Physicochemical and Sensory Characteristics of Fish Gelatin

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ABSTRACT: The physicochemical differences between pork and fish gelatin and the effect of melting point on the sensory characteristics of a gelatin-water gel were investigated. Gelatin gel strength (measured as Bloom) and melting point of gelatin gels were measured, and quantitative descriptive analysis sensory tests were performed. The dependence of the gelatin gel strength and the melting point of fish gels on gel concentration, maturation time, maturation temperature, pH, and the influence of NaCl and sucrose were similar to those for pork gelatin. The flavored fish gelatin dessert gel product had less undesirable off-flavor and off-odor and a more desirable release of flavor and aroma than the same product made with an equal Bloom, but higher melting point, pork gelatin.

Key Words: gelatin, fish, pork, kosher, halal

Introduction

GELATIN IS AN IMPORTANT INDUSTRIAL GELLING BIOPOLYMER normally derived from beef or pork. It is used to increase the viscosity of aqueous systems and to form aqueous gels. Its useful properties include thermo-reversibility, a characteristic rheology described as melt-in-the-mouth, and an excellent release of flavor. Jones (1977) and Anonymous (1980) described the food and nonfood uses of gelatin. Gelatin's single largest use is in gel desserts. Estimated world usage is 200,000 metric tons per year with U.S. usage being about 30,000 metric tons per year for food and about 10,000 metric tons per year for pharmaceutical applications (Herz 1995).

The traditional sources of gelatin present problems for such religions as Judaism and Islam. These communities cannot accept pork gelatin, and beef gelatin is acceptable only if it has been processed in accordance with religious requirements. Products from fish with removable scales (that is, those that can be removed without tearing the skin) are acceptable in Judaism with minimal restrictions, while all fish are acceptable in Islam. In addition to religious needs, the commercial use of fish skins, bones, and swim bladders, which are usually wasted, to yield additional income has both economic and waste management benefits for the fish industry because of the large quantities of these materials generated.

Although some fish gelatin is available commercially, it is less well characterized than pork or beef gelatin. For food applications, gel strength, viscosity, and melting point are the most important properties characterizing gelatin. These properties are affected by many factors, such as concentration of the gelatin solution, gel maturation time, gel maturation temperature, pH, and salt content. A few studies on the food properties of fish gelatin have been done (Norland 1987, 1990; Osborne and others 1990). Leuenberger (1991) directly compared fish and pork gelatins.

In this study, experiments were divided into 2 parts. The 1st part focused on the physicochemical properties of pork and fish gelatins. The gelatin gel strength and melting point of gels were examined by changing key variables, such as maturation time, maturation temperature, pH, and NaCl and sucrose content. The 2nd part focused on the effect of different melting points on the sensory properties of gelatin gels. Gelatins with the same gel strength but different melting point were subjected to quantitative descriptive analysis.

Results And Discussion

Basic characteristics of the 7 gelatins

Gelatin gel strength, MP (melting point), pH, and pI of 7 gelatins were examined (Table 1). Bloom ranged from 110 to 290. The Blooms of the four pork-derived gelatins were well spread through the range (1 110 Bloom, 2 around 220 Bloom, and 1 290 Bloom gelatin), while the Blooms of the fish gelatins were all around 200. MP ranged from 25.0 °C to 33 °C. There was an apparent trend showing that a higher gel strength gelatin has a higher MP within the same source, that is, pork or fish. The MP of all the fish gelatin samples were significantly lower than any of the 4 pork gelatin samples ($p < 0.05$). PH values of gelatins ranged from 4.2 to 6.5, and pI values ranged from 5.2 to 8.0.

Physicochemical properties of gelatins

The gel strength of both fish and pork gelatins increased similarly with concentration (Fig. 1a). The results were fitted to the power law expressed by the following equation:

$$b = kC^n \quad (1)$$

where b = gel strength at a concentration (w/w), k = the proportionality constant, C = total gelatin concentration (w/w) (Ferry, 1948). Even though n varied for each gelatin, generally it was around 1.7 (Table 2). This is consistent with the observation by Ferry (1948) that the gel strength was almost proportional to the square of the concentration of gelatin. An increase in the concentration of the gel solutions, from 2% to 12%, resulted in an 8.1% to 11% increase in the melting point of the gelatins (Fig. 1b). The melting point data also conformed to the power law, but the val-

Table 1—Blooms and melting points of samples used for the sensory tests

	Bloom	Melting point (°C)
1st sensory test		
3.3% of 250B PSG	95 ± 3	29 ± 0.2
3.3% of 260B FSG	95 ± 5	24 ± 0.3
3.3% of mixture (50% 250B PSG + 50% 260B FSG)	95 ± 5	26.5 ± 0.2
2nd sensory test		
3.3% of 250B PSG	95 ± 3	29 ± 0.2
4.2% of 190B FSG	95 ± 5	24 ± 0.3

ues of n were around 0.5. The rate of increase of melting point decreased with increasing concentration, while that of gel strength increased with increasing concentration.

