Metabolic Indices of Bovine Muscle Growth

J.R. Escoubas, J.J. Guenther and K.K. Novotny

Story in Brief

Eight month and twelve month Hereford steer calves were used to initiate an investigation of metabolic growth patterns in the bovine. Tissue samples were obtained from the left Longissimus dorsi muscle immediately postmortem and extracted in the fresh state. Various key oxidative and glycolytic enymes were assayed and the data expressed in specific activity units per gram of protein. Results indicate an increasing trend in glycolytic metabolic activity, a concomitant decrease in the specific activity of enzymes associated with oxidative metabolism, and elevated activities of an enzyme associated with nucleic acid biosynthesis.

Increased activities of a key enzyme associated with fatty acid oxidation were noted with increasing age. These data are preliminary but suggest a metabolic adaptation from a muscle system of predominately red type fibers (eight month old calves) to a muscle system of less predominately red type fibers (twelve month old calves). This adaptation appears to parallel elevated protein synthesis resulting in muscular hypertrophy. Further work is continuing to elucidate these findings.

Introduction

It has been demonstrated that, postnatally, muscle tissue undergoes a cellular, motoneural controlled differentiation which results in the production of red, white and/or intermediate fibers with the red type rich in oxidative enzymes, the white type rich in glycolytic enzymes and the intermediate type having similar oxidative and glycolytic enzymic properties. Since the environment as well as genetics directly affects motoneural innervation and ensuing protein synthesis, an investigator may feasibly monitor muscle metabolic and protein synthesis trends and simultaneously impose specific environmental treatments such that these trends and their changes due to imposed treatments might be indexed. Thus, in order to obtain this information on the bovine, indepth studies must be accomplished on animals of differing sizes and when subjected to differing nutritional and environmental conditions.

Materials and Methods

To initiate a metabolic investigation on bovine muscle tissue, various enzymes were assayed and included those as outlined in Table 1. For this study, muscle tissue was obtained from the left longissimus dorsi in the 13th thoracic region from 500 and 700 pound Hereford steers averaging eight months and twelve months age, respectively. Muscle samples were excised immediately after rapid skinning and chilled promptly in ice. The tissue was then transported to the laboratory for extraction and subsequent enzyme assays. The muscle tissue was extracted in buffered sucrose, using the glass-teflon Potter-Elvejhem apparatus for homogenization, centrifuged and th supernatant obtained utilized as the source for all cell soluble enzymes and the precipitate obtained resuspended in sucrose media and recentrifuged. The mitochondrial pellet obtained from the final centrifugation was again suspended in sucrose media and used as the source of aerobic enzyme analyses.

All enzyme assays were performed on appropriate dilutions of the specific muscle extract. All assays except that for succinate oxidase were made in quartz cuvettes using a Gilford Model 240 spectrophotometer with necessary attachments and maintaining an assay environment of 37° C. Succinate oxidase was determined via the YSI Model 53 Biological Oxygen Monitor System.

Results

The data as reflected in Table 1 suggest an increasing trend in glycolytic metabolism between the cattle contained in the two weight groups. This increase in enzyme activity as evidenced from both glyceraldehyde-3-phosphate dehydrogenase and lactate dehydrogenase could be the result of a cellular adaptation from the predominately red type fiber rich in oxidative enzymes to a muscle cell type less predominate in red fibers and having an increasing quantity of white type fibers. This reasoning is also evidenced in the decreasing trends of the oxidative enzymes malate (NAD) dehydrogenase, succinate dehydrogenase and citrate synthetase. These results coincide favorable with the work of Bass *et al* (1965) in rabbits. It is also interesting to note that total oxygen consumed, reflected as succinate oxidase activityy (Burleigh *et al*, 1969), decreased as the animals aged, indicating simply that total oxidative capacity decreased whether by a decrease in functionality of the mitochondria (Sacktor, 1972), a decrease in number of mitochondria or a "diluting" of the existing mitochondria resulting from fiber hypertrophy (Gauthier, 1970). Irrespective of the exact mechanism, the data in Table 1 suggests a loss of activity of the mitochondrial associated enzymes and an increase in activity of the

Table 1. Average enzyme activities[1] of Hereford steers at two weight groups.

	500 lb.	700 lb.
Lactate Dehydrogenase	314.0	321.0
Glyceraldehyde-3-Phosphate Dehydrogenase	2.08	2.27
Glucose-6-Phosphate Dehydrogenase	0.01	0.03
Malate Dehydrogenase (NAD)	4.14	1.12
Succinate Dehydrogenase	62.5	11.7
Citrate Synthetase	3.40	1.76
β-Hydroxy Acyl CoA Dehydrogenase	1.52	1.80
Succinate Oxidase[2]	3.30	1.02

[1] Enzyme activities expressed as Units of enzyme activity per gram of protein per gram of tissue.
[2] Activity expressed as M Oxygen consumed per minute per gram of protein per gram of tissue.

cell soluble enzymes corrected for protein concentration and the amount of tissue used.

Even though the data suggest a decreasing trend of oxidative metabolism, the activity of β-hydroxyacyl CoA dehydrogenase, a key enzyme of fatty acid oxidation, depicts an increase in its specific activity with increasing age of the cattle. This might indicate that although oxdative metabolism decreases with age, there appears to be an increasing capacity for utilizing energy substrates for mitochondrial oxidation from fatty acid sources (Annison, 1964). The present study also indicates an increasing trend in the activity of glucose-6-phosphate dehydrogenase with age, which has a commonly accepted function of generating reduced nucleotide phosphate cofactors for use in fatty acid biosynthesis. This increase in fatty acid biosynthesis with concomitant increases in fatty acid oxidation would not be acceptable, yet one must realize that the pentose phosphate pathway is also of primary importance in nucleotide and nucleic acid biosynthesis. Nuclotide biosynthesis would be necessary for RNA synthesis and subsequent protein synthesis. Thus, accretions in the specific activities of glucose-6-phosphate dehydrogenase might indicate an increasing trend of protein deposition when taking other enzyme systems into consideration.

These data are preliminary yet they correspond well with past investigations as noted above. It is expected that in continuing research, more detailed metabolic and protein synthsis patterns be investigated in order to shed more light on growth patterns and methods of controlling these patterns in beef cattle.

Literature Cited

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Muscle Fiber Growth of Cattle Differing in Mature Size

J.J. Guenther and J.R. Escoubas

Story in Brief

Changes in muscle fiber diameter of small and large scale beef calves were determined. Fiber diameters were measured, initially, when the calves were approximately 30 days of age and at 56 day intervals thereafter until the calves were about 14 months of age. