Influence of pH on Physical Properties of White and Dark Poultry Meats

G.S MITTAL[1] and S. BARBUT[2]

[1]School of Engineering, [2]Dept. of Animal Science, University of Guelph, Guelph, Ontario, Canada, N1G2W1

SUMMARY: Physical properties of breast and thigh meat batters at various pH levels (4.5 to 7.5) were measured. Breast meat with 4.5 pH showed the greatest pseudo-plasticity (lowest power law index, n). A sharp increase in 'n' was noted with the increase in pH to 5.5. The 'n' decreased gradually with the increase in pH from 5.5 to 7.5. In thigh meat 'n' did not change for pH 4.5 to 5.8, however, it increased sharply with the further increase in pH to 6.5. Batters with pH 4.5 exhibited the lowest rigidity modulus (G) peak values. The intermediate peak values were observed for pH 5.5 and 5.8, and the highest peak values were observed for pH 6.5 and 7.5. In general peak G values increased with the increase in pH.

INTRODUCTION: The objective of this work was to study the effects of pH of white and dark poultry meats on physical properties such as gelation and rheological.

MATERIAL and METHODS: (i) Modulus of rigidity: Continuous evaluation of the modulus of rigidity (G) during thermal processing of the meat batters was performed by using a special constructed thermal scanning rigidity monitor (TSRM) (Yamamoto et. al. 1989). The TSRM consisted of a double jacketed sample holder, heating system and a screen. The rectangular screen (15 mm x 77 mm) was connected through a rod to a 2 kg load cell mounted on an Instron universal testing machine (Model 4204). The sample holder (35 mm dia) was filled to 85 mm depth with the meat batter. The position of the crosshead was adjusted so that the screen immerse in the sample at a depth of 5 mm. The rate of heating was automatically controlled at 0.5 °C/min from 20 to 75 °C, by a Haake PG20 controller (Haake, Berlin, Germany) connected to a heating coil immersed in a water bath. The meat batter and water temperatures were recorded by three thermocouples (T-type). At 2 min intervals a cyclic force (from the upward-downward cyclic motion of the crosshead at 0.5 mm/min) was applied to the samples producing a small variable cyclic deformation. The samples were covered with a thin layer of mineral oil to prevent drying of the surface and were free to expand during cooking to avoid any influence of swelling on the deformation. The peak to peak force was calculated from the recorded data. The modulus of rigidity was calculated as the ratio of maximum shear stress to maximum shear strain (Yamamoto et al. 1989), which is given by:

$$G=\frac{maximum\ shear\ stress}{maximum\ shear\ strain}=\frac{g.F(0.1)/(2.A)}{d/H}$$

where: G = modulus of rigidity, Pa; F = force, g; d = distance screen pulled, cm; H = thickness of the gel on both sides of the screen, cm; A = area of the screen immersed in the gel, cm^2; g = acceleration due to gravity, 980.7 cm/s^2.

(ii) Rheology: The rheological parameters were determined using a Brookfield wide gap, coaxial cylindrical rotary viscometer (model RVTD, Brookfield, Stoughton, MA, U.S.A.) at a temperature of 5 °C. Instrument readings were noted at several spindle speeds (spindle #7). The viscometer readings (readings/100) were converted to torque (τ, dyne-cm) after multiplying by a factor of 673.7 (provided by the manufacturer). Since the yield stress was negligible (because the sample was able to flow with gravity force), the following equation was used (van Wazer et al., 1966) to estimate rheological parameters:

$$\ln(\tau) = n/\ln(\omega) + \ln(2\pi.b.L) - n.\ln(n/2) - n.\ln(R^{-2/n} - R_o^{-2/n})$$

where: n = flow behavior index; b = consistency coefficient; L = spindle length, 5.123 cm; R = spindle radius, 1.56 cm; R_o = container radius; and ω = angular velocity, rad/s. Since R_o >> R, $R_o^{-2/n}$ was ignored in the calculation of 'b' and n.

RESULTS and DISCUSSION: (i) Rheology: The plots of torque versus shear rate (rotor angular velocity) for the breast and thigh poultry meats for different pH are shown in Fig. 1 and 2, respectively. The graphs show non-linear relationships with concave downward; thus indicating pseudo plastic behavior. Previous studies have also indicated similar behavior for meat batters (Mittal and Barbut, 1989). The pH affected the rheological behavior of the batters differently for breast and thigh meats. In case of breast meat batters (Fig. 1), intermediate torques were required at all the angular velocity values for the lowest pH (4.5) meat; however, the lowest torques were required for the batter with a pH of 5.5. Required torques increased with further increase in pH up to 7.5. This shows that the meat pH plays an important role in influencing the rheological characteristics of meat batters.