The gel strength of the 7 gelatin gels rose sharply with increased maturation time up to 4 h. (Fig. 2a). Gel strengths reached constant values with about 16 h of maturation. The behaviors of pork and fish gelatins were similar. Melting points changed primarily during the 1st 3 to 6 h of maturing (Fig. 2b). After 3 to 6 h of maturation, melting points reached constant values, which is consistent with the results of Wainewright (1977) for pork gelatin. However, the melting points of the fish-derived gelatins kept rising up to 5 to 6 h of maturation. Gel strength kept rising up to 16 to 18 h of maturation, while melting point stopped rising after 3 to 6 h of maturation. This increase of gel strength and melting point has previously been attributed to the fact that each polypeptide chain of gelatin becomes ordered, either by the growth of existing junctions or by the formation of new, but less stable, junctions from the regions containing a lower content of pyrrolidine residues (Ledward 1986). However, from this result, it can be concluded that the maturation process for melting point is different from that for gel strength.

As expected, gel strength decreased linearly with increasing maturation temperature (Fig. 3a). The rates of decrease for all gelatin gels were almost the same. Melting point, in contrast, increased with increasing maturation temperature (Fig. 3b). Fish and pork gelatin gels showed similar patterns. The data for gel strength and melting point were fitted to first-order linear lines (R^2 = 0.98 – 0.99). It has been reported that, in most cases, increasing gel strength of a gelatin gel is accompanied by an increased melting point (Veis 1964). Our results are consistent with the observation by Nijenhuis (1981) that a gel matured at higher temperature may have a higher melting point than a gel of the same solution prepared by rapidly chilling to a lower tempera-

Table 2—The values of n and R^2 for gel Bloom and melting point of each gelatin

	Power law			
	Bloom		Melting point	
	n	R^2	n	R^2
300B PSG	1.6	0.998	0.5	0.996
100B PSG	1.8	0.998	0.5	0.996
Knox	1.7	0.999	0.6	0.995
230B PBG	1.6	0.999	0.4	0.989
225B FSG	1.6	0.996	0.4	0.987
200B FSG	1.8	0.997	0.3	0.989
190B FSG	1.7	0.999	0.3	0.99

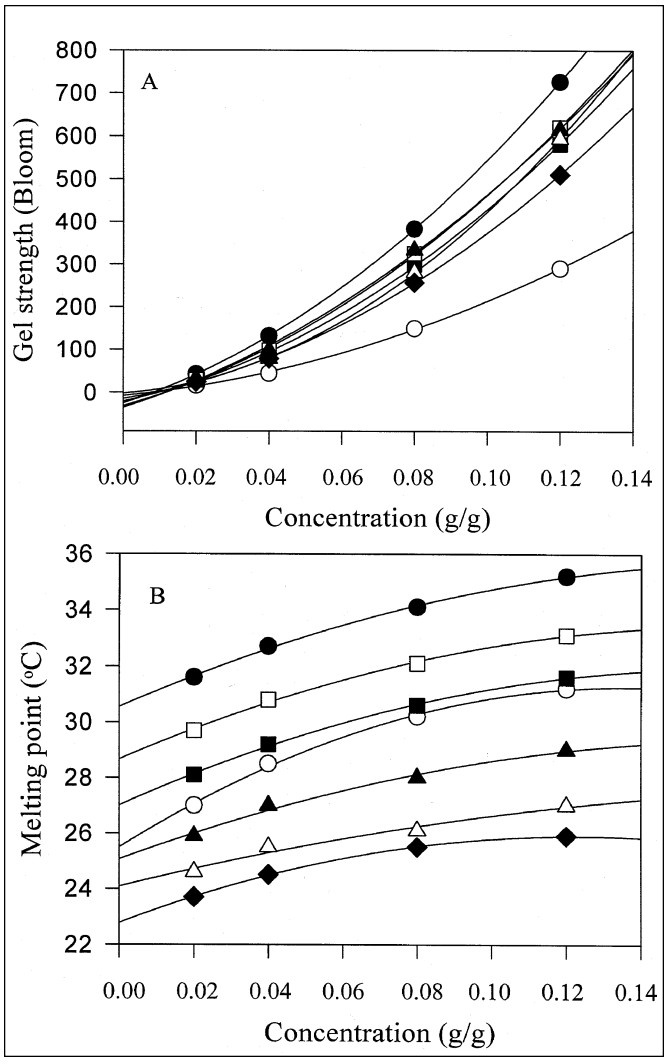

Fig. 1—Gel strength (A) and melting point (B) of 7 gelatins as a function of concentration. ● = 300 Bloom PSG. ○ = 100 Bloom PSG. ■ = Knox. □ = 230 Bloom PBG. ▲ = 225 Bloom FSG. △ = 200 Bloom FSG. ◆ = 190 Bloom FSG.

