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ARTICLE

# Effects of Various Extraction Methods on Quality Characteristics of Duck Feet Gelatin

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**Abstract**

We determined the optimum pretreatment conditions such as pH and time for swelling duck feet and investigated the effects of the extracting method, such as water bath (WB), pressure cooker (PC), and microwave oven (MO), on quality characteristics of the duck feet gelatin for improving utilization of duck feet as a novel source of gelatin. The soaking solution of pH 1 among pH 1-14 with unit intervals was selected due to the highest yield. The quality characteristics of the gelatin tested were color, pH, gel strength, viscosity, and melting point. For the extracted gelatin with different methods, the CIE L*, a* and b* values were in the following order: MO>PC>WB ($p<0.05$), WB>PC>MO ($p<0.05$) and PC>MO>WB ($p<0.05$), respectively. The gelatin extracted using WB showed the highest pH and that extracted using MO showed the lowest pH ($p<0.05$). The gel strength, viscosity, and melting point were the highest for MO ($p<0.05$). The gel strength and melting point were the lowest for PC ($p<0.05$). No significant difference was found in viscosity between the gelatins extracted using WB and PC ($p>0.05$). The quality characteristic of duck feet gelatin was affected by extracting methods, and MO extraction can be one of the effective methods for duck feet gelatin.

**Key words:** duck feet, gelatin, extraction methods, pressure, microwave oven

## Introduction

In recent years, many restaurants and duck meat-processing facilities have been established in Korea. Duck meat has been mainly consumed through duck meat-processing techniques, such as smoking, boiling, and roasting, but the consumption patterns is limited as a raw material compared to beef, chicken, and pork for meat product. As the per capita consumption of duck meat and the market share of the duck industry increase, the amount of duck by-products, which are portions of the duck carcass except the edible duck meat, would also increase. Duck by-products include feather, feet, bone, and liver. In the textile industry, duck down is used to manufacture duck down parka or other winter clothes. However, currently in Korea, duck by-products such as bone, heart, liver, gizzard, feet, and head are rarely used as human food. Duck feet are a good source of proteins and functional collagen materials, and they have been used partly in a human food preparation called "mustard duck feet" that originated in China and Southeast Asia. Thus, duck feet can be considered as useful by-products from the food industry.

Feet of poultry such as chicken and duck contain large amounts of collagen. Several researchers have studied the use of feet of poultry such as chicken and duck in human food (Jang *et al*., 2002; Lim *et al*., 2001; Lim *et al*., 2002a; Lim *et al*., 2002b). However, no studies have focused on duck feet alone. Although gelatin derived from the collagen in duck feet has been used for human consumption, the potential uses of duck feet *per se* have not been studied until now. Therefore, we believe that research is necessary before duck feet gelatin can be used safely as an ingredient in human food.

Collagen is a major fibrous protein that is found in the skin, tendon, and cartilage. Collagen can be extracted from these organs by using appropriate heat treatments. Collagen molecules are composed of 3 polypeptides, called α-chains (Karim and Bhat, 2009), that are tightly wound around each other to form a right-handed triple helix, which is stabilized by the hydrogen bonds between

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the α-chains (McCormick, 1993). Gelatin can be derived from collagen molecules by disrupting the hydrogen bonds in the collagen triple helix. Therefore, to obtain gelatin from the collagen extracted from duck feet for application in human food, some processing, for example, acid or alkali treatments, would be required (Ahmad *et al*., 2011; Arnesen *et al*., 2006; Jang *et al*., 2002).

The objectives of this study were to investigate the effects of extracting method, such as water bath (WB), pressure cooker (PC), and microwave oven (MO), on quality characteristics of the duck feet gelatin and to improve utilization of duck feet as a novel source of gelatin.

## Materials and Methods

### Experiment I. Effect of pH value on swelling of duck feet

#### Materials

Duck feet were purchased from a local market (Choungsan Co. Ltd., Korea). They were washed several times using tap water to remove visible fat, connective tissue, and blood and were placed in polyethylene bags, vacuum-packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Korea), and immediately stored at -20°C until use.

#### Preparation of the soaking solution

Soaking solutions with varying pH values (pH 1-14) were prepared using 0.1 N HCl, 40% NaOH, and distilled water (DW).

