food printing: a categorised review of inks and their development," Virtual Phys Prototyp., vol. 14, no. 3, pp. 203–218, 2019.

[14] D. M. Hamdy and A. G. Hassabo, "Various natural dyes from different sources," Journal of Textiles, Coloration and Polymer Science, vol. 18, no. 2, pp. 171–190, 2021.

[15] K. Addison and O. Jamela, "We've Got the Beet: Using Beetroot, Red Cabbage, and Litmus Strips to Indicate Drink Spiking," Journal of Student Research, vol. 11, no. 4, pp. 1–10, 2022.

[16] G. Grykiewicz and P. Silfirski, "Curcumin and curcuminoids in quest for medicinal status," Acta Biochim Pol., vol. 59, pp. 201–212, 2012.

[17] R. Ahsan, A. Masood, R. Sherwani, and H. Khushbakht, "Extraction and application of natural dyes on natural fibers: An eco-friendly perspective," Rev Educ Adm Law, vol. 3, no. 1, pp. 63–75, 2020.

[18] T. T. Moe, Z. C. Soe Mon, H. H. Shwe, and A. A. Myint, "Characterization and application of natural dye extracted from rinds of pomegranate (Punica granatum L)," IEEE-SEM, vol. 7, no. 8, pp. 7–12, 2019.

[19] S. N. Okonkwo, C. B. C. Ohanuzue, G. C. Onuegbu, H. C. Obasi, and O. O. Nnorom, "Extraction of natural dyes from Whitfieldia lateritia plant and its application on cotton fabric," Journal of Text Science Engineering, vol. 9, no. 1, pp. 1–4, 2019.

[20] J. Arora, P. Agarwal, and G. Gupta, "Rainbow of natural dyes on textiles using plants extracts: Sustainable and eco-friendly processes," Green Sustain Chem., vol. 7, pp. 35–47, 2017.

[21] P. Brudzy, A. Sionkowska, and M. Grisel, "Plant-derived colorants for food, cosmetic and textile industries: A review," Materials, vol. 14, pp. 3–18, 2021.

[22] J. B. Li, F. Hashimoto, K. Shimizu, and Y. Sakata, "Anthocyanins from the red flowers of Camellia saluensis Stapf ex Bean," J Jpn Soc Hortic Sci., vol. 77, pp. 75–79, 2008; J. B. Li, F. Hashimoto, K. Shimizu, and Y. Sakata, "Anthocyanins from red flowers of Camellia cultivar Dalicha," Phytochemistry, vol. 69, pp. 3166–3171, 2008; J. B. Li, F. Hashimoto, K. Shimizu, and Y. Sakata, "A new acylated anthocyanin from the red flowers of Camellia hongkongensis and characterization of anthocyanins in the section Camellia species," J Integr Plant Biol., vol. 51, pp. 545–552, 2009.

[23] M. L. Gulrajani and D. Gupta, "Natural dyes and application to textiles," Department of Textile Technology, Indian Institute of Technology, New Delhi, India, 1992.

[24] A. Ozcan and K. E. Arman, "Natural ink production and printability studies for smart food packaging," Color Res Appl., vol. 18, 2020.

[25] M. C. Silva-Pereira, J. A. Teixeira, V. A. Pereira-Júnior, and R. Stefani, "Chitosan/corn starch blend films with extract from Brassica oleracea (red cabbage) as a visual indicator of fish deterioration," LWT-Food Sci Technol., vol. 61, pp. 258–262, 2015.

[26] The New World Encyclopedia (NWE), "Food coloring," The New World Encyclopedia (NWE), retrieved May 31, 2024.

[27] L. Chungkrang and S. Bhuyan, "Natural Dye Sources and its Applications in Textiles: A Brief Review," International Journal of Current Microbiology and Applied Sciences, vol. 9, no. 10, pp. 261–269, 2020.

[28] M. Jabeen, K. Tariq, A. Rehman, N. Aslam, A. M. Zafar, and S. U. Hussain, "Evaluation of improvised and eco-friendly natural pH-paper indicators," Front Chem Sci., vol. 3, no. 2, pp. 22–31, 2022.

[29] T. H. Vu, Q. T. Nguyen, V. T. Le, and T. T. Le, "Exploring Plant Species in Vietnam for the Production of pH Indicator Paper," Tropical Journal of Natural Product Research, vol. 7, no. 10, pp. 4889–4893, 2023.

[30] F. Saliu and R. Della Pergola, "Carbon dioxide colorimetric indicators for food packaging application: Applicability of anthocyanin and polylysine mixtures," Sensors and Actuators B: Chemical, vol. 258, pp. 1117–1124, 2018.

[31] J.-A. Fenger, M. Moloney, R. J. Robbins, T. M. Collins, and O. Dangles, "The influence of acylation, metal binding and natural antioxidants on the thermal stability of red cabbage and thocyanins in neutral solution," Food & Function, vol. 10, no. 10, pp. 6740–6751, 2019.