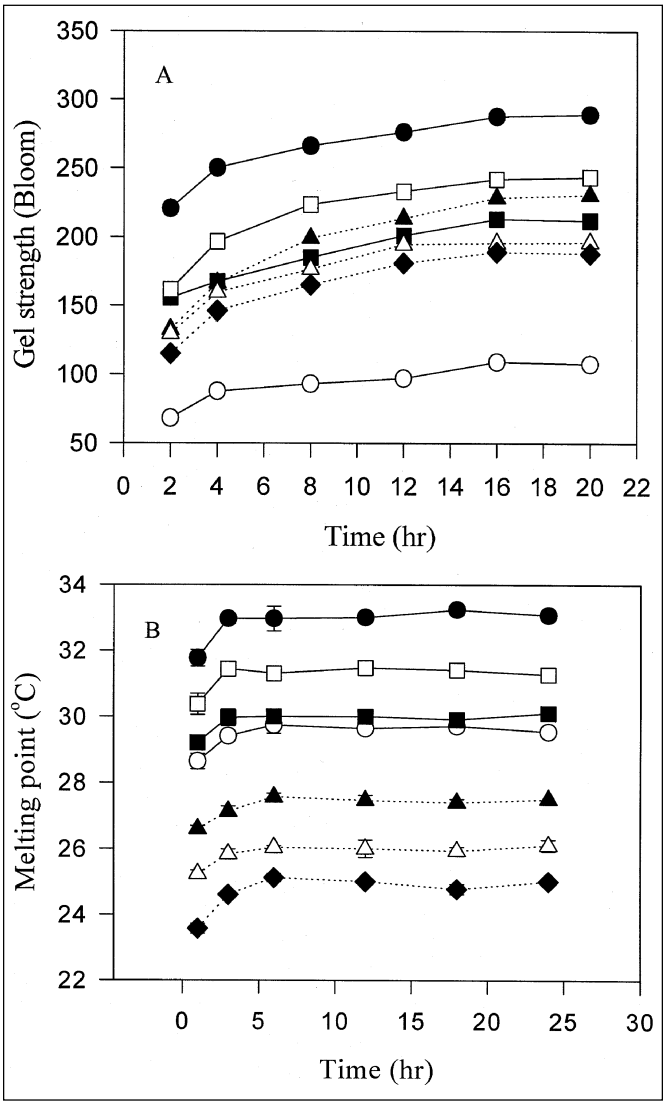

Fig. 2—Gel strength (A) and melting point (B) of 7 gelatins as a function of maturation time. (See Fig. 1 for symbol code.)

ture. The melting point of gelatin is very dependent on the conditions during the first hour of maturing (Veis 1964). If maturation temperature is lower, gelation proceeds more rapidly. This rapid gelation does not allow the gelatin gel to be fully matured to a stable melting point. This gel, therefore, shows a lower melting point. However, in the case of maturation for gel rigidity, a lower maturation temperature makes the gel more rigid.

The gel strengths of all the gelatins decreased markedly below pH 4 and slightly above pH 8 (Fig. 4a). All gelatins showed a maximum gel strength at around pH 8. For the melting point of gelatins, similar pH dependences (Fig. 4b) were observed. Within the range of pH 4 to pH 8, melting point increased slightly. This result is consistent with the observation by Crumper and Alexander (1954) for pork gelatin, which had a maximum rigidity at pH of about 9, a slight falling-away to pH of about 5, and a marked drop below pH 4 and above pH 10. The pH stability over a fairly wide range is very useful for many food applications of gelatin.

NaCl depressed the gel strength and melting point as the concentration increased (Fig. 5a,b). Gel strength decreased sharply up to 2% NaCl. However, above that concentration, the rate of decrease went down. Pork gelatins lost 37% to 54% of their gel strength at 14% NaCl, while fish gelatins lost 64% to 65% of their initial gel strength. Melting points of gelatins decreased roughly linearly as the concentration of NaCl went up to 14%. Fish gelatins were more sensitive to NaCl concentration. The melting points of fish gelatins were reduced by 14% to 18%, while the melting points of pork gelatins were reduced by 9% to 11%. These decreases caused by NaCl are ascribed to the fact that NaCl is capable of breaking both hydrophobic and hydrogen bonds, thus presumably preventing the stabilization of the gel junction sites, either directly by preventing hydrogen bond formation and/or by modifying the structure of the liquid water in the vicinity of these sites (Finch and others 1974).

