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Use of Lime Suspension and Lime Water as a Solution in Goat Skin Appliance as an Initiative for Implementing Clean Products

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Abstract. The study aimed to compare the effects of using lime suspension and saturated lime water in the goat skin liming process, focusing on the properties of the solutions and the characteristics of the skin. Liming was conducted at 26 °C for 60 minutes using a stirrer, with a skin-to-solution ratio of 1:10 and 2 g $Ca(OH)_2$ per 100 ml water. The initial pH values were 11.69 (lime suspension) and 11.62 (lime water), while the initial conductivity was 7439 μS/cm and 4971 μS/cm, respectively. Observed variables included pH, TDS, electrical conductivity, precipitate weight, and skin weight gain and characteristics. Results showed no significant difference in pH between treatments during liming ($p = 0.075$) and no significant difference in skin weight gain ($p = 0.067$). However, solution conductivity differed significantly ($p = 0.002$), with lime suspension producing higher conductivity values. At the end of liming, precipitate weights were 1.53 g for lime suspension and 0.04 g for lime water, indicating more undissolved material in the suspension method. Skin characteristics, such as color, pH, and elasticity, were similar for both treatments. The findings suggest that while lime suspension and lime water produce comparable results in terms of pH and skin weight gain, they differ in conductivity and precipitate formation. The reduced precipitate in lime water indicates a cleaner process, which could contribute to clean production practices in the leather industry by minimizing solid waste without compromising leather quality. This research provides a scientific basis for considering saturated lime water as an alternative to lime suspension, potentially reducing environmental impact while maintaining product performance in goat skin leather processing.

Keywords: goat skin liming; liming; suspension lime; water lime

1. Introduction

Leather processing involves converting raw leather into tanned, ready-to-use material. It is a complex process that requires quite a long time, typically 12 to 15 days, to complete a single leather product. Generally, the leather tanning process can be divided into four stages or categories: wet house or beam house operations, tanning, post-tanning or coloring stage, and finishing. (Purnomo,

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2015 and Hermawan, et al., 2014).

Liming is one of the processes in the beam house operation stage. The purposes of calcifying the skin include removing hair and epidermis, removing remaining inter fiber or interfibrillary components, and opening up the skin fiber structure, or opening up and saponifying some of the skin's natural fat (Buljan and Kráľ, 2019 and Anonymous, 2007).

The whitening process is usually carried out simultaneously with the hair removal or unhairing process, which has the characteristic; consuming lots of water and using materials, such as: slaked lime or slake slime ($Ca(OH)_2$), alkali sulfide, thiol alcohol, enzymes, and surfactants. At this time, a separation began to be made between the liming and unhairing processes related to the implementation of clean product technology or green manufacturing. (Covington, 2009 and Buljan and Kráľ, 2019).

In general, the skin whitening process uses $Ca(OH)_2$ at a concentration of 3%-3.5% by weight, calculated from the skin's weight, to achieve the goal of skin whitening while maintaining the pH of the lime solution in the range of 12-13. Therefore, the lime solution typically used is in the form of a lime suspension, where, at the end of the liming process, some lime remains, which does not bind to the leather fibers and settles (Sharphouse, 2009; and Sarkar, 1991).

At the end of the liming process, chemicals are added that do not bind to the leather fibers and will contribute as liquid waste pollutants, including lime, a product of feather protein degradation, and high pH (Buljan and Kráľ, 2019). Alvarez (2016) reported that $Ca(OH)_2$ is only slightly soluble in water and will decompose into ions after reaching saturation conditions, by ionization.

$$Ca(OH)_{2\,(s)} \leftrightarrow Ca^{2+}{}_{(aq)} + 2OH^{-}{}_{(aq)} \qquad (1)$$

