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CHICKEN MUSCLE HOMOGENATE GELATION PROPERTIES. EFFECT OF pH.

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Background

Xiong [1994] has extensively reviewed research concerning myofibrillar protein functionality and implicated that gelation properties of myofibrillar proteins are influenced by the distribution of specific fibre types in muscle samples from which myofibrillar proteins are extracted. In another review Lesiów and Xiong [2001] noted considerable concentration-dependent differences in gelation properties of chicken and turkey white and red muscle myofibrils, i.e., at low (<2.5%), intermediate (5-7%) and high (10%) protein concentrations, as well as pH-dependent gelation properties of myofibrillar proteins and comminuted meats.

Objective

The objective of this study was to compare gelation properties of chicken breast and thigh muscle homogenates at an intermediate protein concentration (4.5%) and at different pH values (from 5.8 to 6.6) and those of myofibrillar proteins at a low protein concentration (2%).

Methods

Investigation was conducted on chicken broilers stored at 2-4°C after 24 h p. m. Meat homogenates were obtained by homogenisation of 15 g ground breast (B) and 18 g ground thigh (T) muscles with 60 cm^3 0.67 M NaCl cold solution (at pHs specified below) for 1 min at 4000 rpm. The solution pH, depending on natural pH of muscle, was adjusted to: 8.0; 6.5; 6.0 and 5.6 for breast muscle and to: 6.7 - 7.0; 6.0 - 6.2; 5.3 - 5.5 and 3.5 for thigh muscle. The final pH of homogenates was re-adjusted with 0.1 N HCl or 0.1 N NaOH to specific pH value, i.e., 6.6; 6.3; 6.0 and 5.8. The protein content in meat homogenates was approximately 45.5 mg/g. For each pH value, two parallel samples from meat homogenate were placed in the glass tubes (25 mm x 40 mm; Dia. x L) and were heated isothermally at 70°C for 30 min in a water bath. After heating, gels were cooled in an ice slurry for one hour and stored overnight at 2-4°C. Then gels were equilibrated to room temperature for 30 min before examination. Deformation of the gels was measured on a modified "Hoeppler" rheoviscometer equipped with a flat 14.8 mm diameter plunger. Stepwise changed stress, being the multiple of 0.285 kPa, was measured after each 30 s. The stress at failure, i.e., the stress required to rupture the gel, was used to express the gel strength (kPa). Moreover, nondestructive, oscillatory measurements of the muscle homogenates during gelation (heated from 27 to 90°C at 3°C/min) were performed using a TMA/SS 150U (Seiko).

Within each of five replications, for each pH value and muscle type, two parallel measurements for gelation properties were made. The analysis of variance and the Duncan's method were used to test differences [Oktaba, 1986].

Results and discussion

The gel strength of breast muscle homogenates increased with increasing pH up to 6.3 where a maximum strength value was obtained (Table 1) [Lesiów, 2000]. A further increase in the pH to 6.6 slightly (but insignificantly) decreased the gel strength when compared with corresponding value at pH 6.3. Gelation of thigh muscle homogenates was not so sensitive to pH as that for breast muscle homogenate which is in accordance with hen muscle myofibril results obtained by Xiong and Brekke [1991]. The strength of thigh muscle homogenate gels was the highest at pH 6.0. However, it was not significantly different from corresponding values at pH 5.8 and 6.3. At pH 6.6 thigh muscle homogenate gels were weaker than that at pH 6.0. Higher value of optimal gelation pH of breast than thigh muscle homogenate (pH 6.3 versus pH 6.0), and weaker gel formation at greater pH values agreed with the results reported by Xiong and Brekke [1991] and Xiong [1992] for hen/chicken breast and thigh myofibrils (pH 6.0 versus pH 5.5).

The gel strength of thigh muscle homogenates was significantly higher than that of breast muscle homogenates at pH 5.8-6.0 (Table 1). It is in accordance with the observation of Lan et al. [1995] that at 5% protein concentration and pH 6.0, chicken breast myofibrils produced weaker gels than thigh myofibrils. However, gel strength of breast muscle homogenates was significantly higher than thigh muscle homogenates at pH 6.3 (by 14.63%) and at pH 6.6 (by 18.14%). Xiong [1992] found that chicken leg myofibril gels formed at pH 5.5-5.8 were more rigid than breast gels, and above pH 6.0, this was reversed. The finding was consistent with the results obtained for muscle homogenates, however, the pH at which breast muscle homogenate gels were stronger than thigh gels was shifted to higher pH value, i.e., pH 6.3. In contrast, hen breast myofibrillar gels were stronger than leg/thigh myofibrils within the entire pH range studied, i.e., pH 5.5 to 6.5 [Xiong and Brekke 1991] or 5.87 to 6.53 [Xiong and Blanchard 1994]. It appeared that pH-dependent interactions among protein molecules in an intermediate concentration gel matrix of muscle homogenate (mixture of sarcoplasmic and salt-soluble proteins, insoluble fraction of myofibrillar proteins, myofibrillar fragments and connective tissue proteins [Xiong 1993]) may differ from those occurring in dilute protein suspension of myofibrils (salt-soluble proteins and non soluble myofibrils [Xiong and Brekke 1991]).

