EFFECT OF ENDURANCE EXERCISE ON INTRAMUSCULAR COLLAGEN CHARACTERISTICS IN GOATS

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Background and Objective:

Collagen is a major constituent in connective tissues of muscle, and is considered to be associated with meet tenderness. Newly synthesized collagen has fewer pyridinoline crosslinks and should be more heat-labile and less mechanical strength (Bailey, 1984). Han et al. (1999) indicated that acute exercise induced collagen synthesis resulting from repairing the damage of connective tissues in rat. Several reports are available on the impact of training-induced differences in metabolic traits or meat quality of muscles. However, it is still unclear the influence of endurance exercise on the collagen characteristics.

Therefore, the aim of this study was to evaluate the effect of endurance exercise on intramuscular collagen characteristics, meat tenderness and water-holding capacity for various muscles of goats.

Methods:

Six male (from 12 to 15 months of age) and 4 castrated (from 24 to 33 months of age) goats were used. Goats were assigned to one of two treatment groups on the basis of body weight and age, and were kept in a pen to each treatment. They were given ad libitum access to a concentrate (TDN70%, CP15%) and Italian ryegrass hay. Treatment was 2 level of exercise (sedentary and exercised). The sedentary group (CONT) received no exercise and was housed in the pen (6.4 m^2 per animal). The exercised group (EXER) received exercise at a speed of 3.0km/h 3 days per week. The exercise was increased from 20 min to 45 min per day during week 1 to adapt animals to the exercise and was 60 min per day from week 2 to 8. The EXER goats were exercised as one group in a mobile pen which was tugged by a wagon on a shuttle road, 0.5 km in length. In week 8, blood samples of EXER group were collected from the jugular vein before and immediately after exercise to determine plasma L-lactic acid levels. All goats were slaughtered at week 9. The samples of *longissimus dorsi*, *psoas major*, *biceps femoris*, *gastrocnemius* and *soleus* muscles were removed 7 days post-slaughter after storage of the carcass at 2℃, and the samples were frozen at -20℃ until analyses.

Meat samples were thawed at 4℃ and trimmed of external fat and epimysial connective tissue. Two pieces of each *longissimus dorsi* and *biceps femoris* samples were obtained and wrapped plastic bags, then the samples were cooked in a water bath at 70℃ for 1 hr. After cooling in running tap water, a core (1cm^2 in section area) was removed from each cooked meat parallel to the muscle fiber orientation. Each core was sheared using a Warner-Bratzler shear machine. Water-holding capacity of duplicate 1g of samples was determined by centrifuging method (1700 × g for 1.5 hr) as described by Penny (1975).

Ground samples were heated at 77℃ for 70 min in 0.25 strength Ringer's solution and separated into supernatant and residue fractions (Hill, 1966). Hydroxyproline contents in the supernatant fraction and non-heated ground meat sample (to determine total collagen) hydrolyzates were determined by spectrophotometric methods as described by Bergman and Loxley (1963). Collagen contents were calculated by multiplying the hydroxyproline contents of the fresh samples by 7.25 and that of the soluble portions by 7.52. Pyridinoline crosslinks in muscle hydrolyzates were concentrated and separated from the bulk of the other amino acids by selective elution from CF1 cellulose column (Skinner, 1982). The pyridinoline concentration in the fraction was determined using the HPLC method (Arakawa et al., 1992).

Result and Discussion:

The increase of plasma L-lactic acid level was not found after exercise on the EXER group (95 ± 35 mg/l in before, 66 ± 19 mg/l in after exercise). This is indicating that the EXER group was received aerobic exercise. Average daily weight gain was similar for both groups (0.21 ± 0.02 kg/d in EXER group, 0.20 ± 0.01 kg/d in CONT group).

Chemical compositions in the muscles were not affected by the treatments (Table 1). *Soleus* muscle in the EXER goats had higher ($p < 0.05$) total and insoluble collagen contents compared with that in the CONT goats, but in the other muscles, collagen characteristics were not significantly modified by the treatment (Table 1). There were significant ($p < 0.05$) treatment × age or treatment × castration interactions for collagen characteristics in *soleus* muscle. Thus, the differences in total and insoluble collagen contents in *soleus* muscle of young male goats by the treatment were not significant, but we can not reveal whether the interaction is treatment × age or treatment × castration interaction in this experiment. It has been suggested that *soleus* muscle is susceptible to influence of exercise because this muscle has less fast-glycolytic fiber which is not heavily recruited during the

training regimen and may mask any training effect (Zimmermen et al., 1993). Therefore, the significant effects of exercise on collagen characteristics were observed only in *soleus* muscle in present investigation. However, these result do not agree with those obtained by Zimmermen et al. (1993), who reported lower pyridinoline contents in *soleus* muscles of exercised middle- and old-aged rats without any change in total collagen content. This difference may be due to different intensity of exercise. These results suggested that the effect of exercise on intramuscular collagen characteristics depend on the intensity of exercise, various types of muscles and age of animal.

