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Comparative Evaluation of Hydrochloric and Acetic Acid Pretreatments for Chicken-Skin Gelatin and Its Application in Edible Films

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Abstract

Chicken skin is a collagen-rich poultry by-product with potential for gelatin production and biodegradable edible films. This preliminary comparative study evaluated gelatin obtained from broiler chicken skin pretreated with 4% hydrochloric acid (HCl) or 3% acetic acid (CH_3COOH) and its application in edible films. Gelatin yield was calculated as the mass of dried gelatin relative to the initial wet weight of chicken skin. The gelatin was characterized using Fourier-transform infrared (FTIR) spectroscopy, and edible films were prepared using 2% gelatin, 1% carboxymethyl cellulose (CMC), and 1 mL glycerol. Based on an initial wet chicken-skin weight of 1,000 g per treatment, the recorded gelatin yields were 5.4% for HCl and 5.6% for CH_3COOH. Both gelatin samples exhibited characteristic Amide A, I, II, and III absorption bands. The HCl-derived film had a thickness of 0.098 ± 0.002 mm and a tensile strength of 29.59 ± 0.34 MPa, whereas the CH_3COOH-derived film had a thickness of 0.104 ± 0.002 mm and a tensile strength of 25.00 ± 0.17 MPa. Both films were transparent, with the HCl-derived film described as slightly rigid and the CH_3COOH-derived film as slightly elastic. However, each acid pretreatment was applied to only one gelatin-extraction batch, and the acid type was confounded with acid concentration. Therefore, the observed differences are descriptive and cannot establish the superiority of either acid treatment. Further studies using independently replicated extractions and standardized treatment conditions are needed to confirm these preliminary findings.

Keywords: Acetic acid, chicken skin, edible film, FTIR, gelatin, hydrochloric acid, tensile strength.

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1. Introduction

Gelatin is a protein-based biopolymer obtained through the partial hydrolysis of collagen and has been widely utilized in food, pharmaceutical, biomedical, and packaging applications because of its film-forming ability, biodegradability, and functional properties. Growing interest in alternative gelatin sources has encouraged the utilization of animal by-products that are traditionally underused or discarded. In Indonesia, where halal considerations are important in food-related applications, the development of non-porcine gelatin is particularly relevant. The use of gelatin derived from pigs may raise religious concerns among Muslim consumers, making gelatin from alternative animal sources, including chicken, a potential option. However, the halal status of chicken-derived gelatin also depends on the origin of the raw materials and compliance with applicable halal slaughtering and processing requirements. Among poultry-processing by-products, chicken skin represents a potentially valuable collagen-rich material for gelatin production. Previous research demonstrated that chicken-skin gelatin can exhibit favorable physicochemical, rheological, and thermal characteristics and has considerable potential as an alternative to gelatin derived from conventional mammalian sources (Mhd Sarbon et al., 2013). More recent work has also confirmed the feasibility of producing chicken-skin gelatin using both conventional and intensified extraction approaches, highlighting the potential of poultry-derived gelatin for food and other functional applications (Alias & Mhd Sarbon, 2019; Işık et al., 2024;).

The conversion of collagen-rich chicken skin into gelatin generally involves pretreatment followed by extraction. Acid pretreatment is particularly important because it facilitates swelling and structural disruption of collagenous tissues, thereby promoting subsequent gelatin recovery. The characteristics of the resulting gelatin can be influenced by the type and concentration of acid as well as by the subsequent extraction conditions. Previous studies on chicken-skin gelatin have demonstrated that processing conditions can affect gelatin yield and its physicochemical and functional properties (Mhd Sarbon et al., 2013). More recently, Işık et al. (2024) showed that changes in extraction technology can influence the yield, gel strength, thermal characteristics, amino-acid composition, and functional properties of chicken-skin gelatin. These findings indicate that the pretreatment and extraction stage is an important determinant of the subsequent performance of chicken-derived gelatin.

