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RESEARCH ARTICLE

Texture Profile Analysis (TPA) of the jelly dessert prepared from halal gelatin extracted using High Pressure Processing (HPP)

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Abstract

High Pressure Processing (HPP) is a novel extraction method. This technique increases the yield of gelatin and enhances its properties. In this study, the performance of the gelatin extracted from red tilapia fish skin treated with HPP was evaluated using the Texture Profile Analysis (TPA) method, in comparison with the commercial fish gelatin. Based on the Total Soluble Solid (TSS) results, the jelly prepared with HPP-treated gelatin has a longer shelf life. The sensory textures of the lychee jelly were described based on the force-time plot. The results showed that the hardness, adhesiveness, gumminess and chewiness of the jelly prepared using HPP-treated gelatin are higher compared with the commercial gelatin while the cohesiveness and the springiness are similar for both jellies. In conclusion, the jelly prepared using gelatin treated with HPP is preferable compared to the commercial gelatin because it is more rigid, firm and adhesive.

Keywords: Food analysis, gelatin, HPP, TPA, TSS

INTRODUCTION

Gelatin has been widely used in the food industry as a gelling agent, food stabilizer, emulsifier and thickener. Originating mainly from animals' bones and skin, gelatin is a water-soluble macromolecule with a high molecular weight composed of a mixture of heterologous polypeptides. The gelatin is converted from triple helix collagen after thermal hydrolysis due to the denaturation process which causes alterations to the molecular compositions of amino acid residues (Duconseille et al., 2015). Mammalian gelatin has been widely used in the industry. However, the demand for an alternative source of gelatin has increased due to health and religious concerns. A study showed that gelatin from fish skin could substitute mammalian gelatin (Hosseini & Gómez-guillén, 2018). However, fish gelatin has weaker properties compared with bovine and porcine gelatin (Karim & Bhat, 2009). A Chemical treatment is often used to overcome the problem (Tabarestani et al., 2014). However, gelatin extract usually has high chemical residues (da Silva & Pinto, 2012).

High Pressure Processing (HPP) is a novel extraction method. It is also known to be an environmentally friendly technology (Huang et al., 2017). HPP is a technique where a sample is subjected to high pressure levels (up to approximately 1000 MPa) with or without the presence of heat (Gupta & Balasubramaniam, 2012). The process is reported to increase the yield of the gelatin protein and shorten the extraction time (Yusof et al., 2017; Gómez-Guillén et al., 2005; Zhang et al., 2016; Zhang et al., 2011). This is because the pressure disrupts the link of secondary, tertiary and quaternary structures of the gelatin protein during pre-treatment, which helps in releasing more peptide bonds during thermal hydrolysis (Liqing et al., 2012). Besides, more acids were forced into the interior of the protein structure which helps to denature the intermolecular bond, thus increasing the amount of peptide chains released in the extracted solution (Sarupria et al., 2010). In addition, HPP treatment has changed the conformational structure of the gelatin (Spilimbergo et al., 2011). Chang, Niu et al. (2013) stated that the ultrastructure of the protein tissue was changed after treatment under high pressure. The modification also affected the properties of the gelatin produced. The Gel strength and molecular weight of the pig gelatin increased after being treated with HPP (Liqing et al., 2014; Liqing et al., 2012). This is because the high pressure promotes molecular polymerization through the coagulation of the protein component (Peñas et al., 2004). The Performance of the gelatin extracted using the HPP technology in food products is yet to be discovered.

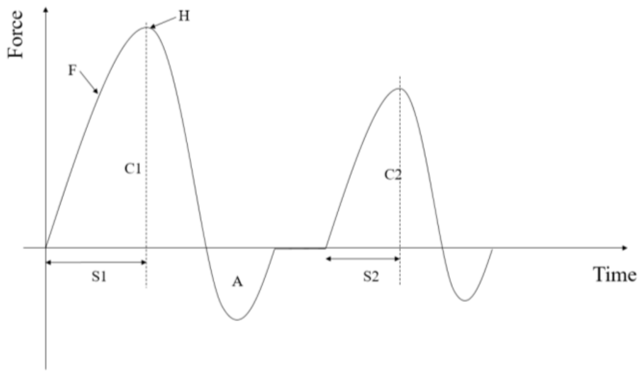

Fig. 1 Typical texture profile analysis (TPA) curve (Mascheroni & Salvadori, 2011).