Researcher Information

ORCID

Adel A. M. Saeed: 0000-0002-1154-2994

Mokhtar S. S. Al-Salimi: 0000-0002-5162-9242

Mohsen T. A. Qashqoosh: 0000-0003-1102-3913

Wejdan Sameer Abdulmajeed: 0009-0006-0154-4730

Thoraia Haleem A. Mohammed: 0009-0007-5992-5285

Sabah Mohammed A. Abdallah: 0009-0002-2003-530X

Omar Mohammed O. BA Fadhl: 0009-0000-6260-4983

Afnan Younis Ahmed Saleh: 0009-0008-2152-5814

Suhair Hamood H. Abdullah: 0009-0004-5194-7349

Wafa Ali Saleh Nagi: 0009-0004-8050-0626

مقالة بحثية

استغلال الأصباغ الطبيعية الصديقة للبيئة من المصادر النباتية: الاستخلاص والتطبيقات المتنوعة

عادل أحمد محمد سعيد[1,*]، مختار سالم صالح السالمي[2]، محسن طالب قشقوش[3]، جمال عبدالله الدهبلي[4]، وجدان سمير عبد المجيد يوسف[1]، ثريا حليم انور محمد[1]، صباح محمد عبدالله عبدالله[1]، عمر محمد عمر بأفضل[1]، أفنان يونس احمد صالح[1]، سهير حمود حسين عبدالله[1] و وفاء علي صالح ناجي[1]

[1] قسم الكيمياء، كلية العلوم، جامعة عدن، عدن، اليمن.
[2] قسم الكيمياء، كلية يافع الجامعية، جامعة لحج، يافع، اليمن.
[3] قسم الكيمياء، كلية التربية، جامعة عدن، عدن، اليمن.
[4] قسم الكيمياء، كلية التربية لودر، جامعة أبين، أبين، اليمن.

* الباحث الممثّل عادل أحمد محمد سعيد؛ البريد الإلكتروني: adel_saeed73@yahoo.com

استلم في: 31 اغسطس 2024 / قبل في: 09 سبتمبر 2024 / نشر في 30 سبتمبر 2024

المُلخّص

توفر الأصباغ الطبيعية المستخرجة من المصادر النباتية بدائل صديقة للبيئة ومستدامة للملونات الاصطناعية. في هذه الدراسة، تم الحصول على عينات من الصباغ من خلال الاستخراج المائي من الشمندر (S1) والملفوف الأحمر (S2) والكركم (S3). تم تقييم خصائصها الفيزيائية والكيميائية والتطبيقات المحتملة بدقة. مشكلة البحث التي تم تناولها في هذه الدراسة هي الحاجة إلى التغلب على قيود الأصباغ الطبيعية، مثل انخفاض ثبات اللون، وانخفاض قابلية اعادة استخدامها، ونطاق الألوان المحدود، من أجل تعزيز تبنيها على نطاق أوسع في مختلف الصناعات كبدائل مستدامة للملونات الاصطناعية. تم تقييم مستخلصات الصباغ لمدى ملاءمتها في صباغة المنسوجات، ومؤشرات الأس الهيدروجيني للورق، وألوان الطعام، وإنتاج الحبر، وتركيبات وسادات الطوابع الطبيعية. تم صبغ أقمشة القطن والصوف بإضافة مواد تقليدية، وأظهرت المنسوجات المعالجة بالصبغة تغيرات مميزة في اللون ومستويات متفاوتة من ثباته. أظهرت عينات الصبغة القدرة على العمل كمؤشرات فعالة للحمض، مع عرض انتقالات ألوان مميزة استجابة لمستويات الأس الهيدروجيني المتفاوتة. عند استخدامها كملونات غذائية طبيعية، تضفي المستخلصات ألوانًا جذابة على الأرز والقشدة دون تغير نكهاتها. كما تم استكشاف جدوى دمج هذه الأصباغ المشتقة من النباتات في تصنيع الحبر وإنتاج وسادة الطوابع. أظهرت صبغة الشمندر خصائص احتباس وثبات فائقة للألوان، بينما أظهرت مستخلصات الملفوف الأحمر والكركم فعالية في تطبيقات مختارة. تسلط نتائج هذه الدراسة الشاملة الضوء على جدوى هذه المصادر النباتية كبدائل طبيعية للملونات الاصطناعية في مجالات متنوعة. تؤكد خصائص الأداء المرصودة والطبيعة الصديقة للبيئة للأصباغ على قدرتها على العمل كبدائل مستدامة في مختلف الصناعات.

الكلمات المفتاحية: الأصباغ الطبيعية، الشمندر، الملفوف الأحمر، الكركم، تطبيقات صديقة للبيئة، مثبت اللون.

How to cite this article:

A. A. M. Saeed, M. S. S. Al-Salimi, M. T. A. Qashqoosh, G. A. A. Al-Dahbali, W. S. Abdulmajeed, Th. H. A. Mohammed, S. M. A. Abdallah, O. M. O. BA Fadhl, A. Y. A. Saleh, S. H. H. Abdullah, W. A. S. Nagi, "EXPLOITING ECO-FRIENDLY NATURAL DYES FROM PLANT SOURCES: EXTRACTION AND DIVERSE APPLICATIONS", *Electron. J. Univ. Aden Basic Appl. Sci.*, vol. 5, no. 3, pp. 320-330, September. 2024. DOI: https://doi.org/10.47372/ejua-ba.2024.3.377