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The Effect of Formalin Concentration and Storage Duration on Elasticity, Tensile Strength, Fur Loss, and Water Absorption of Tanned Rabit Skin

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Abstract. *Rabbit skin is one by-product that can be utilized for its aesthetic value through a tanning process so that the skin is resistant to destructive bacteria, namely Pseudomonas aeruginosa and Staphylococcus aureus. Furtigh is the strengthening of fur in the tanning process, in this research the furtigh process uses formalin so that rabbit fur is stronger and lasts longer. The purpose of this research was to determine the appropriate concentration of formalin and storage length used in rabbit fur tanning in the terms of pliability, tensile strength, fur loss and water absorption. The method used in this research is a laboratory experimental method using a Completely Randomized Design (CRD) with a nested design consisting of 4 treatment and repeated 4 times each. This treatment used formalin of 10%, 15%, 20% and 25%. Variables tested included pliability, tensile strength, fur loss and water absorption. Processing data using analyzed by Analysis of Variance (ANNOVA) and continued with the Duncan Multiple Range Test (DMRT). The results showed that different usage of formalin exerted significant influence (P<0,05) on the tear elasticity of tanned rabbit furs with a result of F1: 29,76%; F2: 32,85%; F3: 41,70%; F4: 41,88%. Different concentration usage of formalin have significant influence of tanned rabbit fur (P<0.05) on rabbit skin tensile strength fur tanning with a results of F1: 36.63 N/mm^2; F2: 39.69 N/mm^2; F3: 43.81 N/mm^2; F4: 48.36 N/mm^2. Fur loss test showed that the use of different formalin exerted highly significant influence (P<0.01) of tanned rabbit fur loss with a result of F1: 4.15; F2: 3.78; F3: 3.49; F4: 3.40. Water absorption test that the use of different formalin concentration have highly significant influence of tanned rabbit fur (P<0.01) with water absorption with a result of F1: 192.12%; F2: 217.95%; F3: 237.85%; F4: 238.27% on 2 hours of water absorption. Storage length did not have significant influence of tanned rabbit fur (P<0.05) on rabbit skin elasticity, tensile strength, fur loss and water absorption.*

Keywords: *Processing, Tanning, Skin, Quality*

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INTRODUCTION

Farm is one of the commodity sectors that has a lot of potential to be developed, one of which is the rabbit livestock commodity. Rabbit meat production in 2023 based on Anonimus (2023), Livestock and Animal Health Statistics in 2023 amounted to 497.12%. Rabbit meat production produces by-products, one of which is rabbit skin. Rabbit skin has a fairly high economic value because it can be processed into food or non food products. The advantage of rabbit skin is that it is included in the exotic skin category because it has soft fur with various color patterns (Rahmawati et al., 2024). Fauzi (2019), added that these advantages are supporting factors in the process of making leather jacket raw materials.

Tanning is the process of preserving raw leather through several stages, namely washing, separating fat and meat on the skin (flashing), immersion process in tanning materials (tanning), stretching the skin (straching), rubbing the inner skin when dry (buffing). The tanning process prevents bacteria that can damage skin tissue, namely *Pseudomonas aeruginosa* and *Staphylococus aureus* bacteria (Zulfa et al., 2018). The characteristics of rabbit skins that are good for furry tanning are having thick and dense fur, fresh skin, smell of leather, not easily torn (Taha et al., 2017).

Tanning can be done with various types of tanning materials including natural materials derived from plants or usually called vegetable tanning, oil tanning materials, and can use chemicals. Tanning using chemicals makes the skin have a longer shelf life and during physical and chemical treatment the skin can be more stable (Pancapalaga and Nurjannah, 2020). The tanning of furry rabbit skins has a preservation process so that the tanned results have a long shelf life. The preservation process requires suitable preservatives, preservatives that can be used for the rabbit skin preservation process, one of which is formalin. Formalin in the tanning process can increase the level of pliability and tensile strength of the skin (Abdulhusein and Kadim, 2024). Formalin has a high absorption capacity in the tanning process, so it quickly binds collagen in the skin and produces a good pliability value (Kusmaryanti, Ibrahim and Riyadi, 2016). The use of 3% Formalin and 2% Teepol in the tanning process of furry rabbit skin can strengthen the tanned fur so that it does not fall off easily and is used at the time of furtigh (Maryarti and Nugroho, 2021).

