

APLIKASI EKSTRAK LIMBAH NANAS PADA PROSES BATING: PENGARUH TERHADAP SIFAT FISIKOKIMIA KULIT GLACÉ KELINCI

APPLICATION OF PINEAPPLE WASTE EXTRACT IN THE BATING PROCESS: EFFECTS ON THE PHYSICOCHEMICAL PROPERTIES OF RABBIT GLACÉ LEATHER

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Abstract. *Commercial bating agents are commonly used in leather processing; however, their dependence on industrial enzyme preparations raises environmental and economic concerns. Although bromelain has been proposed as a sustainable alternative, studies evaluating pineapple waste extract as a bating agent, particularly for rabbit leather, remain limited. This study aimed to evaluate the effectiveness of pineapple waste extract as a natural bating agent in the tanning process and its impact on the physicochemical properties of rabbit glacé leather. Pineapple waste, containing the proteolytic enzyme bromelain, was applied at different concentrations (0.50%, 0.75%, 1.00%, 1.25%, and 1.50%) and compared with commercial bating agent (1.00%). The evaluation included physical properties (tensile strength, seam strength, and elongation) and protein reduction. Increasing the extract concentration decreased tensile strength but increased elongation and protein removal, indicating progressive proteolytic effects during the bating process. The 0.50% extract treatment produced the highest tensile strength (165.58 MPa) while meeting the requirements of SNI 06-1795-1990 for rabbit glacé leather. Higher extract concentrations promoted greater protein reduction and leather flexibility but were associated with reduced mechanical performance, suggesting over-bating. Overall, under the experimental conditions of this study, a 0.50% pineapple waste extract is recommended as an alternative bating agent for rabbit glacé leather processing, offering a sustainable alternative to conventional commercial bating agents.*

Keywords : *Bating process, Extract, Pineapple waste, Rabbit glacé leather*

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INTRODUCTION

Rabbit skin is a livestock byproduct with high economic potential due to its smooth, lightweight, and flexible texture, making it widely used as a raw material for fashion products such as jackets, bags, and accessories. To enhance its utility and durability, rabbit skin must undergo a tanning process that includes the beamhouse, tanning,

and finishing stages. One high-value finished leather product is glazed leather, which is tanned leather that has undergone a finishing process involving polishing to produce a smooth, glossy, and uniform surface (Madhan et al., 2010). These characteristics not only enhance the aesthetic appeal but also reflect the high quality of the hide's surface structure. The success of crea-

ting a glazed hide is heavily influenced by the quality of the hide preparation in the early stages, particularly the bating process. The bating process is designed to remove non-collagenous proteins and unwanted tissue residues, resulting in collagen fibers that are cleaner, more open, and evenly distributed. This condition is essential for producing a smooth leather surface that responds well to the finishing process. Bating plays a key role in enhancing the leather's softness, grain fineness, and overall quality (Chen *et al.*, 2024). Conventionally, the tanning process typically involves the use of chemicals or commercial enzymes, which in some cases, are less environmentally friendly and relatively expensive. Natural enzyme-based processes have been increasingly explored as environmentally friendly alternatives in leather processing (Amalia *et al.*, 2026). One potential source of proteolytic enzymes is bromelain, which is derived from pineapple waste. Recent studies have highlighted the growing application of proteolytic enzymes as environmentally friendly alternatives in leather processing because they can reduce the use of conventional chemicals and improve process sustainability. Proteases play a crucial role in the bating stage by removing non-collagenous proteins, facilitating fiber opening, and improving the penetration of subsequent tanning chemicals, which ultimately contributes to improved leather quality (Hasan *et al.*, 2022). Furthermore, pineapple processing waste has attracted considerable attention as a sustainable source of bromelain because its peel and core contain significant amounts of proteolytic enzymes that can be valorized into high-value bioproducts

rather than being discarded as agro-industrial waste (Meena *et al.*, 2022).