The solubility product or Ksp is the product of the concentration of electrolyte ions in an exactly saturated solution, and Ksp is also related to the molar solubility [S] of compounds that are slightly soluble in water. The K_{sp} value of $Ca(OH)_2$ is 5.5 .10 × 6. (Ibale, 2013 and Shiver et.al., 1999). Based on Equation 1, the K_{sp} $Ca(OH)_2$ as shown in Equation 2 to Equation 3.

$$K_{sp}\ Ca(OH)_2 = [Ca^{2+}_{(aq)}]\ [OH^{-}_{(aq)}]^2 \quad (2)$$

$$K_{sp}\ Ca(OH)_2 = [S]\ [2S]^2 = 4S^3 \quad (3)$$

The solubility of $Ca(OH)_2$ is a function of temperature, where the higher the temperature, the lower the solubility of quenched lime (Saipullaev, 2020), and this relationship is presented in Table 1. Electrical conductivity is a measure of a solution's ability to conduct an electric current. The electric current in the solution is caused by the ions contained in the liquid; the electrical conductivity value only shows the total ion concentration in the solution. The dissolved solids also influence the number of ions in a solution. The greater the amount of dissolved solids in the solution, the greater the number of ions in the solution, so the electrical conductivity value will also be greater. There is a relationship between the amount of dissolved solids expressed and the electrical conductivity value (Toruan et al., 2023).

Table 1. Solubility of lime at various temperatures (Anonymous, 2007)

Temperature, ^{0}C	**Solubility $Ca(OH)_2$ $g.L^{-1}$**	**Temperature, ^{0}C**	**Solubility $Ca(OH)_2$ $g.L^{-1}$**
0	1,72	25	1,49
10	1,66	30	1,44
15	1,62	40	1,32
20	1,56	50	1,21

This research supports the application of a separation method between the unhairing process and the liming process for leather, which is upstream of implementing clean product technology or green manufacturing in the leather liming process. This research aims to investigate the differences between the use of lime suspension and lime water, or saturated lime water, as a lime solution in the whitewashing process of goat skin, by observing the characteristics of the lime solution and the results on the pelt.

2. Methods

2.1. Materials

The research method used in this research is an experimental method, which consists of several continuous stages. The materials used in the goat skin whitening process consist of leather raw materials and auxiliary chemicals. The initial raw material for leather is dry, durable goat skin, which has first been washed and soaked, and the hair removed manually. The process of whitening goat skin is carried out using auxiliary chemicals, including slaked lime powder or calcium hydroxide ($Ca(OH)_2$), lime suspension, lime water, and phenolphthalein (PP) indicator.

The equipment used in this research consisted of tools for the whitewashing process of goat skin and tools for testing or characterizing lime solutions and lime-treated skin. Equipment for the goat skin whitening process includes a 100 ml beaker equipped with a mechanical stirrer. Testing and characterization equipment in the form of: pH meter, total dissolved solids (TDS), liquid conductometer (EC meter), and digital balance.

2.2. Sample preparation

Schematic diagram illustrating the research design used in this study is shown in Figure 1. The implementation of this research was divided into three stages, namely; The first stage is related to making lime suspension or lime suspension and lime water or saturated lime water and studying the dissolution of $Ca(OH)_2$ in water, the second stage is related to the use of lime suspension as a liming solution as a control and the third stage is the use of lime water as a lime solution. In this study, the use of liming solution was excessive, with a ratio of skin weight to lime solution weight of 1:10, whereas a ratio of 1:2-3 is typically used. (Sharphouse, 2009, and Sarkar, 1991).

