Parameters Affecting Viscosity as a Quality Control for Frozen Fish

A. J. BORDERÍAS, F. JIMÉNEZ-COLMENERO, and M. TEJADA

Introduction

Several authors have reported decreases in the viscosity of proteins from frozen fish isolated in high ionic strength solutions, and this has been attributed to protein aggregation, with a subsequent reduction in the number of bonds between the proteins and the medium (Matsumoto, 1980).

Work carried out at the authors' Institute (Jiménez-Colmenero and Borderías, 1983; Tejada et al.[1]) has shown a correlation between the viscosity value and both protein solubility and emulsifying capacity in frozen muscle. It has also been found, and this is especially true for white fish (i.e., blue whiting, cod, hake), that the values obtained using this technique in tests of frozen muscle during the storage period are highly significant, such that the sets of measurement readings provide a clear picture of the quality of the frozen product. Other authors (Groninger et al., 1983) have employed a similar method of measuring the functional properties of proteins.

Therefore, this technique would seem to be appropriate for use as an index of the quality of frozen fish protein. Moreover, the speed and ease of the method, and the fact that it can be performed using relatively unsophisticated equipment, make it ideal for use both in the laboratory and in industrial situations. Our study examined the influence of various parameters affecting apparent viscosity on this quality control method.

[1]Tejada, M., A. J. Borderías, and F. Jiménez-Colmenero. 1984. Contribución de las proteínas miofibrilares y sarcoplásmicas a las modificaciones de ciertas propiedades funcionales del músculo durante su conservación al estado congelado. Paper presented at the International Symposium on Alterations in the Chemical Constituents of Foods in Industrial Processing. Valencia, Spain, 5-7 Nov.

ABSTRACT—The measurement of apparent viscosity may be an appropriate method of quality control for myosystems undergoing frozen storage. Our experiment studied parameters affecting the measurement of apparent viscosity of homogenated muscle of Atlantic cod, Gadus morhua, *in 5 percent NaCl solution as a quality control method for frozen fish.*

Parameters like the ratio of muscle to saline solution, pH, homogenation time and method, time elapsing between homogenation and viscosity measurement, and temperature were studied to establish and standardize the optimum conditions for measurement. On the basis of the results obtained, these conditions were: Ratio of muscle to 5 percent NaCl solution, 1:4; homogenation for 1 minute; a pH of between 6.5 and 7; a time between homogenation and viscosity measurement of 30-60 minutes; and a blending/viscosity measurement temperature of between 2° and 5°C.

Materials and Methods

Atlantic cod, *Gadus morhua*, caught 5-7 days earlier and preserved chilled, was purchased at a local market. The muscle was minced using a mincer with plate orfices 5 mm in diameter. The mince was divided into 300 g lots which were packaged on trays wrapped in aluminium foil. The samples were frozen in a tunnel freezer at −30°C with an air flow of 5 m/second and then vacuum-packed and stored at −24°C for the 5 days during which tests were made.

The apparent viscosity (η_{app}) was measured using a Brookfield[2] model RVT rotary viscometer with flat spindles numbers 2, 3, and 4 at a speed of 20 rpm. Measurements were taken after 3 minutes of spindle operation, and at least four replicates were performed.

The basic steps of this procedure are diagrammed in Figure 1, and the standard conditions applied in the procedure are set out below:

1) Ratio g of muscle:ml 5 percent NaCl solution: 1:4.
2) pH: 6.5-7.0.
3) blender, speed setting, and time: Omni-mixer, setting 7, 1 minute.
4) homogenate temperature: 3-5°C.
5) standing time: 30 minutes.

In addition to the standard conditions, the following variations were also tested:

1) Ratio g of muscle:ml 5 percent NaCl solution: 1:4, 1:6, 1:8, and 1:10, corresponding to 20.0, 14.3, 11.1, and 9.1 g of fish/100 ml of homogenate.
2) pH: 4.85, 5.53, 6.57, 6.61, 6.70, 6.93, 7.60, 8.33, and 9.10.
3) Blender and blending time: Omni-mixer (1, 2, and 3 minutes) and Ultra-turrax (1 minute at middle speed setting).
4) Blending/viscosity measurement temperature (°C): 2.2, 3.6, 4.8, 10.0, 14.5, 14.9, 15.3, 17.5, 21.3, and 25.0.
5) Standing time (minutes): 0, 30, 70, 100, 165, 240, and 300.
6) Homogenate centrifuging conditions: 3 minutes at 3,000 rpm at 3°C.