#### Swelling process

A modified version of the swelling process described by Kim (2011) was used in this study. The duck feet stored at -20°C were thawed using flowing tap water. The thawed duck feet were weighed and were separately soaked in 5 times (v/w) of soaking solution (pH 1-14 with unit interval) at 18°C for 24 h to be swollen. After soaking, the feet were neutralized using flowing tap water at 18°C for 48 h until all the soaked feet showed the same pH (5.5±0.1).

#### Determination of swelling yield

The swelling yield was determined by calculating the difference in the weights of the samples before and after processing using the following formula:

Swelling yield (%) = (weight of sample after swelling/ weight of raw material) × 100

#### Evaluation of pH

The duck feet were cut to obtain 5 g samples after the soaking and washing process. The samples were homogenized with 20 mL DW for 60 s in a homogenizer (Ultra-Turrax SK15, Janke & Kunkel, Germany) and the pH was determined using a pH meter (D-51, HORIBA, Japan).

### Experiment II. Effect of the extraction methods on the quality characteristics of duck feet gelatin

#### Extraction of gelatin from the prepared duck feet

The procedures for extracting gelatin from the processed duck feet are shown in Fig. 1. The swelling was carried out using the soaking solution of pH 1 which results in the highest swelling yield, by using the method described in “Experiment I” in the Methods section. The fully swelled duck feet were drained, placed in polyethylene bags, and vacuum-packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Korea) for extraction. The extraction was performed using 3 different methods as follows: heating in a WB (VS-1901W, Vision Scientific Co. Ltd., Korea) at 95°C for 120 min, heating in PC (CRP-HEG 1070FP, Cuckoo Homesys Co. Ltd., Korea) under 88.2 kPa (0.9 kgf/cm$^2$) for 70 min, and heating covered with a suitable plastic lid in a MO (RE-M400, Samsung, Korea; frequency 2450 Mhz) at 350 W power for 5 min. The extracted gelatin was filtered using a piece of gauze to remove any contaminants. Then, the filtered gel-

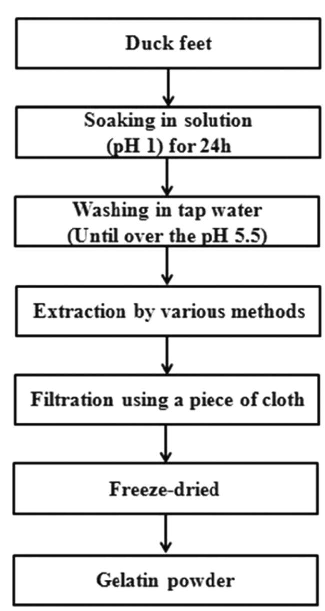


**Fig. 1. The diagram of duck feet gelatin by different extraction methods.**

atin samples were cooled and coagulated at 18°C. The fat layer that formed at the top of the coagulated gelatin was removed. Thereafter, the samples were frozen at -70±1°C and dried at -40°C under $80\times10^{-3}$ torr pressure by using a freeze dryer (PVTFD20R, Ilshinlab, Korea). The samples were dehydrated for 48 h in the freeze dryer until they reached a constant weight (< 15% final moisture).

### Determination of extraction yield

The extraction yield was determined by calculating the difference in the weights of the samples before and after processing using the following formula:

Extraction yield (%) = (weight of sample after extraction/weight of raw material) × 100

### Determination of gelatin powder yield

The gelatin powder yield was determined by calculating the difference in the weights of the samples before and after processing using the following formula:

Gelatin powder yield (%) = (weight of sample after freeze-drying/weight of raw material) × 100

### Evaluation of color

We prepared 6.67% duck feet gelatin samples (w/v) in the form of 2×2×2 cm cubes, and measured the color of the samples by using a colorimeter (Chroma meter CR-400, Minolta, Japan; illuminate C, calibrated using a white standard plate CIE L*=97.83, CIE a*=–0.43, CIE b*=+1.98) that consisted an 8 mm diameter measuring area and a 50 mm diameter illumination area. The CIE L*, a*, and b* parameters of the colors on the surface of the prepared gelatin sample cubes were evaluated, and each measurement was taken in triplicate according to methods described previously (Hao *et al*., 2009; Jamilah and Harvinder, 2002).

