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Research Article

The Effect of Castor Oil (*Ricinus communis*) Concentration on the Physical and Mechanical Characteristics of Tanned Rabbit Fur Skin

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Abstract | This study aims to determine the effect of castor oil concentrations during the oiling step of rabbit fur skin tanning on the physical and mechanical qualities of the final product. The research material consisted of 64 pieces of local rabbit fur skin tanned with castor oil at different concentrations. The experiment was conducted in a completely randomized design (CRD) with 4 treatments (without castor oil/M0, 5% castor oil/M1, 10% castor oil/M2, and 15% castor oil/M3) and 4 replications. To determine its effects towards physical and mechanical qualities, tensile strength (N/cm^2), tear strength (N/cm), elongation (%), water absorption (%), suppleness (mm), and thickness (mm) of the tanned fur skin were observed. Castor oil concentration gave a highly significant effect ($P<0.01$) on tensile strength, tear strength, and water absorption, with values ranging from 622.80 to 1,208.49 N/cm^2, 74.04 to 159.16 N/cm, and 47.10 to 125.52%, respectively. In contrast, elongation (31.33–44.16%), suppleness (3.08–5.24 mm), and skin thickness (0.76–0.93 mm) were not significantly influenced by the treatment ($P>0.05$). This study concludes that castor oil can be used as an alternative natural ingredient in the oiling steps of rabbit fur skin tanning process. Moreover, our study demonstrated that 10% castor oil concentration yielded the optimal physical and mechanical properties. Consequently, this formulation is recommended for industrial tanning applications to enhance the valorization of rabbit fur skin.

Keywords | Castor oil, Rabbit skin, Qualities, Tanning, Physical, Fur

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INTRODUCTION

Rabbit represents a widely reared non-ruminant livestock commodity in Indonesia. This is attributed to its high prolificacy, characterized by litter sizes ranging from 6 to 14 individuals (Fadlilah *et al.*, 2020). The Indonesian Statistics Agency (BPS) recorded a significant increase of reared rabbit population from 248 thousand in 2023 to 630 thousand in 2025 and is projected to increase in the next years (BPS, 2026). This data not only represent the increase in rabbit meat production, but also in its by-products, such as rabbit fur skin. Currently, rabbit fur skin often considered as waste product, even though it can be processed into an added value product through the tanning process (Kanuri *et al.*, 2019).

Raw rabbit fur skin requires proper handling to prevent damage and extend their shelf life, including tanning (Nasr and Taha, 2024). Tanning is a process of transforming raw animal skins into tanned leather by adsorption of tanning agents into the skin's matrices. This allows the tanning agent to bind skin cells and create a physically, chemically, and biologically resistant leather products. The tanning process can be divided into three main steps: beamhouse operations to clean the raw skin, tanning process to stabilize the skin structure by using tanning agent, and post tanning or finishing to transform tanned leather into a finished product with desired characteristics (Sultana *et al.*, 2026). Each of these stages utilize specific chemicals such as alum and salt to alter the protein composition of the hide, thereby increasing its durability. Alternatively, enzymatic treatments such as reported by Fitriyanto *et al.* (2020) can also be done in order to minimize environmental impact of the tannery industry. The tanning process of rabbit fur skin requires coating to maintain the fur softness and prevent damage. Typically, the oil applied to coat the tanned leather and is commonly known as fat liquoring. Fat liquoring is one of the essential steps within the post-tanning process and aimed to modify the structural properties of the fur skin to induce softness, elasticity, and suppleness (Alam *et al.*, 2024). Castor oil (*Ricinus communis*), derived from the seeds of the castor bean plant, is one of the fat liquoring agents that can be used in the coating process. Castor oil contains ricinoleic acid, a hydroxyl fatty acid that helps make the leather texture softer and more supple, improving the elasticity and resilience of fur-bearing rabbit skin (Wen *et al.*, 2022). Moreover, castor oil also contains oleic acid, linoleic acid, palmitic acid, phospholipids, and vitamin E, which have antioxidant properties (Yeboah *et al.*, 2021).