Pineapples (*Ananas comosus*) are available year-round, with national production increasing every year; from 2019 to 2023, the average annual national pineapple production was 2,778,094 tons (Pusat Data dan Sistem Informasi Pertanian, 2024). With such high production volumes, pineapple waste is also abundant and has not yet been fully utilized. Nearly every part of the pineapple contains the enzyme bromelain, giving it great potential to be extracted and used for various purposes. Enzymatically, bromelain is capable of selectively degrading non-collagenous proteins without damaging the primary structure of collagen. Previous studies have suggested that the application of bromelain during the bating process can produce a more uniform fiber structure and smoother leather surface, thereby improving the quality of the subsequent finishing process.

However, studies on the utilization of crude bromelain enzyme from pineapple waste in the tanning process, particularly regarding the physicochemical characteristics of tanned rabbit skin, remain limited. It was hypothesized that crude pineapple waste extract containing bromelain could be used as an alternative bating agent and that different extract concentrations would influence the physicochemical properties of rabbit glaze leather. Therefore, this study aimed to evaluate the effectiveness of crude pineapple waste extract as an alternative bating agent and to determine its effects on the physicochemical properties of rabbit glaze leather.

MATERIALS AND METHODS

1. Materials

The materials used in this study included pineapple waste (peel and core) obtained from a jam manufacturing company in Lampung, Indonesia; six rabbit skins obtained from Yogyakarta, Indonesia; chemicals for leather processing, including Teepol, antimould A4, a wetting agent, water (H_2O), calcium hydroxide [$Ca(OH)_2$], bating agents (pineapple waste extract and Pancreol Bate), a degreasing agent, tanning agents, sodium formate ($HCOONa$), binder, pigment, thinner, filler, dyestuff, Basyntan, syntan, resin, butyraldehyde, sodium sulfide (Na_2S), ammonium chloride (NH_4Cl), formic acid ($HCOOH$), sodium chloride ($NaCl$), sulfuric acid (H_2SO_4), Chromosal, sodium carbonate (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), and oil; as well as chemicals and reagents including sodium sulfate (Na_2SO_4), copper sulfate ($CuSO_4$), sulfuric acid (H_2SO_4), hydrochloric acid (HCl), and sodium hydroxide ($NaOH$). The equipment used in this study included knives, a blender/juicer, and strainers for preparing the pineapple waste extract; leather tanning equipment; and instruments for physical and chemical testing. The tanning process was carried out using a stainless steel drum operated at 15 rpm, stainless steel cutting knives, measuring cups, basins, spoons, cutting boards, plastic measuring cups, buckets, a thickness gauge, a pH meter, BCG indicators, a digital balance (Henherr ACS-H1 LED, Kitoma Indonesia), a timer, a thermometer, wooden boards, plastic sheets, sandpaper, a manually operated stacking machine (custom-built by a local engineering workshop in Yogyakarta, Indonesia) for softening the leather, a

toggling machine (custom-built by a local engineering workshop in Yogyakarta, Indonesia) for stretching the leather, a platting/embossing machine manufactured by Mostardini (Italy) for improving leather surface uniformity, a spray gun manufactured by Meiji (Japan) for applying finishing chemicals, and a leather area measuring device (custom-built by a local engineering workshop in Yogyakarta, Indonesia).

2. Methods

The study began with the extraction of pineapple waste (peel and core). The flowchart for pineapple waste extract preparation is presented in Figure 1.