### Evaluation of gel strength

We prepared 6.67% gelatin samples (w/v) in the shape of 2×2×2 cm cubes. We used a Texture Analyzer (TA-XSK1*i*, Stable Micro System Ltd., Surrey, U.K.) to evaluate the force required to create a 10 mm depression in the sample at a rate of 0.5 mm/s by using a probe 10 mm in diameter. The shear force values (kg) were calculated using the values for the maximum force required to shear through each sample. The gel strength analyses were performed in triplicate at 18°C for each gelatin sample.

### Analysis of viscosity

The flow behavior and time dependency of the 6.67% duck feet gelatin samples (w/v) (liquid phase) were evaluated in triplicate by using a rotational viscometer (HAKKE Viscotester® 550, Thermo Electron Corporation, Karlsruhe, Germany) that was set at 10 rpm. The results were analyzed using a standard cylinder sensor (SV-DIN) at 35±1°C. The time dependency of the 6.67% duck feet gelatin (w/v) (liquid phase) was evaluated by measuring the apparent viscosity under a constant shear rate of 50 $s^{-1}$ for 30 s.

### Determination of melting point

The melting points of the 6.67% gelatin samples (w/v) were determined by calculating the average of the temperature at the start and end of the melting process by using a melting point analyzer (ATM-01, AS ONE, Japan) as follows:

Melting point (°C) = (temperature when the melting starts + temperature when the sample is completely melted) / 2

### Evaluation of pH

We homogenized 5 g of the 6.67% (w/v) gelatin samples with 20 mL DW for 60 s in a homogenizer (Ultra-Turrax SK15, Janke & Kunkel, Staufen, Germany). Then, we determined the pH of the homogenized samples by using a pH meter (D-51, HORIBA, Japan).

### Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) analysis

SDS-PAGE analysis of the gelatin samples was performed by the method of Laemmli (1970). Briefly, we prepared mixtures of 0.67% duck feet gelatin samples (w/v) and Laemmli sample buffer (Bio-Rad Lab, Inc., USA) in the following proportions: 1:2 (0.22%), 1:1 (0.33%), and 3:1 (0.5%). The mixtures were heated to 100°C for 5 min, and then 15 µL of each sample was injected into the wells in the 12% Mini-PROTEAN® TGX™ Precast Gel (Bio-Rad Lab, Inc., USA). The buffer solution used for the electrophoresis was composed of 0.025 M Tris-HCl, 0.250 M glycine, and 0.1% SDS (pH 8.3). The loaded gel was stained using Coomassie Brilliant Blue R250 (B7920, Sigma, USA), and was destained using a destaining solution containing methanol:DW:acetic acid (50:40:10). The separated protein bands were identified by comparing with those of standard protein markers (Precision Plus Protein Standards, catalog number 161-0374, Bio-Rad Lab., USA), which included the 250, 150, 100, 75, 50, 37, 25, 20, 15, and 10 kDa bands.

### Statistical analysis

Analysis of variance was performed on all the measured variables using the General Linear Model (GLM) procedure in the SAS statistical package (SAS Institute, Inc., 2010). Duncan's multiple range test ($p<0.05$) was used to determine the difference among the treatment means.

## Results and Discussion

### Experiment I. Effect of pH value on swelling of duck feet

#### Determination of yield

Yield is one of the most important considerations for the industrial production of duck feet gelatin (Johnston-Banks, 1990). Yield was determined on the basis of the extent of swelling obtained using soaking solutions of various pH values; yield increased in proportion to the increase in the extent of swelling. Fig. 2 shows that the extent of swelling obtained using soaking solutions of various pH values (1-14) follows a U-shaped curve. The swelling was the highest (approximately 148%) at pH 1. At pH values 1-3 the extent of swelling decreased markedly with increase in pH and when the pH was between 3 and 11, the swelling was in the range of 105-107% and showed no significant difference. At pH values 11-13, the extent of swelling increased with increase in the pH value. We could not determine the extent of swelling in the duck feet soaked in solution of pH 14 because they fragmented and melted within 6 h of soaking.

