Effect of temperature and time on the quality of eco-printed leather

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ABSTRACT

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| The leather finishing process is the final stage in the leather tanning process, which makes the leather look attractive and comfortable. One of the leather finishing processes can be done using the ecoprint coloring method. Exposure to excessively hot temperatures can cause several types of damage to the tanned leather, it can make the tanned leather stiff and lose its original flexibility.This research aims to obtain the best quality ecoprint leather at different temperatures and boiling times. Boiling is carried out at temperatures of 60˚C, 70˚C, 80˚C and the boiling time is 1.5 hours and 2 hours. Leather quality is measured by tensile strength, sewing strength, tear strength, leather elongation, and color fastness to wet and dry rubbing. Result, The interaction between temperature and boiling time has a significant effect (P>0.01) on the quality of ecoprint leather, namely tensile strength, sewing strength, tear strength and color fastness from dry and wet rubbing. Conclusion,The best quality ecoprint leather is boiled at a temperature of 70 ˚C for 2 hours. |

*Keywords: Physical quality, color, tanned leather, ecoprint leather, boiling*

1. INTRODUCTION

The leather finishing process is the final stage in the leather tanning procedure that enhances the aesthetic appeal and usability of leather for manufacturing various products such as bags, wallets, shoes, and leather jackets. The technology employed in leather finishing continues to evolve along with advancements in leather products (Oetopo, et al 2023 ), such as ecoprint method, which involves imparting color and patterns to leather.

Producing ecoprint leather with leather material is fundamentally different from ecoprint on fabric. This is because the leather medium is not resistant to high temperatures or heat (Razzaq, et al 2024). Excessive heat exposure can result in several types of damage to tanned leather, including loss of flexibility and stiffness due to the drying and hardening of leather fibers (Shahid, et al 2013). Additionally, it causes the leather to crack or break on the surface. This is due to the sudden loss of moisture (Pervaiz, et al . 2017).

The ecoprinting technique transfers color and shape to leather through direct contact (Ristiani and Isnaini, 2019). To transfer color, heat is required. Heating in the ecoprint process serves an important purpose of activating and stabilizing the natural pigments in the leaves or plants, allowing them to transfer and adhere to the surface of the tanned leather. Heating at a certain temperature and duration can help release the natural pigments from the leaves or flowers, enabling them to transfer to the surface of the tanned leather and produce clear patterns. This step is critical for achieving well-defined and vibrant ecoprint patterns. By breaking down plant cell walls, heat aids in the release and absorption of pigments into the leather, while also accelerating the chemical reactions between the pigments and the leather material (Teklay And Kechi, 2017). Proper heating ensures the pigments bond strongly to the leather, rendering the resulting patterns and colors more resistant to washing and sunlight exposure. Overall, this leather ecoprint represents the latest sustainable leather technology that has the potential to be exploited commercially in the near future. (Kanagaraj, et al 2020).

Since leather is sensitive to high temperatures, employing the ecoprint technique necessitates careful control of heating time and temperature to ensure that plant pigments adhere to the leather without compromising its physical properties. Optimal temperature and heating time enhance pigment adhesion, improving color quality while preserving the leather's structural integrity. Appropriate heat settings allow for sharper and more detailed natural patterns of leaves or flowers to emerge on the leather surface, contributing to an aesthetically pleasing final product.

This research aims to obtain the best quality of ecoprint leather at the optimal boiling temperature and duration, so that it can be sustainably applied in the industry.

2. material and methods

**2.1 Materials**

The research utilized 18 sheets of crust leather derived from sheepskin as the primary material. Crust leather, defined as livestock leather that has undergone chrome tanning but remains unfinished, was sourced from leather artisans in Yogyakarta. Additional materials included natural dyes extracted from mangrove plant stems, tunjung mordant, crayon cloth, mangrove leaves, and clean water.

**2.2 Methods**

The research employed an experimental approach based on a Completely Randomized Design (CRD) with a factorial pattern, focusing on two main factors: temperature and boiling time. Variations in boiling temperature were applied as follows: Factor 1 (Temperature): P1 = 60°C, P2 = 70°C, and P3 = 80°C. Factor 2 (Boiling Time) included two levels: L1 = 1.5 hours and L2 = 2 hours.

**2.2.1 Ecoprint leather quality testing**

There are 2 ecoprint leather quality tests, namely color fastness testing and physical leather testing consisting of Tensile strength testing is carried out according to SNI 4593: 2011 with a tensile testing machine ( BSN-SNI, 2011). Tear strength testing is carried out based on SNI 06-0457-1989 (BSN-SNI, 1989). Elongation testing is carried out according to SNI 4593: 2011 with a tensile testing machine (BSN-SNI2011). Sewing strength testing is carried out according to SNI 06-1117-12011 with a Tensile Testing Machine (BSN-SNI, 2011) and color fastness testing consists of dry rubbing resistance and wet rubbing resistance carried out according to ISO 20433: 2012(BDSN -ISO, 2012). Color fastness testing against dry rubbing is carried out using a crock meter.

