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Quality and functional features of gelatine extracted from chicken skin in comparison with commercial gelatines from porcine, bovine and piscine

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ABSTRACT

Poultry processing industry produces large quantities of by products (skin, bone, and feather) that contain significant amounts of protein. The source of gelatine is of great concern for some societies including Muslims, Hindus, and Jews as gelatine is mostly obtained from porcine sources. In the present study, gelatine was obtained from chicken skin and some quality and functional features were evaluated in comparison with commercial gelatines from porcine, bovine, and piscine sources. Chicken skin gelatine formed stable foams by a foaming stability of 83.3% as well as high emulsion activity of 72.8 $m^2 g^{-1}$ compared to commercial gelatines. On the other hand, gel strength and viscosity of chicken skin gelatine were 307 g and 2.5 cP, respectively, and significantly lower than that of commercial gelatines due to high content of impurities. The results concluded that chicken skin may be used in gelatine manufacturing upon efficient removal of fat, which was the most abundant component in the dry matter of chicken skin.

KEYWORDS

chicken skin, gelatine, quality, gel strength, foaming, emulsion

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1. INTRODUCTION

Gelatine, one of the most popular biopolymers, is widely used in food, pharmaceutical, cosmetics, and photographic applications because of its unique functional and technological properties (Huang et al., 2019). Gelatine production is carried out in a couple of basic steps including pretreatments on collagen rich animal tissues (skin, bone, scale, etc.), isolation of source protein, water extraction of gelatine, and finally post-extraction steps such as filtering, drying, and crushing (Boran and Regenstein, 2010).

Gelatine is generally produced from skin or hides and bones of porcine and bovine, while over half of the global gelatine production comes directly from porcine. Due to concerns of different religious, ethnic, and social groups of consumers, gelatine's source has been an issue to consider and alternative raw materials are gained extensive attention from the researchers in the last two decades. Poultry, specifically chicken as the most widely produced and processed poultry species, has been offering great amount of processing waste, i.e. skin, bone, residues of mechanical deboning, leather etc., which carry a considerable amount of collagen. Therefore, poultry processing waste may be utilised as raw material in gelatine manufacturing, and the resultant gelatine may overcome some of those concerns.

This study was designed to investigate the potential of chicken skin as an alternative raw material in gelatine production and compare the resultant chicken skin gelatine with commercially available gelatines from different sources based on some quality and functional characteristics.

2. MATERIALS AND METHODS

2.1. Materials

Chicken skin was provided by a local meat store. Five commercial gelatine samples were used for comparison, namely fish skin gelatine (FSG), porcine skin gelatine (PSG) and three different bovine hide gelatines (BHG-G, BHG-H, BHG-S) from Jiliding Marine Biotech (Jiangsu, China), Warenhandel (Neckarsulm, Germany), M-Haditech (Bremen, Germany), Halavet (Istanbul, Turkey), and Seljel (Balıkesir, Turkey), respectively. All chemicals used were of analytical grade and obtained from Sigma-Aldrich Co. (St. Louis, MO, USA).

2.2. Gelatine extraction

Fresh chicken skin was separated from visible impurities and portioned into 3 to 3 cm pieces using a knife, divided as 50 g portions in zipped freezer bags, and finally stored at −18 °C until further use. Gelatine extraction was carried out as described by Sarbon et al. (2013) with slight modifications. Chicken skin samples were first soaked in an alkaline solution (0.1% NaOH, w/v) at a ratio of 1:5 skin/solution (w/v) at ambient temperature (~22 °C) for 1 h. Then, the mixture was filtered through four layers of cheese cloth, washed with cold tap water three times, and filtered through the cheese cloth again. Alkali washed skin samples were then soaked in an acid solution (0.1% HCl) at a ratio of 1:5 skin/solution (w/v) at ambient temperature for 1 h and then washed with cold tap water and filtered as previously described. Gelatine extraction was then carried out in distilled water (1:4, w/v) at 50 °C for 7 h. At the end of the extraction, the extract

was obtained by filtration through cheese cloth as previously described, and the resultant extract was poured into heat-resistant plastic pans and dried overnight at 50 °C in a conventional oven to obtain gelatine sheets. These sheets were then crushed using a mortar to obtain dry gelatine powder. The resultant chicken skin gelatine (CSG) along with other commercial gelatines were stored at 4 °C until all analyses were carried out.