An increase in sucrose content in the gel solution resulted in a slight increase in the gel strength and melting point (Fig. 6a, b). The 300B PSG, 100B PSG, and 225B FSG showed 16%, 18%, and 15% increases in gel strength, respectively, at 14% sucrose, while they showed only 3.7%, 3.8%, and 3.8% increases, respectively, in melting point. The other 4 gelatins, Knox, 230B PBG, 200B FSG, and 190B FSG, increased in gel strength (22.5%, 21%, 20%, and 21%, respectively) and also had larger increases in melting point (6%, 5.6%, 6.2%, and 6%). Naftalian and Symons (1974) suggested that this increase of gel strength and melting point is due to the fact that sucrose stabilizes hydrogen bonding.

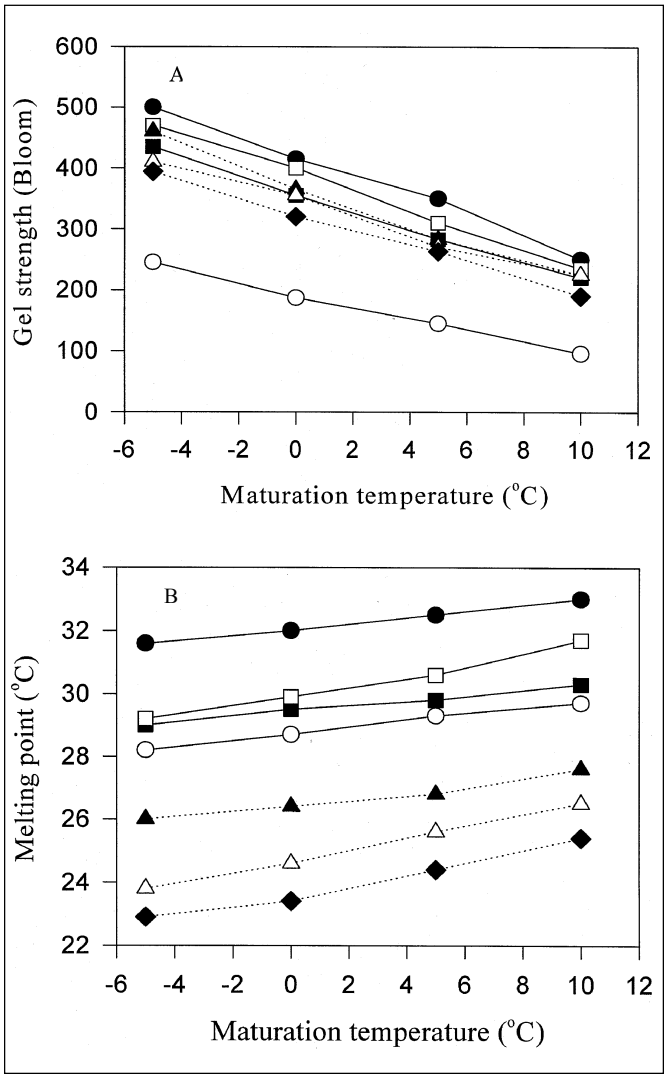

Fig. 3—Gel strength (A) and melting point (B) of 7 gelatins as a function of maturation temperature. (See Fig. 1 for symbol code.)

