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Extraction and physicochemical properties of gelatin from chicken feet of different ages and its effect on sensory evaluation of the developed yogurt

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Background: This study was designed to extract and evaluate the physicochemical properties of gelatin recovered from chicken feet of different ages and its effect on sensory evaluation of the produced yogurt.

Methods: Fresh chicken feet of 12, 14 and 16 weeks old supplied by Al-watania poultry company (Saudi Arabia) were used to extract gelatin in this study.

Results: The highest gelatin yield (3.4%) was obtained from chicken feet aged 16 weeks. No significant differences ($p \geq 0.05$) were observed in both pH (6.21 to 6.34) and WHC (0.90% to 0.92%) of the gelatin. The highest gel strength value was 138.3 Bloom, which was observed in the gelatin extracted from chicken feet of 12- weeks age. The values of the melting point ranged from 29.3 to 33.9 and significantly ($p \geq 0.05$) different. The control sample had the highest lightness value (L^* 80.5), followed by gelatin from chickens aged 14 weeks (L^* 64.9), 15 weeks (L^* 63.1), and 12 weeks (L^* 60.7). The highest yellowness (b^* 25.7) was found in the gelatin from 12-week-old chicken, while the highest redness (a^* 6.1) was also observed in the 12-week-old, followed by the 14-week-old.

Conclusion: Chicken leg gelatin is a natural alternative to gelatin extracted from other sources that many people may not agree to consume. Chicken gelatin has many properties and benefits, which makes it a preferred ingredient in many industries such as yogurt manufacturers, because its molecules work to form a weak gelatinous network structure, which prevents the separation of whey. The yogurt incorporated with gelatin achieved overall acceptability scores exceeding 8 (ranging from 8.5 to 8.7), indicating the successful application of gelatin in food systems.

KEYWORDS

gelatin yield, ross chicken strain, gel viscosity, water holding capacity, sensory evaluation

1 Introduction

1.1 Gelatin and its functional properties

Gelatin is a protein derived from collagen, which is abundant in the connective tissues of all animals, including bones, cartilage, skin, and muscle tendons (Ahmad et al., 2023; Jongjareonrak et al., 2010). It can be obtained by partial hydrolysis/thermal denaturation (Siburian et al., 2020). Gelatin has several critical functional properties (Ghorani et al., 2020; Alipal et al., 2021). In addition to its role as a protein, gelatin is used in a variety of food industries due to its functional properties such as high water-binding capacity, emulsifying power, foaming ability, viscosity enhancement, elasticity, and formation of a protective layer around food (Luo et al., 2022). It has distinct properties when compared to other gel-forming polymers such as pectin and starch (Choe and Kim, 2018). When heated, gelatin transforms into a gel and can melt and solidify repeatedly without fracture (Torrejon et al., 2022).

1.2 Gelatin uses and applications

Technically, it may be used as a component to improve the flexibility, thickness, texture, and stability of food products, particularly in the manufacture of dairy, meat products and confections (Ahmad et al., 2023; Zhang et al., 2024). It is also used for packaging and film production, which provides substantial benefits in industrial applications. It is also utilized as a unique functional material in pharmaceutical, medicinal, and cosmetic products (Milano et al., 2023; Muñoz et al., 2004; Ahmad Anuar et al., 2023). Gelatin is not a complete protein because it lacks tryptophan one of the 10 necessary amino acids required (Mikhailov, 2023).