In the case of thigh meat batters (Fig. 2), the lowest pH (4.5) still resulted in intermediate torque values. However, the original meat pH (5.8) showed the lowest torque values, and 5.5 pH meat the highest. Moreover, further increase in pH above 5.8 required intermediate torques at various angular velocities. These trends are much different from breast meat. This difference is probably due to the different myosin isomers found in the white and dark meats (Asghar and Henrickson, 1982). The rheological parameters for the different treatments are summarized in Table 1. The confidence intervals at the 95% level for 'b' were 16.6 to 30.6 Pa.s^n, and for 'n' 0.17 to 0.29. The 'n' values which are between 0 and 1, indicate pseudo-plasticity. In general, thigh meat batters showed larger values of 'b' compared to breast meat, however at the highest pH (7.5), the 'b' values for both meat types were similar. In thigh meat, the original

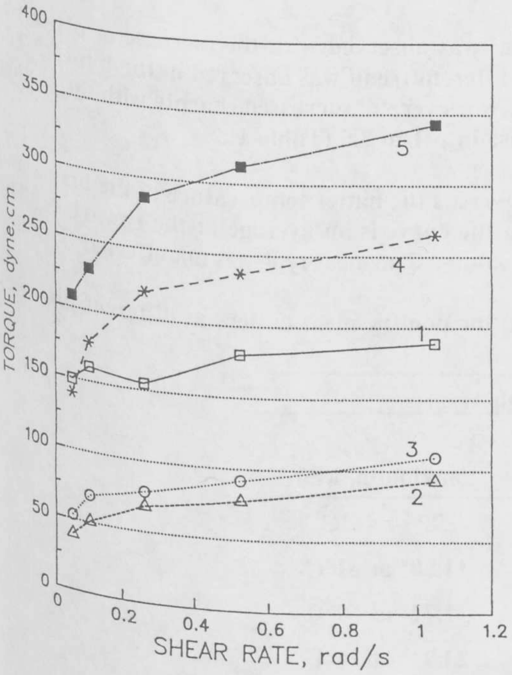

Fig. 1: Relationship between torque and shear rate for poultry breast meat batters at different pH, measured by a wide gap rotational viscometer. pH are: 1 = 4.5, 2 = 5.5, 3 = 5.8, 4 = 6.5 and 5 = 7.5.

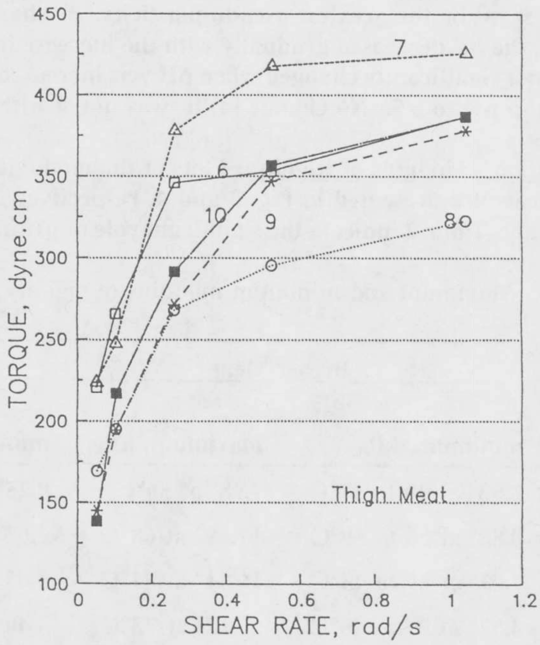

Fig. 2: Relationship between torque and shear rate for poultry thigh meat batters at different pH, measured by a wide gap rotational viscometer. pH are: 1 = 4.5, 2 = 5.5, 3 = 5.8, 4 = 6.5 and 5 = 7.5.

pH (5.8) meat had the lowest 'b' value and meat with 5.5 pH the highest. The changes in 'b' values for breast meat were much larger compared to thigh meat. With the increase in pH from 4.5 to 5..5, the 'b' decreased from 18.38 to 6.84 Pa.s^n. Further increase in pH increased 'b' to 28.98 Pas^n (at 7.5 pH). Comparison of means at 95% indicates the highest

Table 1: Rheological parameters of poultry meat batters at different pH. Parameters* measured by a wide gap rotational viscometer.