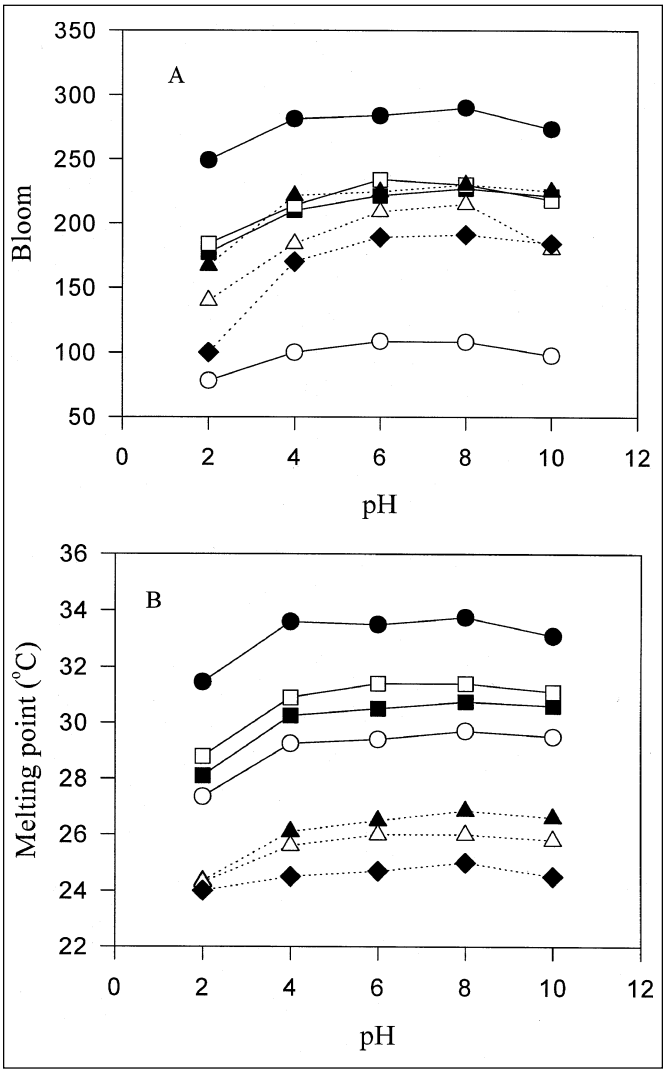

Fig. 4—Gel strength (A) and melting point (B) of 7 gelatins as a function of pH. (See Fig. 1 for symbol code.)

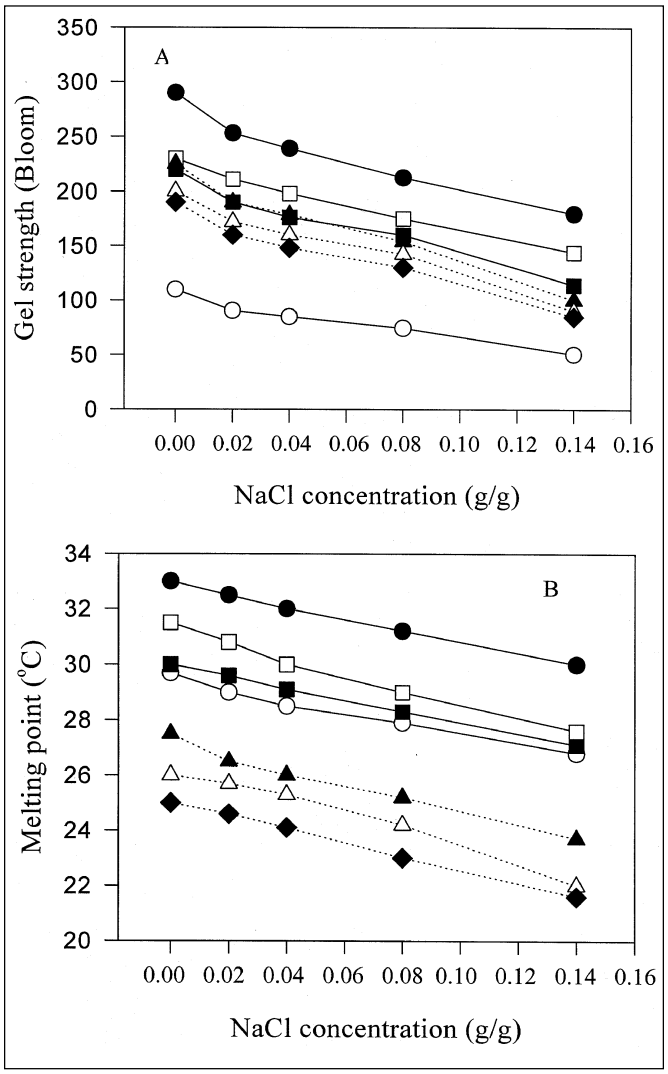

Fig. 5—Effect of NaCl content on gel strength (A) and melting point (B). (See Fig. 1 for symbol code.)

