RHEOLOGICAL PROPERTIES OF CHICKEN MUSCLE HOMOGENATES AS AFFECTED BY pH

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Background

Rheological properties, i.e., viscosity and shear stress of salt soluble proteins (SSP), can affect consistency as well as handling of comminuted meat products. The increase in protein concentration, storage time, and pH results in a higher apparent viscosity of myofibrillar proteins or muscle homogenates of chicken, pork and fish muscles, whereas high ionic strength conditions tend to decrease the viscosity of protein solutions (Borderias et. al., 1985; Xiong & Brekke, 1989; Cofrades et al., 1993; Robe & Xiong, 1993; Xiong & Blanchard, 1994b). Barbut & Mittal (1993) found that in the raw state and high protein concentration (14%), turkey breast meat homogenate exhibited the greatest pseudoplasticity at pH 4.5, which was similar to turkey thigh meat homogenate at pH 5.8 and higher at pH 6.5 and 7.5. In addition, thigh meat batters showed larger values of consistency coefficient compared with breast meat batters at pH$\leq$5.8; however, at higher pH (6.5, 7.5) the consistency coefficient values for both meats were similar.

Objectives

The objective of this paper was to compare rheological properties of chicken breast and thigh muscle homogenates at an intermediate protein concentration (4.5%) but with varying pH values (from 5.8 to 6.6), as well as those of myofibrillar proteins at a low protein concentration ($\leq$2%).

Methods

Investigations were conducted on chicken broilers stored at 2-4°C after 24 h p. m. The protein content in both muscles was determined using the Kjeltec System 1026. Meat homogenates were obtained by homogenisation of 15.0 g ground breast (B), 17.7 g ground thigh (T) muscles and 16.3 g combined B/T muscles (7.5 g breast and 8.8 g thigh) with 60 ml 0.67 M NaCl cold solution (pH depending on natural pH of muscle) for 1 min at 4000 rpm. The final pH of homogenates was re-adjusted with 0.1 N HCl or 0.1 N NaOH to specific values, i.e., 6.6; 6.3; 6.0 and 5.8. The protein content in meat homogenates was 45.5 mg/g. Myofibrils and SSP were prepared as previously described (Xiong 1993; Xiong & Blanchard, 1994a). Myofibrils were suspended in 8 volumes (w/v) of 0.1M NaCl washing solution and adjusted to pH 5.9 using 0.1 N HCl prior to centrifugation. Salt-soluble protein (SSP) was extracted from myofibrils in 0.6 M NaCl, 50 mM sodium phosphate at pH 6.0. Protein concentration was determined by the biuret method. The apparent viscosity of muscle homogenates was measured with a Rotatory viscometer "Rheotest-2" with the attachment H at shear rates 0.3-145.8 and that of SSP was performed using a Model VOR Bohlin rheometr equipped with a bob (25 mm) and cup (cylinder, 28 mm) apparatus and a torque element of 91.6 g·cm at shear rates 0.23-46.1. Moreover, nondestructive, oscillatory measurements of the muscle homogenates during gelation (27-90°C at 3°C/min) were performed using a TMA/SS 150U (Seiko) to compare the changes in G" (loss modulus) of muscle homogenates. The dynamic oscillatory measurements of myofibril and SSP suspensions during gelation (20-74°C at 1°C/min) were performed using a Bohlin VOR rheometer. Within each of three or five replications, for each pH value and muscle type, two parallel measurements for rheological properties were made. The parameters k and n were estimated from linear regression after changing the viscosity equitation to a linear form. The analysis of variance and the *Duncan's* method were used to test differences (Oktaba, 1980).

