Cumhuriyet Sci. J.,47(2) (2026) 329-334
DOI: 10.17776/csj.1799367

Cumhuriyet Science Journal

http://csj.cumhuriyet.edu.tr Founded: 2002 ISSN: 2587-2680 e-ISSN: 2587-246X Publisher: Sivas Cumhuriyet University

Obtaining Natural Dye from Oak Tree and Examination of Dyeing Properties According to Different Methods

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Research Article

History
Received: 08.10.2025
Accepted: 07.04.2026

ABSTRACT

This study investigates the dyeing performance of a natural dye extracted from the branches and leaves of the oak tree (soredar) on muslin fabric. The plant materials were soaked in water for 24 h and subsequently boiled to obtain the dye extract. Dyeing experiments were conducted using conventional dyeing methods with and without mordanting. Copper sulphate, iron sulphate, and potassium dichromate were used as mordants to evaluate their influence on the dyeing behavior of the fabric. The color properties of the dyed samples were determined using spectrophotometric measurements based on the CIELab color system, and color strength (K/S) values were calculated using the Kubelka–Munk equation. In addition, the durability of the dyed fabrics was assessed through washing, rubbing, and light fastness tests according to relevant ISO standards. The results revealed that the type of mordant significantly affected both color strength and fastness performance. Among the tested mordants, copper sulphate produced the highest color strength, while iron sulphate also improved dye uptake compared with the non-mordanted sample. Overall, the findings demonstrate that oak-derived natural dye can be effectively applied to muslin fabric and that mordanting plays a crucial role in enhancing the color depth and durability of natural dyeing processes.

Keywords: *Botanical coloring, Mordanting natural dyeing, Plant-based dye extraction.*

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1. Introduction

Natural dyes are colorants obtained from plant, animal, or mineral sources and have been used in textile dyeing for thousands of years. Prior to the discovery of synthetic dyes in the nineteenth century, natural dyes constituted the primary method for coloring textiles, leather, and other materials. In recent decades, growing environmental concerns and the increasing demand for sustainable production have renewed interest in natural dyeing processes. Unlike synthetic dyes, natural dyes are generally biodegradable, environmentally friendly, and less toxic to humans and ecosystems. For this reason, natural dyeing has gained increasing importance in sustainable textile production and in the manufacturing of organic textile products [1–3].

Plants represent the most widely used sources of natural dyes. Various plant parts such as roots, stems, leaves, bark, flowers, and fruits have historically been used to extract colorants. The chemical composition of plant-derived dyes, particularly the presence of phenolic compounds, flavonoids, and tannins, plays a significant role in determining dye uptake and color durability. However, many natural dyes exhibit limited affinity toward textile fibers. Therefore, mordanting processes are commonly applied to improve the bonding between dye molecules and fibers, enhance color strength, and increase colorfastness. Metal salts such as aluminum sulfate, iron sulfate, and copper sulfate are among the most frequently used mordants in traditional natural dyeing practices [4–6].

Among plant-based dye sources, the oak tree (Quercus spp.) occupies an important place due to its high tannin content. Oak bark, leaves, and acorns have been widely used in traditional dyeing processes in different regions of the world. Tannins present in oak not only contribute to color formation but also act as natural mordanting agents that enhance dye fixation on textile fibers. A compound obtained from oak and locally known as soredar has historically been used as a natural dye source in traditional dyeing applications. Depending on the oak species, the plant part used, and the dyeing conditions, soredar can produce various color shades, particularly brown, chestnut, and reddish tones. The resulting colors can also vary significantly with the use of different mordants [7–9].

Several studies have investigated the use of natural dyes obtained from various plant species and their application in textile dyeing. İşmal [10] discussed recent developments in natural dyeing technologies, including the use of agricultural and industrial by-products as dye sources and the development of environmentally friendly dyeing processes. Mert et al. [11] provided information on different dye plants, their botanical characteristics, and the color shades obtained from these plants. Similarly, Tüm Cebeci [12] examined traditional natural dyeing techniques used in Anatolian textiles and evaluated dyeing recipes applied to wool yarns. In another study, Teker and Günbulut [13] investigated natural dyeing applications using Daphne oleoides and Rubia tinctoria, highlighting the potential of plant-based dyes in modern textile design.