In addition to its direct use as a food ingredient, gelatin has attracted considerable attention as a film-forming biopolymer for edible and biodegradable packaging. Gelatin molecules can form continuous polymeric networks capable of producing flexible films, making gelatin a promising material for reducing dependence on conventional petroleum-derived packaging materials. However, gelatin films generally exhibit limitations in mechanical strength and moisture resistance, and their performance depends strongly on gelatin source, formulation, plasticizer concentration, and interactions with other polymers (Said & Sarbon, 2022). The physical and mechanical characteristics of gelatin-based films, including thickness, tensile strength, and elongation, are therefore important parameters for assessing their suitability for packaging applications (Said & Sarbon, 2022).

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Chicken-skin gelatin has previously been investigated specifically as a film-forming material. Soo and Sarbon (2018), for example, developed edible films from chicken-skin gelatin and demonstrated that incorporation of rice flour could modify several film properties (Soo & Sarbon, 2018). This confirms the feasibility of converting chicken-processing by-products into functional film-forming materials rather than treating them solely as waste. More broadly, chemical literacy can support understanding of food-related issues and informed decisions about nutritious and balanced food consumption (Simanjuntak, 2020). The application of chicken-derived gelatin in edible films is therefore relevant not only from a materials perspective but also from a waste-valorization standpoint.

The properties of gelatin films can be further modified through the incorporation of other film-forming and plasticizing components. Carboxymethyl cellulose (CMC), a water-soluble cellulose derivative, can interact with protein-based polymers and modify the structural and mechanical characteristics of composite films. The incorporation of polysaccharides into gelatin matrices has been reported to influence the mechanical and physical properties of gelatin-based films (Tabari, 2017). Similarly, glycerol is widely used as a plasticizer in gelatin films because it modifies intermolecular interactions within the polymer network and generally improves film flexibility, although its concentration can also influence tensile strength and other functional properties (Vanin et al., 2005). Consequently, the combination of gelatin, CMC, and glycerol provides a practical approach for developing edible film matrices with modified physical and mechanical characteristics.

Despite the increasing number of studies on chicken-skin gelatin, the relationship between acid pretreatment and the subsequent performance of chicken-skin gelatin in edible-film formation remains worthy of further investigation. In particular, direct comparisons between mineral-acid and organic-acid pretreatments under practical laboratory conditions can provide useful information regarding the balance between gelatin recovery and film performance. A comparison of hydrochloric acid (HCl) and acetic acid (CH_3COOH) is particularly relevant because these acids differ substantially in acid strength and chemical characteristics, potentially resulting in differences in the collagen-derived material and its subsequent film-forming behavior. However, the available literature does not justify assuming that one acid will universally produce superior gelatin; the resulting properties depend on the specific processing conditions and application requirements.

Therefore, this study aimed to comparatively evaluate chicken-skin gelatin obtained using 4% HCl and 3% CH_3COOH pretreatments and investigate the application of the resulting gelatin in edible-film preparation. The concentrations were selected as the specific pretreatment conditions investigated in this preliminary study; however, they were not identical, and the comparison was not designed to isolate the effect of acid type from that of acid concentration. The gelatin samples were evaluated based on their yield and Fourier-transform infrared (FTIR) characteristics, while the resulting films were compared in terms of physical appearance, thickness, and tensile strength. Accordingly, the findings provide a descriptive comparison of the two acid pretreatment conditions rather than a direct assessment of acid type alone or an optimization of pretreatment concentration.

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2. Methods

2.1 Materials

Chicken skin was obtained from a local market and used as the raw material for gelatin extraction. Approximately 1,000 g of chicken skin was used for each pretreatment condition. Hydrochloric acid (HCl; 37%) and acetic acid (CH_3COOH; 97%) were used as pretreatment agents. Distilled water was used in the experimental procedures, while carboxymethyl cellulose (CMC) and glycerol were used for edible-film preparation.

The available experimental records did not document the anatomical part of the chicken skin, the age and body weight of the chickens, the storage temperature and duration before processing, or the initial moisture and fat contents of the skin. These parameters were therefore not included as measured characteristics of the raw material.

2.2 Preparation of Chicken-Skin Gelatin

Fresh chicken skin from broiler chickens was used as the starting material. The gelatin preparation involved acid pretreatment using either HCl or CH_3COOH. Two pretreatment conditions were evaluated: 4% HCl and 3% CH_3COOH.