Results and discussion

The consistency index k ($Pa \cdot s^n$) and the power law index n (-) of relationship $\eta' = k \cdot (Dr)^{n-1}$ between apparent viscosity η' (Pa·s) of chicken breast, thigh and combined B/T muscle homogenates and shear rate Dr (s^{-1}) for various pH values (from 5.8 to 6.6) are presented in Table 1. The apparent viscosity of breast and combined B/T muscle homogenates increased with increasing pH up to pH 6.3 where a maximum value was obtained. A further increase in the pH decreased the viscosity of breast and slightly increased the viscosity of combined B/T muscle homogenates when compared with corresponding value at pH 6.3. The apparent viscosity of thigh muscle homogenates increased with pH up to 6.6. The viscosity increase in the pH range of 5.8-6.3 was the highest in breast muscle homogenates and then in combined B/T and thigh muscle homogenates. The apparent viscosity of thigh and the combined B/T muscle homogenates was higher than that of breast muscle homogenates at pH 5.8-6.0. However, apparent viscosity of breast muscle homogenates at pH 6.3 was higher than thigh and the combined B/T; and at pH 6.6 the respective values were not significantly different. All the meat homogenates exhibited pseudoplastic flow (n<1), i.e., apparent viscosity increased rapidly at low shear rates but slowly at high shear rates. The parameters n for all muscle homogenates at pH 5.8 were significantly different and increased with increasing pH from 5.8 to 6.0. Index n for breast muscle homogenate was the highest at pH 6.6 and its value was significantly different from that for thigh and the combined B/T muscle homogenates.

The findings obtained for muscle homogenates were only in partial agreement with the results obtained for myofibrillar proteins. Xiong & Blanchard (1994b) found that chicken breast SSP (10 mg/ml) were more viscous than thigh SSP at pH from 5.75 to 8.0, and that their maximal apparent viscosity was at pH 6.0 in which protein-protein and protein-solvent interactions were balanced. At lower pH, protein net charges decreased, resulting in the formation of more tightly bound aggregates and reduced solute-solvent interactions. Alternatively, at pH $\geq$6.5, increased electrostatic repulsion between protein chains led to decreased association of protein molecules, thereby decreasing apparent viscosity. Morita et al. (1987) reported that chicken breast muscle myosin apparent viscosity was greater than that of leg muscle myosin at pH<6.0 and at pH>6.5. Breast myosin attained maximal apparent viscosity at pH around 5.8 while leg myosin apparent viscosity increased at pH 5.4 to 5.7 and then at pH 5.8-7.6 its values were constant. Also the apparent viscosity of chicken breast myosin at pH 7.0 (Asghar et al., 1984), myofibrillar proteins at pH 6.5 (Skrabka-Błotnicka, 1986) and myofibrils at pH 6.0 (Xiong & Brekke, 1989) was higher than the respective proteins from leg/thigh muscle. It was in accordance with higher apparent viscosity of breast muscle homogenate than thigh and the combined B/T muscle homogenates at pH 6.3. However, the pH at which breast muscle homogenates apparent viscosity was optimal was shifted to higher pH value, i.e., pH 6.3. It appeared that in an intermediate protein concentration range, pH-dependent interactions among proteins may differ from those occurring in dilute suspensions of myofibrillar proteins. An inverse relationship was found between apparent viscosity of breast and thigh muscle homogenates and protein extractability in the examined pH range, i.e., 5.8-6.3 and 5.8-6.6 (Lesiów, 2000). A correlated increase in apparent viscosity of myofibrils and solubility of myofibrillar proteins of chicken breast and thigh muscles at pH up to 6.0 was found (Xiong, 1992; Xiong & Blanchard, 1994a,b). However, solubility of myofibrillar proteins of leg muscles was higher at pH<5.75, and lower at pH>5.75 in comparison with solubility of myofibrillar proteins of breast muscle. Then after obtaining a maximum at pH 6.0 the changes in solubility of myofibrillar proteins were very small but yet, the apparent viscosity of myofibrils from breast and leg muscles decreased as the pH was raised from 6.0 to 8.0. Thus, variations in apparent viscosity between breast and thigh/leg muscle homogenates or myofibrils can not be fully explained by differences in protein extractability; and may be ascribed to the isoforms of myosin and different protein-protein and other meat component interactions.