Despite the projected growth of the rabbit rearing practice in Indonesia, the valorization of rabbit fur skin remains suboptimal (Maryati *et al.*, 2021; Amertaningtyas *et al.*, 2025). In addition, rabbit fur skin often treated as agricultural waste rather than high-value commodities. Furthermore, despite its bioactive properties and its fat liquoring agent potential, the specific application of castor oil (*Ricinus communis*) on rabbit skin is yet to be investigated. Based on the unique fatty acid profile of castor oil, particularly its high ricinoleic acid and antioxidant content, this study aims to evaluate its efficacy as a sustainable fat liquoring agent. Specifically, the objective is to determine the impact of castor oil inclusion on the physical and mechanical quality of tanned rabbit fur, thereby establishing a viable protocol for upgrading local rabbit by-products into commercially viable leather goods.

MATERIALS AND METHODS

Research materials

As much as 64 fresh fur skins were collected from Rex rabbit breed from a local farm in Batu, Indonesia. The tanning materials used were $Al_2(SO_4)_3$ (aluminum sulfate), CH_2O (formaldehyde), teepol, non-iodized coarse salt, and castor oil (Nurra Gemilang LP, Indonesia), as well as Royale fragrance (Multi Indomandiri Ltd., Indonesia).

Rabbit fur skin tanning procedures

The fresh rabbit fur skin was stored and tanned at the Animal Products Technology Laboratory of the Faculty of Animal Science, Universitas Brawijaya, Malang. The physical and mechanical properties of the tanned rabbit fur skin was analyzed at the Yogyakarta Leather, Rubber, and Plastics Center located at Jl. Sukonandi No. 9, Semaki, Umbulharjo District, Yogyakarta City, DIY, 55166. The research was conducted from July 1 to October 1, 2025. Initially, fresh rabbit fur skins were washed and cleaned from dirt and blood. The cleaned rabit fur skins then undergoes *furtigh* process through soaking in a 5 L solution of water mixed with 300 ml of teepol, and 100 ml of CH_2O for 60 minutes. *Fleshing* of the rabbit fur skin was then performed by discarding the *furtigh* solution, adjust the rabbit fur skin pH to neutral, and manually remove any remaining fat and flesh attached to the rabbit fur skins. The tanning of the rabbit fur skins were then performed by soaking in a solution of 5 L water, 300 g of $Al_2(SO_4)_3$, and 300 g of coarse salt. The soaked skins were then stirred for every 6 hours for 7 days. After the tanning process, the tanned rabbit fur skins were rinsed and applied with castor oil at 0% (M0/control), 5% (M1), 10% (M2), and 15% (M3) based on the tanned skin weight (w/w) and heated at at 50°C for 60 minutes. After the oiling process, the rabbit fur skins were carefully squeezed and dried for 7 days under indirect sunlight. During the drying, the rabbit fur skins were frequently turned over, pulled and loosened using a wooden stick.

Physical and mechanical evaluations of rabbit fur leather

Tensile (N/cm^2) and tear (N/cm) strength, elongation at break (%), water absorption (%), tanned leather suppleness (mm) and thickness (mm) were assessed to determine the effect of castor oil concentration on the physical and mechanical qualities of the rabbit fur leather of this study. The resulting rabbit fur leathers were kept under standard atmospheric conditions for 48 h prior to detection of the physical and mechanical properties. The physical and mechanical evaluations of tanned rabbit fur leathers of our study follows standard leather qualities test published by International Organizations for Standardization (ISO), where tensile strength and elongation at break of tanned rabbit fur leather samples were evaluated by following ISO 3376: 2011 (ISO, 2011), tear strength was measured based by following ISO 3377-2: 2016 (ISO, 2016a), water absorption was measured following ISO 2417:2016 (ISO, 2016b), tanned leather thickness was measured following the standards of ISO 2589: 2016 (ISO, 2016c), and tanned suppleness was evaluated following ISO 17235:2015 (ISO, 2015).

Statistical analysis

This research employed a laboratory experiment with a completely randomized design (CRD) consisting of 4 treatments and 5 replications. Data obtained from the test was analysed using Analysis of Variance (ANOVA), followed with Duncan's Multiple Range Test (DMRT) to determine significance at P<0.05 and P<0.01.

RESULTS AND DISCUSSION

Tensile strength

The results of our study demonstrated that the different concentrations of castor oil (*Ricinus communis*) addition in the tanning process of rabbit fur skin had a very significant effect (p<0.01) on tensile strength. The result of the tensile strength analyses of rabbit fur skin are shown in Table 1.

Table 1: Average tensile strength (N/cm^2) of rabbit fur leather.