Generally, all gelatin manufacturing processes consist of 3 main stages: pretreatment of the raw material, extraction of gelatin from collagen, and purification or drying of the extracted gelatin (Kim, 2011). Pretreatment is necessary to prepare native collagen, such as that derived from duck feet, for gelatin extraction using different extraction methods including heating in water (Gómez-Guillén *et al*, 2011). Pretreatment breaks the non-covalent bonds, which disrupts the protein structure, thereby facilitating swelling and collagen solubilization (Campbell, 1994; Stainsby, 1987; Ward and Courts, 1977). Furthermore, the swelling process affects the extraction considerably (Ahmad *et al*., 2011). Liu *et al* (2001) obtained swelled chicken feet by using solutions with various pH values and Ashar *et al* (1982) demonstrated that acetic acid is one of the most effective reagents for swelling. Shin (2002) examined optimal swelling time of pork skin and chicken feet under acidic condition (pH 2.6), and reported that the optimal extracting time is 12 h due to no changes in pH of soaking solution and the weight increase rates of pork skin and chicken feet over 12 h.

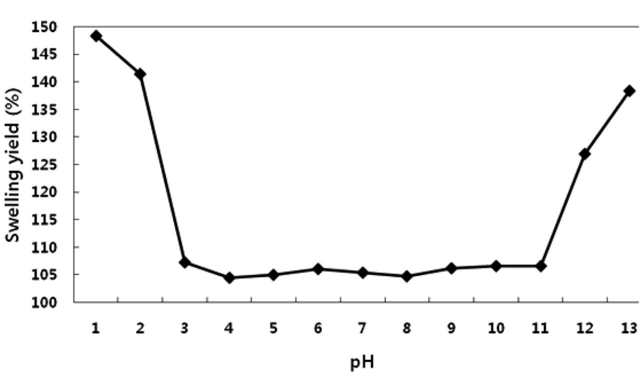


**Fig. 2. The swelling yield by solution with various pH values.**

Depending on the type of pretreatment used, 2 types of gelatin can be obtained; these are known commercially as type-A and B gelatin, which are obtained under acid and alkaline pretreatment conditions, respectively (Ahmad *et al*., 2011; Benjakul *et al*., 2009; Gómez-Guillén *et al*, 2011; Haug *et al*., 2004; Veis *et al*., 1964; Ward and Courts, 1977). The isoelectric point of type-A gelatin is in the range of pH 8-9, and that of type-B gelatin is between pH 4 and 5 (Hinterwaldner, 1977). The extent of protein breakdown increases as the difference between the pH of the soaking solution and the isoelectric point of the protein increases (Djabourov *et al*, 1993; Gómez-Guillén *et al*, 2002). On the basis of the above mentioned results, we concluded that the gelatin extracted from duck feet was type-A gelatin because the highest swelling yield was obtained using a soaking solution of pH 1. Moreover, we also deduced that the isoelectric point of duck feet gelatin would be between pH 8 and 9, because at pH 1 the difference between the pH of the soaking solution and the isoelectric point of the protein was highest. Therefore, the soaking solution of pH 1 was selected for further experiments.

#### Evaluation of pH

Fig. 3 shows the pH values of the duck feet after soaking and washing. The pH values ranged from 1.78 to 12.32. The pH of duck feet increased markedly with the increase in the pH of the soaking solution at pH 1-4 and pH 10-13, whereas it showed no difference at pH 4-10. The pH values of duck feet after washing with tap water ranged from 5.86 to 9.36. After washing, the pH values for all the samples, except those soaked in solutions of pH 1-3 and 11-13, were adjusted to 7-7.5, which was close to the pH of tap water.