Another material that can be used is teepol, tepool can help the tanning process

during fleshing or removal of fat and meat that is still attached to the rabbit skin. Tanning furry rabbit skins with the addition of formalin concentrations and different storage durations is expected to produce the appropriate quality of tanned rabbit skins, namely a maximum pliability value of 30% (BSN., 1990[b]), a tensile strength value of at least 14 N/mm^2 (BSN., 2011), fur loss value with a hedonic scale of 1 (Very fallen), 2 (fallen), 3 (moderately fallen), 4 (slightly fallen), 5 (not fall) (Madhu et al., 2022). Water absorption for 2 hours is at least 100% (BSN, 1990[a]), so it is necessary to conduct research on the value of elasticity, tensile strength, fur loss and water absorption.

LITERATURE REVIEW

Rabbits are a promising livestock commodity, not only for their meat but also for by-products such as skin (Rahmawati et al., 2024). Rabbit skin is considered an exotic type of leather due to its soft fur and variety of color patterns (Fauzi, 2019). Rabbit breeds such as Rex and Bligon are known for their high-quality fur, making them suitable for fur-on tanning (Brahmantiyo et al., 2015; Nisa et al., 2022; Amtriani, 2023).

However, rabbit skin is highly susceptible to microbial contamination, including bacteria such as *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Sarker et al., 2018; Zulfa et al., 2018), necessitating effective preservation techniques. Common preservation methods include dry salting, wet salting, and tanning (Dahlia and Sembiring, 2023). Formalin is a widely used tanning agent due to its aldehyde (H_2CO) content, which reacts with amino (NH_2) groups in collagen, enhancing the physical properties of the skin (Dewi et al., 2016; Kusmaryanti et al., 2016; Abdulhusein & Kadim, 2024). The combination of 3% formalin and 2% Teepol during the furtigh stage has also been shown to strengthen fur attachment in tanned rabbit skin (Maryarti and Nugroho, 2021).

Besides formalin, vegetable tannins such as those extracted from acacia bark offer alternative tanning methods (Dahlia and Sembiring, 2023). Castor oil is another affordable, accessible tanning oil with the added benefit of producing odorless leather, while alum [$Al_2(SO_4)_3$] serves as a mineral tanning agent (Pancapalaga and Nurjannah, 2020). Additional pre-tanning and post-tanning processes such as acidification and fixation with fatty acids are essential to enhance final leather quality (Juliyarsih et al., 2019; Utami, 2022). Ideal rabbit skins for fur-on tanning should be fresh, pliable, with a natural odor, and covered in thick fur (Taha et al., 2017).

Key indicators of tanned rabbit leather quality include elasticity (tensile elasticity), tensile strength, fur retention, and water absorption capacity. Skin diseases such as foot-and-mouth disease (FMD), scabies, and dermatitis can significantly reduce leather quality (Rotinsulu et al., 2015). High water absorption can lead to fungal growth, cracking, and shrinkage in leather products (Prayitno & Kasmusdjiastuti, 2017; Rahmawati et al., 2024). Improper storage conditions further exacerbate leather degradation (Nurichsanto et al., 2022; Khoironi, 2024).

Based on the data presented above, further research is needed on tanned rabbit fur skin regarding the use of formalin as a preservative and fur-strengthening agent (furtigh) in the tanning process. The success of this research will be evaluated through tests on elasticity, tensile strength, fur loss, and water absorption in relation to the storage duration of the tanned rabbit fur skins.