Regression curves were calculated by computer; the significance levels of the

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

The authors are with the Instituto del Frío, Ciudad Universitaria, 28040 Madrid, Spain.

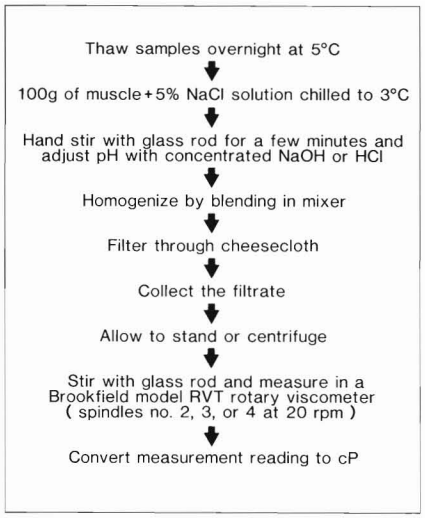

Figure 1.—Method of measuring the apparent viscosity.

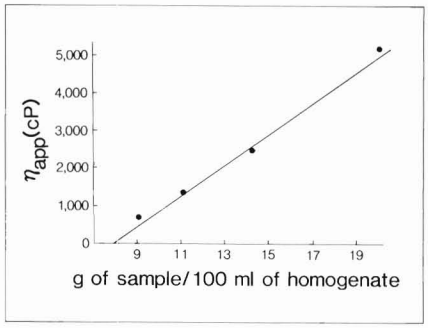

Figure 2.—Changes in apparent viscosity with sample concentration.

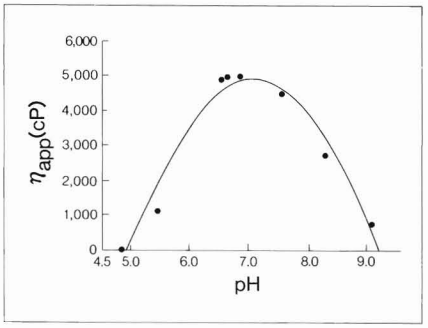

Figure 3.—Apparent viscosity vs. pH.

curves were calculated using an F test and the goodness of fit with the index of determination (r^2).

Results and Discussion

Ratio Samples: 5 Percent NaCl Solution

Figure 2 shows that there is a linear relationship ($r^2 = 0.95$; $P < 0.01$) between homogenated sample concentration and apparent viscosity, as was found for other species (Borderías et al., 1985). In accordance with this relationship, at less than 8 g of muscle/100 ml of homogenate, apparent viscosity did not register on the measurement scale under the experimental conditions employed. At levels above 20 g/100 ml, the homogenate was too viscous, making measurement difficult. The ratio of one part sample to four parts 5 percent NaCl solution was the most appropriate for measuring viscosity for quality control purposes, since a high initial apparent viscosity is needed, because it tends to decrease with storage time, and may even drop to zero in whitefish such as cod after 3 months at −12°C (Tejada et at.[1]).

Effect of pH

The relationship between the pH and apparent viscosity was given by a third-degree polynomial ($r^2 = 0.94$; $P < 0.01$) plotted in Figure 3. Figure 3 shows that the highest viscosity values corresponded to a pH of between 6.5 and 7; minimum values were recorded at pH 4.8 and 9.1. On the basis of these data the behavior of cod muscle would appear to differ from that of red meat, since Hamm (1975) recorded minimum viscosity values at about pH 5.3 (isoelectric point), with values increasing as one moved away from that point. This seems reasonable since the isoelectric point of proteins drops in the presence of NaCl (Schut, 1976). The decrease in viscosity at alkaline pH levels might be due to aggregation, which, in the conditions employed, was not reversible when the medium was neutralized on reaching pH 9.