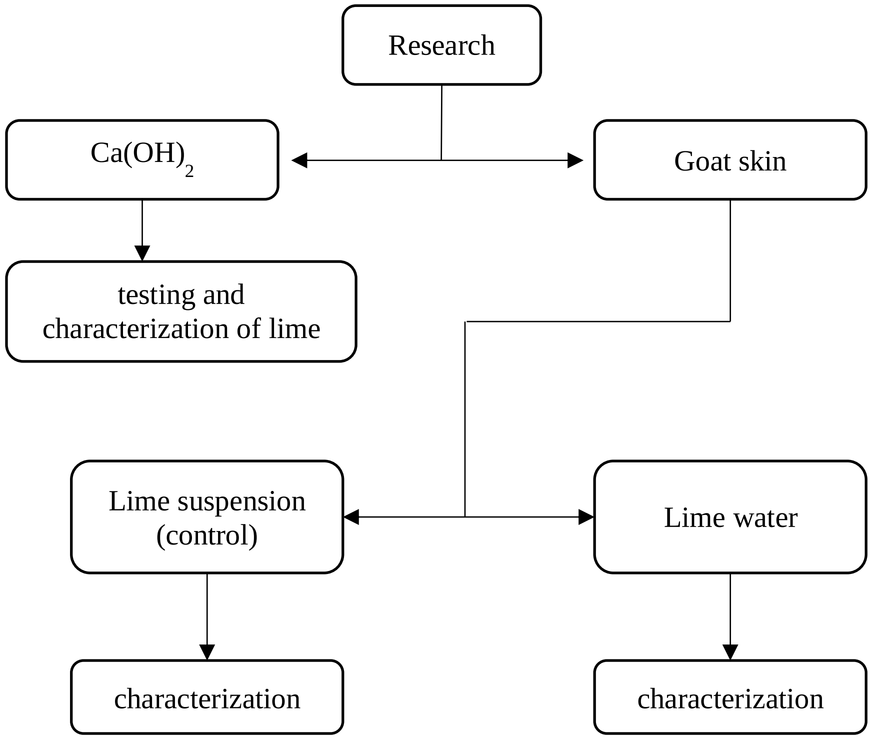

Figure 1. Presents a schematic diagram illustrating the research design used in this study

Making a lime suspension or lime water is done by dissolving 2 grams of $Ca(OH)_2$ in 100 ml of water and then stirring. The differences in manufacture between lime suspension and lime water are listed in Table 2. A schematic diagram showing the setup of the research equipment used in this study is presented in Figure 2.

Table 2. Differences in making liming solutions

Treatment	**Lime suspension**	**Lime water**
24 hours depositions	no	yes
Decantation	no	yes

The study of $Ca(OH)_2$ dissolution in water was conducted in the first stage by adding 0, ½, 1, 1 ½, and 2 grams of $Ca(OH)_2$ gradually to 100 grams of water in a beaker. Next, for each addition of $Ca(OH)_2$, stirring was performed for 5 minutes, followed by a 24-hour settling period. At the end of the stirring, data is taken as a lime suspension, and at the end of settling, the raffinate is taken as a lime water sample. The data taken are pH, total dissolved solids (TDS), and conductivity of the lime solution.

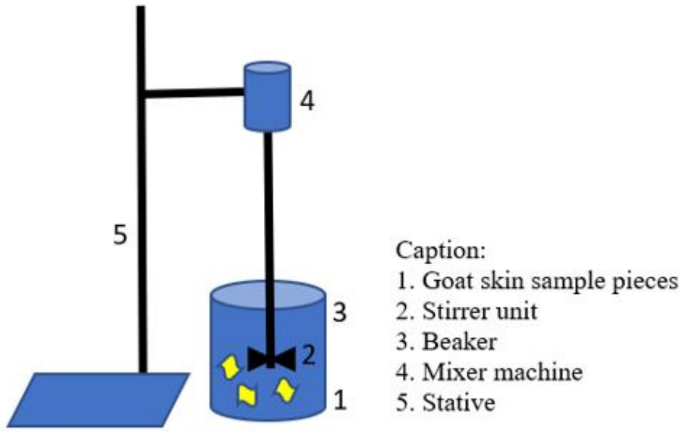

Figure 2. Shows a schematic diagram illustrating the arrangement of the research equipment used in this study