Treatment	Tensile Strength(N/cm^2)	Reference*
M0	622.80 ± 293.02^{a}	Minimum 14N/cm^2
M1	1,208.49 ± 318.09^{b}	
M2	765.60± 304.57^{ab}	
M3	1,199.74± 183.79^{b}	

Note: *Reference = ISO 3376: 2011 (ISO, 2011). $^{a, ab, b}$ Different superscripts in the same column indicate significantly different effects (p<0.01).

The highest tensile strength value was achieved by M1 (5% castor oil) treatment, while the lowest value was achieved by M0 (control). Furthermore, increasing the castor oil concentration more than 5% decreased the tensile strength of the rabbit fur leather. Tensile strength of a leather is influenced by several factors, such as protein in the hide fibers, fat content, and hide thickness. Increasing protein and fat levels tend to decrease the tensile strength of the tanned fur leather (Amertaningtyas *et al*., 2024). In this study, the results of the tensile strength of in Table 1 also showed that they have met the ISO 3376: 2011 standards with a minimum value of 14 N/cm^2. Mostly, tanned leather products that could not meet the ISO standards are due to damaged raw skin (Gargano *et al*., 2023). Interestingly, other research showed that adding an oil percentage of 15-20% to rabbit tanned leather provided a tensile strength value of 1.75-1.77 N/mm^2 (Maryati *et al*., 2021). This finding is also confirmed by other research which demonstrated that an oil concentration of more than 5% is able to produce the best combination of softness and tensile strength in fur tanned rabbit skin (Sousa *et al*., 2016). Our findings thus further revealed that decreasing oil concentration for a more sustainable leather tannery can be done by selecting different type of oil used, such as castor oil.

Tear strength

The results of the study stated that the difference in the percentage of castor oil (*Ricinus communis*) addition in the tanning process of rabbit fur skin had a very significant effect (p<0.01) on tear strength. The average results of the tear strength test of fur-haired rabbit skin are shown in Table 2.

Table 2: Average tear strength (N/cm) of rabbit fur leather.

Treatment	Tear Strength (N/cm)	Reference*
M0	74.04 ± 15.37^{a}	Minimum 12.5 N/cm
M1	138.17 ± 9.12^{b}	
M2	137.48± 8.46^{b}	
M3	159.16± 9.99^{c}	

Note: *Reference = ISO 3377-2: 2016 (ISO, 2016a). $^{a, b, c}$ Different superscripts in the same column indicate significantly different effects (p<0.01).

The highest tear strength of tanned rabbit fur leather was achieved by M3 (15% castor oil) and the lowest was produced by the M0 treatment (control). Typically, increasing the oil concentration linearly affect the tear strength of the tanned leather (Alam *et al*., 2024). The magnitude of the tear strength value indicates the stability of the bond between the tanning agent and the leather layer (Thomasset and Benayoun, 2024). Leather with high tear strength indicates that the tanning agent has been optimally absorbed during the tanning process. The results of rabbit fur leather tear strength of our study are comparable to previous research (Sousa *et al*., 2016; Thomasset and Benayoun, 2024), which also showed that optimal absorption of tanning agents can occur due to the entry or binding of tanning agents into the protein molecules that make up the leather which results in the formation of cross-links between the tanning agent and the polypeptide chain determining the high or low tear strength of the leather. The tear strength of tanned leather is contingent upon the extent of oil absorption. As oil incorporation within the dermal matrix increases, elasticity is enhanced, thereby improving the mechanical resilience (Alam *et al*., 2024).

Furthermore, the tear strength of rabbit fur leather of our study (Table 2) have met the ISO 3377-2: 2016 standards with a minimum value of 12.5 N/cm. Tear strength is one of the main parameters in assessing the quality of leather. Tear strength values below the standard indicate the low quality of leather and easier to tear (Thomasset and Benayoun, 2024). Oil emulsions that evenly coat the leather fibers will make the leather fibers denser and more difficult to tear when applied at the appropriate percentage (Kamely, 2022). The results of previous research indicate that the addition of 25% oiling provides the highest tear strength value of 36.82 N/cm (Maryati *et al*., 2021).

Elongation

The results of the study stated that the difference in the percentage of castor oil (*Ricinus communis*) addition in the tanning process of fur-haired rabbit skins did not have a different effect ($p>0.05$) on elongation. The average results of the elongation test for fur-haired rabbit skins are shown in Table 3.

Table 3: Average elongation (%) of rabbit fur leather.