2.3. Quality attributes of gelatines

2.3.1. Gel strength. Gel strength of gelatines was measured according to BSI (1975) with slight modifications. 40 mL of gelatine solution was matured at 4 °C for 16–18 h for gel formation in capped polypropylene cups. Gel strength was measured using a texture analyser (TA-XT II, Stable Micro Systems Ltd., Godalming, UK) equipped with a 12.7 mm diameter spherical probe.

2.3.2. Viscosity. Viscosity was determined according to the method given by GMIA (2019). Cannon Fenske routine calibrated viscometer (CANNON, State College, PA, USA) was used for the measurement.

2.3.3. Melting and gelling temperatures. Melting and gelling temperatures of gelatine solutions were determined according to Arnesen and Gildberg (2007) using a rotational rheometer (RV III Ultra, Brookfield, MA, USA) equipped with a low viscosity adaptor and a cylindrical spindle. Viscosity was continuously recorded at a rotation speed of 40 r.p.m., while cooling the sample from 40 to 10 °C or heating from 10 to 40 °C at 10 s intervals. Temperatures at which a sharp increase or decrease in viscosity is observed were given as gelling and melting temperatures, respectively.

2.3.4. Transparency and pH. Gelatine solutions (1%, w/v) were used for transparency measurement using an UV–VIS spectrophotometer (UV-Mini 1240 UV–VIS, Shimadzu, Kyoto, Japan). Transmittance of the samples were read at 640 nm and transparency was expressed as percentage (Cho et al., 2004). 20 mL of gelatine solution was used for pH measurement using a portable multimeter (SevenGO SG23, Mettler Toledo, OH, USA) (Kim et al., 2012).

2.4. Functional properties of gelatines

2.4.1. Water holding capacity. Water holding capacity (WHC) of gelatine samples were determined by the method given by Cho et al. (2004).

2.4.2. Fat binding ability. Fat binding ability (FBA) was measured according to the procedure given by Cho et al. (2004). The method was identical with that of WHC except that 10 mL of sunflower oil was used instead of 50 mL of distilled water.

2.4.3. Foaming capacity and stability. Foaming capacity (FC) and foaming stability (FS) were determined according to the method given by Cho et al. (2004).

2.4.4. Emulsion activity index and emulsion stability index. Emulsion activity index (EAI) and emulsion stability index (ESI) were determined according to Pearce and Kinsella (1978).

2.4.5. Textural parameters. Gelatine gels were prepared as previously described and matured in 50 mL centrifuge tubes. Inner surface of the tubes was oiled for ease of taking out samples. Matured gels were cut in cylindrical portions with dimensions of 20 mm in height and 30 mm in diameter. Texture profile analysis (TPA) was done using a texture analyser (TA-XT II, Texture Technologies, Godalming, UK) equipped with a circular probe with a diameter of 50 mm. Samples were compressed up to 20% of their heights, i.e. 4 mm compression for both compression cycles. TPA parameters were calculated according to the TPA graph (Bourne, 2002).

2.5. Statistical analysis

Results were statistically analysed using JMP 8.0 statistics software (SAS, NC, USA). ANOVA and Tukey-Kramer tests were utilised to determine which pairs were significantly different at a probability level of 95%. Measurements of analytical parameters were all done in triplicates at least and further repeated when needed.