1.3 Gelatin from chicken feet

Many research works have been dedicated recently with the objectives of extracting and studying the properties of gelatin from chicken feet (Bagal-Kestwal et al., 2019; Mokrejš et al., 2019; Abedinia et al., 2020; Fatima et al., 2022; Aidat et al., 2023; Goudie et al., 2023; Harini et al., 2023; Sedaghat and Mohsenzadeh, 2022; Rather et al., 2022; Lu et al., 2022; Lamers et al., 2024; Usman et al., 2024; Al-Gheethi et al., 2021; Zambuto et al., 2024). Waste from slaughterhouses pollutes the environment and has negative effects on human health (Arshad, 2023; Ragasri and Sabumon, 2023; Wang et al., 2024). It is very important to treat the slaughterhouse waste by recycling and turning them into secondary materials that can be used (Philipp et al., 2021; Chowdhury et al., 2022; Ungureanu et al., 2024). It can be used in various food products such as yogurt, beverages, bakery, meat, and dairy products as thickening, binding, stabilizing and emulsifying agent (Usman et al., 2023; Gao et al., 2024). Saudi Arabia has a significant poultry industry, leading to abundant chicken feet as a byproduct. However, utilizing these chicken feet for gelatin extraction can reduce waste and create an alternative gelatin product.

1.4 Properties of chicken feet gelatin

The physicochemical properties of gelatin extracted from these chicken feet could vary based on chicken ages and the yogurt containing chicken feet gelatin will have enhanced sensory attributes properties such as taste, texture, color, and overall quality of the developed yogurt. Therefore, the objective of this research was to investigate the physicochemical properties of gelatin extracted from chicken feet of varying ages from a local poultry slaughterhouse in Saudi Arabia. Additionally, the study aimed to evaluate the impact of the extracted gelatin on the sensory properties of the developed yogurt.

2 Materials and methods

2.1 Materials

Fresh chicken feet of the ROSS strain were obtained from slaughterhouse of Al-watania Poultry Company, Buraidah, Qassim, Saudi Arabia and transported to the meat laboratory, Faculty of Agriculture and Food, Qassim University for gelatin extraction purpose. Chicken feet from the mentioned strain at three different ages (12, 14, and 16 weeks) which are produced and available in Al watania Poultry Compony, Saudi Arabia were chosen for extraction. Bovine standard gelatin, hydrochloric acid, sodium hydroxide and acetic acid were purchased from Sigma-Aldrich, Saudi Arabia.

2.2 Sample preparation

Chicken feet were prepared at the Meat Laboratory, College of Agriculture and Food, Qassim University according to the slightly modified method of Potti and Fahad (2017). The samples of chicken feet were first cleaned by removing the skin and fat. The samples were immersed in boiling water at 100°C for 40 min and then dried in an oven for 18 h at 50°C. Alkaline pretreatment was performed using sodium hydroxide solution (NaOH) with a concentration of 0.2% (wt/vol) to remove the non-collagenous material and mineral ions and dried in the oven. The dried samples were soaked in hydrochloric acid solution with a concentration of 89 0.2% (wt/vol at room temperature (27 ± 1°C). The soaking solution was changed every 3 days for 9 days.

2.3 Extraction of gelatin

Gelatin extraction was carried out according to the method of Ab Rahim et al. (2021). The pre-treated chicken feet were cut into small pieces and were immersed in distilled water at a temperature of 70°C in a ratio of 1:9 (w/v) in a shaking water bath and shaken for 90 min. This process was repeated three times until the chicken feet became soft and ready for extraction. After that, the samples were soaked in acetic acid at a concentration of 0.2% (v/v) for 40 min. The resulting acidic extract was then dried and washed with distilled water until the pH became neutral. The extract was filtered using two layers of cheese cloth, pour it sanitized trays individually

and dried in the oven at 105°C for 24 h. The dried gelatin obtained was ground individually using electric grinder model Moulinex, AR110027, France. The powders of the final gelatin of the different ages were obtained.

2.4 Gelatin yield

Gelatin yield (GY) was calculated using the following equation according to the method of [Balaji Wamanrao and Tanaji \(2022\)](#) according to [Equation 1](#) below:

$$GY = \frac{\text{Weight of extracted gelatin (g)}}{\text{Weight of whole chicken feet (g)}} \times 100 \quad (1)$$

2.5 pH measurement

The gelatin solution was prepared individually by dissolving the gelatin powder in the ratio of 1:10 gelatin: distilled water (w/v). A pre-calibrated pH meter (pH meter HI 2211 – pH Meter HANNA) was used for pH measurement.