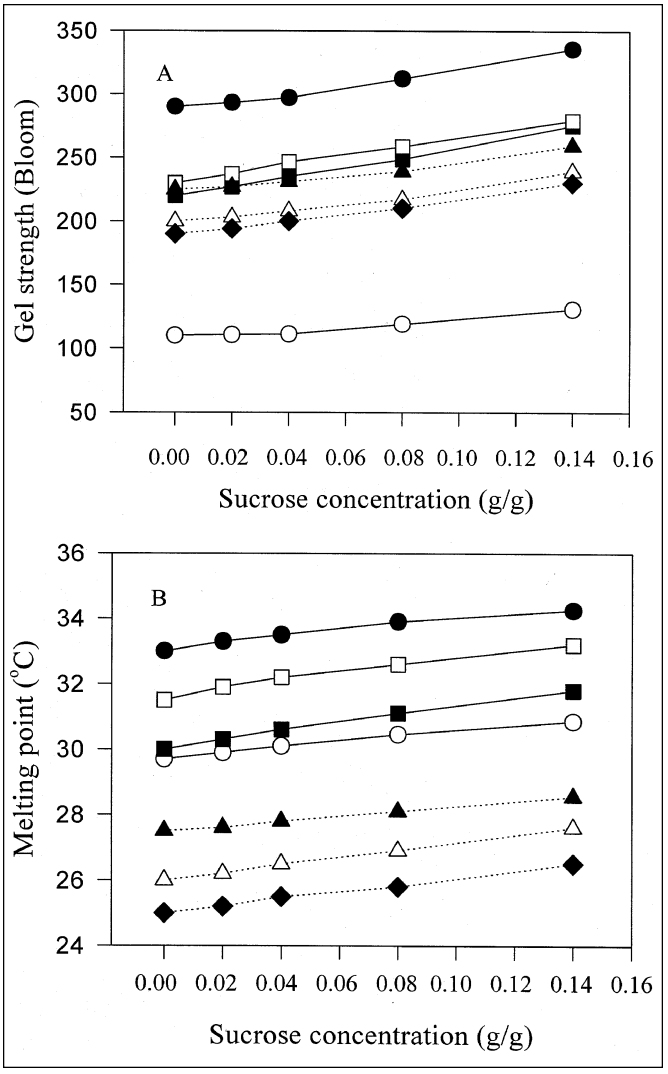

Fig. 6—Effect of sucrose content on gel strength (A) and melting point (B). (See Fig. 1 for symbol code.)

Sensory analysis

Quantitative descriptive analysis (QDA) was performed to determine the effect of the melting point on the sensory characteristics of gelatin gels. All samples had a Bloom of 95 ± 5, but different melting points (Table 1). It was assumed that flavor or aroma differences that might arise from using different sources (fish or pork) would impact only on flavor and odor, but not physical properties, such as firmness and rate of melt. Fig. 7 shows the results of the 2nd sensory test. The results for the 1st test were similar (data not shown). Of the 13 attributes, 6 were found to be significantly different among the 3 samples. These include off-odor (less in fish), fruit aroma (fish stronger), fruit flavor (fish stronger), sweetness (fish stronger), the rate of melt (fish faster), and viscosity (lower in fish). The samples used in this experiment retained some source odor (typical porky and fishy odor). Panels preferred the fishy odor to the porky odor. The lower melting temperature seems to assist in the release of fruit aroma, fruit flavor, and sweetness. If Bloom had been the only factor that affects firmness, the 3 samples in the 1st test would have been rated the same. However, there was a 1-scale-point (8.8 for pork and 7.8 for fish gelatin) difference between the pork and fish gelatin, suggesting that the melting point, as well as Bloom, may affect perceived firmness. Since pork gelatin melts more slowly than

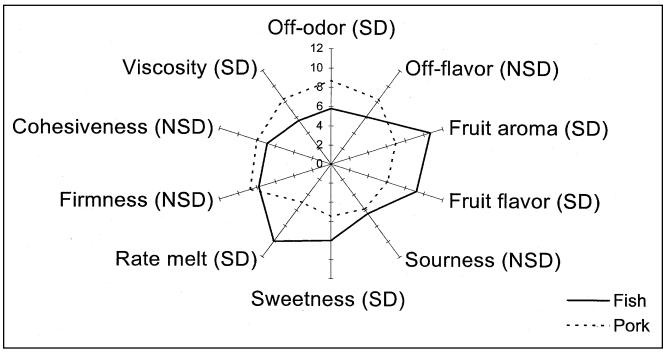

Fig. 7—Average response for each attribute of the gelatin gel. NSD = not significantly different. SD = significantly different.

fish gelatin in the mouth, the perceived viscosity of pork gelatin might be expected to be higher than that of the fish gelatin under the same condition. A lower viscosity perception may be a negative attribute in some foods. The 2nd test was with 2 samples with the same Bloom, but a 4 °C difference in melting point. The results from this test were very similar except that the intensity of color was significant (fish more intense). Again, the perceived

firmness seemed to be affected not only by gel strength, but also by melting point. The panels rated the firmness of the pork gelatin much higher than the fish gelatin ($p = 0.063$), even though they were not quite statistically different.