3. RESULTS AND DISCUSSION

Compositions of commercial gelatines were, in general, similar according to the datasheets of the manufacturers. Their parameters were 12–15% moisture, 83–86% protein, and about 2% mineral. Proximate compositions of fresh chicken skin and chicken skin gelatine (CSG) obtained in this study are given in Table 1. As seen, CSG was lower in protein and higher in mineral and fat contents compared to commercial samples. High fat content of chicken skin was the major challenge in terms of protein isolation. Previous studies reported higher protein concentrations in gelatines obtained from chicken parts. For example, Sarbon et al. (2013) reported that protein content of freeze-dried gelatine from dried and defatted chicken skin was about 81%. Raw materials used in gelatine extraction and process parameters employed for purification may lead to significant differences in content of gelatines. On the other hand, water content of CSG, which was about 9%, was lower compared to commercial counterparts and under the limit prescribed by Gelatine Manufacturers of Europe (2017). Furthermore, the mineral content of CSG was slightly higher than 3%, which is considered the upper limit of good quality reported by the Food Chemicals Codex (1998). Also, the ash content of chicken skin gelatine was found significantly higher than those of porcine skin and fish (tilapia) skin previously noted by Xin et al. (2021). Chicken skin used in the study and the resultant CSG are presented in Fig. 1.

Gels of gelatine samples were used for measurements of gel strength and textural parameters, while dry gelatines were used for analyses of other parameters. Quality attributes including gel strength, viscosity, melting and gelling temperatures, transparency, and pH values of the samples are given in Table 2. Gel strength of CSG was a bit lower compared to that of other commercial

Table 1. Proximate composition (%) of chicken skin and chicken skin gelatine

	Dry matter	Protein ($N \times 5.4$)	Fat	Ash
Chicken skin	48.5 ± 0.2	11.5 ± 0.5	35.0 ± 0.1	0.6 ± 0.4
Chicken skin gelatine	90.9 ± 0.3	71.7 ± 0.8	7.3 ± 0.7	3.1 ± 0.1

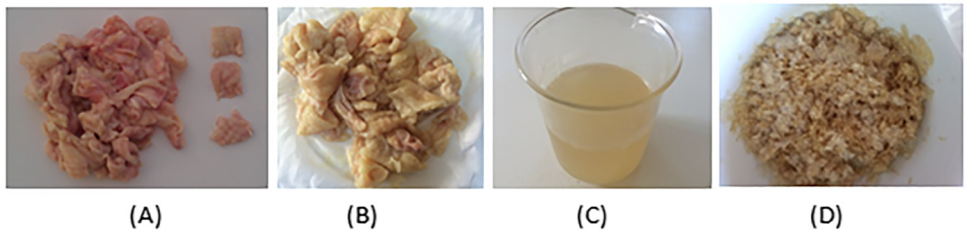

Fig. 1. Chicken skin (A), pretreated chicken skin (B), gelatine extract (C), dried gelatine (D)

Table 2. Some quality attributes of gelatines from different sources

	CSG (This study)	BHG-S (Seljel)	BHG-H (Halavet)	BHG-G (Germany)	FSG (China)	PSG (Germany)
Gel strength (g)	307 ± 9^{c}	411 ± 7^{b}	415 ± 14^{b}	301 ± 6^{c}	561 ± 46^{a}	432 ± 8^{b}
Viscosity (cP)	2.5 ± 0.0^{d}	3.9 ± 0.1^{d}	4.1 ± 0.1^{c}	5.4 ± 0.0^{a}	4.6 ± 0.0^{b}	4.7 ± 0.0^{b}
Melting temp. (°C)	29.5 ± 0.8^{bc}	30.2 ± 0.3^{a}	30.0 ± 0.7^{ab}	28.5 ± 0.7^{c}	26.8 ± 0.2^{d}	30.7 ± 0.3^{a}
Gelling temp. (°C)	19.0 ± 0.0^{b}	19.2 ± 0.3^{b}	20.0 ± 0.0^{a}	18.7 ± 0.3^{b}	16.7 ± 0.2^{c}	20.5 ± 0.0^{a}
Transparency (%)	2.4 ± 0.0^{e}	75.1 ± 1.1^{d}	89.4 ± 1.0^{b}	87.1 ± 1.1^{c}	89.7 ± 0.1^{b}	95.5 ± 0.4^{a}
pH value	2.99 ± 0.02^{f}	5.79 ± 0.05^{a}	4.92 ± 0.03^{e}	5.68 ± 0.04^{b}	5.53 ± 0.05^{c}	5.19 ± 0.03^{d}