2.6 Gel strength

The gel strength was determined using the method of [Hirbo et al. \(2023\)](#). Gelatin solution was prepared by mixing the dried gelatin with distilled water. The mixture was left at room temperature for 30 min, pre-heated at a temperature of 65°C for 20 min until the gelatin was completely dissolved. The samples were stored at a refrigerator adjusted at a temperature of 4°C for 16 ± 2 h. To determine the gel strength the gelatin sample was transferred to a cylindrical mold measuring 3 cm in diameter and 2.5 cm in height to assess gel strength. A texture analyzer (Stable Micro System, Surrey, UK) with a 5 kg load cell, a crosshead speed of 1 mm/s, and a 1.27 cm diameter flat-faced cylindrical teflon plunger was used to evaluate gel strength. When the plunger penetrated 4 mm into the gelatin gels, the maximum force (in grams) was recorded.

2.7 Gel viscosity

The gel viscosity was measured according to the modified method. Gelatin powder was dissolved in distilled water in a ratio of 1:10 (W:V) and heated to 60°C. The viscosity was measured using a Brookfield digital viscometer model RVDV- I with spindle No. 1 at a speed of 60 rpm and a temperature of 40 ± 1°C.

2.8 Melting point (MP)

The melting point was measured according to the modified method of [Choi and Regenstein \(2000\)](#). The gelatin solution used in gel viscosity test was used in this measurement. It was placed in a screw cap test tubes. The samples were tightly closed and stored in the refrigerator at 7°C for 16 to 18 h. After that,

the sample was transferred to a water bath at 10°C and placed upside down inside the water bath so that the temperatures were controlled. The heating process was carried out in stages by increasing the temperature by 1°C per min, and the melting point (MP) of the extracted gelatin was obtained by averaging the temperatures between the starting and ending melting points as follows ([Equation 2](#)):

$$MP (^{\circ}C) = \text{starting melting temperature} + \text{ending melting temperature}/2 \quad (2)$$

2.9 Water holding capacity (WHC)

Modified method described by [Warner \(2014\)](#) was used to determine the WHC of the gelatin. One gram of the extracted gelatin was placed in a centrifuge tube using a device (SIGMA 3K30) and centrifuged at a speed of 920 rpm for 10 min. The percentage of centrifuged water was calculated by subtracting the weight of gelatin after the centrifugation process from the first basic weight (1.0 g), then the result was calculated as a percentage. The WHC values were calculated according to the following [Equation 3](#):

$$WHC \% = \frac{((\text{basic weight of gelatin} - \text{weight of gelatin after centrifugation}))}{\text{basic weight}} \times 100 \quad (3)$$

2.10 Color measurement

The gelatin solution was prepared and cooled at 10 ± 1°C for 18 h. The color of the gelatin was determined according to [Kim et al. \(2020\)](#). The colorimeter (Hunter lab, model 16, Minolta Ltd., Japan) was used in the measurement. The device was calibrated using a white plate; $L^* = +97.83$, $a^* = -0.43$, and $b^* = +1.98$. The following colors values were obtained (Lightness L^* , redness a^* and yellowness b^*) which represent the mean intensity of lightness, redness, and yellowness, respectively.

2.11 Proximate analysis

The proximate analysis values (moisture, protein, fat and ash) of the extracted gelatin were determined according to the method of AOAC ([Horwitz and Latimer, 2000](#)) and carbohydrates were obtained by subtraction from 100.

2.12 Preparation of the yogurt for sensory evaluation

The yogurt samples were prepared according to the modified published method of [Arioui et al. \(2018\)](#). Fresh cow milk was used in yogurt preparation. The total soluble solids and fats were maintained to be 15 and 3%, respectively. The milk was homogenized and heated to 90°C for 3 min for pasteurization.

Once cooled to 45°C, the gelatin powder was incorporated individually in percentages of 0%, 1%, 2%, 3% into the pasteurized milk and stirred until completely dissolved in the milk. The starter [(*Streptococcus thermophilus* (YC-X16) and *Lactobacillus bulgaricus* (CHN-11), CHR HANSEN Denmark)] was added the incorporated milk at a percentage of 3%. The treated milk samples were poured into yogurt cups and distributed randomly using different three-digit numbers and kept into incubation room set at 45°C for 4 h. The yogurt samples incorporated with the gelatin were then cooled to 4°C overnight for sensory evaluation.