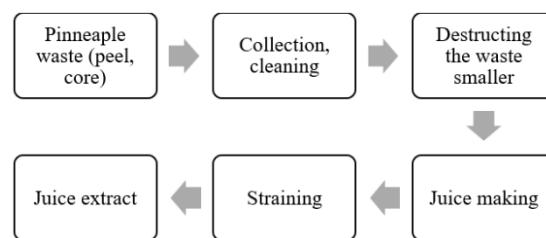


Figure 1. Extract making from pineapple waste

Pineapple waste (peel and core) was washed with distilled water, cut into small pieces, and processed using a household juicer. The expressed juice was filtered through four layers of muslin cloth, followed by Whatman No. 1 filter paper to remove coarse particles. From 1,500 g of pineapple waste, approximately 1,400 mL of filtrate was obtained. The filtrate was then allowed to stand until suspended solids settled, and approximately 150 mL of the clear supernatant was collected and used as the crude bromelain extract for the bating process. The extract was prepared on the same day as the bating process, stored in sterile amber bottles at 4°C, and used

within 24 h to minimize enzymatic activity loss.

The next step was the bating process using pineapple waste extract to remove non-collagenous (globular) proteins during leather processing. The amount of pineapple waste extract added was calculated on a weight-by-weight (w/w) basis relative to the drained limed pelt weight, i.e., the weight of the limed pelt after washing and draining to remove excess surface water. The treatment concentrations were T1 = 0.50%, T2 = 0.75%, T3 = 1.00%, T4 = 1.25%, and T5 = 1.50% (w/w). The control treatment (TC) used 1.0% (w/w) commercial bating agent (Pancreol Bate), also calculated based on the drained limed pelt weight. Below are the formulation and stages of skin processing (Figure 2).

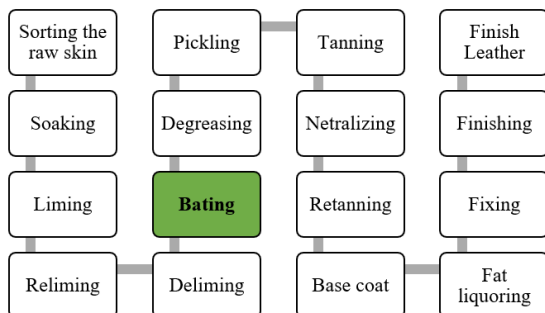


Figure 2. Stages of rabbit skin processing

To evaluate the effectiveness of the extract in reducing protein content during the bating process, total nitrogen (N) tests were conducted on

the hides before and after bating. These tests were accompanied by moisture content analysis to calculate the total nitrogen content. Meanwhile, to assess the effectiveness of extracts in relation to the quality of the rabbit glacé leather, the tanning process was continued until the leather was finished, followed by physical tests (tensile strength, elongation (SNI 06-1795-1990), seam strength (SNI 06-1117-1989) and protein reduction. Because each treatment was represented by a single biological replicate (one rabbit skin per treatment), inferential statistical analysis was not appropriate. Therefore, the physicochemical data were analyzed descriptively by comparing the measured properties among treatments. A limitation of this study is the absence of biological replication for the physicochemical tests; consequently, the findings should be considered preliminary and interpreted with caution until confirmed through experiments with adequate biological replication.

RESULT AND DISCUSSION

A comprehensive comparison of the physical properties of rabbit glace leather treated with different bromelain extract concentrations is presented in Table 1, while the overall performance of each treatment is visualized using the radar diagram shown in Figure 3.

Table 1. Physical properties of rabbit glacé leather

Samples	Tensile Strength		Seam strength	
	(kg/cm ²)	Elongation (%)	(N/cm)	
TC	102.19	68.00	50.89	
T1	165.58	58.67	75.02	
T2	147.60	64.67	65.99	
T3	127.09	72.67	67.40	
T4	131.09	77.33	65.89	
T5	131.48	68.67	65.12	
SNI method	SNI 06-1795-1990	SNI 06-1795-1990	SNI 06-1117-1989	