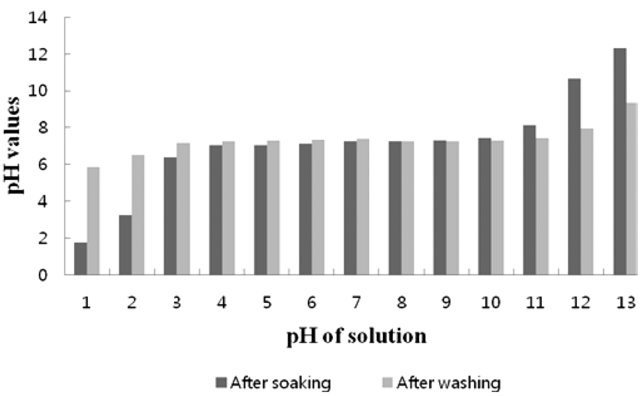


**Fig. 3. The pH values after soaking and washing process.**

## Experiment II. Effect of extraction methods on the quality characteristics of duck feet gelatin

### Determination of extraction yield and gelatin powder yield

Extraction yield is another important factor to be considered while determining the optimum conditions for industrial production of duck feet gelatin because it can markedly affect the feasibility of mass production of the gelatin (Johnston-Banks, 1990). The heat treatment involved in each of the different extraction methods functions to break the hydrogen bonds in the collagen molecule, which disrupts the 3-dimensional structure irreversibly, leading to the solubilization of collagen to form gelatin (Ahmad *et al*., 2010; Ahmad *et al*., 2011). Generally, gelatin is distributed as a powder type, providing convenience to consumer and user. In many processing parts of extraction to prepare powder, each yield can change according to the extracting method. Table 1 shows the extraction yield and gelatin powder yield for the duck feet gelatin extracted using different techniques. The extraction yield among the treatments ranged from 17.58% to 51.83% in the following order: WB>PC>MO ($p<0.05$). Gómez-Guillén *et al* (2005) reported that extraction yield for the gelatin extracted at high pressure was lower than that for the gelatin extracted at atmospheric pressure. We observed that the yield of gelatin was lower in the PC and MO extractions than in the WB extraction. This could be caused by the moisture in the swelled duck feet was converted to vapor by the combination of extremely high pressure and high temperature. In addition, the yield from MO was significantly lower than that from PC. This could be because microwaves cause a considerable amount of drying of the surface of duck feet, which might have inhibited gelatin extraction.

Gelatin powder yield refers to the amount of dehydrated gelatin obtained using duck feet as raw material or the relative ratio of dehydrated gelatin to the raw material. This value indirectly represents the maximum amount of gelatin that can be extracted from the specific raw material. The gelatin powder yield for the different treatments used in this study ranged from 0.75% to 3.31%, the yield from PC being the highest ($p<0.05$) and that from MO being the lowest ($p<0.05$). These results suggest that the high temperature and pressure in PC extraction facilitated the extraction of gelatin. On the other hand, the high degree of surface drying caused by the microwaves in the MO extraction could have prevented the efficient extraction of gelatin from duck feet.

### Evaluation of color

The results of the color evaluation of duck feet gelatin are presented in Table 2. For the various extraction methods, the L* values for the extracted gelatin showed the following order: MO>PC>WB ($p<0.05$). The a* value was the highest for WB and the lowest for MO ($p<0.05$). The b* value was the highest for PC ($p<0.05$). This result may be associated with the excessive extraction of the yellow bone marrow from the bones in the duck feet due to the high temperature and pressure.

Jamilah *et al*. (2011) showed that color values varied with the type of gelatin, and Ahmad (2011) reported that

**Table 1. Effect of various extraction methods on extraction and gelatin powder yields of duck feet**

| Traits | Treatments[1)] | | |
|---|---|---|---|
| | WB | PC | MO |
| Extraction yield (%) | $51.83\pm1.27^{A}$ | $22.06\pm1.04^{B}$ | $17.58\pm1.42^{C}$ |
| Gelatin powder yield (%) | $3.02\pm0.15^{B}$ | $3.31\pm0.19^{A}$ | $0.75\pm0.06^{C}$ |

All values are mean±SD of three replicate.
[1)]WB: extracted using a water bath; PC: extracted using an electric pressure cooker; MO: extracted using a microwave oven
[A-C]Means in a row with different superscript letters are significantly different ($p<0.05$).

**Table 2. Effect of various extraction methods on instrumental color evaluation**

| Traits | Treatments[1)] | | |
|---|---|---|---|
| | WB | PC | MO |
| CIE L* | $24.79\pm0.14^{C}$ | $27.82\pm0.24^{B}$ | $34.71\pm0.14^{A}$ |
| CIE a* | $-0.65\pm0.02^{A}$ | $-0.87\pm0.02^{B}$ | $-0.99\pm0.08^{C}$ |
| CIE b* | $-1.36\pm0.12^{C}$ | $-0.24\pm0.15^{A}$ | $-1.19\pm0.05^{B}$ |

All values are mean±SD of three replicate.
[1)]WB: extracted using a water bath; PC: extracted using an electric pressure cooker; MO: extracted using a microwave oven
[A-C]Means in a row with different superscript letters are significantly different ($p<0.05$).

the variations in color did not influence the functional properties of gelatin. However, Jang *et al*. (2002) indicated that chicken feet gelatin treated with acid is suitable for appearance compared to that treated with alkali due to a bright color. Thus, the color of gelatin could influence satisfaction of appearance. Our results suggest that microwave oven extraction might be one of effective methods for improving color of duck feet gelatin.

