EFFECT OF FREEZING RATE ON THE GELATION AND RHEOLOGICAL PROPERTIES OF POULTRY MEAT BATTERS

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SUMMARY

The effects of three freezing rates (0.2, 5.5 and 9.6°C/min, corresponding with cryogenic, blast freezing and slow freezing) on the gelation and rheological properties of poultry meat batters were studied. Using a thermal scanning rigidity monitor to continuously evaluate the modulus of rigidity (G) during cooking indicated differences in the gelation patterns only above 64°C. The control (non frozen meat) resulted in the lowest final G value followed by the cryogenic, fast and slow freezing treatments. These differences could be related to the degree of damage to the muscle due to slower freezing. The relationships between shear rate and shear stress for the different raw meat batters were found to be nonlinear and followed the Bingham pseudoplastic behaviour.

LITERATURE REVIEW

Food is frozen to preserve raw materials for processing, retail sale and home storage. Freezing does not enhance the food quality, but rather leads to some quality losses during a long-term preservation period. Most physical and chemical changes occurring in foods during freezing are caused directly or indirectly by water to ice transformation. Therefore, higher freezing rates are considered advantageous because of the uniform dispersion of small ice crystals and the minimum dislocation of water (Sebranek, 1982). Several freezing methods which offer high freezing rates are commercially available. They mainly include air blast, indirect and direct contact with cryogenic fluids.

Meat freezing usually results in an increased exudate released during thawing. Sebranek et al. (1978) found that beef patties frozen at slow rates showed significantly lower cooking losses than patties frozen by cryogenic methods. Nusbaum et al., (1983) also reported that at higher freezing rates, higher degrees of palatability and smaller structural changes can be observed in ground beef patties. Overall, the quality variations observed in meat frozen at different rates seem to be more related to structural changes than chemical alterations in the tissue (Sebranek, 1982).

Knowledge of the rheological behaviour of meat batters is essential for the design of process conditions. However, few results have been reported on the effect of freezing rates on the rheological properties of meat. The development of an acceptable texture in a meat system involves the coagulation of various proteins to form an elastic gel which is responsible for the unique characteristics of each product. Continuous rigidity scanning has been shown to be a sensitive method for detecting these sol to gel transformations and to assist in understanding the physical properties of the protein involved. Thus, the objectives of this study were to determine the effect of different freezing methods on the rheological and gelation properties of poultry meat.

MATERIALS AND METHODS

Dark poultry meat was trimmed of all visible fat and connective tissue and then chopped for 1.5 min in order to obtain an homogeneous mass. The meat was then stuffed into moisture proof casings (6.2 cm diameter). The meat was frozen by liquid N_2, direct air blast freezing and a slow freezing rate. The three methods required 2 min, 555 min and 964 min to decrease the product centre temperature from 5 to -5°C, respectively. The meat was kept frozen at -18°C for one week and thawed at 3°C overnight. Non-frozen meat was used as a control treatment.

Gelation and Rheology
Salt (1.25% NaCl) was mixed with the meat in order to extract some of the functional salt soluble proteins.

Thermal scanning rigidity monitor (TSRM) was used to continuously evaluate the modulus of rigidity (G). The TSRM was mounted on an Instron Universal Testing machine and at 2 min intervals a cyclic force was applied to the samples producing a small variable cyclic deformation. The G value was calculated as the ratio of maximum shear stress to maximum shear strain (Barbut and Mittal, 1988).

The rheological parameters were determined by using a Haake-type rotary viscometer (model RV3, Haake, Berlin, West Germany), at a temperature of 5°C.

The experiment was replicated twice. Statistical analyses included analysis of variance, the Duncan's multiple range test and regression analyses.

RESULTS AND DISCUSSION

Gelation - Modulus of Rigidity
Plots of modulus of rigidity (G) versus internal temperature of the meat batters are shown in Fig. 1. The meat batter frozen by the slow freezing rate exhibited the highest final G value followed by the blast freezing, N_2 freezing and the non-frozen (control) meat. Thus, freezing increased the modulus of rigidity of the cooked batters. The final G values indicated that batters prepared from the frozen meat had a firmer texture, which in turn can be interpreted by the consumer as a tougher texture. Cryogenic methods of meat freezing have the potential to minimize tissue damage, and therefore, better maintain the quality of the meat as compared to slower freezing methods (Sills, 1969). Overall, it has been reported that quick frozen foods generally exhibit minimum textural damage, release less thaw exudate and undergo fewer chemical changes compared to foods frozen at low rates (Sebranek, 1982). However, Hanenian et al. (1989) did not find any significant effect of freezing rates on the Warner-Bratzler shear values of cooked beef patties.