Texture Profile Analysis (TPA) is an instrumental method to analyze the textural properties of the food. The method was invented in 1963 at the General Foods Corporation Technical Centre and has been used widely for food characterization and quality control (Trinh & Glasgow, 2012). The methodology was done using a texture analyzer machine with a specific probe and the method is proven scientifically (Delgado & Bañón, 2015). The process involves dual compression on the sample, imitating two-bites and generates a force-time graph (Fig. 1). From the graph, primary textural parameters such as hardness (H), adhesiveness (A), cohesiveness (C = C2/C1), and springiness (S =

S2/S1) are derived, while secondary characteristics like gumminess (H x C) and chewiness (G x S) are calculated based on the primary values. In this study, the performance of the gelatin extracted from fish skin using HPP treatment was evaluated using the TPA method in comparison with the commercial fish gelatin. Red tilapia fish was chosen for this study because gelatin from this source has similar properties to the mammalian gelatin (Pang et al., 2017) and is already commercilized.

EXPERIMENTAL

Materials

Red tilapia fish was bought from a market in Gombak, Selangor, Malaysia. The fish was cleaned and the skin was removed using a sharp knife. The fish skin was kept at -80ºC overnight before the removal of excess water using freeze dryer. Later, the skin was cut into small pieces (1 cm x 1 cm) and was stored at -20°C until further use. All chemicals used are analytical grade. Commercial fish gelatin was bought from Shaanxi Orient Industrial Co., Ltd, China.

Extraction of fish gelatin assisted by HPP

Extraction of the gelatin from red tilapia fish skin assisted by HPP was done according to Yusof et al. (2017) with slight modifications. Fish skin was soaked in 0.2 % sodium hydroxide and 0.2% sulphuric acid for 40 min each. For high pressure treatment, the skin and 1.0% citric acid were sealed in a polyethelyne bag and the mixture was placed inside the pressure chamber. The skin was treated at 250 MPa for 10 min at room temperature. The sample was extracted for 12 hours in water (45ºC). The supernatant (liquid-containing gelatin extract) was kept for further analysis while precipitate was discarded. Powdered gelatin was obtained after drying the supernatant using the freeze-drying method.

Gel strength

Bloom test was done according to the British Standards Institution. (1975). Based on the standard method, 6.67% gelatin solution was prepared and refrigerated for 18 hours for gel maturation. The gel strength was tested using a texture analyzer (CT3 Pro Texture Analyzer) equipped with a load cell of 5-kg, cross-head speed 1 mm/s and equipped with a 0.5 inch (27-mm) diameter, flat bottomed plunger. The tests were done in triplicates.

Physicochemical properties

The pH, ash content, moisture content and TSS were done according to AOAC method (AOAC, 1990). All tests were carried out in triplicates.

Jelly dessert

Jelly gel was prepared according to Choi & Regenstein (2000) with modifications. 5 grams of gelatin were dissolved in 95 ml lychee juice (5% w/v). The jelly was allowed to mature at 7ºC for 16~18 hours and was cut into 2 cm cubes.

Texture Profile Analysis

Texture Profile Analysis (TPA) was carried out according to Bourne (1978) with some modifications. Texture analyzer (Brookfield CT3 Texture Analyzer) was attached to a 50-kg load cell. The probe with a diameter of 5 cm was used to compress 40% of the jelly cubes twice from their original height. The compression rate was 0.5 mm/s and the delay between the compressions was 5 sec. The test was done at room temperature. Textural parameters such as hardness, cohesiveness, adhesiveness, springiness, gumminess and chewiness were generated from the force-time graph.

RESULTS AND DISCUSSION

Physicochemical properties of gelatin and jelly dessert

Table 1 shows the physicochemical properties of the HPP-treated gelatin and commercial gelatin. Gel strength is a significant parameter to determine the quality of the gelatin (Lin et al., 2017). Gelatin with a higher gel strength will produce a harder jelly. The results show that the HPP-treated gelatin has a higher gel strength compared with the commercial gelatin. The HPP treatment promotes the molecular polymerization in the gelatin protein and makes it more favorable for the formation of larger amounts of macromolecular polymers. The presence of more high molecular weight components is a main factor in the formation of a high gel strength gelatin (Zhang et al., 2011). The pH for commercial gelatin is 6.5 while HPP-treated gelatin has a low pH of (2.91). Gelatin treated with HPP has a higher ash content compared with commercial gelatin. This is because commercial gelatin undergoes additional processes such as deionization to remove salt (Almeida et al., 2013). An Ash level below 3% is acceptable for gelatin extract before salt removal (Haug & Draget, 2011). Besides, the ash content has no significant impact on gel strength and transparency (Safari & Malek, 2014). The Moisture content for commercial and HPP-treated gelatin is 11.12% and 5.53% respectively, which is below the maximum acceptable moisture percentage (15%). The Moisture content is important to determine the shelf life and purity of the protein (Baziwane & He, 2003). Low moisture content increases the product's stability, thus increasing the shelf life of the product (Chukwu & Abdullahi, 2015).