RESEARCH METHODS

The research was conducted from May to September 2024. The hairy leather tanning process was carried out at the Laboratory of Animal Product Technology, Faculty of Animal Science, Brawijaya University, Malang. Tests for elasticity, tensile strength, hair loss, and water absorption were conducted at the Leather Technology Academy Polytechnic (ATK) in Yogyakarta.

Materials

The research material consisted of 144 fresh rabbit hides sourced from local meat-type rabbits (Bligon) obtained from a rabbit farm in Batu City, Malang, East Java. The materials used in the tanning process included 8.4 liters of formalin from Nurra store, 16.8 liters of tepol, aluminum sulfate (alum) $Al_2(SO_4)_3$ branded 'Kembali Belanja,' and non-iodized salt obtained from 'Nurra Lab,' a chemical supply store in Malang City, as well as Downy-brand fabric softener.

Equipment

The equipment used in this study included plastic buckets, wooden stirrers, scout sticks, clothes hangers, newspapers, garbage bags, a digital scale (SF-400), a thermohygrometer, and scissors, all of which were used in the rabbit hide tanning process. Equipment used for testing the elasticity and tensile strength of the tanned rabbit leather included a GESTER-branded tensile strength tester, a digital thickness gauge, a sample cutter, and a vernier caliper. For the water absorption test of the tanned leather,

petri dishes, an analytical balance, and a timer were used.

Research Method

The research employed an experimental method using a Nested Completely Randomized Design (Nested CRD), as the study focused on storage duration while using the same materials across all trials. Therefore, the storage durations at weeks 5, 10, and 15 equivalent to 35, 70, and 105 days did not interact directly but were interrelated. The research design consisted of two interrelated factors. Factor 1 was the percentage of formalin used, while Factor 2 was the storage duration. The details of Factors 1 and 2 are explained in Table 1:

Table 1. Nested Completely Randomized Design (Nested CRD) Experimental Method

Numb.	Formalin Concentration	Storage Duration-% Formalin	Replicates				Total Storage Duration-% Formalin
			1	2	3	4	
F1		M1	F_1U_1	F_1U_2	F_1U_3	F_1U_4	F_1M_1
		M2	F_1U_1	F_1U_2	F_1U_3	F_1U_4	F_1M_2
		M3	F_1U_1	F_1U_2	F_1U_3	F_1U_4	F_1M_3
2.	F2	M1	F_2U_1	F_2U_2	F_2U_3	F_2U_4	F_2M_1
		M2	F_2U_1	F_2U_2	F_2U_3	F_2U_4	F_2M_2
		M3	F_2U_1	F_2U_2	F_2U_3	F_2U_4	F_2M_3
3.	F3	M1	F_3U_1	F_3U_2	F_3U_3	F_3U_4	F_3M_1
		M2	F_3U_1	F_3U_2	F_3U_3	F_3U_4	F_3M_2
		M3	F_3U_1	F_3U_2	F_3U_3	F_3U_4	F_3M_3
4.	F4	M1	F_4U_1	F_4U_2	F_4U_3	F_4U_4	F_4M_1
		M2	F_4U_1	F_4U_2	F_4U_3	F_4U_4	F_4M_2
		M3	F_4U_1	F_4U_2	F_4U_3	F_4U_4	F_4M_3

Description:

F1: formalin 10%

F2: formalin 15%

F3: formalin 20%

F4: formalin 25%

M1: 5-week storage duration

M2: 10-week storage duration

M3: 15-week storage duration

U1: Replicates 1

U2: Replicates 2

U3: Replicates 3

U4: Replicates 4

Elasticity

The elasticity value is inversely proportional to the tensile strength value; as the elasticity of tanned skin increases, its tensile strength decreases (Sitorus, Riyadi and Susanto, 2020). According to BSN (1990b), the requirement for good elasticity in tanned

rabbit skin is a maximum of 30%. The elasticity value of fur-on tanned rabbit skin can be obtained and calculated using the formula outlined in BSN (1990b) as follows:

$$\text{Elasticity (\%)} = \frac{P2-P1}{P1} \text{ x } 100\%$$

Description:

P1 = the length before being stretched (mm)

P2 = the length after being stretched (mm)

Tensile Strength

Tensile strength is the maximum force required to stretch the skin until it breaks per unit area of the skin (BSN, 2012). A high tensile strength test value results in a strong garment product that is not easily torn during sewing or use (Maryati and Nugroho, 2021). According to BSN (2011), the minimum tensile strength requirement for fur-on tanned rabbit skin is 14 N/mm². The tensile strength can be calculated using the formula established by BSN (1990) as follows:

$$\text{Tensile strength } \left(\frac{N}{mm^2}\right) = \frac{\text{Load weight (kg)}}{\text{Cross sectional area } (cm^2)}$$

Fur Loss

The degree of fur loss can affect the quality of the tanned skin produced. According to Koralina et al. (2023), the causes of fur loss include nutritional deficiencies, age, environment, and hormones, which can damage the fur follicles of rabbits, leading to easy fur loss. The fur loss test was conducted by pulling fur from the tanned rabbit skin using a hedonic scale: 1 (very lost), 2 (lost), 3 (moderately lost), 4 (slightly lost), and 5 (not lost) (Madhu et al., 2022).

Water Absorption

Water absorption in tanned skin can vary depending on the thickness of the fur and skin fat. According to Prayitno and Kasudjiastuti (2017), excessive water absorption can cause the tanned skin to lose its shape, while if the absorption is too low, the skin will become brittle and stiff. The water absorption standard for tanned skin, as outlined by BSN (1990a), is a minimum of 100% absorption within 2 hours. The water absorption value can be determined by calculating it using the formula based on ISO 19074: 2015 as follows:

$$A_i \text{ (\%)} = \frac{(m_1 - m_0)x\ 100\%}{m_0}$$

Description:

W_i = wicking value

W_A = maximum distance on the front side

W_B = maximum distance on the back side

RESULTS AND DISCUSSION

Elasticity

The results of the study indicated that variations in formalin concentration during the tanning process of hairy rabbit hides had a highly significant effect ($P<0.01$) on the elasticity value (%). The mean elasticity values of tanned hairy rabbit hides are presented in Table 2.

Table 2. Average Elasticity (%) of Tanned Fur-on Rabbit Skin with Formalin Addition and Storage Duration

No	%Formalin	Storage Duration			Average
		M1	M2	M3	
1	F1	$32,66 \pm 15,58^{c}$	$29,74 \pm 8,42^{b}$	$26,87 \pm 11,57^{a}$	$29,76 \pm 11,85^{c}$
2	F2	$33,18 \pm 7,22^{b}$	$34,00 \pm 10,30^{c}$	$31,36 \pm 2,46^{a}$	$32,85 \pm 6,67^{f}$
3	F3	$48,14 \pm 15,22^{c}$	$35,11 \pm 5,47^{a}$	$41,88 \pm 9,45^{b}$	$41,70 \pm 10,05^{g}$
4	F4	$48,21 \pm 12,60^{c}$	$37,35 \pm 5,17^{a}$	$40,10 \pm 12,02^{b}$	$41,88 \pm 9,93^{h}$
	Average	40,55 ± 12,66	34,04 ± 7,34	35,05 ± 8,88	

Description: Different superscripts in the columns (a, b, c, and d) and in the rows (e, f, g, and h) indicate a significant effect ($P<0.05$) of formalin concentration on the elasticity (%) of tanned fur-on rabbit skin.