For the HCl treatment, the chicken skin was subjected to pretreatment using 4% HCl, whereas the second batch was subjected to pretreatment using 3% CH_3COOH. The laboratory records indicate that approximately 1,000 g of chicken skin was used for each treatment. Following the respective acid treatment, the material was processed to obtain gelatin, which was subsequently collected and dried.

The dried gelatin obtained from each pretreatment was weighed and the yield was calculated according to Equation (1):

$$\text{Gelatin yield (\%)} = \frac{\text{mass of dried gelatin (g)}}{\text{initial mass of chicken skin (g)}} \times 100 \qquad (1)$$

The recorded masses of dried gelatin were 54 g for the HCl treatment and 56 g for the CH_3COOH treatment, corresponding to yields of 5.4% and 5.6%, respectively.

2.3 FTIR Characterization of Gelatin

The functional groups of the resulting gelatin samples were characterized using Fourier-transform infrared (FTIR) spectroscopy. FTIR spectra were recorded using a PerkinElmer Spectrum IR instrument. The spectra were obtained over the wavenumber range of approximately 4000–600 cm^{-1}.

The characteristic absorption bands associated with the protein structure of gelatin were identified and compared between the HCl- and CH_3COOH-derived gelatin samples. Particular

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attention was given to the characteristic amide regions, including Amide A, Amide I, Amide II, and Amide III.

2.4 Preparation of Gelatin-Based Edible Films

Edible films were prepared separately using gelatin obtained from the HCl and CH_3COOH pretreatments. According to the laboratory records, the formulation consisted of 2% gelatin, 1% CMC, and 1 mL glycerol in 200 mL distilled water. For each formulation, 4 g gelatin and 2 g CMC were used with 200 mL distilled water and 1 mL glycerol.

Three film specimens were prepared for each gelatin formulation. The HCl-derived gelatin produced films described in the laboratory notes as transparent and slightly rigid. The CH_3COOH-derived gelatin produced transparent films described as slightly elastic.

2.5 Determination of Film Thickness

Film thickness was determined at five different points on each film specimen. Three specimens were evaluated for each gelatin formulation. The five measurements obtained from each specimen were averaged to obtain the mean thickness of that specimen.

The overall thickness for each treatment was then expressed as the mean ± standard deviation of the three specimen-level mean values.

For the HCl-derived films, the specimen means were 0.096, 0.100, and 0.098 mm, resulting in an overall thickness of:

$$0.098 \pm 0.002\ mm$$

For the CH_3COOH-derived films, the specimen means were 0.104, 0.106, and 0.102 mm, resulting in:

$$0.104 \pm 0.002\ mm$$

2.6 Tensile Strength

Tensile strength was measured for films prepared using gelatin from each acid pretreatment. The recorded tensile-strength values were 29.59 ± 0.34 MPa for the HCl-derived film and 25.00 ± 0.17 MPa for the CH_3COOH-derived film.

The available records identify three tensile-strength measurements per treatment but do not conclusively establish whether these measurements came from independently cast film specimens or repeated tests associated with the same film preparation. Accordingly, the number of independent film preparations and specimens must be distinguished from technical measurements when describing the experimental replication and interpreting the results.

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2.7 Data Analysis

The experimental data were organized according to the two acid pretreatment treatments. Film thickness and tensile-strength results were expressed as mean ± standard deviation (SD) based on the three recorded film specimens/measurements for each treatment.

Because the gelatin extraction itself was performed as one batch for each acid pretreatment, the present study was treated as a comparative experimental evaluation rather than a replicated extraction experiment. Consequently, statistical inference regarding differences between the two gelatin extraction treatments was not performed. The results were interpreted descriptively by comparing gelatin yield, FTIR characteristics, film thickness, tensile strength, and qualitative film appearance.

3. Result and Discussion

3.1. Gelatin Yield

The gelatin yield obtained from the two acid pretreatment conditions is presented in Table 1. Using 1,000 g of broiler chicken skin as the initial raw material, the 4% HCl pretreatment produced 54 g of dried gelatin, corresponding to a yield of 5.4%. In comparison, the 3% CH_3COOH pretreatment produced 56 g of dried gelatin, corresponding to a yield of 5.6%.