2.13 Sensory evaluation studies

The prepared yogurt samples were evaluated the following day by 25 untrained faculty members and students from the College of Agriculture and Food, Qassim University, KSA, who regularly consume yogurt. This evaluation followed the guidelines and protocols established by the university's ethical committee of the university (details provided in the declarations). The yogurt samples were evaluated to the following attributes: taste, smell, color, texture, and overall acceptability. The panelists were asked to indicate how much they liked or disliked the prepared yogurt using a hedonic scale [1 = dislike extremely, 9 = like extremely]. The scores were obtained and statistically analyzed.

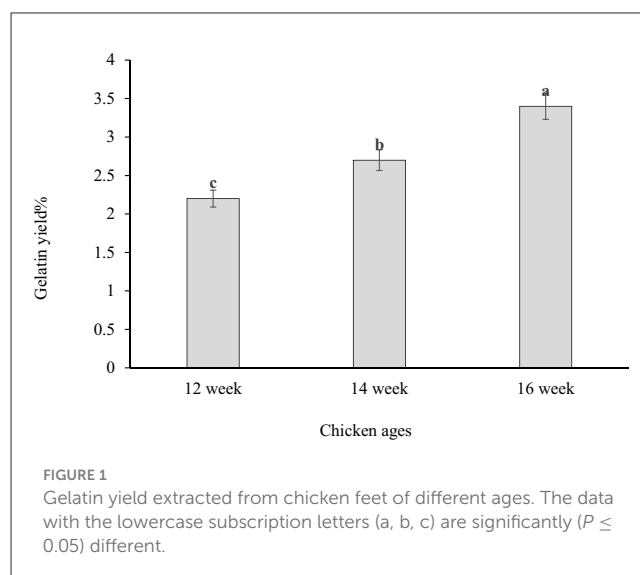
2.14 Statistical analysis

The data obtained from 3 replicates were statistically analyzed. The statistical analysis was performed using Two-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test with $P \leq 0.05$ significance level. Minitab Statistical Software version 17 was used for data analysis.

3 Results and discussion

3.1 Gelatin yield

Figure 1 shows the yield of the gelatin. The percentage was 3.4%, obtained from the chicken feet of 16 weeks, followed by 2.7%, obtained from chicken feet of 14 weeks and 2.2%, obtained in the chicken feet of 12 weeks' age. It was noticed that the yield of the gelatin obtained increased as the age of the chicken increased. This result suggests a correlation between the yield of the gelatin and the age of the chicken extracted from their feet which means that older chicken feet produce higher gelatin yield. This finding agreed with the earlier finding observed by Rana et al. (2024). They found that older chickens (42 days old) yielded more gelatin compared to younger ones (21 and 35 days old). Specifically, the gelatin yields on a dry weight basis were 0.132% for 21-day-old chickens, 0.182% for 35-day-old chickens, and 0.215% for 42-day-old chickens. Older chicken develops tougher connective tissues which may be more abundant and denser offering more collagen to convert into gelatin when the extraction condition is optimized. However, the acid treatment and the temperature used in gelatin extraction process in this study may also affect the yield of gelatin. The difference in



gelatin yield might be due to the different collagen contents in raw materials (Rao and Poonia, 2023). The variation in gelatin yield may result from varying amounts of collagen in the raw materials (Rao and Poonia, 2023). Sinthusamran et al. (2014) claimed that the gelatin yield was influenced by the raw material composition and the extraction conditions. However, Aykin-Dinçer et al. (2017) and Zou et al. (2024) stated that the different gelatin yields may result from variations in the length of the polypeptide chains caused by pretreatment, pH, temperature, and extraction time. Fatima et al. (2022) found that a high yield of 7.5% can be obtained from chicken feet if the extraction conditions are optimized with pretreatment of the chicken feet with acetic acid in a concentration of 4.2% and an extraction temperature of 66°C for 4.2 h. In another study Usman et al. (2024) investigated gelatin extraction condition in native chicken feet gelatin using 1:3 (w/v) of distilled water at 55°C for 6 h. They found that the yield obtained from native and broiler chicken feet using 10% acetic acid was found to be 7.93 and 7.06%, respectively, on a dry basis.