pH	b, Pa.s^n	SEE	n	SEE	MSE
Breast Meat					
4.5	18.38^b	0.10	0.072^d	0.020	0.18
5.5	6.84^c	0.08	0.279^b	0.021	2.70
5.8	8.08^c	0.08	0.240^b	0.050	1.99
6.5	21.69^b	0.08	0.208^b	0.015	1.50
7.5	28.98^b	0.08	0.174^c	0.010	1.05
Thigh Meat					
4.5	32.65^a	0.08	0.189^b	0.027	1.22
5.5	35.14^a	0.08	0.243^b	0.022	2.05
5.8	25.87^b	0.08	0.230^b	0.030	1.84
6.5	28.65^b	0.07	0.332^a	0.015	3.84
7.5	29.54^b	0.07	0.338^a	0.019	3.97

*b = consistency coefficient, n = flow behavior index, SEE = standard error of estimate, MSE = mean sum of square of error, P > F for all the estimates is 0.0001; degree of freedom for error = 28. a-d: Numbers followed by the same superscript within the same column are not statistically significant at the 95% level.

level 'b' valuesfor thigh meat at pH 4.5 and 5.5 and lowest for breast meat at 5.5 and 5.8. There was no significant difference in 'b' values at other pH.

For Newtonian material, the value of n equals 1, thus pseudo-plasticity will increase with the decrease in 'n' below 1. The behavior of breast and thigh meats are different at different pH. Breast meat with pH 4.5 showed the lowest 'n' or the greatest pseudo-plasticity. A sharp increase in 'n' was observed with the increase in pH to 5.5. Further, the 'n' decreased gradually with the increase in pH to 7.5. A different trend was observed in thigh meat. The 'n' was not significantly changed when pH was increased from 4.5 to 5.8, however, 'n' increased sharply with the further increase in pH to 6.5. No change in 'n' was noted with further increase in pH to 7.5 (Table 1).

(ii) Gelation - Modulus of Rigidity: Plots of the modulus of rigidity (G) versus the batter temperature of the breast and thigh meats are presented in Fig. 3 and 4, respectively. Each point on the curve is an average of the two trials. The Figures and Table 2 indicate the significant role of pH in influencing G values. The meat type has not affected G values

Table 2: Maximum and minimum modulus of rigidity values (G, kPa) for poultry meat batters at different pH.

pH	Breast Meat		Thigh Meat	
	minimum, kPa	maximum, kPa	minimum, kPa	maximum, kPa
4.5	2.63[b] at 30 to 37°C	7.98[c] at 56°C	0.25[c] at 61 to 65 °C	4.58[c] at 46°C
5.5	0.88[c] at 26 to 39°C	17.49[b] at 68°C	2.63[b] at 38°C	11.80[b] at 61°C
5.8	1.07[c] at 29 to 48°C	16.81[b] at 71°C	3.65[b] at 32 to 42°C	11.72[b] at 60°C
6.5	3.57[b] at 27 to 40°C	27.17[a] at 73°C	3.40[b] at 40 to 44°C	23.94[a] at 74°C
7.5	4.24[a] at 19°C	26.15[a] at 67°C	4.67[a] at 46°C	25.98[a] at 71°C

[a-d] Numbers followed by the same superscript within the same column are not statistically significant at the 95% level.

significantly. The breast meat exhibited minimum G (0.88 to 4.24 kPa) between 19 °C and 48 °C, and the maximum G (7.98 to 27.17 kPa) between 56 and 73°C. On the other hand, the thigh meat showed the minimum G (0.25 to 4.67 kPa) between 32 to 65 °C, and the maximum G (4.58 to 25.98 kPa between 46 and 74°C). The trends were similar in both meat types. These plots can be grouped under three categories: (i) pH 4.5, (ii) pH 5.5 and 5.8, and (iii) pH 6.5 and 7.5. The batters with pH 4.5 exhibited the lowest G peak values. The intermediate peak values were observed for pH 5.5 and 5.8 meat batters, and the highest peak values were observed for meat with pH 6.5 and 7.5. Thus, in general, peak G values increased with the increase in pH. However, the rate of increase was not constant.

In case of the breast meat batters (Fig. 4) with pH 4.5, there was a negligible change in G values up to 38 °C. G values increased gradually to peak at 56 °C, it then gradually decreased to 4.26 kPa at 72 °C. Thus, at low pH (4.5), the gel formation was weak, and the G of the gel decreased at high temperatures (>56 °C). Breast meat batters at pH 5.5 and 5.8 showed very similar G- temperature relationships during heating. There were negligible changes in G values up to 48 °C, however, these G values were the lowest as compared to other treatments. With the further increase in temperatures, G increased sharply up to 68 to 71 °C. This indicates the formation of stable, stiff, and elastic matrix structures typical of heat induced protein gels. Batters with pH of 6.5 and 7.5 showed similar G- temperature relationships. There were negligible changes in G up to 43 °C; however, G values for the 7.5 pH batters, were higher than low pH batters at the same temperature range. A gradual increase in G was noted from 43 to 52 or 55 °C. Further increase in temperature resulted in a sharp increase in G values up to 67 or 73 °C depending on the pH. Similar trends were observed for thigh meat batters, except at higher temperatures for pH 5.5 and 5.8 (Fig. 4). The batters at pH 5.5 exhibited no increase in G up to 33 °C, a gradual increase up to 46 °C, and then a sharp decrease up to 58 °C. This behavior shows the incomplete formation of a gel followed by a breakdown of the gel at high temperatures. Thus proper pH is extremely important for gel formation particularly in thigh meat.