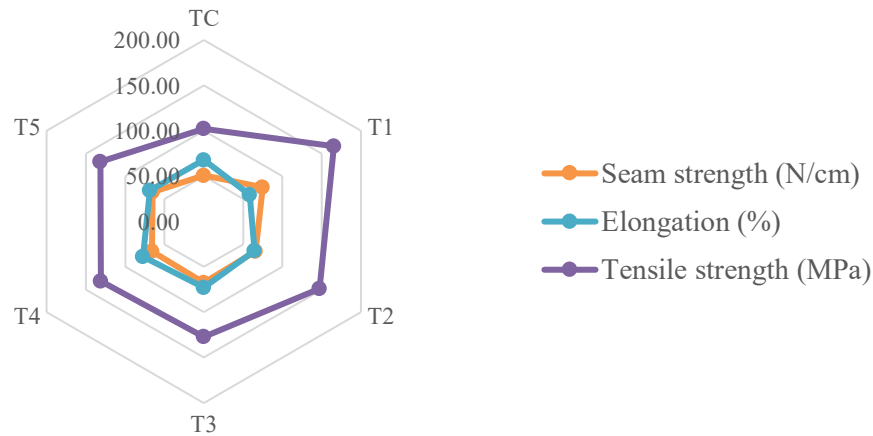


Figure 3. Radar diagram of the physical properties of rabbit glaze leather treated with different pineapple extract concentrations

1. Physical Properties

1.1 Tensile strength.

Based on Table 1 and Figure 3, rabbit leather treated with 0.50% pineapple waste extract exhibited the highest tensile strength (165.58 kg/cm²) among all treatments. Tensile strength was determined according to SNI 06-1795-1990, which specifies the test method for leather tensile strength and elongation. Since no Indonesian National Standard specifically establishes the quality requirements for rabbit glacé leather, the tensile strength values were compared with SNI 06-0253-1989 for glazed goat leather as a general industrial reference because both materials are lightweight apparel leathers with similar functional characteristics. According to SNI 06-0253-1989, the minimum tensile strength requirement for glazed goat leather is 150 kg/cm². Therefore, the leather treated with 0.50% pineapple waste extract exceeded this reference value, indicating that the treatment was able to maintain the mechanical performance of the leather under the conditions of this study.

The superior tensile strength observed at the 0.50% extract concentration suggests that this bromelain level promoted sufficient hydrolysis of non-collagenous proteins while preserving the integrity and organization of the collagen fiber network. The relatively limited protein removal likely maintained a compact collagen structure with restricted fiber mobility, resulting in high tensile strength but comparatively lower elongation than treatments with higher extract concentrations. This condition indicates that the collagen fibers remained well organized and were therefore able to transfer tensile loads efficiently.

In contrast, increasing the pineapple waste extract concentration above 1.00% resulted in a gradual decline in tensile strength. Overall, the tensile strength of rabbit leather treated with pineapple waste extract decreased by approximately 20% as the extract concentration increased from 0.50% to 1.50%. This finding indicates that increasing bromelain concentration did not proportionally improve the mechanical properties of the leather, suggesting that bromelain has an optimum effective concentration. Similar obser-

vations have been reported by (Novaes et al., 2016), who stated that enzymatic performance depends on an optimum concentration and is influenced by environmental conditions.

The reduction in tensile strength at higher extract concentrations may be explained by more extensive hydrolysis of non-collagenous interfibrillar proteins during the bating process. This proteolytic action likely modified the interfibrillar matrix, promoted collagen fiber opening, increased interfibrillar spacing, and enhanced fiber mobility. Protease-assisted bating has been reported to improve fiber dispersion through the removal of interfibrillar substances, thereby facilitating the penetration of subsequent tanning agents into the collagen matrix (Zhang et al., 2021; Zhu et al., 2023). However, excessive proteolytic action may also lead to excessive fiber opening and loosening of collagen packing, reducing the compactness and cohesion of the collagen fiber network. Consequently, the collagen fibers become less efficient in transferring tensile loads, resulting in lower tensile strength despite the higher elongation observed at intermediate extract concentrations. This inverse relationship between tensile strength and elongation is consistent with the principles of material mechanics, in which materials capable of greater deformation before failure do not necessarily exhibit higher tensile strength (Callister & Rethwisch, 2018).