Despite the extensive research conducted on natural dyes, studies focusing on certain locally known dye plants remain limited. In particular, the plant locally referred to as the "red tree," which has historically been used in traditional dyeing practices in the region, has not been sufficiently investigated in scientific studies. Considering the historical importance of traditional dyeing practices in Anatolia and the rich botanical diversity of the region, further investigation of such plants is important both for preserving traditional knowledge and for developing sustainable dyeing alternatives.

Therefore, the aim of this study is to investigate the dyeing performance of natural dye obtained from the branches and leaves of the oak tree (soredar) on muslin fabric. In this study, conventional dyeing and mordanting processes were applied using different mordants, including copper sulfate, iron sulfate, and potassium dichromate. The effects of mordant type and dyeing method on color properties were evaluated using spectrophotometric measurements based on CIELab color values. The findings of this research are expected to contribute to the development of environmentally friendly textile dyeing processes and to the preservation of traditional natural dyeing practices.

2. Materials and Methods

2.1 Collection of Plant Material

The plant material used in this study was obtained from the oak tree. The bark, leaves, and roots of the oak tree were collected and dried under natural conditions for several days before use. Drying was carried out to facilitate peeling and to improve the efficiency of dye extraction, as commonly reported in natural dye extraction studies [14].

2.2 Natural Dye Extraction

To obtain the natural dye, the collected plant materials were first weighed and placed in a plastic container containing 1.5 L of water. The mixture was left to stand for 24 hours in order to allow the dye compounds present in the plant material to dissolve into the water. Soaking prior to boiling is a common method used to enhance the extraction efficiency of plant-based dyes [14-15].

After soaking, the plant materials together with the soaking water were boiled for 1 hour to extract the dye components. Boiling extraction is widely used in natural dyeing studies to release tannins and other phenolic compounds from plant materials into the aqueous medium [15]. During boiling, the loss of water due to evaporation was compensated by adding water to maintain the total volume at 1.5 L. After boiling, the dye solution was allowed to cool and then filtered to remove plant residues. The obtained filtrate was used as the dye solution for the dyeing experiments.

2.3 Dyeing Process

The dyeing experiments were carried out using muslin fabric as the textile material. Prior to dyeing, the muslin fabrics were pre-soaked in water to ensure uniform dye absorption. Pre-wetting of textile materials is a commonly used step in natural dyeing processes to promote better dye penetration into fibers [16].

Two different dyeing methods were applied. In the first method, the pre-wetted muslin fabric was directly immersed in the prepared dye solution. In the second method, the muslin fabric was tied with thread to obtain patterned effects, soaked in water, and then placed in the dye solution and boiled at low temperature for 1 hour. After dyeing, the fabrics were allowed to cool, rinsed with clean water, and dried under natural conditions.

In order to investigate the effect of additional plant materials on dyeing properties, the same dyeing procedure was repeated with the addition of apple bark and juniper bark, and the results were compared.

2.4 Mordanting Process

In order to improve dye fixation and color intensity, mordanting treatments were applied to the samples. Mordanting is widely used in natural dyeing to enhance the interaction between dye molecules and textile fibers and to improve color fastness [14,17]. In this study, copper sulfate, iron sulfate, and potassium dichromate were used as mordanting agents.

Three different mordanting methods commonly reported in natural dyeing studies were considered: pre-mordanting, simultaneous mordanting, and post-mordanting [17].

In the pre-mordanting method, the muslin fabrics were first treated with the mordant solution before the dyeing process. The fabrics were immersed in the mordant solution for a certain period and then transferred to the dye bath.

In the simultaneous mordanting method, the mordanting agent was added directly to the dye bath, and the fabrics were dyed in the presence of both the dye solution and the mordant at the same time.

In the post-mordanting method, the fabrics were first dyed using the prepared dye solution and then treated with the mordant solution after the dyeing process.

These mordanting methods were applied separately using copper sulfate, iron sulfate, and potassium dichromate, and the effects of different mordants and mordanting techniques on the dyeing properties of the muslin fabrics were investigated.

2.5 Color Measurements

A reflectance spectrophotometer (Gretaq Macbeth – Colour Eye 2180UV) was used for the color measurements. Reflectance measurements of the experimental samples were carried out in accordance with the CIE Lab* system using a 10° observer and the D65 daylight standard. The total color difference was calculated using Formula 1 in the evaluation. Here, L* represents lightness, a* indicates redness–greenness, and b* denotes yellowness–blueness.

$$\Delta Eab^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (1)$$

In addition to CIELab parameters, the color strength (K/S values) of the dyed samples was calculated using the Kubelka–Munk equation:

$$K/S = \frac{(1-R)^2}{2R} \quad (2)$$

where R represents the reflectance of the dyed sample at the wavelength of maximum absorption. The K/S value is commonly used to evaluate the color strength and dyeing efficiency of dyed textiles.

2.6 Color Fastness Tests

The washing fastness of the dyed samples was evaluated according to the ISO 105-C06 standard [18] using a Gyrowash washing fastness tester (James H. Heal Co. Ltd.). The test results were assessed using the gray scale rating system.

The light fastness of the fabrics was determined in accordance with the TS 1008 EN ISO 105-B02 standard [19] using a James H. Heal light fastness testing instrument. The obtained results were evaluated based on the blue scale.

The rubbing fastness of the dyed fabrics was measured according to the TS 717 EN ISO 105-X12 standard [20] using a Crockmeter rubbing fastness tester (James H. Heal 255 A). The fastness values were determined under both dry and wet rubbing conditions.

The fastness properties of muslin fabric dyed with a natural dye obtained from the oak tree are presented in Table 1.

Table 1. Color fastness properties of the samples(A:Non-mordant Conventional Dyeing, B:Copper sulphate Mordant Conventional Dyeing, C:Iron sulphate Mordant Conventional Dyeing, D:Potassium dichromate Mordant Conventional Dyeing)

	Light Fastness	Wash Fastness							Rub Fastness	
		Color Change	Staining						Dry	Wet
Dyeing Method			CA	CO	PA	PET	PAN	WO		
A	1	1	2-3	2-3	2	2	2	3	2-3	2-3
B	1-2	2	2	3	2-3	2-3	2-3	3	3-4	3-4
C	2	2-3	2-3	2-3	2-3	2-3	2-3	3-4	3	4
D	2	3	3	3	2-3	2-3	3	4	3	4

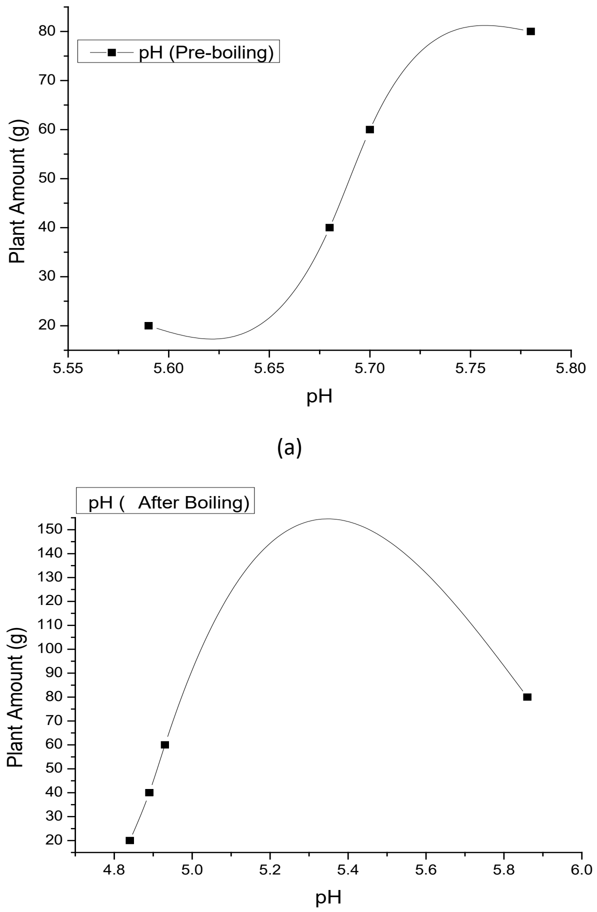
The results indicate that mordanting significantly influences the fastness performance of the dyed fabrics. The non-mordant conventional dyeing exhibited the lowest light fastness (1) and color change rating (1), indicating poor resistance to light exposure. In contrast, the use of mordants improved light fastness, with iron sulphate and potassium dichromate mordanting showing relatively better values (2). Wash fastness results revealed moderate staining on adjacent fibers, generally ranging between 2 and 3 for most fibers. However, slightly higher values were observed for wool (WO), particularly in potassium dichromate mordant dyeing, reaching up to 4. Similarly, rub fastness values improved with mordant application. While the non-mordant sample showed moderate dry and wet rubbing fastness (2–3), the copper sulphate mordanted samples exhibited better ratings (3–4). Overall, mordanting, especially with potassium dichromate and iron sulphate, enhanced the fastness properties of the oak-based natural dye on muslin fabric, resulting in improved color durability during washing, rubbing, and light exposure.