The findings demonstrated that treatments with formalin concentrations of 10%, 15%, 20%, and 25% had significantly different effects ($P<0.05$) on the elasticity values of tanned hairy rabbit hides. Elasticity tests indicate the elasticity of the leather (Pancapalaga & Nurjanna, 2020). The average elasticity values for treatments with 10%, 15%, 20%, and 25% formalin were 29.76 ± 11.85%, 32.85 ± 6.67%, 41.70 ± 10.05%, and 41.88 ± 9.93%, respectively. Among these, only the treatment with 10% formalin (F1) complied with the Indonesian National Standard (SNI 06-1795-1990), which sets the maximum elasticity for rabbit tanned leather at 30%, with a result of 29.76%. The high standard deviation may be attributed to the manual tanning process, which can result in inconsistent speed and precision. This is supported by Pratama & Laksito (2022), who stated that high standard deviation values may occur when there is wide variability within a data set, while low values indicate more uniform data distribution. The study also revealed that higher formalin concentrations resulted in greater elasticity values of the tanned rabbit leather. This may be due to the use of teepol during the furtigh (hair

strengthening) process. According to Ardinal & Salmariza (2019), teepol enhances the penetration ability of other chemical agents into the hide, thereby affecting the elasticity value of the leather.

Treatments F2 (32.85 ± 6.67%), F3 (41.70 ± 10.05%), and F4 (41.88 ± 9.93%) did not meet the SNI 06-1795-1990 standard. This may be due to the loss of elastin. Elastin is a fibrous protein that forms highly elastic fibers due to its amino acid chains, which bend under tension and return to their original shape when the tension is released. The degradation of elastin in the hide's protein structure can reduce the elasticity of the tanned leather (Faishal et al., 2017). According to Maharani et al. (2015), excessive elasticity in a leather product can increase its stretchability, thereby negatively impacting the shape and aesthetic value of the final product. This phenomenon can be influenced by the concentration level of the tanning agents used.

The use of formalin as a chemical tanning agent at concentrations of 10%, 15%, 20%, and 25% with storage durations of 5, 10, and 15 weeks resulted in elasticity values of 29.76%, 32.85%, 41.70%, and 41.88%, respectively. Compared to previous research by Pancapalaga & Nurjannah (2020), who used mimosa (dragon fruit peel extract, *Selenicereus undatus*) as a tanning agent with concentrations of 20% and soaking durations of 60 minutes (P1), 90 minutes (P2), and 120 minutes (P3), elasticity values were 25.95%, 23.79%, 24.31%, and 17.55%, respectively. These results indicate that the type of tanning agent used can significantly influence the elasticity value of tanned hairy rabbit leather.

The results also showed that different storage durations—5 weeks, 10 weeks, and 15 weeks—had no significant effect ($P>0.05$) on the elasticity of the tanned rabbit leather. The mean elasticity values for 5, 10, and 15 weeks of storage were 40.55 ± 12.66%, 34.04 ± 7.34%, and 35.05 ± 8.88%, respectively. The lack of significant effect may be attributed to the use of formalin as the tanning agent. According to Dewi (2019), formalin, as a preservative, binds proteins and other compounds that are then absorbed into the dermal layer of the hide, offering protection against air exposure and slowing down evaporation. Additionally, the storage process itself may have contributed to the lack of significant impact on elasticity. This aligns with the findings of Khoironi (2024), who stated that tanned hides can remain preserved and intact if stored in low, evenly stacked or rolled layers with support.

Tensile Strength

The results of the study indicated that variations in formalin concentration during the tanning process of hairy rabbit hides had a significant effect (P<0.01) on the tensile strength value (%). The average tensile strength values of the tanned hairy rabbit hides are presented in Table 3.

Table 3. Average Tensile Strength (N/mm²) of Tanned Fur-on Rabbit Skin

No	%Formalin	Storage Duration			Average
		M1	M2	M3	
1	F1	$40,45 \pm 11,52^{b}$	$40,46 \pm 4,40^{c}$	$28,97 \pm 3,54^{a}$	$36,63 \pm 6,49^{e}$
2	F2	$44,21 \pm 17,48^{c}$	$37,53 \pm 4,11^{b}$	$37,32 \pm 6,33^{a}$	$39,69 \pm 9,30^{f}$
3	F3	$46,49 \pm 5,32^{b}$	$38,47 \pm 4,91^{a}$	$46,48 \pm 7,34^{c}$	$43,81 \pm 5,85^{g}$
4	F4	$47,43 \pm 9,96^{b}$	$46,43 \pm 10,69^{a}$	$51,22 \pm 17,19^{c}$	$48,36 \pm 12,61^{h}$
	Average	44,64 ± 11,07	40,72 ± 6,03	41,00 ± 8,60	

Description: Different superscripts in the columns (a, b, c, and d) and in the rows (e, f, g, and h) indicate a significant effect (P<0.05) of formalin concentration on the tensile strength (N/mm²) of tanned fur-on rabbit skin.