Table 1 Properties of commercial gelatin and HPP-treated gelatin.

Properties	Commercial gelatin*	HPP-treated gelatin
Gel strength (g)	150	184 ± 0.1
pH	6.50	2.91 ± 0.1
Ash (%)	0.65	2.10 ± 0.2
Moisture (%)	11.12	5.53 ± 0.25

**Shaanxi Orient Industrial Co., Ltd, China.*

Lychee jelly was prepared according to Choi & Regenstein, (2000). The Physicochemical properties of the jelly dessert prepared using commercial and HPP-treated gelatin were measured and the results are shown in Table 2. The pH of the lychee dessert prepared using commercial gelatin was 4.88, while pH 2.96 was recorded for the HPP-treated gelatin. The pH of the lychee dessert prepared using commercial gelatin is lower compared with the initial pH of the commercial gelatin powder (Table 1) due to the pH of lychee juice (3.38 pH). The percentage of ash for the jelly dessert is 0.26% and 0.41% for the jelly prepared with commercial gelatin and the HPP-treated gelatin, respectively. The high value of the ash content for the jelly prepared using treated gelatin is caused by the high ash content of the gelatin powder. The moisture content for jelly with commercial gelatin and with HPP-treated gelatin is 85.69% and 86.07%, respectively. Jelly is one of the high moisture foods (Richardson et al., 2017). Hartel et al. (2017) suggested that foods with higher moisture content should be stored with relative humidity (RH) of 55-65%, to increase their shelf life.

Food stability based on total soluble solid (TSS)

Table 2 Physicochemical properties of gelatin dessert.

Properties	Properties of jelly dessert	
	HPP-treated gelatin	Commercial gelatin
pH	2.96 ± 0.1	4.88 ± 0.1
Ash (%)	0.41 ± 0.11	0.26 ± 0.02
Moisture (%)	86.07 ± 0.05	85.69 ± 0.02
Total soluble solid (°Brix)	16 ± 0.0	15.7 ± 0.0

Sugar content and organic compounds in the food products are represented by the total soluble solids (TSS) (Curi et al., 2017). It is an important parameter to determine the quality of the food (Xia et al., 2016). TSS test was done using a refractometer and the unit is °Brix. A high value of TSS shows a high amount of sugar. TSS results for the jelly prepared from commercial gelatin and HPP-treated gelatin are shown in Table 2. Both possess a similar Brix number, which signifies the similarity of the sugar content for both jellies. Literature has shown that high pressure has no significant impact on the soluble solid content of the food components. For example, TSS for fresh pineapple puree remained constant after treatment with high pressure (Chakraborty et al., 2015), and untreated cactus fruits had a similar soluble solid content to the HPP-treated juice (Moussa-Ayoub et al., 2017).

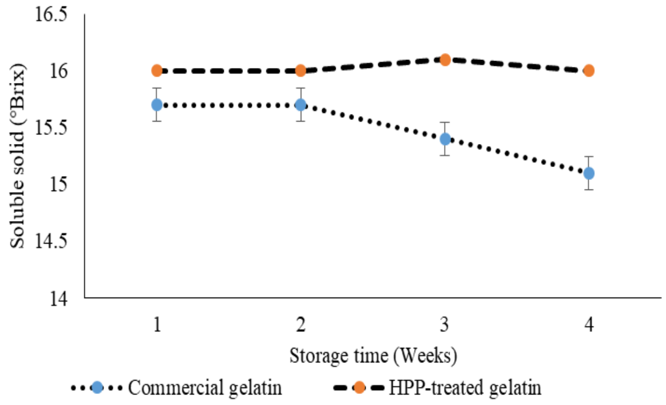

Fig. 2 Total soluble solid against storage time for lychee juice, jelly with gelatin treated by HPP and jelly with commercial gelatin.