3.2 pH measurement

Figure 2 shows the pH values which range from 6.21 to 6.34. This result suggested that pH value of the gelatin was not influenced by NaOH pretreatments during extraction process ($p \geq 0.05$). This finding disagreed with the finding of Saenmuang et al. (2019). They found that the pH of gelatin extracted from black-bone chicken feet and skin were acidic ranging from 3.71 to 4.81. Furthermore, the washing technique is essential for eliminating acid and/or alkaline residues. In addition, the washing procedure is an important step in removing acid and/or alkaline residues. The pH levels of chicken gelatins were previously reported by Kim et al. (2012) and Widayarsi and Rawdkuen (2014). In those investigations, the pH of chicken gelatins was found to be close to neutral, ranging from 6.1 to 6.8 which is in a good agreement with finding in this study. The control gelatin's pH dropped from 6.5 to 6.2 in the treated samples. The same observation was reported by Taufik (2010) who

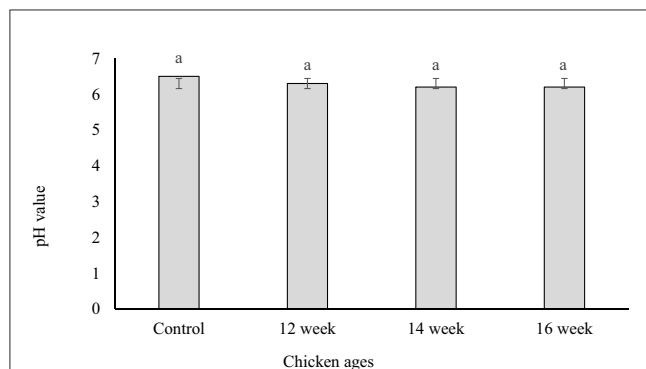


FIGURE 2
pH values of gelatin extracted from chicken feet of different ages. The data with the lowercase subscription letters "a" above the bars are not significantly ($P \geq 0.05$) different.

TABLE 1 Physicochemical parameters measured in the gelatin extracted from different chicken strain feet.

Treatment	Physicochemical parameters			
	Gel strength (lbf/100 ft ²)	Gel viscosity (N.s/m ²)	Melting point (°C)	Water holding capacity %
Control	138.3 ± 5.3 ^a	7.3 ± 0.9 ^a	33.9 ± 0.2 ^a	0.92 ± 0.02 ^a
12 week	111.2 ± 3.1 ^d	6.2 ± 0.3 ^d	29.3 ± 0.1 ^c	0.90 ± 0.10 ^a
14 week	120.8 ± 3.4 ^c	6.7 ± 0.3 ^c	29.5 ± 0.1 ^c	0.91 ± 0.01 ^a
16 week	130.2 ± 6.5 ^b	7.1 ± 1.3 ^b	30.4 ± 0.2 ^b	0.91 ± 0.03 ^a

Different letters within the columns indicated the significant differences ($P \leq 0.05$).

noted that immersing the feet in a mixture of sodium hydroxide and acetic acid and repeating the process helps decrease the acidity of the gelatin.