The findings showed that treatments with formalin concentrations of 10%, 15%, 20%, and 25% had significantly different effects (P<0.05) on the tensile strength of the tanned hairy rabbit hides. Tensile strength is a crucial testing parameter in the leather industry, as failure to meet standard tensile strength can cause leather to easily tear or crack (Prasannena et al., 2018). The mean tensile strength values for formalin concentrations of 10%, 15%, 20%, and 25% were 36.63 ± 6.49 N/mm²; 39.69 ± 9.30 N/mm²; 43.81 ± 5.85 N/mm²; and 48.36 ± 12.61 N/mm², respectively.

These values meet the tensile strength standard (N/mm²) according to SNI 4593:2011 regarding tensile strength testing for sheep or goat leather jackets, which stipulates a minimum tensile strength value of 14 N/mm² for hairy tanned leather used in fur jacket production. The findings confirm that the tensile strength values of the tanned hairy rabbit hides exceed the minimum threshold set by the standard. This is supported by Sahubawa and Puspita (2021), who stated that the higher the tensile strength of tanned leather, the better the quality of the resulting product. The tensile strength of tanned leather can be influenced by both thickness and leather structure, as the physical properties of leather are determined by its collagen fiber structure (Maharani et al., 2015).

The tensile strength values resulting from the use of different formalin concentrations (10%, 15%, 20%, and 25%) were 36.63 N/mm², 39.69 N/mm², 43.81 N/mm², and 48.36 N/mm², respectively. These results can be compared to a previous

study by Maryati and Nugroho (2021), which examined the use of mineral tanning agents combined with different oil concentrations (5%, 15%, and 25%) on tanned hairy rabbit hides. They found that an increase in oil concentration to 25% led to a reduction in tensile strength to 39.9%, from an initial 82.5% at 5% oil. Another study by Amertaningtyas et al. (2024) reported that the best tensile strength achieved with 300 g of aluminum sulfate as a tanning agent was 33.91 N/mm². These comparisons highlight that both the type and concentration of tanning agents used can significantly influence the tensile strength of hairy rabbit tanned leather.

The study also showed that different storage durations 5 weeks, 10 weeks, and 15 weeks did not have a significant effect (P>0.05) on the tensile strength of hairy rabbit leather treated with 10%, 15%, 20%, and 25% formalin. The mean tensile strength values for storage durations of 5, 10, and 15 weeks were 44.64 ± 11.07 N/mm², 40.72 ± 6.03 N/mm², and 41.00 ± 8.60 N/mm², respectively. The lack of significant impact may be due to the close relationship between the thickness and structural components of the hide, which form a protective network that prevents rapid evaporation (Maharani et al., 2015). This is further supported by the use of formalin as a tanning agent. According to Dewi (2019), formalin binds to collagen proteins and other compounds, which are then absorbed into the dermal layer of the hide, providing protection from air exposure and slowing down evaporation.

Fur Loss

The results of the study demonstrated that variations in formalin concentration used during the tanning process of hairy rabbit hides had a highly significant effect (P<0.01) on fur loss values. The mean values of fur loss for tanned hairy rabbit hides are presented in Table 4.