There was no effect of the exercise treatment on shear force values of *longissimus dorsi* and *biceps femoris* muscles and water-holding capacity of five muscles (Table 1). Aalhus and Price (1990) indicate that response of meat quality to endurance exercise in sheep needed long-term effect, which is longer than 18 weeks, so that the short term of this experiment may not allow for observation of meat quality differences.

Conclusions:

In the present study, exercise did not affect the meat tenderness and water-holding capacity in *longissimus dorsi* and *biceps femoris* muscle. Only in *soleus* muscle of castrated goats from 26 to 35 months of age, the exercise increased in both total and insoluble collagen content without any change in collagen solubility. These results indicate that endurance exercise could effect intramuscular collagen characteristics in goats, and the effect seemed to depend on intensity of exercise, various types of muscles and age or castration of animal. Further studies are needed to determine if using a more active form of intensive or long-term exercise could affect meat quality.

Pertinent literature:

Aalhus, J.L. and Price, M.A. (1990). The effect of endurance exercise on live animal performance and carcass growth and development in sheep. Canadian Journal of Animal Science, 70, 97-105.

Arakawa, N., Kim, M., and Otsuka M. (1992). An improved high-performance liquid chromatographic assay for the determination of pyridinoline in connective tissues. Journal of Nutritional Science and Vitaminology, 38, 375-380.

Bailey, A.J. (1984). Recent Advances in the Chemistry of Meat. Special Publications No. 47, 22-40. The Royal Society of Chemistry, London.

Bergman, I. and Loxley, R. (1963). Two improved and simplified methods for the spectrophotometric determination of hydroxyproline. Analytical Chemistry, 35, 1961-1965.

Han, X.Y., Wang, W., Komulainen, J., Koshinen, S.O., Kovanen, V., Vihko, V., Trackman, P.C., Takala, T.E. (1999). Increased mRNAs for procollagens and key regulating enzymes in rat skeletal muscle following downhill running. European Journal of Physiology, 437, 857-864.

Hill, F. (1966). The solubility of intramuscular collagen in meat animals of various age. Journal of Food Science, 74, 161-166.

Penny, I.F. (1975) Use of a centrifuging method to measure the drip of pork *Longissimus dorsi* slices before and after freezing and thawing. Journal of the Science of Food and Agriculture, 26, 1593-1620.

Zimmerman, S.D., McCormick, R.J., Vadlamudi, R.K. and Thomas, D.P.(1993). Age and training alter collagen characteristics in fast- and slow-twitch rat limb muscle. Journal of Applied Physiology, 75, 1670-1674.

Table 1. Effect of endurance exercise on chemical compositions, collagen characteristics, shear values and water-holding capacities of *longissimus dorsi*, *biceps femoris* and *soleus* muscles

	Longissimus dorsi		*Biceps femoris*		*Soleus*	
Treatment	EXER	CONT	EXER	CONT	EXER	CONT
Water (%)	71.8	72.0	74.2	74.4	74.9	75.8
Fat (%)	6.1	6.4	3.6	3.9	2.2	1.9
Protein (%)	21.8	21.2	21.9	21.2	22.2	21.6
Total collagen (%)	0.546	0.515	0.902	0.959	0.461	0.359*
Soluble Collagen (%)	0.074	0.076	0.090	0.105	0.052	0.042†
Insoluble collagen (%)	0.427	0.440	0.812	0.854	0.409	0.317*
Collagen solubility (%)	13.6	41.6	10.0	11.2	11.5	11.2
Pyridinoline (mol/mol of collagen)	0.201	0.193	0.181	0.204	0.198	0.177
Warner-Bratzler shear value (kg)	4.7	5.7	6.4	7.0	Not determined	
Water-holding capacity (%)	49.9	49.1	50.4	51.0	53.6	52.6

Significant effects of treatment: *$p<0.05$; †$p<0.10$