3.3 Gel strength

The gel strength values of the gelatin are presented in [Table 1](#). [Saenmuang et al. \(2019\)](#) reported that gelatin is generally divided into three categories: high bloom (200–300 g), medium bloom (100–200 g), and low bloom (50–100 g) at 6.67 percent (Bloom value). The values of gel strength in this study are significantly ($P \leq 0.05$) different and were ranged from 111.2 to 138.3 g, classifying as medium bloom gelatin. However, this result agreed with [Santana et al. \(2020\)](#) who reported that gel strength of chicken feet gelatin had gel strength value of 119.1 g bloom. The control sample had the highest value of 138.3 bloom followed by 130.2, 120.8, and 111.2 g, in gelatin extracted from chicken feet aged 16, 14, and 12 weeks, respectively. The chicken feet from the oldest chickens exhibited the highest gel strength values. It was reported that gelatin with medium bloom has moderate gel-forming ability and is commonly used in thickening food products such as yogurt ([Supavititpatana et al., 2008](#)), curiating a strong and flexible gels ([Bahar and Kusumawati, 2021](#)). According to [Calvarro et al. \(2016\)](#) this variation in the bloom strength may be due to chicken feet pretreatment and

TABLE 2 Color parameters measured in the gelatin extracted from different chicken strain feet.

Treatments	L*	a*	b*
Control	80.5 ± 0.7 ^a	0.2 ± 0.2 ^d	16.2 ± 0.1 ^d
12 week	60.7 ± 4.4 ^d	6.1 ± 1.4 ^a	25.7 ± 0.9 ^a
14 week	64.9 ± 6.8 ^b	3.5 ± 2.1 ^b	22.8 ± 1.1 ^b
16 week	63.1 ± 9.6 ^c	2.5 ± 1.5 ^c	19.1 ± 0.4 ^c

Different letters within the columns indicated the significant differences ($P \leq 0.05$).

hydroxyproline and proline content in chicken feet, because hydroxyline and proline are major components of collagen and play key roles in stabilizing the protein structure ([Revert-Ros et al., 2024](#)).

3.4 Gel viscosity

The viscosity values are present in [Table 1](#). The values range from 6.2 to 7.3 cP. This result agreed with viscosity value reported ([Rafeian et al., 2015](#)). They found that most gelatin viscosity values ranged from 6 to 7 cP. [Mirzapour-Kouhdashti et al. \(2019\)](#) claimed that high viscosity of gelatin may be due to the formation of random chain gelatin molecules because of the breakdown of hydrogen linkage from the triple helix structure. However, low viscosity (1–2 cP) the gelatin solution is quite thin, and gelatin derived from poultry with low viscosity may form softer or weaker gels when incorporated in food systems ([Ashrafi et al., 2023](#)). It was observed that physical properties in gelatin such as viscosity affect the properties of the gel, especially at the point of gel formation ([Kurt et al., 2024](#)). It was reported that gelatin with viscosity values ranged from 6 to 8 cP in gelatin solutions formed thicker, denser and stronger gels ([Rather et al., 2022](#)), making it suitable for application as thickener ingredient for many food products such as yogurt ([Kurt et al., 2022](#)).

3.5 Melting point

[Table 1](#) shows the melting point of gelatin for each age. The average values of the melting point range from 29.3 to 33.9 °C. The values are significantly ($P \leq 0.05$) different. This finding is coincided with that reported by [Goudie et al. \(2023\)](#). They reported that typical melting point of gelatin ranges between 30°C and 35°C. The highest value of the melting point was observed in control (33.9°C) followed by 30.4°C which recorded in the gelatin obtained from the chicken feet of 16 weeks' age. [Zhang et al. \(2020\)](#) reported that the variation in the melting point of gelatin depends on the exact method of extraction and the gelatin concentration. However, there was no significant ($P \geq 0.05$) difference in the melting points values of the gelatin extracted from the chicken feet of 12- and 14-weeks' age, respectively. [Avallone et al. \(2021\)](#) reported that gelatin melts when exposed to body or room temperature. This fact supports the finding in this research regarding the values of melting point.

TABLE 3 Proximate composition of gelatin extracted from different chicken feet.