Table 4. Average Fur Loss Score of Tanned Fur-on Rabbit Skin

No	%Forma-lin	Storage Duration			Average	Descrip-tion
		M1	M2	M3		
1	F1	4,03 ± 0,58^{a}	4,04 ± 0,53^{b}	4,38 ± 3,54^{v}	4,15 ± 0,48^{e}	Slightly lost
2	F2	3,47 ± 0,45^{a}	4,25 ± 0,62^{c}	3,62 ± 0,64^{b}	3,78 ± 0,57^{f}	Moderately lost
3	F3	3,13 ± 0,16^{a}	3,72 ± 0,46^{c}	3,62 ± 0,72^{b}	3,49 ± 0,45^{g}	Moderately lost
4	F4	3,30 ± 0,71^{b}	3,10 ± 0,11^{a}	3,80 ± 0,67^{c}	3,40 ± 0,50^{h}	Moderately lost
	Average	3,48 ± 0,48	3,78 ± 0,43	3,86 ± 0,60		

Description: Different superscripts in the columns (a, b, c, and d) and in the rows (e, f, g, and h) indicate a highly significant effect (P<0.01) of formalin concentration on the hair lost of tanned fur-on rabbit skin.

The findings revealed that the addition of formalin at concentrations of 10%, 15%, 20%, and 25% had a highly significant effect ($P<0.01$) on the degree of fur loss in the tanned hairy rabbit hides. Fur loss was assessed organoleptically by trained panelists using a hedonic scale: 1 (very lost), 2 (lost), 3 (moderately lost), 4 (slightly lost), and 5 (no lost) (Madhu et al., 2022). The average fur loss scores for tanned hides treated with 10%, 15%, 20%, and 25% formalin were 4.15 ± 0.48, 3.78 ± 0.57, 3.49 ± 0.45, and 3.40 ± 0.50, respectively.

These values indicate that the 10% formalin treatment resulted in the highest average score (4.15, indicating slightly lost), followed by the 15%, 20%, and 25% treatments, which were categorized as moderately lost. Thus, the 10% formalin treatment yielded the most favorable result in terms of hair retention. Fur loss affects the final quality of tanned leather. According to Koralina et al. (2023), factors such as nutritional deficiencies, age, environment, and hormones can damage rabbit hair follicles, making the hair prone to falling out. Furthermore, excessive formalin concentration during tanning may lead to over-drying, which significantly reduces the elasticity of the hide and its hair due to the high reactivity of formalin (Marsal et al., 2018).

In this study, a formalin concentration of 10% with a soaking duration of 3 hours resulted in a fur loss score of 4.15 (slightly lost). This finding can be compared to prior research conducted by Wahono, Masyukan, and Supriyono (2015), which showed that the concentration of tanning agents affects the interaction with rabbit hair and penetration into the dermal layer, thereby enhancing hair strength. In their study, NaOH at a 6% concentration and a 60-minute soaking period was used to strengthen the hair on tanned goat hides. Another study by Rahmawati et al. (2024) reported a fur loss score of 4.34 (slightly lost) in rabbit hides tanned with Chromosal B at a shrinkage temperature of 85°C. The comparison of these studies suggests that both the type and concentration of tanning agents (e.g., formalin vs. NaOH) can significantly influence the extent of fur loss in tanned rabbit hides.

Hairy tanned rabbit hides can be further processed into finished products such as fur jackets, gloves, shoes, bags, and others. To maintain fur quality as seen in Table 6 and prevent further lost, pre-tanning procedures can be employed. According to Juliyarsih et al. (2019), pre-tanning treatments involving the addition of 1–2 types of acids, such as sulfuric acid, formic acid, or hydrochloric acid (1 liter), can help stabilize the pH to

around 4.5–5.5, thereby enhancing hair retention.

The study also showed that different storage durations 5 weeks, 10 weeks, and 15 weeks did not have a significant effect (P>0.05) on the degree of fur loss in the tanned rabbit hides, with average scores of 3.48, 3.78, and 3.86, respectively. This could be attributed to the strong binding affinity of formalin with collagen in the skin. Rachmawati et al. (2020) reported that formalin can form stable complexes that make the hide denser, reducing the risk of damage during storage. Another factor might be the storage conditions; in this study, hides were not exposed to direct sunlight. Khoironi (2024) stated that storing tanned hides under direct sunlight may cause folding or wrinkling, which can deteriorate hide quality.

Water Absorption

The results of the study showed that varying concentrations of formalin in the tanning process of hairy rabbit hides had a highly significant effect (P<0.01) on water absorption. The mean values of water absorption for tanned rabbit hides are presented in Table 5.

Table 5. Average Water Absorption Value (%) of Tanned Fur-on Rabbit Skin

No	%Formalin	Storage Duration			Average
		M1	M2	M3	
1	F1	205,77 ± 37,57^{b}	206,04 ± 26,68^{c}	170,56 ± 26,91^{a}	192,12 ± 30,39^{a}
2	F2	213,56 ± 31,92^{b}	230,14 ± 24,87^{c}	210,15 ± 20,19^{a}	217,95 ± 25,67^{b}
3	F3	225,58 ± 41,91^{a}	239,08 ± 15,32^{b}	249,10 ± 39,93^{c}	237,85 ± 32,39^{c}
4	F4	213,65 ± 10,58^{a}	250,79 ± 29,99^{c}	250,36 ± 32,90^{b}	238,27± 24,29^{d}
	Average	214,59 ± 30,50	231,51 ± 24,21	231,51 ± 29,84	

Description: Different superscripts in the columns (a, b, c, and d) and in the rows (e, f, g, and h) indicate a highly significant effect (P<0.01) of formalin concentration on the water absorption (%) of tanned fur on rabbit skin.

Treatments using 10%, 15%, 20%, and 25% formalin demonstrated significantly different effects (P<0.01) on water absorption. The average water absorption values for F1, F2, F3, and F4 were 192.12 ± 30.39%, 217.95 ± 25.67%, 237.85 ± 32.39%, and 238.27 ± 24.29%, respectively, measured over a 2-hour period. All four treatments met the Indonesian National Standard (SNI 06-1752-1990) for "samoa" tanned leather, which stipulates a minimum water absorption value of 100% within 2 hours. Variations in water absorption can be influenced by hair thickness and fat content in the hide. According to Prayitno and Kasudjiastuti (2017), high water absorption values may occur when

hydrophilic tanning agents are used.

Compared with previous studies, this research using formalin resulted in water absorption values of 192.12%, 217.95%, 237.85%, and 238.27% for concentrations of 10%, 15%, 20%, and 25%, respectively. Anggraimi and Maryati (2023) reported that water absorption of hairy rabbit hides tanned with castor oil at concentrations of 15%, 20%, and 25% reached 469.45%, 333.62%, and 405.86%, respectively. Meanwhile, Amertaningtyas et al. (2024) found that aluminum sulfate at levels of 250g, 300g, 350g, and 400g yielded 2-hour water absorption values of 174.52%, 162.83%, 185.81%, and 174.57%, respectively. These results indicate that the type and concentration of tanning agent significantly affect the water absorption capacity of tanned rabbit hides under 2-hour testing conditions.

Additionally, different storage durations of 5, 10, and 15 weeks did not result in significant differences ($P>0.05$) in water absorption, with average values of 214.59%, 231.51%, and 220.04%, respectively. This may be attributed to the characteristics of the tanning agents. According to Pahlawan et al. (2021), salt used during the pickling stage is easily absorbed into the skin tissue and prevents swelling and deterioration due to its acidic properties. Moreover, Dewi (2019) noted that formalin, as a preservative, can protect tanned hides from environmental exposure and slow down evaporation. These factors may explain why formalin-treated hides maintained their quality during the 15-week storage period.

CONCLUSION

This study concludes that the optimal concentration of formalin for tanning hairy rabbit hides is 10%, which produced favorable results across several parameters: elasticity of 29.76%, tensile strength of 36.63 N/mm², hair lost score of 4.15 (slightly lost), and water absorption of 192.12%. Storage duration had no significant effect on the elasticity, tensile strength, hair lost, or water absorption of the tanned hides.

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