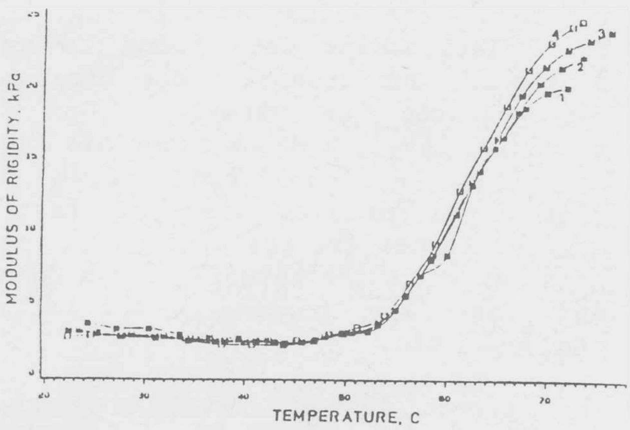

Figure 1: Shear rigidity modulus profile of poultry meat batters, frozen by various freezing rates, during cooking. "1" = fresh meat; "2" = liquid nitrogen immersion freezing; "3" = air blast freezing; and "4" = slow freezing.

During heating, all the batters showed a negligible increase in rigidity up to 52°C, followed by a rapid increase up to 66°C. With further heating the increase in rigidity continued but at a slower rate. The rapid increase between 52 to 66°C indicates the formation of stable, stiff, matrix structures typical of heat induced protein gels. In the gelation curves, two transition temperatures could be observed the first at 52 and the second at 68°C. The general gelation pattern observed here is similar to the pattern observed in poultry meat emulsions containing various phosphates (Barbut and Mittal, 1988).

The shear modulus values were highly correlated ($P \leq 0.0001$) with temperature for all the treatments. Generally, G increased with the increase in temperature.

The following regression model can be applied to predict the G values (in Pa):

$$G = -13900 + 452\ (Treat) + 424\ (Temp)$$

Raw Batter Viscosity
The relationships between shear rate and shear stress for the different treatments are illustrated in Fig. 2. The relationships were found to be nonlinear, and resembled the Bingham pseudoplastic behaviour. On a molecular level, Bingham materials are envisioned as consisting of a 3 dimensional network when at rest. Applied forces are resisted up to the point at which the network breaks down and the flow becomes essentially pseudoplastic.

The general power law (Herschel-Bulkley) model with yield stress, was used to fit the data.

$$\tau = T_o + b\,\gamma^n$$

In this model "τ" is shear stress, Pa; "γ" is shear rate, s^{-1}; "T_o" is yield stress, Pa; "b" is consistency coefficient, $Pa.s^n$; and "n" is the flow behaviour index. This equation was found to be an adequate model for describing the flow behaviour of meat batters in the range of the experimental conditions used. The "T_o" varied between 25 and 783 Pa, "b" from 196 to 889 $Pa.s^n$, and "n" between 0.264 and 0.607. The statistical analysis showed that these rheological parameters were unaffected by the treatments at the 95% level. However, the values of "T_o" increased due to slow freezing and N_2 freezing. The N_2 freezing also increased the "n" and decreased the "b" values.

Apparent viscosity was also calculated. Apparent viscosity decreased sharply from 880 to 1260 Pa when shear stress increased from 0.7 to 1.7 kPa. Basically, with further increase in shear stress, the increase in apparent viscosity was marginal for all the treatments.

The rheological differences among the freezing methods indicated that freezing resulted in some modification of the muscle proteins; however, these effects could only be demonstrated under certain conditions (i.e. intermediate shear rate but not at low and high rates Fig. 2).

Overall this study indicated that higher freezing rates resulted in better retention of the gelation quality of the meat proteins.

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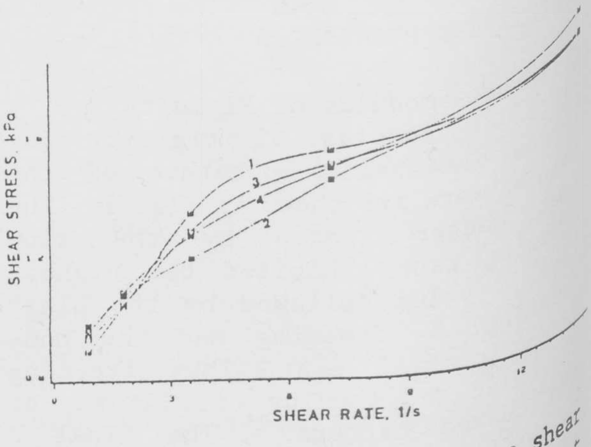

Figure 2: Relationship between shear stress and shear rate for poultry meat frozen by various freezing rates, measured with a Haake rotational viscometer. "1" = fresh meat; "2" = liquid nitrogen immersion freezing; "3" = air blast freezing; and "4" = slow freezing.