1.2 Elongation.

As shown in Table 1, the elongation of rabbit glacé leather ranged from 58.67% to 77.33%. The lowest elongation was observed in the 0.50% pineapple waste extract treatment (T1), whereas the highest value was obtained

in the 1.25% extract treatment (T4). Compared with the commercial bating agent (68.00%), the application of pineapple waste extract initially reduced elongation at the lowest concentration but subsequently increased elongation with increasing extract concentration, reaching a maximum at 1.25%, before declining to 68.67% at the highest extract concentration (1.50%). Since no Indonesian National Standard (SNI) specifically establishes quality requirements for rabbit glacé leather, the elongation values were compared with SNI 06-0253-1989 for glazed goat leather as a general reference. This standard was selected because glazed goat leather and rabbit glacé leather are both lightweight apparel leathers with comparable functional characteristics, although the standard is not directly applicable to rabbit leather. According to SNI 06-0253-1989, the minimum required elongation for glazed goat leather is 55%, and all treatments in the present study exceeded this reference value. The observed trend suggests that bromelain in the pineapple waste extract promoted the hydrolysis of non-collagenous proteins, facilitating collagen fiber opening and increasing fiber mobility up to an optimum concentration. However, further increasing the extract concentration did not provide additional improvements in fiber mobility and may have resulted in excessive proteolytic action, partially disrupting the collagen fiber network. Similar observations have been reported for protease-assisted bating, in which the removal of interfibrillar substances enhances fiber dispersion, increases interfibrillar spacing, and improves leather extensibility and flexibility (Zhang et al., 2021; Zhu et al., 2023).

1.3 Seam strength

There is currently no specific Indonesian National Standard (SNI) specifying the seam strength requirement for rabbit glacé leather. Therefore, the seam strength results were compared with the quality requirement specified in SNI 06-0463-1989 for combination-tanned sheep/goat leather, which was used only as a general industrial reference because both materials are thin garment-type leathers. According to SNI 06-0463-1989, the minimum seam strength requirement is 20 N/cm. The seam strength of rabbit glacé leather in the present study ranged from 50.89 to 65.12 N/cm, exceeding this reference value. However, this comparison should not be interpreted as indicating that SNI 06-0463-1989 is directly applicable to rabbit leather.

Leather treated with the commercial bating agent exhibited the lowest seam strength compared with leather treated with pineapple waste extract. This observation may reflect a higher or more consistent proteolytic activity of the commercial bating agent than that of the crude pineapple waste extract. However, enzyme activity was not determined in the present study; therefore, this explanation remains speculative. Proteases exhibiting higher activity toward collagen fibers induce greater collagen hydrolysis, which may result in excessive fiber opening and

deterioration of leather structure when enzyme activity is not properly controlled (Zhang *et al.*, 2018). This condition results in a less compact fiber structure and reduces the leather's mechanical strength. In contrast, pineapple waste extract, which contains the enzyme bromelain, acts more moderately, effectively removing non-collagen proteins without damaging the primary collagen structure, thereby producing leather with better stitch strength. Previous research has reported that the uncontrolled use of protease enzymes can cause damage to the collagen structure and reduce the strength of the leather (Zhu *et al.*, 2023).

2. Protein Reduction

Protein content was determined using the Kjeldahl method, which measures the total nitrogen content of the leather. As shown in Table 2, all bated treatments exhibited lower protein content than the untreated sample (T0), indicating that the proteolytic compounds present in the pineapple waste extract promoted the reduction of non-collagenous proteins during the bating process. Effective bating aims to eliminate interfibrillar proteins and other non-collagenous substances while preserving the collagen fiber network, which is responsible for the mechanical strength of leather (Song *et al.*, 2019).