Table 1. Gelatin yield obtained from broiler chicken skin following acid pretreatment.

Acid pretreatment	Initial chicken skin (g)	Dried gelatin (g)	Yield (%)
4% HCl	1,000	54	5.4
3% CH_3COOH	1,000	56	5.6

The yield obtained using CH_3COOH was slightly higher than that obtained using HCl, with a difference of 0.2 percentage points. Relative to the HCl treatment, this corresponds to an approximately 3.7% higher recorded yield for the CH_3COOH treatment. The difference, however, was relatively small.

For comparison, Aykın-Dinçer et al. (2017) reported a gelatin yield of 6.5% on a wet-weight basis for broiler chicken skin. The yields obtained in the present study were lower than this reported value by 1.1 percentage points for the HCl treatment and 0.9 percentage points for the CH_3COOH treatment. However, differences in raw-material characteristics and extraction procedures may contribute to variation among studies, so the values should not be interpreted as a direct comparison of extraction efficiency.

The observed difference in gelatin recovery may be related to differences in the interaction of the two acids with the collagenous matrix of chicken skin during pretreatment. Acid pretreatment

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facilitates the disruption and swelling of collagen-containing tissues, thereby facilitating the subsequent conversion and recovery of gelatin. However, the present study evaluated only one concentration of each acid and one extraction batch for each treatment. Therefore, the observed difference in yield should be regarded as a descriptive comparison between the two specific treatments, rather than evidence that CH_3COOH provides a statistically superior yield to HCl.

The difference of 0.2 percentage points represents only 2 g of dried gelatin per 1,000 g of initial wet chicken skin. Because only one extraction batch was conducted for each treatment, the variability associated with extraction, material handling, drying, and weighing could not be estimated from independent replicates. The available data are insufficient to determine whether this difference exceeds the uncertainty of the weighing procedure or process-related losses. Accordingly, the slightly higher recorded yield for CH_3COOH should not be interpreted as evidence of a reproducible improvement in gelatin recovery.

The relatively similar yields indicate that dried gelatin was recovered under both pretreatment conditions investigated. Importantly, gelatin yield alone does not necessarily reflect the functional quality of the resulting gelatin. Therefore, further comparison based on FTIR characteristics and the performance of the resulting edible films is necessary. Nevertheless, FTIR analysis and film properties alone cannot establish comprehensive gelatin quality without additional measurements of gel strength, viscosity, pH, moisture, ash, and protein content.

3.2. FTIR Characteristics of Chicken-Skin Gelatin

FTIR spectroscopy was used to characterize the functional groups present in the gelatin obtained after pretreatment with 4% HCl and 3% CH_3COOH. The FTIR spectra of the two gelatin samples are presented in Figure 2.