The second stage of the research involved adding 100 ml of lime suspension to a beaker, followed by the addition of 10 grams of goat skin to the lime suspension and stirring for 1 hour (as an experimental control). Every 15 minutes, measurements were taken, including pH, TDS value, electrical conductivity of the lime solution, and skin weight. At the end of the liming process, lime suspension is deposited for 24 hours. The lime suspension used in the second stage is prepared according to the specifications outlined in Table 2. The third stage of research involved adding 100 ml of lime water to a beaker, followed by the addition of 10 grams of goat skin, which was then stirred for 1 hour. Every 15-minute time interval, measurements were taken, including pH, TDS value, electrical conductivity of the lime solution, and skin weight. At the end of the soaking process, the lime water is left to stand for 24 hours. The lime water used in the third stage is made by referring to Table 2.

Next, a discussion of research related to; goat skin resulting from the liming process, the effect of adding lime on the pH and TDS of the lime solution in the $Ca(OH)_2$ dissolution study, measuring pH, TDS and electrical conductivity in lime suspension and lime water and the increase in skin weight during the liming process, as well as $Ca(OH)_2$ deposits at the end of the liming process.

2.3. Characterization

When the experiment was carried out using either $Ca(OH)_2$ dissolution studies, the use of lime suspension, or lime water, several tests were conducted. Tests in the $Ca(OH)_2$ dissolution study include pH, total dissolved solids (TDS), and conductivity of the lime solution, as well as the color of the lime solution. Meanwhile, tests on the use of lime suspension and lime water include pH, total dissolved solids (TDS), and conductivity of the lime solution, as well as the recovery of lime deposits. Followed by characterization of the skin, including skin weight, skin color, smoothness, swelling, and cross-sectional color of goat skin after adding the PP indicator.

The percentage change in weight of the goat skin resulting from liming was carried out by weighing the calcified skin every 15 minutes and comparing it with the initial skin weight. Calculation of the percentage change in skin weight is according to Equation 4.

$$Weight\ change\ (\%) = \frac{chalky\ skin\ weight - initial\ skin\ weight}{initial\ skin\ weight} \times 100\% \tag{4}$$

The weighing of the solids that settle at the end of the liming process is carried out after the solids have been dried for 5 hours at a temperature of 500 °C. Calculation of the percentage of $Ca(OH)_2$ deposits at the end of the liming process is according to Equation 5.

$$Ca(OH)_2\ precipitated\ (\%) = \frac{Weight\ of\ Ca(OH)_2\ precipitated}{initial\ weight\ of\ Ca(OH)_2} \times 100\% \tag{5}$$

3. Results and discussion

3.1. Calcified goat skin

Photos of the skin at the end of the calcification process and a cross-section of the skin after the PP indicator was dropped are presented in Figure 3. On goat skin resulting from the whitening process, characterization or process control was carried out using organoleptic tests and observation of the pH of the cross-section of the skin. The results are presented in Table 3.

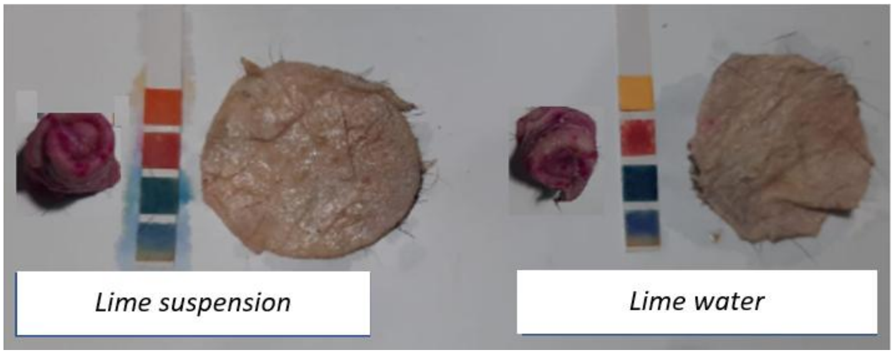

Figure 3. Photo of the cross-sectional color of the leather after the PP indicator was dropped and the grain of the goat leather resulting from the whitening process