3. Results and Discussion

Natural dyes may contain compounds such as anthocyanins, flavonoids, or tannins derived from plant sources. The chemical structure of these compounds can react to changes in pH, which may cause variations in the color and intensity of the dye. Under different pH conditions, these molecules dissolve in different ways, thereby affecting the color and performance of the dye.

Many natural dyes contain pigments that are sensitive to pH changes. These pigments can produce different colors at different pH levels. For example, in an acidic medium some dyes may yield brighter, more reddish or pinkish tones, while in a basic medium the same dye may take on more purplish, bluish, or greenish tones. pH can also affect how well the dye adheres to the material. Some dyes bond more effectively within a certain pH range, while others may bond more weakly. Thus, pH influences the strength of the dye's attachment to fabric, yarn, or other materials, and can determine the durability of the coloration.

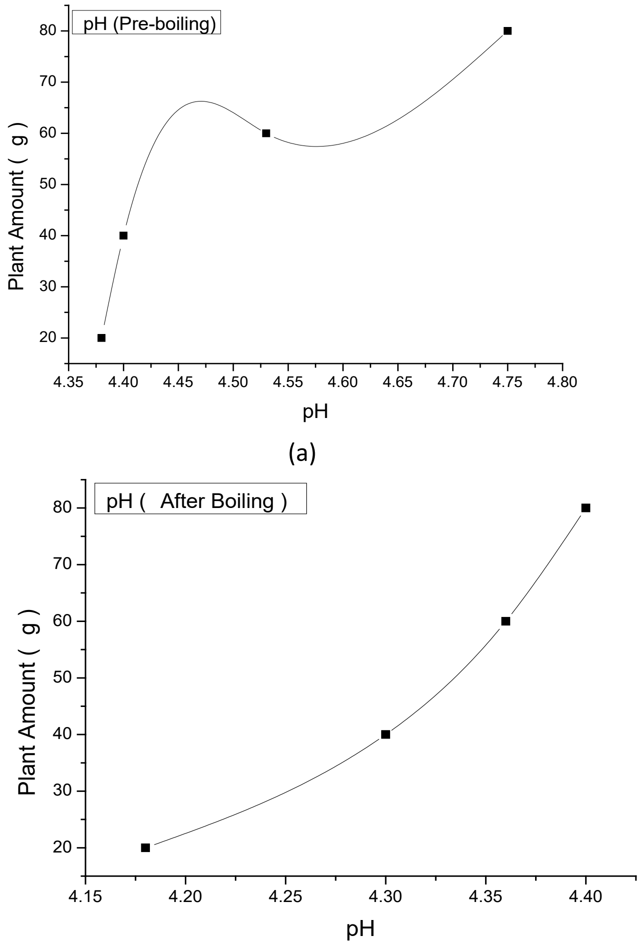
To investigate the effect of material quantity, four different measurements (20 g, 40 g, 60 g, 80 g) were carried out. The pH values measured before and after boiling are presented in Figure 1.



(a)

(b)

Figure 1. pH values of the samples measured (a) pre-boiling, (b) after boiling.



(a)

(b)

Figure 2. pH values of the samples with added hawthorn measured (a) pre- boiling, (b) after boiling.

Another plant obtained from the region, hawthorn, was added to the oak tree material at a ratio of 50% by weight, and the same experiments were repeated. The measured pH values are presented in Figure 2.