Treatments	Moisture%	Protein	Fat%	Ash%	Carbohydrate %
Control	0.87 ± 0.01 ^d	98.9 ± 2.4 ^a	0.02 ± 0.01 ^c	0.12 ± 0.02 ^a	33.9 ± 0.2 ^a
12 week	0.99 ± 0.03 ^c	98.9 ± 1.9 ^a	0.08 ± 0.07 ^a	0.12 ± 0.01 ^a	29.3 ± 0.1 ^c
14 week	1.31 ± 0.79 ^b	98.5 ± 2.5 ^a	0.04 ± 0.03 ^b	0.13 ± 0.06 ^a	29.5 ± 0.1 ^c
16 week	1.59 ± 0.60 ^a	98.2 ± 3.6 ^a	0.03 ± 0.06 ^b	0.15 ± 0.28 ^a	30.4 ± 0.2 ^b

Different letters within the columns indicated the significant differences ($P \leq 0.05$).

TABLE 4 Sensory evaluation attributes of the yoghurt incorporated with chicken feet gelatin.

Treatments	Taste	Odor	Color	Texture	Overall acceptability
Control	7.1 ± 0.9 ^b	6.2 ± 1.4 ^b	8.8 ± 0.3 ^a	7.1 ± 1.72 ^b	8.6 ± 0.3 ^a
12 week	7.7 ± 0.9 ^b	8.3 ± 0.37 ^a	7.3 ± 0.2 ^b	7.6 ± 1.43 ^b	8.7 ± 0.6 ^a
14 week	7.8 ± 0.6 ^b	8.1 ± 0.6 ^a	8.5 ± 0.29 ^a	7.8 ± 0.91 ^b	8.5 ± 0.5 ^a
16 week	8.1 ± 0.4 ^a	8.0 ± 0.7 ^a	8.1 ± 0.35 ^a	8.7 ± 1.24 ^a	8.6 ± 0.9 ^a

Different letters within the columns indicated the significant differences ($P \leq 0.05$).

3.6 Water holding capacity (WHC)

Table 1 shows the WHC of the gelatin extracted from different chicken strain feet. The values range from 0.90% to 0.92%, there was no significant ($P \geq 0.05$) difference in the WHC. This finding is in a good agreement with that of Rasli and Sarbon (2015), but it was observed that the ability to retain water increased from 0.90 to 0.91% with increasing chicken ages. Higher WHC however, indicates that the gelatin can absorb and hold more water (Fairuza and Amertaningtyas, 2024; Khalesi et al., 2024). Another explanation for the high WHC of the gelatin may be the interaction between protein molecules and gelatin polysaccharides, which may form compounds with positively charged protein bonds in the gel, which increase the structure of the protein gel, leading to a high hydrophilicity of the gel and a higher WHC (Derkach et al., 2022).

3.7 Color measurement

Table 2 shows that all the obtained color values differ significantly ($P \leq 0.05$). The control sample had the lightest gelatin ($L^*80.5$), whereas the gelatin extracted from chickens at 14, 15, and 12 years old yielded 64.9, 63.1, and 60.7, respectively. The gelatin extracted from the feet of 12 weeks age had the greatest redness value ($a^* 6.1$) followed by 14 weeks age, 16 weeks age and control. The yellowness values showed a similar pattern. It was reported that the color values of gelatin depend on the extraction and degree of drying, as the color has no effect on the functional properties of the gelatin, but it influences its acceptance by the consumer (Rather et al., 2022). It was reported that a higher L^* value indicates lighter, more transparent gelatin. Du et al. (2013) found that gelatin derived from chicken head exhibited higher L^* and b^* values, but lower a^* values compared to gelatin extracted from turkey heads. Similarly, Chakka et al. (2017) observed increased L^* and b^* values alongside reduced a^* values under varying acid concentrations. The type of raw material and the extraction conditions significantly influence the color characteristics of gelatin (Du et al., 2013). However, a

positive b^* value reflects yellow tones, which may be expected in chicken-derived gelatin.