Table 3. Organoleptic test results of goat skin and lime solution

Character	Lime suspension (Control)	Lime water
Skin color	White	Whiter and cleaner
Leather cross-section color + PP indicator	Red	Red
Skin swelling	Swollen	Swollen
The slippery nature of the skin	the skin feels slippery and there are coarse grains of $Ca(OH)_2$ residue	skin feels slippery without $Ca(OH)_2$ grains

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The skin whitening process in the study was carried out at a temperature of 26 °C for 60 minutes. This is by the statements by Covinton (2009) and John (1996), who recommend a liming temperature below 300 °C or 280 °C to avoid denaturation of skin proteins.

Goat skin resulting from the liming process using lime water has a white skin color and is cleaner and smoother than using lime suspension. Meanwhile, the organoleptic characteristics of goat skin, both in the form of swelling phenomena and the cross-sectional pH of the skin, did not show significant differences. John (1996) states that control of the calcification process includes checking for swelling and plumping, as well as organoleptic assessments of the skin.

3.2. *Effect of adding $Ca(OH)_2$ on pH and TDS in $Ca(OH)_2$ dissolution studies*

The test results of the impact of adding $Ca(OH)_2$ on pH and TDS in the Ca(OH)2 dissolution study are presented in Figure 4. Based on Figure 4, the effect of adding 0 to 2 grams of $Ca(OH)_2$ on the pH and TDS of the lime solution in the $Ca(OH)_2$ dissolution study resulted in the pH of the lime water increasing from 6.64 to 11.62 and the TDS rising from 447 ppm to 2489 ppm. Meanwhile, the lime suspension resulted in the pH of the lime suspension rising from 6.64 to 11.69 and the TDS increasing from 447 ppm to 3714 ppm.

Referring to Equation 1, the greater the amount of $Ca(OH)_2$ dissolved in water, the greater the concentration of hydroxide ions (OH-) in the lime solution, thereby increasing the pH. (Ibale, 2013) Although research data indicates that adding 0.5 to 2 grams of $Ca(OH)_2$ to the lime solution tends to maintain a constant pH. At a temperature of 25 °C, $Ca(OH)_2$ has a solubility of 0.022 mol/L or 1.49 g/L and a pH of approximately 12.6. In this experiment, the maximum pH of the lime solution was 11.62 for lime water and 11.69 for lime suspension. The difference in pH value between the calculation results and the research results could be caused by differences in data on Ksp $Ca(OH)_2$ values, assumptions in pH calculations, or accuracy of readings from pH meters.