Consequently, because of the fluctuations in viscosity with pH, it is imperative to adjust the mixture's pH level before any measurement readings are taken. It is further advisable to adjust the pH prior to blending, since differences in viscosity were observed when the pH was adjusted before and after homogenation. The recommended pH is between 6.5 and 7, corresponding to the point at which the highest viscosity values were recorded.

Effect of Blender, Speed Setting, and Blending Time

The greater destruction of tissues during homogenation led to a decrease in apparent viscosity (Fig. 4). Maximum viscosity in the shortest time was obtained by blending in an Omni-mixer for 1 minute.

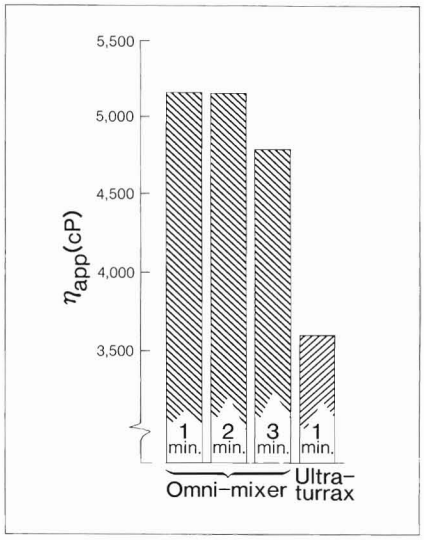

Figure 4.—Apparent viscosity vs. blender, speed setting, and blending time.

Standing Time

It is advisable to allow some standing time between homogenation and the viscosity measurement to permit the release of air bubbles formed during blending, since these may result in measurement variations, and also to permit the formation of bonds between the proteins and the solvent.

To study this effect, various standing times were employed between homogenation and viscosity measurement.

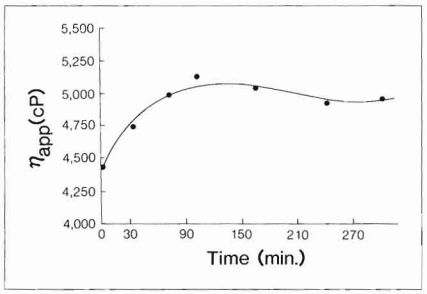

Figure 5.—Apparent viscosity vs. the time elapsing from blending to measurement.

Figure 5 shows that the relationship between the viscosity of the homogenate and the time elapsing between blending and measurement was given by a third-degree polynomial ($r^2 = 0.95$; $P < 0.05$). Figure 5 also indicates that the measurement readings stabilized after a standing time of 60 minutes or more at 3-5°C.

Effect of Centrifuging

Centrifuging the homogenates prepared as described in the section on materials and methods was also used to eliminate the air bubbles, employing the method described by Hermansson (1975). However, centrifuging makes the quality control method more complicated, and the authors found no advantage in its use.

Blending/Measurement Temperature

Figure 6 shows that the relationship between apparent viscosity and temperature was given by a second-degree polynomial ($r^2 = 0.84$; $P < 0.01$). The curve indicates that fluctuations in viscosity are lowest and viscosity values are highest at between 0° and 7°C, hence it is advisable to make readings at a temperature of from 2° to 5°C. At higher temperatures, alterations in the properties of the proteins are more likely.

Summary

From the foregoing it would appear that the optimum condition for applying this technique of apparent viscosity measurement as a quality control method are as follows:

1) Grams of muscle:ml 5 percent NaCl solution: 1:4.
2) Blending time: 1 minute.
3) Blender: Omni-mixer.
4) Blending/measuring temperatures: 2-5°C.
5) pH: 6.5-7.0.
6) Standing time in refrigerator between blending and measurement reading: 60 minutes.

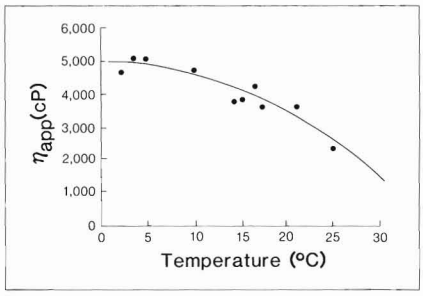

Figure 6.—Apparent viscosity vs. temperature.

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