3.8 Proximate composition

Table 3 presents the results of the proximate analysis of gelatin. The moisture content values were significantly different ($P \leq 0.05$), with higher moisture levels observed in older samples. The control sample exhibited the lowest moisture content at 0.87%. The moisture content of the extracted gelatin ranged from 0.99% to 1.59%. The protein content of the extracted gelatin in this study exceeded 98%, which is higher than the protein percentage reported in the study by Widyasari and Rawdkuen (2014), where the protein content of chicken feet was found to be 90.06%. However, these findings disagree with those from previous studies on gelatins extracted from normal chicken waste, which reported protein levels ranging from 80% to 90% (Rafeian et al., 2015; Sarbon et al., 2013; Widyasari and Rawdkuen, 2014). Additionally, Almeida and Lannes (2013) observed that the protein content in chicken by-products was only 84.96%. The ash content ranged from 0.12% to 0.15%. These values were highly dependent on the age of the chickens; as the age of the chickens increased, the ash content also increased, although no significant differences were observed ($P \geq 0.05$). These findings disagreed with those reported by Usman et al. (2024), who found that the ash content in native and broiler chicken feet gelatins was 2.06 and 1.85%, respectively.

3.9 Sensory evaluation studies

Table 4 shows the sensory evaluation attributes of the yogurt prepared using the extracted gelatin. There were significant ($P \leq 0.05$) differences in the attributes evaluated. The control had the lowest values for both texture and odor attributes. The scores were 7.1 and 6.2, respectively. No significant ($P \leq 0.05$) differences observed between control yogurt and samples prepared

using 1 and 2% of the extracted gelatin in terms of taste, color, texture and overall acceptability. The yogurt prepared using 3% of the gelatin showed the highest score values for taste, texture and overall acceptability of 8.5–8.7. This finding agreed with that of [Guo et al. \(2022\)](#) who reported the sensory evaluation properties of yogurt supplemented with glycyrrhiza polysaccharide as potential replacement for gelatin in concentration of 0.1% and found that the highest total acceptance scores of 8.5. This finding suggested that adding the appropriate percentage of gelatin was sufficient to improve yogurt's sensory qualities. It has been noted that some food systems based on gelatin enhance the sensory quality of dairy products. This might be mostly because the final products fortified with gelatin have better flavors and textures/mouthfeel ([Ares et al., 2007](#); [Mudgil et al., 2018](#); [Riantiningtyas et al., 2021](#); [Mohammadnezhad and Farmani, 2022](#); [Nami et al., 2023](#)).

4 Conclusion

In conclusion, extraction yield, color, gel strength, melting point, water holding capacity and viscosity are important properties for applications of gelatin, with the latter 4 properties being the main criteria to determine the quality of gelatin. The quality properties of gelatin extracted from the feet of ROSS strain chickens were significantly influenced by the age of the chickens studied and the experiment's condition. Considering the results, it can be concluded that the gelatin extracted from ROSS strain chickens' feet could be utilized as thickening food grade to develop yogurt and enhance its sensory evaluation properties.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was not obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article because the research was conducted by the following guidelines of the Committee of Research Ethics Institutional Review Board (IRB), Qassim University, constructed according to the decision no. 344859 dated 9/8/1437H – 16/05/2016. Ethics approval and consent to participate No animal or human study was involved in this work; however, for sensory evaluation study, the participants (all above 18 years old) gave their consent to participate. Proper protocols approved by the Ethical Committee were followed during the sensory evaluation. Further, the research was carried out following the guidelines provided by the Qassim University Ethics committee (Dr. Osama Mohamed, Dr. Abdullah Saleh, Dr. Ibrahim Saheh,

Dr. Saad Ali, Dr. Fahad Saleh, Dr. Abdulrahman Mohamed, Dr. Abduaziz Abdulmohsen, Dr. Fahd Muqrin) constituted by the Qassim University, KSA. The Committee of Research Ethics Institutional Review Board (IRB), Qassim University approved the study.

Author contributions

AM: Supervision, Writing – original draft, Methodology, Validation, Conceptualization, Writing – review & editing. MA: Writing – original draft, Data curation, Methodology, Formal analysis, Supervision, Investigation, Resources, Writing – review & editing. RH: Project administration, Conceptualization, Writing – review & editing, Writing – original draft, Funding acquisition. IA: Resources, Methodology, Formal analysis, Data curation, Investigation, Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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