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Journal of Food Engineering 81 (2007) 492–499

JOURNAL OF FOOD ENGINEERING

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# Rheological properties of selected fish paste at selected temperature pertaining to shaping of surimi-based products

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Received 26 June 2006; received in revised form 28 November 2006; accepted 29 November 2006
Available online 23 January 2007

**Abstract**

The rheological properties of fish meat pastes were investigated by dynamic rheological measurement in a range of 5–30 °C, in order to establish the optimum temperatures for shaping. Storage moduli ($G'$) on temperature sweep analysis for walleye pollack, white croaker and threadfin bream meat pastes were considerably higher than loss moduli ($G''$) and showed maximum at 20, 27 and 28 °C, respectively. Frequency sweep analysis and SDS–PAGE revealed that all meat pastes hardly formed suwari gels upon heating until 30 °C. The maximal degrees of recovered $G'$ were observed at 20 and 30 °C for walleye pollack and threadfin bream meat pastes by interval thixotropy analysis, respectively. On the other hand, the $G'$ recovery of white croaker meat paste was almost constant in a range of 5–25 °C, but markedly decreased at 30 °C. These results suggest that the rheological properties of walleye pollack, white croaker and threadfin bream meat pastes are species-specific and their optimum temperatures for shaping are at 20 °C, below 25 °C and at 28 °C, respectively.


*Keywords:* Electrophoresis; Fish meat paste; Interval thixotropy analysis; Storage modulus; Temperature sweep analysis; Thermal gel shaping; Viscoelasticity

## 1. Introduction

In manufacturing processes of surimi-based products such as kamaboko and seafood imitation ones, frozen surimi is thawed, chopped, and further mixed with water for adjusting the protein concentration. Then, surimi is ground with 2.5–3.0% neutral salt. At this stage, surimi becomes viscous sol called meat paste due to solubilization of myofibrillar proteins (Sano, Noguchi, Tsuchiya, & Matsumoto, 1988). Subsequently, the meat paste is heated, facilitating viscous sol to elastic gel (Numakura, Kimura, Toyoda, & Fujita, 1990). In general, thermal gel is formed in two-step heating process (Takagi, 1973). The first heat treatment is called setting which is provided at a moderate temperature around 40 °C. The gel formed by the setting is referred to as suwari gel (Kimura et al., 1991). The setting is an important process to enhance the gel strength of surimi-based products. The second step is proceeded at high temperatures over 80 °C, in which rigid and irreversible gel is formed (Montejano, Hamann, & Lanier, 1984).

Besides the two-step heating process, meat paste is provided with various shapes manually or by molding machines at moderate temperatures below 30 °C to reply on market demands, which is referred to as shaping (Okada, 1992). Preparation of meat paste by grinding with salt is to be performed below 10 °C to prevent denaturation of fish proteins and to keep gel-forming ability (Lee, 1984). However, if fish meat paste is subjected to shaping immediately after grinding, the shape of the meat paste is frequently collapsed. To avoid such unfavorable changes, several companies in Japan maintain fish meat paste at

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doi:10.1016/j.jfoodeng.2006.11.029

room temperature overnight or treat them by ohmic heating at about 30 °C for shaping (Shiba, 1992, 1993). Interestingly, such thermal treatments avoid collapse of the shape formed while meat paste is on the way in the sol–gel transition (Yamazawa, Seki, & Fukuda, 2003). It has also been known that the effects of thermal treatment at moderate temperatures on shaping of meat paste are different depending on fish species. However, little information is available on changes in rheological properties of fish meat pastes in a temperature range below 30 °C.

In this study, the rheological properties of fish meat pastes from walleye pollack, white croaker and threadfin bream, which are representative species used for fish meat gel products, were examined at moderate temperatures below 30 °C. Temperature and frequency sweep analyses were performed in order to investigate the changes in dynamic rheological parameters and whether meat paste was in a sol or gel states during thermal treatment. In addition, the optimum temperature for shaping was determined by interval thixotropy analysis.