**2.2.2 Ecoprint process on leather using boiling technique**

Boiling technique in ecoprint is done by: mordant leather then the leather is stretched so that the leather position is flat and horizontal, then mangrove leaves are attached or placed on the leather. The leather that has been placed parts of the plant is then coated with cloth that has been dyed with natural mangrove dyes, plastic, rolled with wood until tight, then tied with insulation so that water cannot seep into the leather. After that the leather is boiled according to the treatment, namely a temperature of 60 ° C; 70 ° C; 80 ° C and a boiling time of 1.5 hours; 2 hours.

**2.3 Data Analysis**

The physical quality data of ecoprint leather were analyzed using analysis of variance (ANOVA), using the SPSS program. To determine the specific differences between treatments, the Duncan test was performed as a post-hoc analysis. In contrast, the color fastness data were analyzed descriptively. The assessment of color fastness involved comparing the color difference to a standard gray scale. The rankings were as follows: value 5 (very good, with no noticeable change in the color of the ecoprint leather); value 4 (good, with a slight color change); value 3 (sufficient, with a noticeable color change); value 2 (moderate, with a significant color change); and value 1 (poor, with a very significant color change).

3. results and discussion

The results of the quality of ecoprint leather with different temperatures and boiling times are presented in Table below.

**3.1 Tensile Strength**

Table 1: Optimizing Conditions for Tensile Strength (N/cm2)

|  |  |  |
| --- | --- | --- |
| Temperature ( ̊C) | Boiling duration( hours) | |
| 1,5 | *2* |
| 60 | 1147.68±141.97a | 1111.75±155.41a |
| 70 | 1163.44±151.95a | 1530.17±199.91b |
| 80 | 1128.99±138.70a | 1162.86±144.59a |

Note: different notations show significant differences (P<0.05)

The tensile strength values presented in Table 1 indicate that all ecoprint leather samples produced under varying temperature and boiling time treatments meet the minimum standard of 1000 N/cm². Furthermore, Table 1 demonstrates a significant interaction effect between temperature and boiling time on the tensile strength of the resulting ecoprint leather.

The highest tensile strength was observed at a temperature of 70°C with a boiling time of 2 hours, yielding a value of 1530.17 ± 199.91 N/cm². Conversely, tensile strength decreased when the boiling temperature reached 80°C. This decline is attributed to the excessive heat, which can damage the collagen fibers in the leather, leading to reduced tensile strength and elasticity. Excessive boiling temperatures render the leather more fragile and susceptible to tearing.

Leather with high tensile strength offers greater durability and resistance to damage, making it particularly suitable for applications that involve significant stress or pulling forces, such as shoes, belts, or bags (Pancapalaga and Nurjanah, 2020). Such leather can withstand substantial loads without stretching or tearing, ensuring its functionality and reliability for items requiring enhanced resilience.

**3.2 Elongation**

Table 2: Optimizing Conditions for elongation (%)

|  |  |  |
| --- | --- | --- |
| Temperature ( ̊C) | Boiling duration( hours) | |
| 1,5 | 2 |
| 60 | 58.86±21.03a | 55.51±25.08a |
| 70 | 57.62±34.93a | 51.28±30.08a |
| 80 | 58.48±18.21a | 59.68±23.87a |

Note: different notations show significant differences (P<0.05)

The elongation values for ecoprint leather, as shown in Table 2, indicate that all samples produced under different temperature and boiling time treatments comply with the Indonesian National Standard (SNI 4593:2011), which sets a maximum elongation limit of 60%. This finding suggests that the elongation properties of the ecoprint leather are within acceptable ranges, reflecting good quality.

The lowest elongation value, 51.28 ± 30.08%, was observed at a boiling temperature of 70°C for 2 hours. Generally, the elongation of ecoprint leather tends to increase with higher boiling temperatures and longer boiling durations. However, this research found that the elongation values were not significantly influenced by temperature and boiling time. Even at 80°C for 2 hours, the leather did not exhibit excessive elongation.

This outcome indicates that collagen damage in the leather remained within permissible limits according to national standards. The integrity of the collagen chemical bonds in the leather was largely preserved, preventing excessive stretching or deformation under load.

**3.3** **Sewing Strength**

Table 3: Optimizing Conditions for Sewing Strength (N/cm)

|  |  |  |
| --- | --- | --- |
| Temperature ( ̊C) | Boiling duration( hours) | |
| 1,5 | 2 |
| 60 | 658.72±58.68a | 902.03±55.66b |
| 70 | 611.91±71.98a | 929.18±59.34b |
| 80 | 616.91±45.53a | 710.71±64.75a |

Note: different notations show significant differences (P<0.05)

Table 3. demonstrates that all ecoprint leather samples produced under varying temperature and boiling time treatments exhibited sewing strength values exceeding the minimum standard limit of 500 N/cm. This indicates that the sewing strength of the ecoprint leather across different treatment conditions is of satisfactory quality. High sewing strength in leather enhances the durability, robustness, and resistance of leather products to seam damage. As leather is sensitive to high temperatures, prolonged exposure or excessive heat can impact its sewing strength and overall quality. Therefore, careful control of temperature and boiling time is essential to prevent quality deterioration ( Pancapalaga, et al 2022).