The breakdown of gel was also observed in thigh meat batters at pH 5.5 and 5.8 (Fig. 4). These batters showed negligible changes in G up to 45 °C. A gradual increase was noted up to 53 °C (a slight decrease in G at pH 5.8). Further increase in temperature up to 61 °C increased G sharply indicating stiff gel formation. However, further increase in temperature resulted in a gradual decrease in G indicating a gel break down. Thus pH up to 5.8 is not enough for the formation of a stable gel during heating. There was a small change in G values up to 44 °C (at pH 6.5) and 49 °C (at pH 7.5) (Fig. 4). A sharp increase in G was noted with further increase in temperature up to the peak values (71 to 74 °C). This indicates the formation of a stable gel. A small decrease in G at pH 7.5 is due to the slippage of gel in the TSRM. The rapid increase in G has been attributed to myosin denaturation (Wright et al., 1977).

This study indicates that commercial meat batters prepared from either breast or thigh poultry muscles exhibit different gelation patterns (i.e. G values, transition ranges and the rate of rigidity changes) which are affected differently by pH. Such changes should be taken into account when attempts are made to mix these muscles with other meats/ingredients or when the pH is altered during processing.

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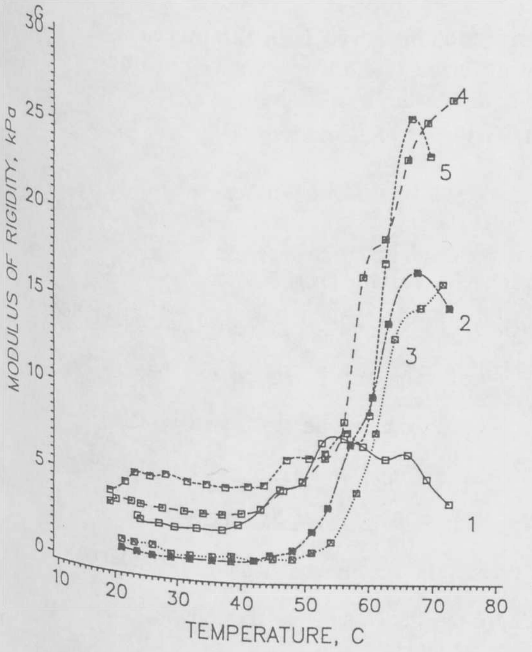

Fig. 3: Modulus of rigidity profiles of poultry breast meat batters at different pH during cooking. pH are 1 = 4.5, 2 = 5.5, 3 = 5.8, 4 = 6.5 and 5 = 7.5.

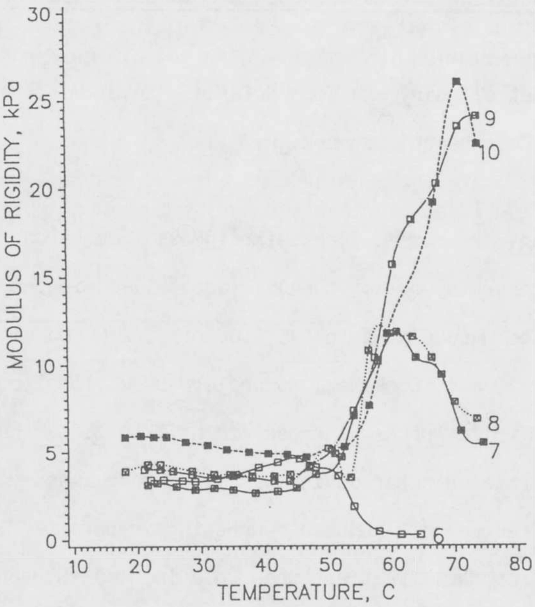

Fig. 4: Modulus of rigidity profiles of poultry thigh meat batters at different pH during cooking. pH are 1 = 4.5, 2 = 5.5, 3 = 5.8, 4 = 6.5 and 5 = 7.5.

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