Conclusion

FISH GELATIN HAS VERY SIMILAR PROPERTIES TO PORK GELATIN. This makes fish gelatin a potential substitute for pork and beef (with properties fairly similar to those of pork gelatin) gelatin in many food applications and could extend the gelatin market to some of the religious groups that cannot currently accept available pork and beef gelatin. The fact that fish gelatin usually has a lower melting point than pork and beef gelatin extends the possible choices of gelatin for many and varied applications. Because fish gelatin has a better release of aroma and gives a stronger flavor, it may offer new opportunities to product developers.

Materials and Methods

Gelatins

Seven different powdered gelatins were used for the physicochemical studies and 3 different gelatins were used for sensory tests. The 7 gelatins used for the physicochemical studies were: 300 Bloom pork skin gelatin (300B PSG), No. G-2500 (Sigma Chemical Co., St. Louis, Mo., U.S.A.); 100 Bloom pork skin gelatin (100B PSG), No. G-6144 (Sigma); Knox commercial gelatin (Nabisco Foods Inc., East Hanover, N.J., U.S.A.); 230 Bloom pork bone gelatin (230B PBG), No. 1384 (Kind & Knox Gelatine Inc., Sioux City, Iowa, U.S.A.); 225 Bloom fish skin gelatin (225B FSG) (from tilapia, Sea-Source Technologies Inc., Weston, Conn., U.S.A.); 200 Bloom fish skin gelatin (200B FSG) (Sea-Source Technologies); and 190 Bloom fish skin gelatin (190B FSG) (AquaGel, Inc., London, U.K.). The 3 samples used for sensory evaluations were: 260 Bloom fish skin gelatin (260B FSG) prepared commercially in Costa Rica; 190 Bloom fish skin gelatin (190B FSG) (AquaGel), and 250 Bloom pork skin gelatin (250B PBG), No. 1383 (Kind & Knox Gelatine).

Determination of gelatin pH

The B.S. 757 (British Standard Institute) method (Leach and Eastoe 1977) was used. A 1.0% (w/v) solution of the gelatin was prepared in distilled water, cooled to room temperature, about 25 °C, and the pH was measured as a liquid solution with a glass electrode (pH-103 Metrohm/Brinkmann, Brinkmann Instruments Inc., Westbury, N.Y., U.S.A.).

Gelatin gel strength determination

The Bloom method was used. The test determines the weight required to push an AOAC Bloom Gelometer plunger (12.7 mm diameter) 4 mm into a gelatin gel. Gelatin solutions, 6.67% (w/w), were prepared with distilled water and kept in a water bath (Mw-1120A, Blue M Electric Co. Blue Island, Ill., U.S.A.) at 45 °C for 40 min. A 60-g sample was then transferred to a Bloom bottle (C. Stevens and Son Ltd., St. Albans, U.K.) and closed with a rubber stopper. The Bloom bottles were cooled immediately in ice-chilled water for 10 min and kept refrigerated in a water bath previously equilibrated to 10 °C for 16 to 18 h. After this 17-h (±1 h) maturation period, the bottles were removed from the water bath and moved immediately to the Gelometer (Stevens-L.F.R.A. Texture Analyser, C. Stevens and Son Ltd.). The instrument was adjusted to the following: penetration speed, 1.0 mm/sec; penetration distance, 4 mm into surface.

Melting point determination

The melting point measurement method described by Wainewright (1977) was modified. Gelatin solutions, 6.67% (w/w), were prepared and a 5-mL aliquot of each sample was transferred to a small glass tube (Fisherbrand® borosilicate disposable culture tube, 12 mm × 75 mm, Fisher Scientific Co., Pittsburgh, Pa., U.S.A.) previously coated with Sigmacote® (Sigma Chemical Co.). The samples were degassed in a vacuum desiccator for 5 min. The tubes were then covered with Parafilm (Laboratory Film, Greenwich, Conn.) and heated in a water bath at 60 °C for 15 min. The tubes were immediately cooled in ice-chilled water and matured at 10 °C for 16 to 18 h. Five drops of a mixture of 75% chloroform and 25% reddish brown dye (food color AFO OWS 550, lot 5-057039; Miles Inc., Elkhart, Ind., U.S.A.) were placed on the surface of the gel. The gels were put in a water bath at 10 °C and the bath was heated at 0.2 to 0.4 °C/min. The temperature of the bath was read using an electronic digital thermometer (accuracy: ± 0.2 °C, NIST Thermometers, Fisher Scientific). The temperature at which the drops began to move freely down the gel was taken as the melting point.

Physicochemical properties of gelatins

Concentration effect. The 7 gelatin solutions were prepared at 2%, 4%, 8%, and 12% (w/w). Gel strength and melting point at each concentration were measured.