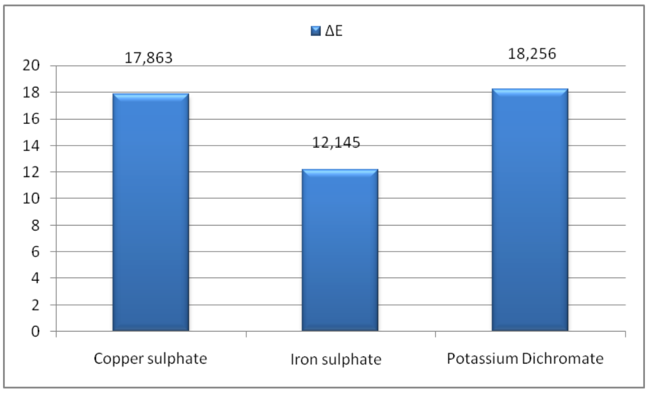
pH can have a direct effect on color in the extraction of natural dyes, as well as influence the durability and adhesion of the dye. Controlling pH during the extraction and application of the dye is a critical factor for achieving the desired color tones and enhancing the longevity of the dye. In the present study, it was observed that as the amount of material increased, the pH value also increased, but the dyeing properties decreased.

The measured pH values fell within the acidic range, and adding hawthorn at 50% by weight significantly reduced the dyeing performance. Using only the oak plant’s own roots and leaves in natural dye extraction can significantly improve the quality of the resulting dye.

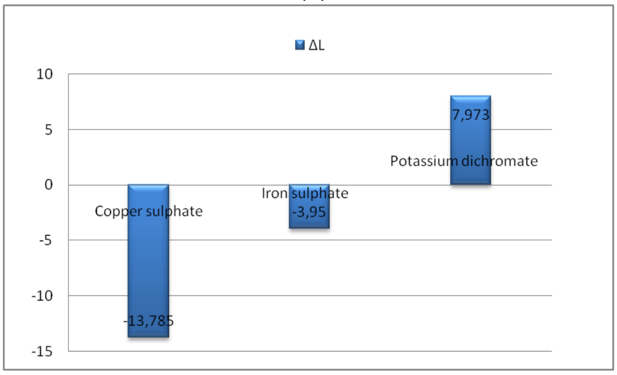
In addition to these procedures, the dyeing properties were examined using three different mordants. Most natural dyes are treated with metal salts, called “mordants,” to better adhere to fibers and achieve more durable colors. The mordanting process can affect the color and brightness of the dye, and its effect may vary depending on the pH of the medium.

The spectrophotometric measurement results (CIELab values) of the samples dyed using the conventional method are presented in Figure 3.

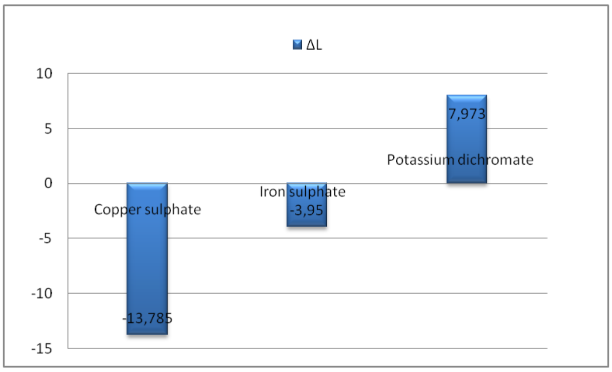
In colorimetric measurements, the sample without mordanting was taken as the reference. The ΔE value used in these measurements indicates the total color difference between the samples. If ΔE < 1, the color difference between the measured sample and the standard sample is very small; however, if ΔE > 1, the color difference is significantly larger [21]. The analyses revealed that there were considerable color differences between the mordanted samples and the standard samples. The metal salts used during mordanting cause different bonds to form between the muslin fabric and the dye, which alters the bond energies. These changes in energy affect the amount of light absorbed and reflected by the material, thereby modifying color perception. The ΔL value expresses the lightness difference of the measured sample. If ΔL is negative, the sample is darker compared to the standard sample; if ΔL is positive, it has a lighter shade. According to these findings, some of the dyed samples are darker and some are lighter than the standard sample. The Δa value represents the color difference along the red–green axis. Positive Δa values indicate a dominance of red tones in the sample, while negative Δa values indicate a dominance of green tones. As seen in Figure 3, green tones were observed to dominate in most of the samples.