The Jelly dessert was stored at a low temperature for 28 days. The amounts of the soluble solids for lychee jelly throughout the storage are shown in Fig. 2. The TSS value for jelly with gelatin treated with HPP remained constant for four weeks. Similar results were found from a study done by Mani-lópez et al. (2017). In their work, the Brix reading for the mango gelatin dessert remained unchanged after being kept at 5°C for 28 days. On the other hand, TSS for the jelly prepared with commercial gelatin started to decrease after refrigeration for two weeks. These results show that the HPP-treated gelatin could retain the consistency of the food for a longer period. The changes in TSS value signifies the modifications in textural attributes (Delgado & Bañón, 2015). Khairallah (2011) explained that the changes happened due to the interaction between the protein's peptide fraction and the lychee juice components. As mentioned earlier, TSS is an important parameter to determine the quality of food products. Thus, the gelatin treated with HPP could preserve the quality of food products and increase the shelf life of the jelly compared with commercial fish gelatin.

Texture Profile Analysis (TPA)

TPA is also known as the two-bite test because the sample will be compressed twice using the suitable probe. A Preliminary study indicates that the appropriate compression for the sample is 40% from its original height, which is similar to a study done by Sow & Yang (2015). The Force vs time plot is presented in Fig. 3 and the textural parameters are shown in Table 3.

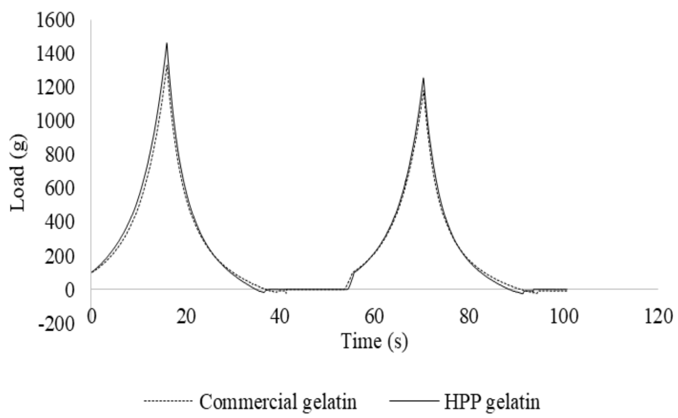

Fig. 3 Comparison of TPA results between jelly prepared with commercial gelatin and HPP-treated gelatin.

Table 3 Texture parameters of lychee jelly produced from different sources of gelatin.

Properties	Commercial gelatin	HPP-treated gelatin
Hardness (N)	13.11 ± 0.13	14.19 ± 0.22
Adhesiveness (Ns^{-1})	0.2 ± 0.0	0.45 ± 0.49
Cohesiveness	0.89 ± 0.03	0.87 ± 0.05
Springiness (mm)	0.92 ± 0.01	0.93 ± 0.02
Chewiness (N mm)	85.7 ± 3.39	90.85 ± 5.44
Gumminess (N)	11.65 ± 0.21	12.26 ± 0.44

Hardness

Hardness, also known as firmness, is the most significant sensorial parameter for TPA analysis. It is a factor that is used to evaluate the mouthfeel and is defined as the force required to attain a given deformation (Garrido et al., 2014; Kek et al., 2013). The hardness of the jelly prepared using the HPP-treated gelatin and commercial gelatin is 14.19 N and 13.11 N, respectively. The results show that the HPP-treated gelatin produced a firmer gum compared with the commercial gelatin. The hardness of the jelly is affected by the gelatin concentration (Garrido et al., 2014). In this study, the concentration for both desserts is equivalent, which is 5% w/v. However, as stated in Table 1, the strength of the protein structure for gelatin treated with HPP is higher than the commercial gelatin. A higher protein content improves the structural bonding of the gelatin (Rahman & Al-Mahrouqi, 2009). The firmness of the lychee jelly dessert in this study was similar to honey jelly candies (Mutlu et al., 2018). In addition, the hardness of the jelly is directly related to the moisture content. As the moisture content drops, the texture changes from soft to hard (Delgado & Bañón, 2015). However, since the moisture content for both kinds of jelly is the same, the hardness of the gel highly depends on the type of gelatin used. Foods with a small-scale firmness and high springiness have a good chewiness property (Kek et al., 2013).