Treatment	Elongation (%)	Reference*
M0	44.16 ± 15.36	Maximum 60%
M1	31.33 ± 6.57	
M2	33.52 ± 17.67	
M3	52.20± 9.11	

Note: *Reference = ISO 3376: 2011 (ISO, 2011). No different superscripts in the same column indicate no different effect ($p>0.05$).

The highest elongation value on rabbit fur leather was produced by the M3 treatment (15% castor oil) and the lowest elongation value was produced by the M1 treatment (5% castor oil). Skin elasticity is related to the level of laxity or elasticity which is influenced by the reduction of elastin during the process of calcification and protein erosion. Elongation is also influenced by the high protein and fiber content as well as the final tanning processes such as stretching, softening and sanding. The high elongation value of leather occurs due to the large amount of oil that coats the fiber surface, so that the leather becomes more flexible and easier to shape (Alam *et al*., 2024; Thomasset and Benayoun, 2024). The results of elongation in Table 3 have met the ISO 3376: 2011 standards with a maximum value of 60%. Oil or fat can change the essential properties of skin, such as softness, elasticity, and surface smoothness. This increase in elongation is in line with the increase in the percentage of oil used so that the skin becomes more flexible. Moreover, elongation characteristic of a tanned leather is related to the elasticity or softness of the skin produced. Tanned leather products are weakened by a reduction in elastin during the calcification process and protein erosion (Thomasset and Benayoun, 2024). Previous research stated that applying 15% oil had the highest elongation value of 175.44% (Maryati *et al*., 2021).

Water absorption capacity

The results of the study showed that differences in the concentration of castor oil added to the tanning of fur-bearing rabbit skins with different percentages resulted in a very significant effect ($p<0.01$) on water absorption capacity. The average results of the water absorption test rabbit fur tanned leather is shown in Table 4.

Table 4: Average water absorption (%) of rabbit fur leather.

Treatment	Water absorption capacity (%)	Reference*
M0	85.44 ±1.22^{a}	2 hours (min. 100%)
M1	83.09 ±1.53^{b}	
M2	125.52 ±2.33^{c}	
M3	47.10 ±0.82^{d}	

Note: *Reference = ISO 2417: 2016 (ISO, 2016b). ^{a,b,c,d} Different superscripts in the same column indicate significantly different effects ($p<0.01$).

The highest water absorption value for rabbit fur tanned leather was produced by the M2 treatment (10% castor oil), and the lowest elongation value was produced by the M3 treatment (15% castor oil). This can occur because castor oil is composed of ricinoleic acid triglycerides with an -OH group on the 12th carbon tail, making it a fat liquor that can be emulsified in water, diffuse into the collagen interfibrillar space, then form a lubricating film on the fibers. This is also comparable to previous research that stated that increasing the polarity of castor oil produces a self-emulsified fat liquor that interacts more easily with water (Sahu *et al*., 2021). This is important so that the oil film evenly wraps the fibers, reducing the effective surface area exposed to water. This extensive coverage makes the hydrophilic surface of the collagen covered by oil, making it more difficult for free water to enter, while the bound water that maintains flexibility is maintained.

The 24-hour water absorption test is generally higher than the 2-hour water absorption test and will maintain water absorption when the saturation point is reached (Pancapalaga *et al*., 2021). An inappropriate oil percentage can cause a decrease in the physical strength of the leather because the tanning process during pre-tanning, from soaking, degreasing, burning, and pre-tanning, will affect the structure of the skin's collagen fiber density, causing uneven water absorption (Maina *et al*., 2019). The higher the percentage of castor oil used, the less optimal the water absorption. This occurs because increasing the percentage of castor oil increases the volume fraction of the oil film in the tissue, resulting in more blocked pores or microcapillaries, decreasing the skin's surface tension, and reducing the surface area that can bind water. Blocked skin pores due to the high percentage of castor oil used prevent water from entering the skin, resulting in low absorption.

Suppleness

The results of the study demonstrated that the difference in the percentage of castor oil (*Ricinus communis*) addition in the tanning process of fur-haired rabbit skins did not have a different effect ($p>0.05$) on the softness. The average results of the softness test for fur-haired rabbit skins are shown in Table 5.

Table 5: Average suppleness (mm) of rabbit fur leather.

Treatment	Suppleness (mm)	Reference*
M0	5.24 ± 0.88	5.0-7.6 mm
M1	3.08 ± 0.95	
M2	3.88 ± 1.49	
M3	3.94 ± 1.20	

Note: *Reference = ISO 17235: 2015 (ISO, 2015). No different superscripts in the same column indicate no different effect ($p>0.05$).