CSG: chicken skin gelatine; BHG: bovine hide gelatine; FSG: fish skin gelatine; PSG: porcine skin gelatine. Results are mean ± standard deviation of triplicate measurements. Different letters in each row indicate significant difference among the samples at a level of 95%.

gelatines, although that of BHG-G was similar, suggesting that even low purity CSG may result in reasonable gel strength. Aykin-Dinçer et al. (2017) reported that gel strength of broiler skin gelatine (167 g) was significantly ($P < 0.01$) lower than that of commercial bovine gelatine (238 g). Gel strength is greatly affected by intrinsic factors such as chain structure and amino acid profile of collagens from different animals and tissues. Gel strength is also highly correlated with hydrolysis level, i.e. average molecular weight and purity of the gelatine (Ee et al., 2019). It was previously reported that black bone chicken skin and chicken feet gelatine had 239 and 204 g bloom value, respectively, which was slightly different than that of bovine gelatine (229 g) (Sarbon et al., 2013; Saenmuang et al., 2020).

Viscosity, which is known to be an important physical feature of gelatine solutions at a standard concentration of 6.67% (w/v), generally ranging 2.0 to 7.0 cP for commercial gelatines (Sae-Leaw et al., 2016), was low in CSG, with a value of 2.5 cP, compared to that of other gelatine samples ($P < 0.05$). In a previous study, Aykin-Dinçer et al. (2017) reported that viscosity of broiler skin gelatine obtained by acid extraction was 1.35 cP, which was lower than findings in the present study. Besides, Bichukale et al. (2018) reported viscosity values of gelatine extracted from poultry skin at five different temperatures (40, 45, 50, 55, and 60 °C) as 3.83, 5.53, 4.43, 4.07, and 4.03 cP, respectively.

Considering gelling and melting temperatures, the results indicated that gelling temperature of CSG was not significantly different from that of BHG-S and BHG-G, while it was significantly different from three other samples, namely BHG-H, PSG, and FSG ($P < 0.05$). Furthermore,

melting temperature of CSG was similar to that of BHG-H, while it was significantly different from other samples ($P < 0.05$). Melting temperature of gelatine gels of bovine and porcine origins were previously reported by Cho et al. (2004) as 33.8 and 36.5 °C, respectively. Results were generally in agreement with those observed in previous studies, in which gelling and melting temperatures were reported as 24.88 and 33.57 °C by Sarbon et al. (2013) and 23.68 and 32.64 °C by Rasli and Sarbon (2015).

Transparency and pH values of CSG were 2.37% and 2.99, respectively, and were significantly different from that of other gelatines ($P < 0.05$). Low transparency was evidently linked with high fat content and other impurities found in CSG (Tables 1 and 2). As reported by Muyonga et al. (2004), insufficient filtration may be the cause of turbidity in gelatine gels, and high fat content also seemed to impair the appearance of gelatine gels in case of CSG. In previous studies, pH values of chicken skin gelatines, which were obtained under different pretreatment and extraction conditions, were reported to be 3.71 and 5.00 by Saenmuang et al. (2020) and Xin et al. (2021), respectively, and as 4.83 in a gelatine from chicken deboner residue (Rafieian et al., 2013).

Some functional characteristics, including water holding capacity (WHC) and fat binding ability (FBA) as well as foaming and emulsion related features of gelatine samples are given in Table 3. WHC and FBA values of CSG were lower than that of other commercial gelatines. However, in the study conducted by Aksun-Tümerkan et al. (2019), the WHC value of chicken skin gelatine was determined to be 650%, which was quite close to the one in this study, while foaming and emulsion related features were, generally speaking, similar. WHC refers to the ability of the protein to absorb and retain water in the protein matrix. WHC is affected by the amount of hydrophilic amino acids, size of the peptides, and conformational structure of the protein, and whether there were lots of pores and spaces within the gel network (Cho et al., 2004). Regarding the commercial samples, WHC of BHG-S and FSG were almost identical, whereas BHG-G and BHG-H showed lower WHC values ($P < 0.05$). Bouaziz et al. (2014) reported that intrinsic factors like presence of lipids and carbohydrates on the surface affect water holding capacity of proteins. This fact also seemed to correlate well with low FBA, as fibrous structure of collagen fractions was imparted due to these impurities.