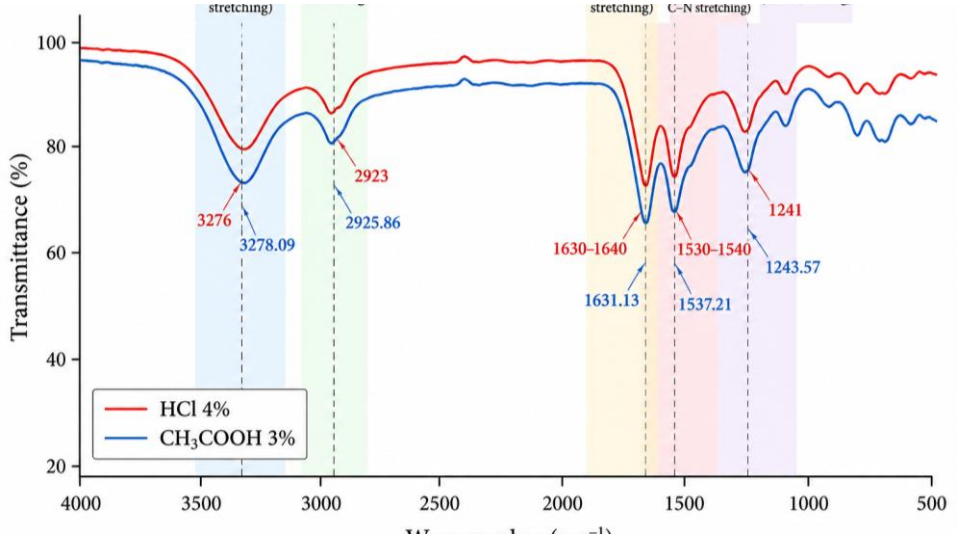


Figure 1. FTIR spectra of chicken-skin gelatin obtained using 4% HCl and 3% CH_3COOH pretreatments.

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Both gelatin samples exhibited absorption bands characteristic of proteinaceous gelatin, particularly in the Amide A, Amide I, Amide II, and Amide III regions. Similar FTIR profiles have been reported for gelatin obtained from chicken skin and other poultry-derived collagenous materials, confirming the characteristic protein structure of the extracted gelatin (Mhd Sarbon et al., 2013), (Puspawati et al., 2021).

The HCl-derived gelatin exhibited a broad absorption band at approximately 3276 cm^{-1}, corresponding primarily to N–H stretching vibrations with possible contributions from O–H stretching. The absorption band around 2923 cm^{-1} was associated with C–H stretching vibrations. In the amide region, the band observed at approximately 1630–1640 cm^{-1} was assigned to Amide I, which is predominantly associated with C=O stretching of peptide bonds. The band around 1530–1540 cm^{-1} corresponded to Amide II, generally associated with N–H bending and C–N stretching, while the band around 1241 cm^{-1} was located in the Amide III region. Similar characteristic bands have been reported for chicken-derived gelatin (Işık et al., 2024).

The CH_3COOH-derived gelatin showed a comparable spectral pattern, with characteristic bands at 3278.09, 2925.86, 1631.13, 1537.21, and 1243.57 cm^{-1}. The close similarity of the major absorption bands between the two samples indicates that both acid pretreatments produced gelatin with comparable characteristic protein functional groups. Comparable FTIR profiles have also been reported for chicken-skin gelatin obtained using different extraction approaches (Işık et al., 2024), (Cansu & Boran, 2022).

The relatively small differences in peak positions between the two treatments may reflect differences in the molecular environment of the functional groups. However, the present FTIR data do not provide sufficient evidence to conclude that the two pretreatments generated fundamentally different protein structures. Therefore, the FTIR results are interpreted primarily as confirmation of the characteristic gelatin functional groups rather than as evidence of specific molecular conformational changes.

Table 2. Major FTIR absorption bands of chicken-skin gelatin obtained using HCl and CH_3COOH pretreatments.

Assignment	**HCl 4% (cm^{-1})**	**CH_3COOH 3% (cm^{-1})**
Amide A / N–H and O–H stretching	~3276	3278.09
C–H stretching	~2923	2925.86
Amide I	~1630–1640	1631.13
Amide II	~1530–1540	1537.21
Amide III	~1241	1243.57

The relatively small differences in peak positions between the two treatments may reflect differences in the molecular environment of the functional groups. However, the present FTIR data do not provide sufficient evidence to conclude that the two pretreatments generated fundamentally different protein structures. Therefore, the FTIR results are interpreted primarily as confirmation

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of the characteristic gelatin functional groups rather than as evidence of specific molecular conformational changes.

3.3. Physical Characteristics of Edible Films

The gelatin obtained from the two acid pretreatment conditions was subsequently used to prepare gelatin-based edible films. The film formulations consisted of 2% gelatin, 1% CMC, distilled water, and glycerol. Three film preparations were recorded for each gelatin treatment. Based on the experimental observations, the films prepared using gelatin obtained from 4% HCl pretreatment were described as transparent and slightly rigid. In comparison, films prepared using gelatin obtained from 3% CH_3COOH pretreatment were described as transparent and slightly elastic.

Table 3. Physical characteristics of edible films prepared from chicken-skin gelatin obtained using different acid pretreatments.