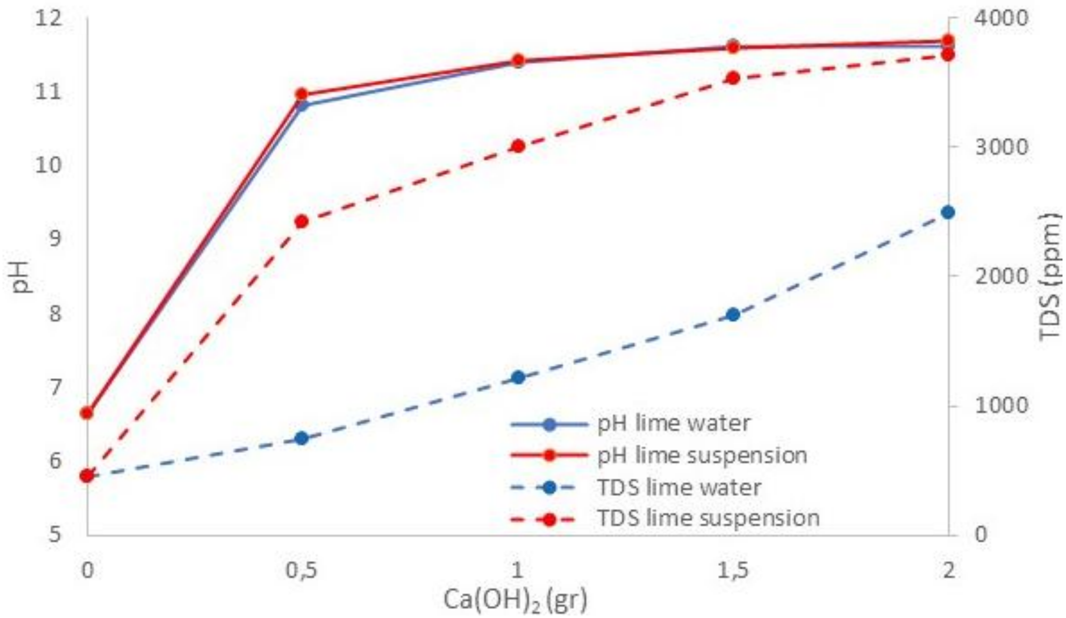

Figure 4. Effect of adding $Ca(OH)_2$ on pH and TDS in dissolution studies.

The results of the observations showed that when 0.5 grams of $Ca(OH)_2$ was added to 100 mL of water, $Ca(OH)_2$ deposits appeared at the bottom of the beaker. This is by the reference solubility data which shows that the solubility value of $Ca(OH)_2$ has been exceeded, namely exceeding 1.49 grams/liter or 0.149 grams/100 ml. (Alvarez, 2016) The total dissolved solid value in the lime dissolution study increased with increasing $Ca(OH)_2$ added, this was caused by an increase in the concentration of ions or dissolved particles resulting from the dissolution of $Ca(OH)_2$.

3.3. *pH of lime suspension and lime water and percentage change in skin weight in the skin calcification process*

Based on Figure 5, it is evident that during the liming process, the pH decreased when using lime suspension and lime water, while the percentage of skin weight increase increased. In the liming process using lime suspension for 60 minutes, the pH decreased from 11.69 to 11.61, and the skin weight increased by 67.71%. Meanwhile, when using lime water, the pH decreases from 11.62 to 11.52, and the skin weight rises by 48.17%. The calculation results show that during skin whitening, there is no significant difference in pH between the lime suspension and the lime water. Parametric statistical analysis of the T test with a value of ∝ 0.05 produces a p value of 0.075.