CSG showed very low foaming capacity of about 20%. Significant differences were observed not only between gelatines from different species but also gelatines from the same species. On the contrary, foaming stability (FS) of CSG was mostly higher than that of other gelatines ($P < 0.05$). In addition, FC as well as FS60 of three different bovine skin gelatines differed significantly, suggesting that the length of collagen fractions depending on hydrolysis level is probably more effective on foaming features than the source of gelatine (Kittiphattanabawon et al., 2010). On the other hand, the highest FC was observed in FSG, probably because of the high hydrophobic amino acid content that can form a large hydrophobic sphere on the surface of FSG and its high purity, which was also evident by transparency and strength of the gels of FSG (Shakila et al., 2012).

Emulsion activity index (EAI) and emulsion stability index (ESI) determine usability of gelatines in emulsified products. Results showed that EAI of CSG was significantly higher most probably due to high content of fat in CSG. Previous reports for chicken skin gelatine had a similar observation for EAI ranging from 43 to 63 (Rasli and Sarbon, 2015; Bichukale et al., 2018; Aksun-Tümerkan et al., 2019). In addition, impurities of CSG might have been involved in binding of fat to collagen fractions, which eventually led to higher EAI. Meanwhile, ESI relates

Table 3. Some functional properties of gelatines from different sources

Parameter (unit)	CSG (This study)	BHG-S (Seljel)	BHG-H (Halavet)	BHG-G (Germany)	FSG (China)	PSG (Germany)
Water holding capacity (%)	683 ± 49^{f}	$1{,}237 \pm 39^{b}$	$1{,}026 \pm 14^{d}$	843 ± 40^{e}	$1{,}209 \pm 3^{c}$	$1{,}336 \pm 7^{a}$
Fat binding ability (%)	116 ± 6^{e}	222 ± 3^{c}	228 ± 4^{b}	258 ± 3^{a}	233 ± 2^{b}	178 ± 2^{d}
Foaming capacity (%)	20.0 ± 0.0^{e}	34.6 ± 2.3^{d}	43.3 ± 1.1^{c}	53.3 ± 1.1^{b}	66.6 ± 2.3^{a}	42.0 ± 2.0^{c}
Foaming stability FS30 (%)	83.3 ± 0.0^{b}	83.1 ± 0.7^{b}	70.2 ± 0.7^{d}	77.8 ± 1.1^{c}	68.4 ± 0.6^{d}	87.7 ± 0.8^{a}
Foaming stability FS60 (%)	83.3 ± 0.0^{a}	74.2 ± 1.2^{b}	69.7 ± 0.5^{c}	73.4 ± 1.9^{b}	62.0 ± 1.0^{d}	82.6 ± 2.0^{a}
Emulsion activity index ($m^2\ g^{-1}$)	72.8 ± 0.7^{a}	65.5 ± 3.5^{b}	63.5 ± 3.1^{b}	63.1 ± 2.2^{b}	66.5 ± 1.3^{b}	56.0 ± 3.1^{c}
Emulsion stability index (min)	12.7 ± 0.2^{abc}	12.9 ± 0.5^{ab}	12.4 ± 0.7^{abc}	11.7 ± 0.5^{bc}	13.4 ± 1.1^{a}	11.1 ± 0.1^{c}

CSG: chicken skin gelatine; BHG: bovine hide gelatine; FSG: fish skin gelatine; PSG: porcine skin gelatine. Results are mean ± standard deviation of triplicate measurements. Different letters in each row indicate significant difference among the samples at a level of 95%.