Gelatin pretreatment	Gelatin	CMC	Distilled water	Glycerol	Observed physical characteristics
HCl 4%	2%	1%	200 mL	1 mL	Transparent, slightly rigid
CH_3COOH 3%	2%	1%	200 mL	1 mL	Transparent, slightly elastic

The two formulations produced transparent films, indicating that both gelatin preparations were capable of forming continuous film matrices under the preparation conditions used. A qualitative difference was observed in their apparent mechanical character: the HCl-derived gelatin film was described as slightly rigid, whereas the CH_3COOH-derived gelatin film was described as slightly elastic.

These differences may be associated with variations in the physicochemical characteristics of the gelatin obtained following the different acid pretreatments. However, the available experimental records do not contain quantitative measurements of optical transparency, flexibility, elongation, or elastic modulus. Therefore, the observations in this section are presented only as qualitative physical characteristics and should not be interpreted as quantitative evidence of differences in elasticity or transparency.

The qualitative observations provide supporting context for the mechanical properties discussed in the following section. In particular, the HCl-derived film showed a higher tensile strength than the CH_3COOH-derived film, while the latter was qualitatively described as slightly more elastic.

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3.4. Film Thickness

Film thickness is an important physical property of edible films because it can affect their mechanical performance and functional characteristics. In this study, the thickness of the films prepared from chicken-skin gelatin obtained using 4% HCl and 3% CH_3COOH pretreatments was measured at five different points for each film specimen. Three film preparations were evaluated for each pretreatment.

The individual measurements and mean thickness values are presented in Table 4.

Table 4. Thickness of edible films prepared from chicken-skin gelatin obtained using different acid pretreatments.

Gelatin pretreatment	Replicate	Point 1 (mm)	Point 2 (mm)	Point 3 (mm)	Point 4 (mm)	Point 5 (mm)	Mean (mm)
HCl 4%	1	0.09	0.1	0.09	0.1	0.1	0.096
HCl 4%	2	0.1	0.09	0.11	0.1	0.1	0.1
HCl 4%	3	0.09	0.09	0.1	0.11	0.1	0.098
HCl 4%	**Overall**	—	—	—	—	—	**0.098 ± 0.002**
CH_3COOH 3%	1	0.1	0.11	0.1	0.1	0.11	0.104
CH_3COOH 3%	2	0.11	0.1	0.11	0.11	0.1	0.106
CH_3COOH 3%	3	0.1	0.11	0.1	0.1	0.1	0.102
CH_3COOH 3%	**Overall**	—	—	—	—	—	**0.104 ± 0.002**

The CH_3COOH-derived film showed a numerically greater reported thickness than the HCl-derived film. However, the reported values and standard deviations should be checked against the original measurement records to ensure that the reported precision is supported by the instrument resolution. Because only one gelatin-extraction batch was conducted for each pretreatment condition, the observed difference in film thickness is descriptive and cannot establish a reproducible treatment effect. Furthermore, the acid type and concentration differed between treatments (4% HCl and 3% CH_3COOH), so the effect of acid type cannot be isolated.

3.5. Tensile Strength

Tensile strength was evaluated to assess the mechanical resistance of the edible films prepared from chicken-skin gelatin obtained using different acid pretreatments. The available experimental data consisted of three tensile-strength measurements for each film formulation. The results are presented in Table 5.

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Table 5. Tensile strength of edible films prepared from chicken-skin gelatin obtained using different acid pretreatments.

Gelatin pretreatment	Replicate 1 (MPa)	Replicate 2 (MPa)	Replicate 3 (MPa)	Mean ± SD (MPa)
HCl 4%	29.2	29.85	29.72	29.59 ± 0.34
CH_3COOH 3%	24.8	25.1	25.1	25.00 ± 0.17

The edible film prepared from gelatin pretreated with 4% HCl exhibited a mean tensile strength of 29.59 ± 0.34 MPa, whereas the film prepared from gelatin pretreated with 3% CH_3COOH exhibited 25.00 ± 0.17 MPa. Thus, the HCl-derived film showed a tensile strength approximately 4.59 MPa higher than the CH_3COOH-derived film, corresponding to approximately 18.4% higher tensile strength relative to the CH_3COOH-derived film.