An inverse relationship was found between strength of breast muscle homogenate gels and protein extractability in the examined pH range, while for thigh muscle homogenate gels, such relationship was not evident [Lesiów, 2000]. Thus, variations in gel strength between breast and thigh muscle homogenates cannot be fully explained by differences in protein extractability; and may be ascribed to the isoforms of myosin [Asghar et al. 1984, Morita et al. 1987] and different protein-protein and other meat component interactions. Xiong and Brekke [1991] had shown that the solubility differences between chicken breast and leg myofibrils only partially contributed to the variation in gel strength, because such differences could only alter the volume of the effective gelling components without

affecting the specific protein bonds in the gel matrix. This hypothesis can be supported by the observation that at pH > 6.0, where changes in solubility of myofibrillar proteins of breast muscle were very small but yet, the proteins formed substantially weaker gels as the pH was raised from 6.0 to 7.0 [Xiong 1994]. In the case of myofibrils from leg muscles, their gelation properties are even less directly related to protein solubility because their optimal gelation pH was 5.5 at which the protein solubility was low compared with the solubility at higher pH values.

Results of dynamic testing for gelation of chicken muscle homogenates are presented at Table 2 [Lesiów, 2001]. Rheological properties of muscle homogenates were clearly pH-dependent. At pH 6.0 storage modulus (G') of breast muscle homogenate was lower than for thigh muscle homogenate. However, at pH 6.3 a reverse trend was observed with breast muscle homogenate that produced a more elastic gel. The value of G' for breast meat homogenate at pH 6.3 was higher than that at pH 6.0, and for thigh meat homogenate these corresponding values were not significantly different. Therefore, optimum gelation for breast meat homogenate was at pH 6.3 and for thigh muscle homogenate it spread over a slightly broader pH range (6.0-6.3). Chicken breast (white) SSP and myofibrils developed a more elastic gel structure (greater G') than thigh protein at pH greater than 6.0, indicating that thigh proteins were less able to form a cross-linked gel network. However, differing from muscle homogenate systems, a pH of 6.0 favours the formation of an elastic gel network for isolated breast muscle proteins when compared to other pH conditions [Xiong and Blanchard 1994, Wang 1990]. In spite of a similar pattern of changes in storage modulus of chicken breast and thigh SSP (pH 6.0), myofibrils (pH 5.87, 6.19-6.38) [Xiong 1994, Xiong and Blanchard 1994] and muscle homogenates (e.g. after reaching a maximum, the G' sharply declined to a minimum), muscle homogenates attained peak values at higher temperatures than SSP or myofibrils. This difference was more pronounced at pH 6.3, probably reflecting the contribution of muscle constituents other than myofibrillar proteins.

Conclusions

The optimal gelation condition for breast muscle homogenates as determined by gel strength or dynamic elasticity testing was at pH 6.3, and for thigh muscle homogenates, it was at pH 6.0-6.3. Similarly, isolated chicken breast proteins (SSP, myofibrils) had a higher pH optimum than thigh counterpart (pH 6.0 versus 5.5) for gelation, although for both muscle types, the pH optima shifted to a lower level when compared with muscle homogenates. Breast muscle homogenate gels were weaker at pH 5.8 and 6.0 than thigh muscle homogenates and the reverse relation was found at pH 6.3 and 6.6. Breast myofibril and salt-soluble proteins generally formed stronger gels than leg proteins except at low pH conditions (pH<5.8).

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Table 1
Stress at failure of chicken breast (B) and thigh (T) muscle homogenate gels at pH 5.8- 6.6 [Lesiów, 2000].

Type of muscle / pH / Stress at failure (kPa)							
$B_{pH\ 5.8}$	$B_{pH\ 6.0}$	$B_{pH\ 6.3}$	$B_{pH\ 6.6}$	$T_{pH\ 5.8}$	$T_{pH\ 6.0}$	$T_{pH\ 6.3}$	$T_{pH\ 6.6}$
4.20 (0.5)^{a}	5.16 (0.7)^{b}	7.80 (0.5)^{c}	7.38 (0.5)^{cd}	6.99 (0.7)^{dc}	7.27 (0.4)^{cde}	6.66 (0.5)^{ef}	6.04 (0.4)^{f}

$^{a-f}$Means with different superscripts are significantly different at P<0.05.

Table 2.Transition temperatures (T'_{max} and T'_{min}) and storage modulus at 75°C ($G'_{75°C}$) of chicken breast (B), thigh (T) salt soluble proteins (SSP) [Xiong, 1994], myofibrils [Xiong and Blanchard, 1994] and muscle homogenates [Lesiów, 2001] at pH close to 6.0 and 6.3.

Attribute	Type of sample / pH									
	SSP^{x}		myofibrils^{x}		myofibrils^{x}		muscle homogonate^{xx}		muscle homogonate^{xx}	
	$B_{pH\ 6.0}$	$T_{pH\ 6.0}$	$B_{pH\ 5.87}$	$T_{pH\ 5.87}$	$B_{pH\ 6.38}$	$T_{pH\ 6.38}$	$B_{pH\ 6.0}$	$T_{pH\ 6.0}$	$B_{pH\ 6.3}$	$T_{pH\ 6.3}$
T'_{max} (°C)	50.0	51.5	49.4 (0.3)^{a}	51.0 (0.0)^{b}	50.3 (0.6)^{a}	51.5 (0.5)^{a}	52.7 (1.2)^{a}	52.5 (0.7)^{a}	55.6 (1.0)^{b}	54.8 (0.9)^{b}
T'_{min} (°C)	55.0	58.0	55.0	55.0	55.0	58.0	58.6 (0.2)^{a}	55.7 (0.5)^{b}	59.0 (0.9)^{a}	58.5 (0.9)^{a}
$G'_{75°C}$	461.0	106.0	629.0 (102)^{a}	198.0 (24)^{b}	355.0 (95.0)^{a}	67.0 (10.0)^{b}	72.4 (8.5)^{a}	144.8 (12.6)^{b}	163.4 (2.8)^{cd}	152.5 (2.3)^{bd}

$^{a-d}$Means with different superscripts in the same row (separately for each type of sample) are sig. different at P<0.05), G' (^{x}Pa, ^{xx}kPa).