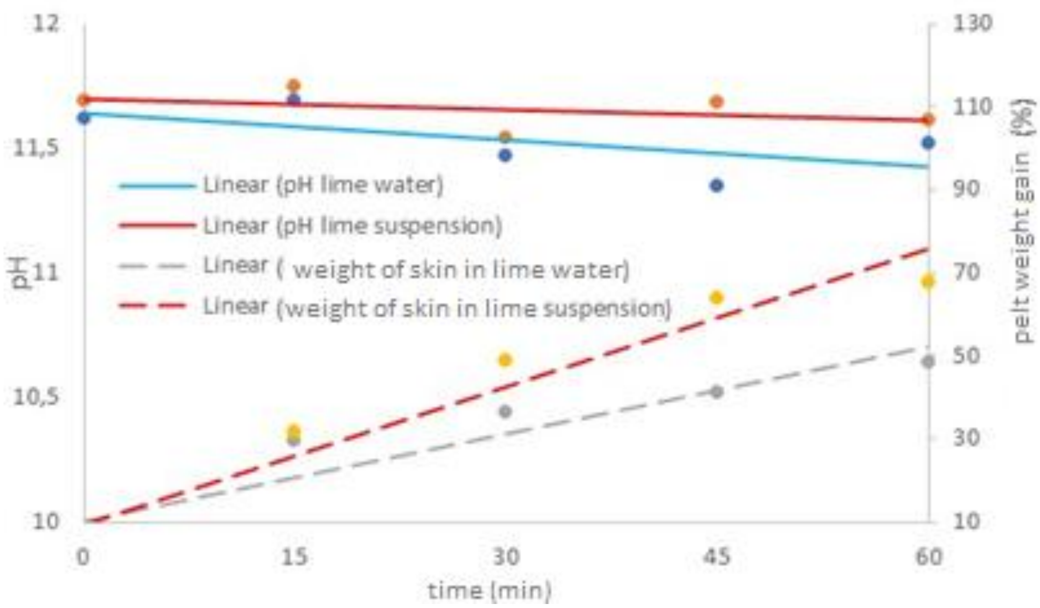

Figure 5. Effect of liming time on the pH of lime suspension and lime water and the percentage of skin weight gain

The pH of the lime suspension and lime water during liming experienced a slight decrease. This is because the pH range of goat skin initially, or before liming, is around 4.5-5.5. Therefore, to increase the pH of the skin during liming, a source of hydroxide (OH-) is needed, which comes from a lime solution. This causes the pH of the lime solution to decrease.

The percentage of skin weight gain during skin whitening shows that there is no significant difference between the use of lime suspension and lime water. Parametric statistical analysis of the T test with a value of ∝ 0.05 produces a p value of 0.067. Skin at pH conditions outside the electrical iso point will experience swelling, characterized by increased weight and thickening. This is due to the entry of water into the skin fibers due to the charge effect and lyotropic swelling. (Thostensen, 1991, and Covington, 2009).

3.4. *TDS and electrical conductivity of lime suspension and lime water during the skin whitening process*

The TDS test results and electrical conductivity of lime suspension and lime water during the lime process are presented in Figure 6. Based on Figure 6, during the liming process, the TDS value and electrical conductivity of lime suspension and lime water increased. When using lime suspension, the TDS value increases from 4971 ppm to 7627 ppm, and electrical conductivity increases from 7439 μS/cm to 8716 μS/cm. Meanwhile, when using lime water, the TDS increased from 2489 ppm to 3813 ppm, and the electrical conductivity increased from 3714 μS/cm to 4346 μS/cm. This is based on the research results of Irwan et al. (2016 which states that there is a positive relationship between an increase in TDS and an increase in the electrical conductivity value of the solution. The greater the amount of dissolved solids in the solution, the greater the number of ions in the solution, so the electrical conductivity value will also be greater.

The conductivity of the solution during skin whitening shows a significant difference between the use of lime suspension and lime water. Statistical analysis of the T test with a value of $\propto 0.05$ produces a p-value of 0.02. The TDS and conductivity of using lime suspension and lime water increased during skin whitening, but after 30 minutes tended to remain constant, because equilibrium had begun to occur between the skin and the lime solution. Electrical conductivity is a measure of the ability of a solution to conduct electric current, carried by the ions contained in the liquid.