The results of dynamic testing for maximum viscosity (G''_{max}) of chicken muscle homogenate gels are presented in Table 2. The G''_{max} of breast muscle homogenate at pH 6.0 was lower than that of thigh and combined B/T muscle homogenates. However, at pH 6.3 a reversed trend was observed with the exception that G''_{max} values of breast and combined B/T muscle homogenates were not significantly different. It is consistent with apparent viscosity results for breast and thigh muscle homogenates with respect to differences between rheological properties of both muscle homogenates at pH 6.0 and 6.3. Surprisingly the significant increase of apparent viscosity of thigh muscle homogenates at pH 6.0 and 6.3 did not correspond to insignificant changes in loss modulus G''_{max} (Table 1,2). The T''_{max} of muscle homogenates significantly increased with the pH increase from 6.0 to 6.3. P. major myofibrils at pH 5.9 showed a higher loss modulus (G''_{max}) and a lower T''_{max} than thigh myofibrils, which was in accordance with the results for muscle homogenates at pH 6.3. Moreover SSP or myofibrils at pH 6.0 or 5.9 attained T''_{max} at lower temperatures than muscle homogenates. These differences probably reflect the apparent involvements of other muscle constituents than myofibrillar proteins.

Conclusion

The optimal apparent viscosity for chicken breast muscle homogenates was at pH 6.3. The apparent viscosity of thigh and combined B/T muscle homogenates increased in the examined pH range from 5.8 to 6.6. Isolated chicken breast and thigh proteins (SSP, myofibrils) had an optimum viscosity at pH 6.0; the pH optimum shifted to a lower level when compared with muscle homogenates. Breast muscle homogenates were less viscous at pH 5.8 and 6.0 than combined B/T and thigh muscle homogenates and the reverse relation was found at pH 6.3. These results are consistent with loss modulus G" versus pH dependence. The apparent viscosity of breast SSP was higher than leg SSP at all measured pH conditions. At pH 5.9 breast myofibrils attained a higher loss modulus value than thigh myofibrils. Because rheological characteristics of comminuted chicken is greatly influenced by the batter pH, the presence of different muscle constituents, and muscle fibre type, poultry food processors must carefully taken into consideration these factors in order to produce high-quality products.

Literature

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Table 1. Means for equation $\eta' = k \cdot (Dr)^{n-1}$ parameters of relationship between apparent viscosity and shear rate for breast (B), thigh (T) and combined B/T muscle homogenates at different pH.

Type of muscle	Parameter	pH 5.8	6.0	6.3	6.6
breast (B)	k ($Pa \cdot s^n$)	826.08^ax	1183.06^bx	3047.22^cx	2826.03^dx
thigh (T)	k	1471.63^ay	2129.13^by	2578.51^cy	2772.90^dx
B/T	k	1060.24^az	1685.22^bz	2783.13^cz	2903.33^cx
breast (B)	n (-)	0.0962^ax	0.1618^bx	0.1798^{bc}x	0.1853^cx
thigh (T)	n	0.1657^ay	0.1835^bx	0.1771^{ab}x	0.1727^{ab}y
B/T	n	0.1262^az	0.1761^bx	0.1711^bx	0.1634^by

Different superscripts within a row and letter in a column (separately for k and n) stand for significant differences, $P \leq 0.05$

Table 2. Loss modulus (G''_{max}) and transition temperature (T''_{max}) of chicken breast (B), thigh (T) and combined (B/T) muscle homogenates at pH 6.0 and 6.3 (Lesiów, 2001), breast SSP or myofibrils at pH 6.0 (Xiong, 1993) and myofibrils at pH 5.9 (Xiong & Blanchard 1994a).

Attribute	Type of sample / pH									
	SSP^x	$Myofibrils^x$	$Myofibrils^x$	Muscle homogenate^{xx}						
	$B_{pH\,6.0}$	$B_{pH\,6.0}$	P.m.$_{pH\,5.9}$	$T_{pH\,5.9}$	$B_{pH\,6.0}$	$T_{pH\,6.0}$	$B/T_{pH\,6.0}$	$B_{pH\,6.3}$	$T_{pH\,6.3}$	$B/T_{pH\,6.3}$
G''_{max}	74.7	44.5	69.8	25.4	6.2^a	23.3^b	10.6^c	31.4^d	24.0^b	28.6^d
T''_{max} (°C)	49.4	51.1	44.9	47.7	52.2^{ab}	51.5^a	52.4^b	55.4^c	54.4^d	54.9^c

Different superscripts within a row for muscle homogenate stand for significant differences, $P \leq 0.05$, G" (^{x}Pa, ^{xx}kPa).