Postmortem Change in the Tensile Strength of Muscle Fibers and Their Relation to Tenderness of Poultry Meat

To study postmortem changes in the tensile strength of muscle fibers and tenderness, experiments were made on Pectoralis major muscles from epinephrine-treated, untreated, and fatigued birds. The meat obtained from epinephrine-treated and fatigued birds was more tender than that from untreated birds. The tensile strength of muscle fibers immediately after slaughter and 24 hr postmortem did not vary much in these tests, but the maximum value of tensile strength obtained between 4–6 hr postmortem varied markedly. The results indicate a high correlation (r = 0.65) between the shear force value of aged meat and the tensile strength of muscle fibers at 4–6 hr postmortem.

A close relationship between tenderness and the state of contraction of the muscle has been shown, and it has been postulated that tenderness of poultry meat decreases with an acceleration of postmortem glycolysis (de Fremery, 1966; de Fremery and Pool, 1960). Although tensile strength and extensibility of muscle fibers have been measured (Wang *et al.*, 1956; Sato *et al.*, 1967), the quantitative influence of contraction during rigor on ultimate tenderness of meat has not been studied in detail.

The object of this study was to determine changes in the tensile strength of muscle fibers during postmortem aging of tough and tender meat. In these tests, tender meat was obtained by treating birds with epinephrine before slaughtering or by enforced exercising. Relation of the tensile strength of muscle fibers and tenderness of meat was also investigated.

EXPERIMENTAL

Pectoralis major muscles were obtained from 12- to 14-month-old chickens (White Leghorn, female, approximately 1.5 kg live weight). They were raised under similar environmental and nutritional conditions. All birds were killed by cutting the jugular vein and carotid arteries, skinned without scalding, and eviscerated. The carcass was placed in a plastic bag and aged in drained crushed ice. To obtain the tender meat, enforced exercise and premortem injection of epinephrine (an intramuscular dose of 4 mg/kg of body weight) were used according to the conditions previously described (Khan and Nakamura, 1970; Nakamura, 1970). Effectiveness of treatment was checked by measuring the pH of muscles after aging for 24 hr. In this experiment, epinephrine-injected birds had a pH of 6.8–7.1 and exercised birds had a pH of 6.0–6.3 (pH of control birds was 5.6–5.8). Each experimental group contained seven birds.

Tensile strength measurements were made on 8–10 muscle bundles, prepared in 50% glycerol, by the use of a strain gauge attached to an automatic recorder (Shinkoh Tsushin Kogyo K. K., Tokyo). Each muscle bundle was 2–3 cm in length and contained about 25 single fibers. These test conditions were established by tensile strength measurements made on muscle bundles containing less than 25 and up to 100 single fibers of various length and by various preparation solutions (Nakamura, 1972).

Shear force value was measured by a Warner–Bratzler type apparatus. Muscle samples were clamped in a special mold designed according to de Fremery and Pool (1960) and cooked to an internal temperature of 82–85°C (about 1 hr in boiling water). Strips 1-cm square in cross section were cut and 8–12 determinations were made on each sample. Shear force measurement was made at the time when the tensile strength of muscle fibers reached the maximum value and when the tensile strength of muscle fibers decreased to final value, namely, 24 hr postmortem.

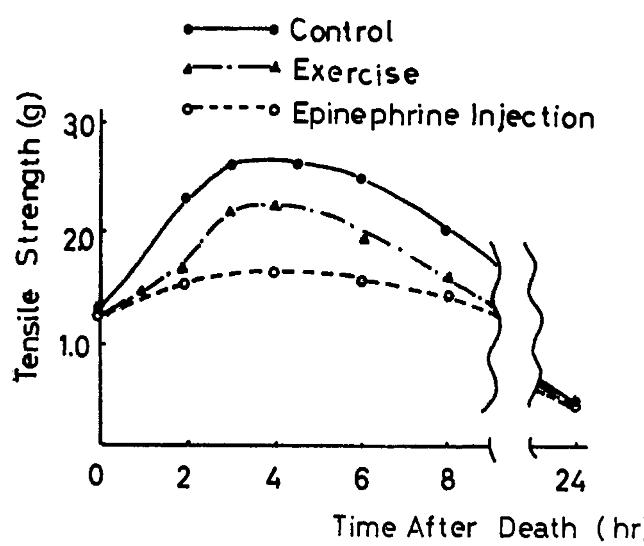

Figure 1. Changes in the tensile strength of muscle fibers

The pH of muscles was measured directly with a needle-type glass electrode using Hitachi–Horiba pH meter (Hitachi Co. Ltd., Tokyo).