### Analysis of physicochemical properties

Physicochemical properties depend not only on the species, but also on the specific treatment used for extraction (Montero *et al*., 2002). The physicochemical properties, such as the pH, gel strength, viscosity, and melting point, of the gelatin extracted using different methods are shown in Table 3.

Until now, no researchers have studied the relationship between the pH of gelatin and the specific technique used for its extraction. We used 3 different techniques to extract gelatin from duck feet and analyzed the pH variations in the extracted gelatin, and our results showed that specific extraction techniques significantly affected the pH of the extracted gelatin. The pH values ranged from 4.80 to 5.97 for the gelatin extracted using different techniques, and the gelatin extracted using WB showed the highest pH (6.05), whereas the gelatin extracted using MO showed the lowest pH (5.75) ($p$<0.05).

Gel strength, viscosity, and melting point are the most important physical properties of gelatin (Wainewright, 1977; Karim and Bhat, 2009). Furthermore, gel strength is affected by the proline and hydroxyproline content in the raw material (Ahmad *et al*., 2011; Jongjareonrak *et al*., 2006) and the strength of the acid used in the swelling process (Ahmad *et al*., 2011; Giménez *et al*., 2005). Choi and Regenstein (2000) showed that gel strength is directly proportional to the concentration of gelatin. Previously, Lee *et al*. (2012) noted that the contents of amino acid (hydroxyproline/proline) in duck skin treated with alkali or acid were 12.94%/7.75% and 12.78%/8.84%, respectively. However, there is little information available in the studies related to the hydroxyproline and proline contents in duck feet.

**Table 3. Effect of various extraction methods on the physical properties**

| Traits | Treatments[1)] | | |
|---|---|---|---|
| | WB | PC | MO |
| pH | 5.97±0.01$^{A}$ | 4.83±0.01$^{B}$ | 4.80±0.01$^{C}$ |
| Gel strength (kg) | 0.62±0.04$^{B}$ | 0.19±0.05$^{C}$ | 0.70±0.03$^{A}$ |
| Viscosity (pa·s) | 0.0074$^{B}$ | 0.0037$^{B}$ | 0.015$^{A}$ |
| Melting point (ºC) | 38.69±0.31$^{B}$ | 33.06±0.13$^{C}$ | 39.38±0.25$^{A}$ |

All values are mean±SD of three replicate.
[1)]WB: extracted using a water bath; PC: extracted using an electric pressure cooker; MO: extracted using a microwave oven
[A-C]Means in a row with different superscript letters are significantly different ($p$<0.05).

The gel strength of duck feet gelatin might be associated with the degree of protein degradation caused during the swelling and various heating processes. Gel strength of the gelatin extracted in this study ranged from 0.19 kg to 0.70 kg. Among the 3 extraction technique used in this study, MO obtained the gelatin that showed the highest gel strength value ($p$<0.05). The short extraction time in MO extraction may have resulted in the extraction of collagen before complete denaturation of the protein. This resulted in a collagen extract that contained molecules that were more complex than those extracted after complete denaturation. On the other hand, the gel strength was the lowest in PC extraction ($p$<0.05). This could be because the high temperature and pressure in the PC would cause complete denaturation of the collagen molecule, which would in turn result in lowering the gel strength (Gómez-Guillén *et al*, 2002). High pressure has been shown to cause protein denaturation by disrupting the balance of the non-covalent interactions (Gómez-Guillén *et al*., 2005; Masson, 1992). However, some characteristics including gel strength, viscoelastic properties, and melting point of thermally treated gelatin improved under high pressure processing (Montero *et al*., 2002). In addition, Funami (2011) empirically deduced that as the viscosity or gel strength of food increased, the intensity of perceived taste in the mouth decreased.

Viscosity is the second most commercially important physical property of gelatin (Jamilah *et al*., 2004; Ward and Courts, 1977). The gelatin extracted using WB and PC showed no significant difference in their viscosity ($p$>0.05). However, the viscosity of the gelatin extracted using MO was significantly higher than that of the gelatin extracted using WB and PC ($p$<0.05). The viscosity of duck feet gelatin reflects the specific hydrodynamic volume of liquid phase gelatin (Haug *et al*., 2004). In liquid phase gelatin, the breakdown of hydrogen, and probably the electrostatic bonds, in hot water destroys the triple helical structure of collagen to produce random chain gelatin molecules, which in turn contribute to the high viscosity of the solution (Badii *et al*., 2006). For application in food, Johnston-Banks (1983) indicated that the quality of gelatin could determine the gel strength, and Badii *et al*. (2006) suggested that gelatin which has high viscosity is commercially valuable.

The melting point of the gelatin extracted using different techniques ranged from 33.06 to 39.38°C and varied in the following order: MO>WB>PC ($p<0.05$). According to Johnston-Banks (1990) and Gómez-Guillén *et al.* (2005), increase in the melting point is directly related to the increase in the average molecular weight of the duck feet gelatin. Thus, we concluded that the gelatin extracted using PC would have the lowest average molecular weight among the extracted gelatin samples because the high temperature and pressure in the PC would cause considerable protein degradation. Furthermore, Choi and Regenstein (2000) reported that for a specific raw material, melting point was associated with gel strength. They claimed that as the gel strength of gelatin increased, the melting point of gelatin would increase proportionally. Haug *et al.* (2004) reported that the melting point of gelatin was dependent on the proportion of proline and hydroxyproline in the raw material. Also, further studies about the contents of hydroxyproline and proline in duck feet are necessary, as well as changes in the content by extracting methods.

### Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) analysis

Cao and Xu (2008) reported that SDS-PAGE is the most commonly used analytical technique for the identification of collagen chains. Fig. 4 shows the results of the SDS-PAGE analysis of different concentrations of the duck feet gelatin extracted using different extraction methods. The increase in the number and intensity of protein bands in all treatments were observed with increasing gelatin concentration in loaded sample. The WB and MO treatments showed 3 different major bands, comprising the α 1 and α 2 chains that were derived from type I collagen and the β chains. The molecular weight of the α 1 and α 2 chains is approximately 120-130 kDa and that of the β chains is approximately 200 kDa (Shin, 2002). This pattern is similar to that of chicken feet collagen reported by Shin (2002). On the other hand, the band pattern of the PC treatment was different from that of both WB and MO treatments. Thus, the characteristic of collagen was affected by extracting condition such as pressure and temperature, depending on concentration of duck feet collagen. Also, MO extraction can be one of effective methods for improving quality characteristics, including gel strength, melting point, and viscosity of duck feet gelatin.

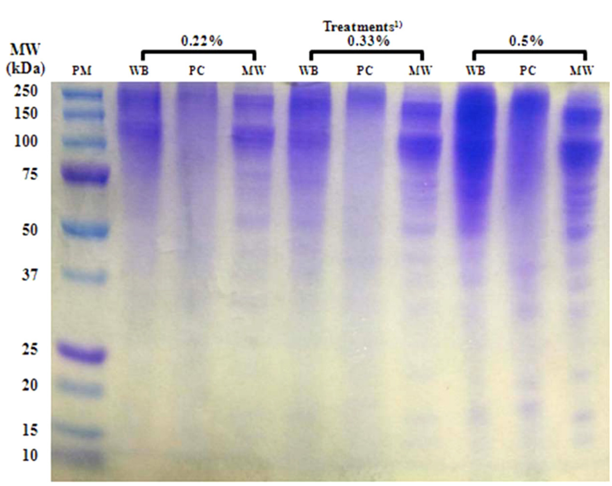


**Fig. 4. Electrophoretogram (SDS-PAGE analysis) of duck feet gelatin by different extraction methods and level of concentration.** [1)]Treatments: WB, extracted using a water bath; PC, extracted using an electric pressure cooker; MO, extracted using a microwave oven; PM, standard protein marker; MW, molecular weight.

## Acknowledgements

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