Maturation temperature effect. The 7 gelatin solutions, 6.67% (w/w), were matured at −5, 0, 5, and 10 °C for 16 to 18 h. Gel strength and melting point of each sample were measured.

Maturation time effect. The 7 gelatin solutions, 6.67% (w/w), were matured for 2, 4, 8, 12, 16, and 20 h for gel strength and 1, 3, 6, 12, 18, and 24 h for melting point. Gel strength and melting point of each sample was measured.

pH effect. The pH values of the 7 gelatin samples were adjusted to 2, 4, 6, 8, and 10 with 0.1 N NaOH and 0.1 N HCl. The final gelatin concentration was 6.67% (w/w). Gel strength and melting point of each sample were measured.

NaCl and sucrose effect. The 7 gelatin solutions, 6.67% (w/w), were prepared with 2%, 4%, 8%, and 14% (w/v) added NaCl or sucrose. Gel strength and melting point of each sample was measured. All of the above tests were done in triplicate.

Sensory analyses

Sample preparation. Several gelatins were tested to obtain Bloom 100 gelatins with different melting points. Gelatin solutions at 2.4%, 2.6%, 3.0%, 3.8%, and 4.2% (w/w) were prepared with cherry juice (Juicy Juice cherry juice, Nestlé Beverage Co., San Francisco, Calif., U.S.A.) and matured at 7 °C for 16 to 18 h. Gel strength and melting point were then measured. The gel strength and melting point for each gelatin were plotted in contrast to gelatin concentration and the gelatins that had a gel strength of 100, but melting points that differed by about 2 to 3 °C, were selected for further testing. The gelatins were retested 3 times by measuring gel strength and melting point at a concentration at which the gelatin previously showed a Bloom of 100. Table 3 shows the gelatins used for the 2 gel sensory tests. One third of the cherry juice was added cold (7 °C) to the gelatin powder and allowed to sit for 10 to 12 min. The rest of the juice was heated in a microwave oven (high power) for 1 min, added to the cold mixture, and stirred gently with a glass rod until the gelatin was completely dissolved (about 10

Table 3—Basic characteristics of the 7 gelatins

	pH	Bloom	MP (°C)	pI
300B PSG[a]	4.5	290	33	6.2
100B PSG	4.8	110	29.7	6.7
Knox	4.9	220	30	6.4
230B PBG	5.5	230	31.5	5.2
225B FSG	6.5	225	27.5	8
200B FSG	5.3	200	26	6.9
190B FSG	4.2	190	25	6

[a]P = Pork. F = Fish. S = Skin. B = Bone. G = Gelatin

min). The mixture was poured into a pan (9 in × 9 in × 1 in) and the pan was covered with aluminum foil. After 16 to 18 h at 7 °C, the gel was cut into 1-in cubes.

Quantitative descriptive analysis. Five Cornell University students (2 male and 3 female graduate students in Food Science) participated in a ballot generation session. In the course of generating terminology for the descriptive ballot using 2 pork gelatins and 1 fish gelatin, they observed, smelled, and tasted various cherry gelatin samples. The 13 terms (intensity of color, clarity, springiness, off-odor, fruit aroma, firmness, cohesiveness, rate of melt, viscosity of melted mass, fruit flavor, sweetness, sourness, and off-flavor) were arranged in order of temporal occurrence during consumption of the samples within the general categories of appearance, aroma, texture, and flavor. The ballot used was a 15-point unlabeled box scale with word anchors to describe the intensity or extremes of each attribute. Seven Cornell University graduate students in Food Science (3 males and 4 females) and 2 staff (1 male and 1 female) in Food Science participated in the descriptive test. Each panelist was individually instructed by the author as to the specific terminology on the test ballot. Each attribute was defined and/or a physical reference (that is, springiness: gummy bear; firmness: rubber eraser; off-odor: cardboard (oxidized); and fruit flavor: cherry juice) was used to exemplify the particular attribute. Panelists received 3 ballots to mark their responses. Each panelist received 3 randomly coded samples at one time. They were permitted unlimited time to complete the evaluation. A replicate was done 2 d later. A 2nd test was performed with only 2 gelatins to reduce fatigue. The same 9 panelists were used. A replicate was done 30 min later on the same day.

Statistical analysis

For the sensory data, repeated 1-way analysis of variance was used to examine the difference caused by melting point with MINITAB 10 (Minitab Inc., State College, Pa., U.S.A.). For the 1st test, where 3 samples were used, if significant difference among the samples was found, then Duncan's test was done for a paired comparison. The other data (usually done in triplicate) were analyzed with the student t-test using MINITAB 10. All statistics were done at an α level of 0.05.

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MS 19990427 received 4/8/99; revised 8/26/99; accepted 9/9/99.

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