The highest softness value in hairy rabbit tanned leather was produced by treatment M0 (control) and the lowest softness value was produced by treatment M1 (5% castor oil). Previous researchers stated that using castor oil percentages of 15%, 20%, and 25% influenced skin laxity and produced laxity values of 5.35 mm, 4.61 mm, and 4.63 mm. The application of castor oil in tanning functions as a lubricating agent, which helps improve the structure of collagen fibers by increasing water penetration as well as the formation of a lipid film on the surface of the leather, thereby increasing the aesthetic and functional appeal of the resulting leather. Based on previous research, the application of oil on leather tanning is influenced by the oxidation of the oil (Alam *et al*., 2024). Castor oil works by cross-linking collagen molecules in the skin, where the cross-linking of the collagen fibers is distributed in the skin matrix, causing the skin to become stable. The effect of fillers on the tanning process is influenced by the remaining fat and meat attached to the skin. If there is less tannin in binding the amino acids in collagen, the skin structure will become less dense. The result of this process weakens the leather due to the available space that is not filled by the tanning agent (Thomasset and Benayoun, 2024). Thus, leather thickness acts as a determinant of suppleness, where thicker fur leather typically yield lower softness readings.

Skin thickness

The results of the study showed that differences in the percentage of castor oil (*Ricinus communis*) added to the tanning process of fur-haired rabbit skins did not significantly affect skin thickness ($p>0.05$). The average results of the fur-haired rabbit skin thickness test are shown in Table 6.

Table 6: Average skin thickness (mm) of rabbit fur leather.

Treatment	Skin thickness (mm)	Reference*
M0	0.93 ± 0.12	Min. 0.2 mm
M1	0.76 ± 0.21	
M2	0.77 ± 0.09	
M3	0.87 ± 0.13	

Note: *Reference = ISO 2589: 2016 (ISO, 2016c). No different superscripts in the same column indicate no different effect ($p>0.05$).

The highest value of skin thickness on rabbit fur leather was produced by treatment M0 (control) and the lowest value of elongation was produced by treatment M1 (5% castor oil). Moreover, the thickness of rabbit fur leather between experimental treatments of this study did not show significant differences. This is influenced by the less-than-optimal fleshing stage so that the tanning material cannot be evenly distributed over the skin and results in lower skin thickness test values. Consistent with earlier literature, skins retaining significant lipid layers exhibit resistance to preservation treatments, likely due to limited penetration of curing agents (Wu *et al*., 2017). Moreover, the results of all rabbit fur leather thickness of our study meet the ISO 2589: 2016 standard, which has a minimum of 0.2 mm. Moreover, the non-uniform thickness of the rabbit fur leather produced by each treatment in this study was due to the characteristics of the raw skins which also affect the fleshing process, such as previously also reported by Amertaningtyas *et al*. (2024). Another factor contributing to the ineffectiveness of castor oil on skin thickness is that its high natural viscosity inhibits penetration into the deepest layers of the collagen matrix, causing its molecules to be retained in the surface zone and limiting the scope of collagen micro-swelling. The abundant ricinoleic acid composition in castor oil makes it somewhat polar, making it easier to bind with the polar groups of collagens on the surface than to penetrate the hydrophobic layers between the deepest fibrils.

CONCLUSION

Based on the research results, it can be concluded that the addition of 10% castor oil to the tanning of fur-bearing rabbit skin is the most optimal concentration in terms of tensile strength (Ncm^2), tear strength (N/cm), elongation (%), water absorption (%), suppleness (mm), and skin thickness (mm). Further research is recommended to comprehensively evaluate the shelf life of the skin, along with more extensive investigation of its physicochemical, mechanical, and durability characteristics to ensure long-term stability and performance.

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NOVELTY STATEMENT

The novelty of this research lies in the utilization of castor oil as an eco-friendly natural fatliquoring agent for rabbit fur skin tanning, a specific application that has not been previously investigated. This study successfully identifies an optimal bio-oiling formulation threshold of 10% that balances high water absorption capacity with robust tensile and tear strengths meeting international quality standards. This provides a cleaner production strategy for the leather industry while upgrading agricultural rabbit waste into value-added commodities.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: conception: DA; methodology: RLMSAW; data analysis: ASDS and BS; validation: DA; writing original manuscript: ASDS and BS; writing manuscript revision: DA, ARA, and CWD.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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