## 2. Materials and methods

### 2.1. Materials

Frozen surimi (SA grade) of walleye pollack (*Theragra chalcogramma*) and threadfin bream (*Nemipterus virgatus*) containing 4% sorbitol, 4% sugar and 0.25% polyphosphates were kindly supplied by Maruha Co., Ltd. (Tokyo, Japan). Frozen surimi of white croaker (*Pennahia* spp.) containing 5.7% sorbitol was purchased from Nagasaki Kamaboko Marine Product Manufacturing Cooperative Association (Nagasaki, Japan). These were cut into 500 g blocks while frozen, packed into polyethylene bags, and stored at −40 °C until use.

### 2.2. Preparation of fish meat paste

Frozen surimi was thawed at 0 °C overnight, chopped and ground with cold distilled water to adjust the protein concentration at 60 mg/cm$^3$ using a UMC-5E food cutter (Stephan, Illinois, USA). Then, NaCl was added to a final concentration of 2.5% and ground for 2 min below 10 °C using the same food cutter.

### 2.3. Measurement of rheological properties

Rheological properties of fish meat paste were analyzed using a MCR300 rheometer (Physica, Stuttgart, Germany) equipped with a 25 mm-parallel plate geometry at a gap of 1.0 mm. The space between the parallel plate geometry and sample table was covered with paraffin oil to prevent dehydration. Temperature sweep analysis to measure the changes in dynamic rheological parameters including storage moduli ($G'$), loss moduli ($G''$) and tangent of phase angle ($\tan\delta$) during heating were performed according to Fukushima, Satoh, Nakaya, Ishizaki, and Watabe (2003) at a constant frequency of 1.0 Hz and amplitude strain of 1%, which was within the linear viscoelastic region, from 5 to 30 °C at an increasing rate of 1 °C/min.

Frequency sweep analysis for $G'$ was also performed according to Fukushima, Satoh et al. (2003) at a constant amplitude strain of 1% and in a frequency range of 0.1–10 Hz at 5, 10, 15, 20, 25 and 30 °C. Frequency sweep analysis for $G'$ was also carried out at 37 °C for samples heated at this temperature for 1 h under the same conditions expect for measuring temperature.

Interval thixotropy analysis was for $G'$ was performed under the following sequential conditions by changing a magnitude of amplitude strain: first at an amplitude strain of 1% for 60 s, second at an amplitude strain of 500%, which was in the nonlinear viscoelastic region, for 30 s and third at an amplitude strain of again 1% for 300 s.

In the second phase, $G'$ decreased to about 1 Pa and $\tan\delta$ increased over 1 (data not shown), indicating that the meat paste turned to dynamic state by an amplitude strain of 500%. All conditions were set at a constant frequency of 1.0 Hz and analyzed at 5, 10, 15, 20, 25 and 30 °C. Interval thixotropy analysis for $G'$ was also carried out at 37 °C for samples heated at this temperature for 1 h under the same conditions expect for measuring temperature. Data were collected every 5 s.

The experiments for temperature sweep, frequency sweep and interval thixotropy analyses were repeated two times for three different preparations of meat paste and a typical example of the results observed is shown in each figure.

### 2.4. Sodium dodecyl sulfate–polyacrylamide gel electrophoresis

Protein samples were solubilized in an SDS–urea solution containing 2% SDS, 2% 2-mercaptoethanol, 8 M urea and 50 mM Tris–HCl (pH 8.0) by the method of Weber and Osborn (1969). SDS–polyacrylamide gel electrophoresis (SDS–PAGE) was performed by the method of Laemmli (1970) using 12.5% polyacrylamide slab gels containing 0.1% SDS. After electrophoresis, gels were stained with a solution containing 0.05% Coomassie Brilliant Blue R-250, 50% methanol and 10% acetic acid, and destained with a solution containing 25% methanol and 7% acetic acid.

## 3. Results

### 3.1. Temperature sweep analysis

Dynamic rheological measurement determines changes in rheological properties of samples serially and nondestructively by variables such as time and temperature (Egelandsdal, Martinsen, & Autio, 1995; Hamann, 1991). At first, the dynamic rheological parameters of walleye pollack meat paste were investigated during heat treatment in a range of 5–30 °C on temperature sweep analysis. As shown