The relatively small standard deviations within each treatment indicate that the three tensile-strength measurements were relatively close to one another. The HCl-derived film showed values ranging from 29.20 to 29.85 MPa, while the CH_3COOH-derived film showed values ranging from 24.80 to 25.10 MPa.

The higher tensile strength of the HCl-derived film is consistent with the qualitative observation reported in Section 3.3, in which the film was described as slightly rigid. In contrast, the CH_3COOH-derived film was described as slightly elastic and exhibited a lower tensile strength. These observations suggest that the two gelatin preparations produced films with different mechanical responses under tensile loading.

The higher tensile strength observed for the HCl-derived film is consistent with the general importance of gelatin matrix structure and polymer–polymer interactions in determining the mechanical properties of gelatin-based films (Said & Sarbon, 2022). Previous studies have also demonstrated that the incorporation of CMC can modify the tensile strength and extensibility of gelatin-based films, indicating that interactions between gelatin and polysaccharide components can substantially influence film performance (Tabari, 2017), (Nur Hazirah et al., 2016).

Interestingly, the CH_3COOH-derived film had a slightly greater thickness (0.104 ± 0.002 mm) than the HCl-derived film (0.098 ± 0.002 mm), but its tensile strength was lower. This indicates that, within the two formulations investigated, the difference in tensile strength was not simply associated with film thickness. The result may instead reflect differences in the characteristics of the gelatin matrix and its interactions with the other film-forming components, particularly CMC and glycerol. Glycerol acts as a plasticizer in gelatin-based films by modifying intermolecular interactions within the polymer matrix and generally increasing film flexibility, although its concentration can also influence tensile strength and other functional properties (Suderman & Sarbon, 2020).

However, because gelatin extraction using each acid was performed only once, and no independent replication of the extraction process was available, the present results should be interpreted as a comparison of the two specific formulations rather than as evidence of a statistically significant superiority of HCl. Similarly, the available dataset does not allow the effect of acid concentration to be separated from the effect of acid type.

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Overall, the results demonstrate that both acid pretreatments produced gelatin capable of forming mechanically measurable edible films, while the HCl-derived gelatin produced the higher tensile strength under the conditions investigated. This finding is particularly relevant when the intended application requires greater resistance of the film to tensile deformation.

3.6. Comparative Discussion

The results obtained in this study demonstrate that both acid pretreatments were capable of producing gelatin from broiler chicken skin and that the resulting gelatin could subsequently be incorporated into edible-film formulations. However, differences were observed between the two treatments in terms of gelatin yield, qualitative film characteristics, film thickness, and tensile strength.

The 3% CH_3COOH pretreatment produced a slightly higher gelatin yield (5.6%) than the 4% HCl pretreatment (5.4%). The difference was relatively small, amounting to only 0.2 percentage points. Because each acid treatment was performed using a single gelatin-extraction batch, this difference cannot be evaluated statistically and should not be interpreted as evidence that CH_3COOH is intrinsically more effective than HCl for gelatin recovery. Rather, it represents the yield obtained under the specific experimental conditions used in this study.

Despite the difference in acid pretreatment, the FTIR spectra of the two gelatin samples showed comparable characteristic absorption regions associated with gelatin, including Amide A, Amide I, Amide II, and Amide III. This similarity indicates that both pretreatment approaches resulted in proteinaceous materials exhibiting the characteristic functional-group profile of gelatin. The relatively small differences in peak positions suggest that the two samples had broadly similar chemical functionality based on FTIR analysis.

The differences became more apparent after the gelatin was incorporated into the edible-film matrix. The film prepared from HCl-derived gelatin had a thickness of 0.098 ± 0.002 mm, whereas the CH_3COOH-derived film had a thickness of 0.104 ± 0.002 mm. Thus, the latter was approximately 6.1% thicker. Nevertheless, the HCl-derived film exhibited substantially higher tensile strength (29.59 ± 0.34 MPa) than the CH_3COOH-derived film (25.00 ± 0.17 MPa).