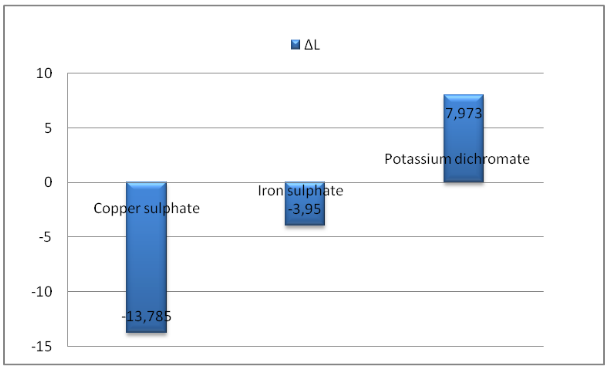
(a)



(b)



(c)



(d)

Figure 3. Spectrophotometric measurement results of the samples: (a) ΔE values of the samples dyed by the conventional method, (b) ΔL values of the samples dyed by the conventional method, (c) Δa values of the samples dyed by the conventional method, (d) Δb values of the samples dyed by the conventional method.

The Δb value represents the color difference along the blue–yellow axis. A positive Δb value indicates stronger yellow tones, while a negative Δb value indicates stronger blue tones. Depending on the metal salts used for mordanting, variations in the shades of blue and yellow were observed in the samples.

Figure 4 presents the color strength (K/S) values of the samples measured at a wavelength of 540 nm.

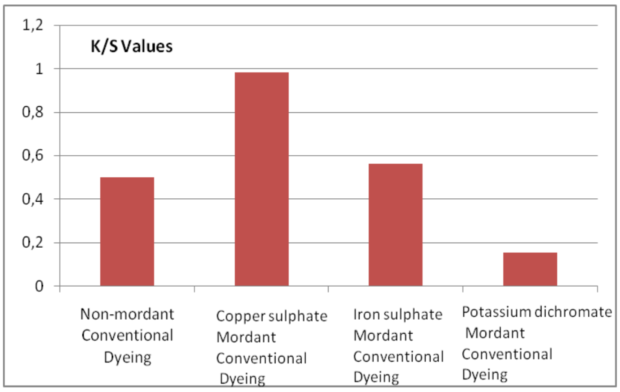


Figure 4. The color strength values of the samples

The K/S value is an indicator of color depth, and higher values correspond to greater dye uptake and darker shades on the fabric. As seen in the graph, the highest K/S value (approximately 0.98) was obtained in the copper sulphate mordanted conventional dyeing method, indicating that copper sulphate significantly enhances the interaction between the dye molecules and the fiber, resulting in deeper coloration. The iron sulphate mordanted sample exhibited a moderate K/S value (around 0.55), suggesting that iron mordant also contributes to improved color strength compared to the non-mordanted sample. The non-mordant conventional dyeing method showed a K/S value of approximately 0.50, indicating relatively lower color depth due to the absence of a mordant. In contrast, the lowest K/S value (about 0.15) was observed in the potassium dichromate mordanted sample, implying that this mordant was less effective in promoting dye fixation with the oak-derived natural dye. Overall, the results demonstrate that copper sulphate is the most effective mordant for enhancing the color strength of fabrics dyed with oak-based natural dye.

4. Conclusions

In this study, the dyeing performance of a natural dye extracted from the branches and leaves of the oak tree was evaluated on muslin fabric using conventional dyeing methods with and without mordanting. Color properties were analyzed using CIELab parameters and color strength (K/S) values, while washing, rubbing, and light fastness tests were conducted to assess dye durability. The results showed that mordanting significantly affected both color strength and fastness properties. Among the mordants used, copper sulphate produced the highest K/S value, indicating greater dye uptake and deeper coloration. Iron sulphate also improved color strength compared with the non-mordanted sample, whereas potassium dichromate showed relatively lower color intensity. Mordanting generally enhanced the washing and rubbing fastness of the dyed fabrics. These findings demonstrate that oak-derived natural dye can be successfully applied to muslin fabrics and that mordanting plays an important role in improving color depth and durability in natural dyeing processes.

Conflict of Interest

There are no conflicts of interest in this work.

Acknowledgments

This study was supported by the Scientific Research Projects Unit of Munzur University within the scope of project number GPMUB023-02.

Declaration of Generative AI

The author did not use any generative AI or AI-assisted technologies in the preparation of this manuscript, including the data analysis and writing stages.

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