The data in Table 3 further reveal that the highest sewing strength value, averaging 929.18 ± 59.34 N/cm, was achieved by boiling the leather at 70°C for 2 hours. This finding suggests that the specified treatment provides optimal conditions for maintaining sewing strength. At 70°C, the collagen protein in the leather attains peak stability, ensuring that the protein remains intact and does not degrade, resulting in high sewing strength. Conversely, increasing the temperature beyond this point or extending the boiling duration can degrade collagen proteins, reduce fiber density, and consequently lower sewing strength. Additionally, the thickness of the leather significantly influences sewing strength, as it directly impacts the calculation of this property. Thicker leather generally exhibits higher sewing strength, whereas thinner leather yields lower values (Nada and Widowati. 2020).

Improper control of boiling temperature and duration can compromise leather quality, making it more prone to tearing at stitching holes. Fragile leather may not withstand the tension exerted when stitching threads are pulled, increasing the likelihood of seam failure.

**3.4** **Tear Strength**

Table 4: Optimizing Conditions for Tear Strength (N/cm)

|  |  |  |
| --- | --- | --- |
| Temperature ( ̊C) | Boiling duration( hours) | |
| 1,5 | 2 |
| 60 | 131.47±28.28a | 195.96±30.99ab |
| 70 | 191.94±18.31ab | 210.01±20.64b |
| 80 | 181.15±44.09ab | 154.99±42.42a |

Note: different notations show significant differences (P<0.05)

Table 4 illustrates that all ecoprint leather samples subjected to varying temperature and boiling time treatments exhibit tear strength values exceeding the minimum standard limit of 125 N/cm. Tear strength is a critical parameter in determining the suitability of leather for specific applications, as leather with high tear strength demonstrates greater resistance to pressure and tearing. This makes it more durable and reliable, particularly for products subject to intensive use. The tear strength of leather reflects its capacity to withstand forces attempting to tear it, whether at stitched seams or unstitched areas, thereby serving as a key indicator of tanned leather quality (Pratap Singh, et al. 2020).

According to Table 4, the highest tear strength value, 210.01 ± 20.64 N/cm, was achieved by boiling at 70°C for 2 hours. However, increasing the temperature to 80°C resulted in a decline in tear strength. This decrease is attributed to the detrimental effects of high temperatures on collagen fiber bonds, which form the structural backbone of leather. Damage to these collagen fibers weakens the leather, making it more susceptible to tearing under stress. The composition of fibers within the leather significantly influences tear strength, with collagen being the primary protein responsible for its mechanical integrity. Collagen fibers provide structural support, and a reduction in non-collagen proteins during tanning facilitates better binding of tanning agents to collagen, which contributes to the thickness and tear strength of the leather (Laksono and Subiyati, 2021).

The test results emphasize the importance of maintaining appropriate treatment conditions to preserve leather quality. Tear strength is also closely related to leather thickness, which depends on the raw material's initial thickness. Generally, thicker leather tends to exhibit higher tear strength. Conversely, tear strength values below the standard threshold compromise the leather's durability and reduce its suitability for product applications. Achieving high tear strength is essential, as it ensures the leather meets standard load resistance requirements, thereby enhancing the quality and reliability of the final product ( Qadariyah, et al 2018 ).

**3.5** **Wet and Dry Colorfastness**

Table 5: Optimizing Conditions for Wet and Dry Colorfastness

|  |  |  |
| --- | --- | --- |
| Temperature ( ̊C) | Boiling duration( hours) | |
| 1,5 | 2 |
| **WET** | | |
| 60 | 4 | 4 |
| 70 | 3 | 4 |
| 80 | 4 | 3 |
| **DRY** | | |
| 60 | 4 | 4 |
| 70 | 3 | 5 |
| 80 | 4 | 3 |

Table 5 indicates that the ecoprint leather treated at 70°C for 2 hours exhibits excellent colorfastness values. For dry rubbing, the colorfastness value is 5, signifying no visible color change, while for wet rubbing, the value is 4, indicating a slight color change after testing with a Crockmeter. However, when the boiling temperature increases to 80°C for the same duration, the colorfastness values decline. This reduction is attributed to changes in the leather's texture, such as roughness or wrinkling, caused by excessive heat.

The boiling process at higher temperatures, such as 80°C, can impair the leather's capacity to absorb materials like dyes or finishing agents. This adversely affects the uniformity and durability of the coloring or finishing process. Additionally, high temperatures weaken the dye's adhesion to the leather fibers. Structural changes in the fibers at elevated temperatures reduce the binding strength of color pigments, making the leather more prone to fading, especially during wet rubbing tests

4. Conclusion

The quality of ecoprint leather is significantly influenced by the temperature and boiling time during the ecoprint process. the best eco-printed leathers were found to be at 70°C for 2 hours. Thus, findings offer insight into the optimal circumstances for improving the physical characteristics and color fastness of tanned leather. This study aims to provide manufacturers with sustainable solutions and new technologies that enhance natural dye retention, mechanical qualities, and crucial parameter values, hence extending commercial applications.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the wr

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**COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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