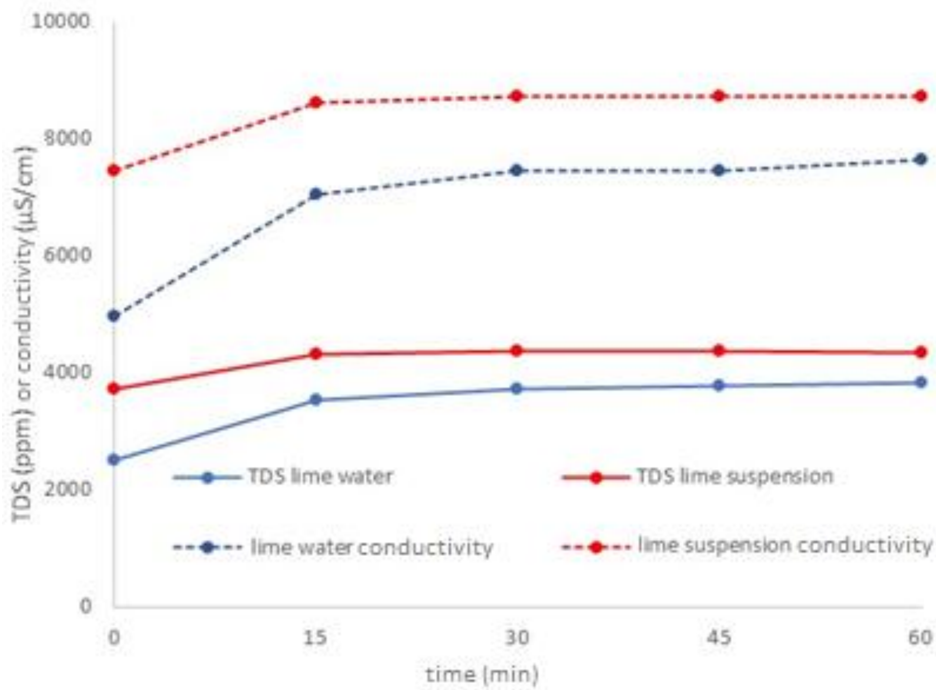

Figure 6. TDS results and electrical conductivity of the lime solution during the liming process

3.5. *$Ca(OH)_2$ Deposition at the End of the Skin Calcification Process*

The weight of the $Ca(OH)_2$ precipitate at the end of the liming process is presented in Table 4. Based on Table 4, it is evident that the $Ca(OH)_2$ deposits remaining at the end of the skin whitening process using a lime suspension still weigh 1.53 grams, or 76.5% of the lime used, namely 2 grams. This indicates that the remaining lime solution, when using a lime suspension, has a high $Ca(OH)_2$ pollutant load. On the other hand, using lime water is more environmentally friendly. (Anonymous, 2003) The 0.04 grams of sediment in lime water is not residual $Ca(OH)_2$, but is thought to be due to the dissolution of non-structural proteins and dermatan sulfate resulting from hydrolytic action at high pH. (Covington, 2009).

Based on Figure 7, at the end of the liming process, the color and turbidity of the lime water solution appear more transparent than when using lime suspension. This is based on experimental data, which shows that the TDS, conductivity, and $Ca(OH)_2$ deposition values when using lime water are relatively lower than when using lime suspension.

Table 4. Weight of $Ca(OH)_2$ precipitate

Lime solution	Weight of $Ca(OH)_2$ precipitate (gr)	Percentage of $Ca(OH)_2$ sediment (%)
Lime suspension	1,53	76,5
Lime water	0,04*	-

*Not as $Ca(OH)_2$ precipitated

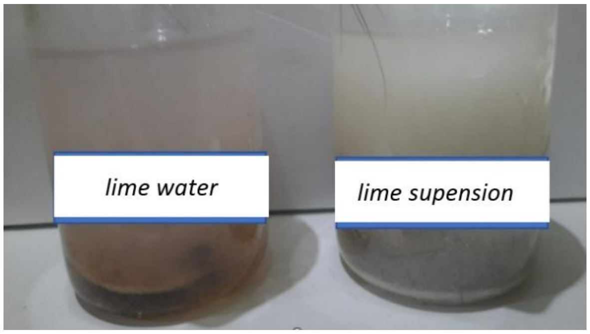

Figure 7. Color and turbidity of lime water and lime suspension at the end of the skin whitening process

4. Conclusions

This study investigated the differences between using lime suspension and saturated lime water as liming solutions in the goat skin whitewashing process, focusing on both solution characteristics and the resulting pelt quality. The findings indicate that the use of lime suspension and lime water yields no significant differences in solution pH or skin weight gain, suggesting comparable liming effectiveness in these aspects. However, significant differences were observed in electrical conductivity, with the lime suspension showing higher values, and in precipitate formation, where the lime suspension produced substantially more undissolved material than the lime water. Despite these differences, the organoleptic characteristics of the pelts, including color, pH, and elasticity, remained similar for both treatments. Overall, saturated lime water demonstrates potential as a cleaner alternative to lime suspension, reducing solid residues in the process while maintaining comparable leather quality.

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