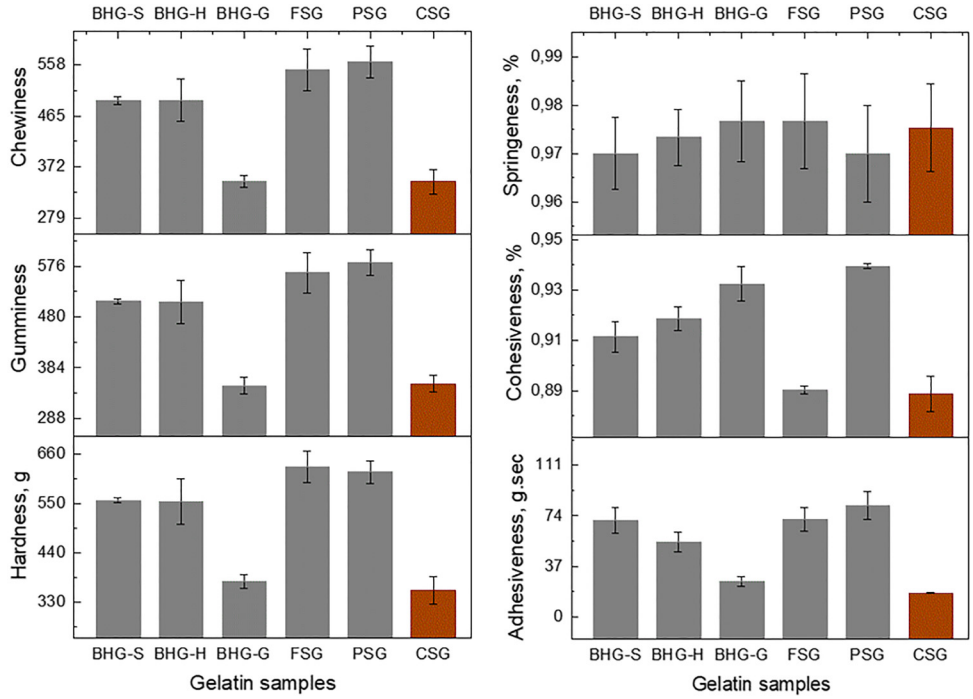

Fig. 2. Textural attributes of gelatine gels

to protein size that provide inter facial films around the emulsion droplets (Wan Omar and Sarbon, 2016). Generally speaking, ESI of CSG values were similar to that of other gelatines, although ESI of FSG were significantly different from that of PSG ($P < 0.05$).

Textural features of the gel samples are given in Fig. 2. Results indicate that there was no significant difference among the samples in terms of springiness. However, the CSG presented significantly lower cohesiveness values compared to other gelatine samples ($P < 0.05$). Springiness of CSG and other gelatine samples varied between 0.96 and 0.99. These results are in good agreement with those previously reported by Muyonga et al. (2004). Almeida and Lannes (2013) also reported that springiness of the gelatine from skins and tendons of chicken feet was 0.95. CSG gave hardness, gumminess, and chewiness values similar to those of BHG-G in the present study. Nile perch skin and commercial fish skin gelatines showed similar hardness and chewiness as reported by Muyonga et al. (2004). Hardness, gumminess, and chewiness are affected by the protein content that strengthen the network structure of gelatine gels.

4. CONCLUSIONS

Chicken skin was used for gelatine extraction despite of its high fat content, which eventually impaired the quality of the resultant gelatine. Nevertheless, a gellable CSG was obtained with gel strength at an acceptable level. However, high fat content of CSG caused turbidity and faded

quality. On the other hand, this study concluded that chicken skin might be utilised in gelatine manufacturing effectively after reducing its high fat content. Gelatine extraction from chicken skin, even under laboratory conditions, led to a yield of dry gelatine as high as 5–6% of the amount of fresh skin used, which may be further improved to 8–9% in a scale-up manufacturing process. Further isolation and purification procedures industrially available may place poultry skin in an advantageous position as an alternative raw material in gelatine manufacturing, overcoming major concerns of different consumer groups.

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