Adhesiveness

Adhesiveness (also known as stickiness) indicates the work required to overcome the attractive forces between the surface of the food and the surface of the material with which the food comes into contact (e.g. tongue, teeth, palate) (Mutlu et al., 2018). The TPA test signifies the work required to detach the probe from the sample after the first compression (Garrido et al., 2014). The adhesiveness for the commercial gelatin is 0.2 Ns-1 while a value of 0.45 Ns-1 was reported for the jelly with the HPP-treated gelatin. These values depend on the surface properties and the combined effect of adhesive and cohesive forces (Hamedi et al., 2018) which are related to the molecular structure of the products (Mutlu et al., 2018). Studies have shown that jellies with a high-scale firmness also have a high value of adhesiveness (Asmoudi et al, 2010; Benet, 2005; Daryaei, 2008; Mutlu et al., 2018).

Cohesiveness

The rate at which the material deforms under mechanical enforcement which is related to the strength of internal structure and difficulty in breaking down the internal bonds is measured as cohesiveness (Hamedi et al., 2018). The jelly is easy to chew and swallow when it has a low cohesiveness value. In the real world, cohesiveness is the most important parameter for the acceptance factors for all ages (Kawano et al., 2017). Since both of the samples possess a similar cohesiveness value (0.88 ± 0.01), the products will receive the approval from consumers despite having different firmness levels. In contrast to the hardness, the cohesiveness decreases with the increase in gelatin concentration (Garrido et al., 2014). Based on this theory, the cohesiveness of jelly with treated gelatin should be higher compared with the commercial gelatin. These results have shown a unique food behaviour for the HPP-treated gelatin because even though the jelly is firmer compared with the commercial gelatin, it can be chewed easily. Besides, literature has shown that the cohesiveness of jelly candies is between 0.54 and 0.82 (Mutlu et al., 2018) which is similar to the results obtained in this study.

Springiness

The springiness of food is inversely proportional to hardness (firmness increases, elasticity decreases) (Kreungngern & Chaikham, 2016). A previous study has shown that the springiness of jelly candy is between 0.90-1.50 (Khouryieh et al., 2005) and the results obtained in this study are within that range (Table 3). Also known as elasticity, springiness represents the rate at which the deformed sample returns to its initial condition after the removal of the deforming force (Garrido et al., 2014). The parameter is related to the concentration of the gelatin (Hamedi et al., 2018). Since the concentration of gelatin used in this study is constant (5%), both jellies obtained similar springiness results. For food sensory testing, this parameter is important in perceiving the rubberiness of the jelly in the mouth since it measures the amount at which the gel structure is broken down by the first compression (Hamedi et al., 2018).

Gumminess

A secondary parameter, gumminess, was calculated as the product of hardness times cohesiveness. Literature shows that the gumminess of a product increases when hardness increases (Mutlu et al., 2018) because the energy needed to disintegrate a semi-solid food product to a state ready for swallowing increases when the jelly is harder (Garrido et al., 2014; Kreungngern & Chaikham, 2016). Gumminess for the jelly prepared with gelatin treated with HPP is 12.26 N which is higher than 11.65 N recorded for the commercial gelatin. These results are similar with the hardness results since jelly cooked with gelatin treated with HPP is firmer compared with the commercial gelatin.

Chewiness

Chewiness is one of the important texture characteristics for a jelly product and it represents the energy required to masticate a solid food to a state ready for swallowing (Calvarro et al., 2016). Similar to gumminess, chewiness will increase if the degree of hardness increases (Mutlu et al., 2018). Results show that the chewiness for the commercial gelatin is 85.7 Nmm, which is 5 Nmm lower than the other sample. These findings are acceptable because the hardness of the jelly prepared using gelatin treated with HPP is higher. Delgado & Bañón. (2018) has stated that the value of chewiness is more useful than gumminess for discriminating elasticity in jellies, a solid matrix.

CONCLUSION

Findings show that the jelly with HPP-treated gelatin could preserve the quality of food products and increase their shelf life. Based on the instrumental sensory evaluation, the hardness, adhesiveness, gumminess and chewiness of the jelly gel prepared with gelatin treated with high pressure are higher compared with the jelly that uses commercial gelatin due to their gel strength property. In contrast, springiness and cohesiveness for both jellies are similar. As a conclusion, jelly with the HPP-treated gelatin is preferable because the gumminess is more rigid, firm and adhesive.

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