The combination of thickness and tensile-strength results is noteworthy. The CH_3COOH-derived film was slightly thicker but exhibited lower tensile strength, while the HCl-derived film was slightly thinner but exhibited higher tensile strength. Therefore, film thickness alone does not appear to explain the difference in tensile strength between the two formulations. The mechanical behavior may instead be related to differences in the characteristics of the gelatin incorporated into the film matrix and its interactions with CMC and glycerol. However, this interpretation remains tentative because the available dataset does not include additional measurements such as elongation at break, Young's modulus, water vapor permeability, moisture content, or molecular-weight distribution.

The qualitative observations provide additional context. The HCl-derived film was described as transparent and slightly rigid, whereas the CH_3COOH-derived film was described as transparent and slightly elastic. The higher tensile strength of the HCl-derived film is consistent with its more rigid qualitative appearance, while the lower tensile strength of the CH_3COOH-derived film is consistent with its observed slightly elastic character. Nevertheless, these

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observations are qualitative and should not be interpreted as quantitative measurements of elasticity.

Overall, the comparison indicates that the two acid pretreatments produced gelatin with similar characteristic FTIR functional groups but resulted in edible films with different physical and mechanical characteristics. The CH_3COOH treatment gave a marginally higher gelatin yield, whereas the HCl treatment resulted in a film with lower thickness and higher tensile strength under the conditions investigated.

Table 6. Comparative characteristics of chicken-skin gelatin and edible films obtained using HCl and CH_3COOH pretreatments.

Parameter	**4% HCl**	**3% CH_3COOH**	**Comparative observation**
Gelatin yield (%)	5.4	5.6	CH_3COOH slightly higher
FTIR	Amide A, I, II, III	Amide A, I, II, III	Broadly similar
Film appearance	Transparent, slightly rigid	Transparent, slightly elastic	Qualitative difference
Film thickness (mm)	0.098 ± 0.002	0.104 ± 0.002	CH_3COOH ~6.1% higher
Tensile strength (MPa)	29.59 ± 0.34	25.00 ± 0.17	HCl ~18.4% higher

Taken together, the findings suggest that selection of acid pretreatment should depend on the intended application of the resulting gelatin. Under the specific conditions examined in this study, CH_3COOH provided a slightly higher recorded gelatin yield, while HCl-derived gelatin produced an edible film with greater tensile strength. Therefore, if mechanical resistance is prioritized, the HCl-derived gelatin showed the more favorable performance in the present comparison. This conclusion is limited to the specific concentrations and processing conditions investigated and should not be generalized to all HCl or CH_3COOH gelatin-extraction systems.

4. Conclusion

Chicken-skin gelatin was successfully obtained using both 4% HCl and 3% CH_3COOH pretreatments, with recorded yields of 5.4% and 5.6%, respectively. The slightly higher yield obtained with CH_3COOH indicates that both acid pretreatments were capable of re-covering gelatin from broiler chicken skin under the conditions investigated, although the difference in yield should be interpreted descriptively because each extraction treatment was performed as a single batch.

FTIR analysis showed comparable characteristic absorption regions for the two gela-tin samples, including Amide A, Amide I, Amide II, and Amide III, indicating broadly similar protein functional-group characteristics. The resulting gelatin was also capable of forming transparent edible films when formulated with CMC and glycerol.

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Differences were observed in the physical and mechanical properties of the resulting films. The HCl-derived film exhibited a thickness of 0.098 ± 0.002 mm and a tensile strength of 29.59 ± 0.34 MPa, whereas the CH_3COOH-derived film showed a thickness of 0.104 ± 0.002 mm and a tensile strength of 25.00 ± 0.17 MPa. The HCl-derived film was qualitatively described as slightly rigid, while the CH_3COOH-derived film was described as slightly elas-tic.

Overall, the findings indicate that both acid pretreatments can be used to produce chicken-skin gelatin suitable for edible-film formation, but they resulted in different film characteristics under the specific conditions investigated. The CH_3COOH treatment pro-duced a marginally higher gelatin yield, whereas the HCl treatment resulted in an edible film with higher tensile strength. Further studies involving independent extraction replicates and additional film characterization would be required to establish the statistically robust-ness and broader applicability of these observations

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