Table 2. Protein content and protein reduction of rabbit glacé leather

Sample	N total	Protein (%)	Protein reduction (%)
T0	3.43	21.44	0.00
TC	3.05	19.06	11.08
T1	3.26	20.38	4.96
T2	2.98	18.63	13.12
T3	2.95	18.44	13.99
T4	2.45	15.31	28.57
T5	2.34	14.63	31.78

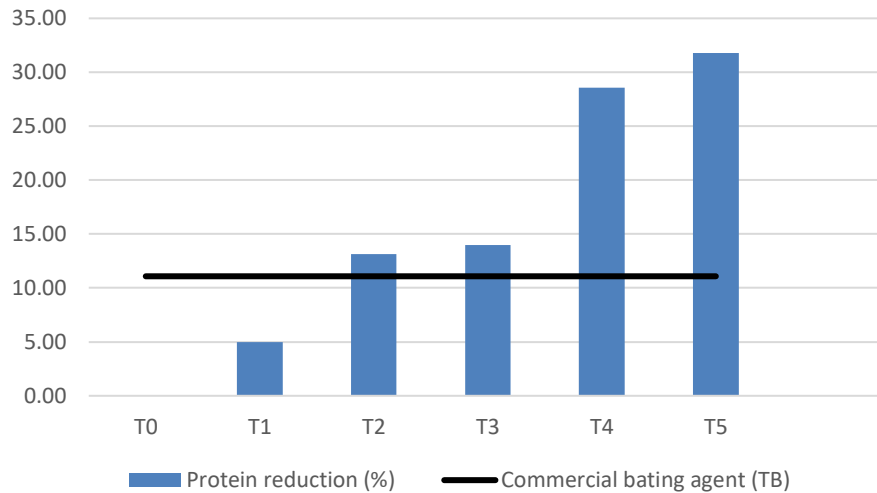


Figure 4. Trends of protein reduction in bating process

Description:

T0 = sample before the bating process

TC= sample use commercial bating agent

T1 = sample use 0.50% extract

T2 = sample use 0.75% extract

T3 = sample use 1.00% extract

T4 = sample use 1.25% extract

T5 = sample use 1.50% extract

As shown in Figure 4, protein reduction increased with increasing pineapple waste extract concentration. Compared with the untreated sample, protein reduction ranged from 4.96% in the 0.50% extract treatment (T1) to 31.78% in the 1.50% extract treatment (T5). The 0.75% (T2) and 1.00% (T3) extract treatments produced protein reductions of 13.12% and 13.99%, respectively, which were comparable to that achieved by the commercial bating agent (11.08%). In contrast, the 1.25% (T4) and 1.50% (T5) extract treatments resulted in substantially greater protein reductions of 28.57% and 31.78%, respectively. Although increasing the extract concentration promoted greater protein reduction, this trend was not consistently associated with improved leather quality. The higher protein reductions observed at 1.25% and 1.50% coincided with lower tensile

strength, suggesting that excessive proteolytic activity may have caused over-bating and partial degradation of the collagen fiber network. Excessive protease activity has been reported to reduce leather strength through the over-degradation of collagen-associated structures (Zhu et al., 2023).

It should be noted that protein content is not included as a quality requirement in SNI. Therefore, the protein content measured in this study was used solely as an indicator of the effectiveness of the bating process rather than as a criterion for compliance with the standard. Consequently, the effectiveness of each treatment was interpreted together with the physical properties of the glaze leather, particularly tensile strength, elongation, and softness.

CONCLUSION

The application of pineapple waste extract as a bating agent affected the physical properties and protein reduction of rabbit glacé leather. Among the tested treatments, the 0.50% extract provided the best overall leather quality, producing the highest tensile strength (165.58 MPa) while meeting the requirements of SNI 06-1795-1990 for rabbit glacé leather. Increasing the extract concentration generally enhanced protein removal and leather flexibility; however, excessive concentrations were associated with reduced mechanical performance, suggesting over-bating. Therefore, under the experimental conditions of this study, a 0.50% pineapple waste extract is recommended as an alternative bating agent for rabbit glacé leather processing.

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