The Influence of Changes in Muscle DNA Content and Nuclear Number on Muscle Growth in Feedlot Cattle

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Story in Brief

DNA, nuclear number and fiber width were determined on longissimus dorsi sections obtained from Hereford and Charolais crossbred steers slaughtered at 500, 700 and 900 lb. Results showed a significant decrease in longissimus DNA concentration with increased feedlot weight. This appeared to suppress the rate of growth of the longissimus muscle as well as the individual muscle fibers, particularly after the 700 lb slaughter period. Nuclear number increase also diminished after the animals had reached 700 lb live weight, suggesting that the amount of muscle tissue and cell volume supported per nucleus had increased with feedlot weight. Results indicated that the longissimus muscle from these experimental animals approached biological maturity at about 700 lb live weight and that this was related to the DNA concentration in the muscle.

Introduction

Deoxyribonucleic acid (DNA), found almost exclusively in the cell nucleus, is responsible for the cellular synthetic mechanisms and is quite constant in its concentration per mammalian diploid nucleus (6.2 picograms). Since skeletal muscle tissue is multinucleated, the DNA content is not constant relative to cell numbers. Moreover, nuclear numbers increase in muscle tissue post-natally at a diminished rate with age as "biosynthetic maturity" is attained. It is believed that the amount of sarcoplasmic material that a single nucleus can maintain is limited. Hence, an increase in the number of nuclei would be necessary for sustained muscle growth.

Protein synthesis, nuclear concentration and various cell measurements in skeletal muscle tissue have been extensively studied with laboratory animals. However, the beef animal has received little attention concerning these parameters. Thus, the objective of this study was to examine the DNA, nuclear number and nuclear number per unit volume of the beef animal during growth.

Materials and Methods

Muscle samples were obtained from 18 Hereford and Charolais crossbred steer calves. Six of the steers were slaughtered at each of the following weight groups: 500 lb,

Table 1. DNA concentration, section weight, total section DNA and fiber width in longissimus dorsi muscle of 500, 700 and 900 pound beef steers.

Slaughter Weight Group (Pounds)	DNA Concentration (μg/100mg)	Longissimus Dorsi Section Weight (Kilograms)	Total DNA Per Muscle Section (Grams)	Muscle Fiber Width (Microns)
500	57.567	2.69	1.55	62.9
700	55.662	3.39	1.89	67.9
900	48.534	4.38	2.13	70.2

Table 2. Nuclear number per section, muscle tissue supported per nucleus and fiber width supported per unit of DNA in longissimus dorsi muscle of 500, 700 and 900 pound beef steers.

Slaughter Weight Groups (Pounds)	Nuclear Number Per Muscle Section ($x10^{11}$)	Grams Muscle Tissue Supported Per Nucleus ($x10^{-9}$)	Unit of Fiber Width Supported Per Unit DNA (Microns)
500	2.50	1.10	1.09
700	3.05	1.10	1.22
900	3.43	1.30	1.45

700 lb and 900 lb. Muscle sections were removed from the 7th-13th rib section of the right longissimus dorsi of the freshly slaughtered animals, chilled in ice and prepared for analysis.

DNA was isolated and quantitated by procedures modified from Schneider, 1945 and Burton, 1956. Total grams DNA was determined by multiplying the DNA (μg/100mg) by 0.00001 and then by the muscle section weight. Total nuclear number per muscle section was determined by dividing the total grams DNA by 6.2×10^{-12} grams. Grams of tissue supported per nucleus was determined by dividing the muscle section weight by the total nuclear number per section. Fiber width was determined by a microscopic technique previously described.

Results and Discussion

Results in Table 1 show that the DNA concentration (μg/100mg) decreased as the feedlot weight of the animals increased. This decrease in DNA concentration appeared to accelerate with increased weight and age of the cattle.

The longissimus dorsi section weight increased with feedlot weight, as did the total longissimus section DNA content and the average muscle fiber width. However, if the longissimus section weight is expressed as a percentage of the slaughter weight, a definite abatement in weight accretion of the longissimus section can be noted, beginning with the 700 lb slaughter group. This depression in longissimus muscle growth rate was accompanied by lesser increases in both the total DNA per muscle section and muscle fiber width data, all of which may be attributed to the decrease in absoulte DNA concentration.

As may be observed in Table 2, total nuclear number per longissimus section showed an overall increase as slaughter weight and, hence, feedlot time were increased. Yet this increase in nuclear number tended to diminish after the animals had reached 700 lb live weight. This suggests that each cell nucleus had begun to support a greater quantity or volume of muscle tissue as well as a greater portion of the individual muscle fibers at this period of feedlot life. These results would indicate that the longissimus muscle had approached biosynthetic maturity at the 700 lb period and that this degree of maturation was related to the DNA concentration in the muscle.

Literature Cited

Schneider, W. C. 1945. Phosphorous compounds in Animal tissues. I. Extraction and estimation of deoxyribonucleic acid and ribonucleic acid. J. Biol. Chem. 161:293.

Burton, K. 1956. A study of the conditions and mechanisms of the diphenylamine reaction for the colorimetric estimation of deoxyribonucleic acid. Biochem. J. 62:315.