RESULTS AND DISCUSSION

The tensile strength of the muscle fibers obtained from three test groups used in these experiments increased during the first 4–6 hr postmortem and decreased thereafter (Figure 1). Differences in both initial and final values of tensile strength were small, but the maximum value of tensile strength varied markedly among these three test groups. The control (untreated) muscle samples gave the highest value, while muscles from epinephrine-injected birds gave the lowest value. The muscles showing the highest tensile strength during the first 6 hr postmortem were toughest. These differences in toughness did not disappear during 24 hr of aging period (Table I). Since the tensile strength of muscle fibers

Table I. Effect of Epinephrine Treatment and Enforced Exercise on Tensile Strength of Muscle Fibers and Shear Force Value of Pectoralis Major Muscle

	Tensile strength (g/25 muscle fibers)[a]		Shear force value (kg)[a]	
Treatment	4–6 hr postmortem	24 hr postmortem	4–6 hr postmortem	24 hr postmortem
Control	2.6 ± 0.4	0.5 ± 0.2	>5	2.0 ± 0.2
Exercised	2.2 ± 0.3	0.5 ± 0.2	3.4 ± 1.2	1.3 ± 0.2[b]
Epinephrine-injected	1.6 ± 0.2[b]	0.5 ± 0.2	2.6 ± 0.6[b]	1.0 ± 0.2[b]

[a] Mean ± SD, $n = 7$. [b] Significantly different from control ($p < 0.05$).

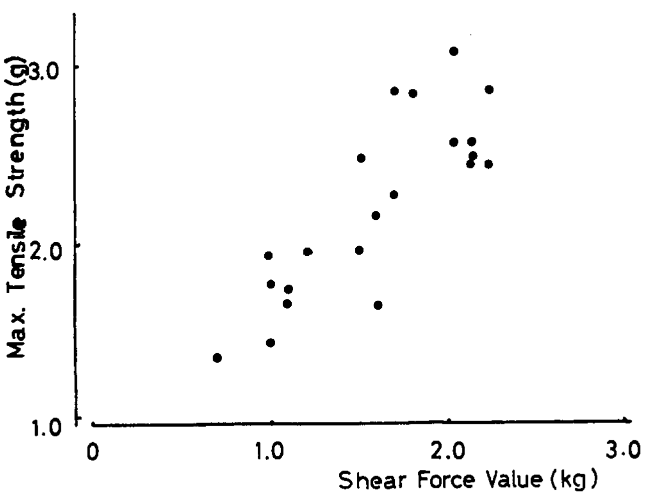

Figure 2. Relation between maximum tensile strength of muscle fibers and shear force value of aged meat

at 24 hr postmortem was almost the same for the three test groups, the tensile strength of muscle fibers does not appear to be the only factor determining the ultimate tenderness.

The relationship between the shear force value of aged meat and the maximum tensile strength of muscle fibers is shown in Figure 2. The sample correlation coefficient, r, calculated from the data in Figure 2 was 0.65. Both the sample size, 21, and the size of r, 0.65, show that the null hypothesis can be rejected at the 1% level (Snedecor and Cochran, 1956). This means that the relationship between the shear force value of aged meat and the maximum tensile strength of muscle fibers is not due to sampling error. This r value is considered to be relatively high, for tenderness is a very complicated property and might be affected by many factors.

It is generally considered that actin and myosin combine to form actomyosin during postmortem aging and this actomyosin formation in muscles is due to the disappearance of ATP (Lawrie, 1966). Since the depletion of ATP occurs more rapidly in muscles from epinephrine-injected (de Fremery, 1966) or from exercised brids (Nakamura, 1970) as compared to muscles from the control birds, the properties of actomyosin formed during postmortem aging may be different in muscles from these three test groups. Although the exact nature of this difference is not known, the physicochemical properties of actomyosin (Herring *et al.*, 1969a,b) as well as the ratio of actin to myosin in actomyosin (Fujimaki *et al.*, 1965) have been shown to differ among meats with different tenderness.

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LITERATURE CITED

de Fremery, D., J. Agr. Food Chem. **14,** 214 (1966).
de Fremery, D., Pool, M. F., *Food Res.* **25,** 73 (1960).
Fujimaki, M., Arakawa, N., Okitani, A., Takagi, O., *J. Food Sci.* **30,** 937 (1965).
Herring, H. K., Cassens, R. G., Briskey, E. J., *J. Food Sci.* **34,** 389 (1969a).
Herring, H. K., Cassens, R. G., Fukazawa, T., Briskey, E. J., *J. Food Sci.* **34,** 571 (1969b).
Khan, A. W., Nakamura, R., *J. Food Sci.* **35,** 266 (1970).
Lawrie, R. A., "Meat Science," 1st ed., Pergamon Press, London, 1966, p 80.
Nakamura, R., J. Agr. Food Chem. in press (1972).
Nakamura, R., *Jap. J. Zootechnol. Sci.* **41,** 471 (1970).
Sato, Y., Watanabe, K., Asai, A., *Nippon Shokuhin Kogyo Gakkai-Shi* **14,** 235 (1967).
Snedecor, G. W., Cochran, W. G., "Statistical Methods," 5th ed., The Iowa State Univ. Press, Ames, Iowa, 1956, p 160.
Wang, H., Doty, D. M., Beard, F. J., Pierce, J. C., Hankins, O. G., *J. Anim. Sci.* **15,** 97 (1956).

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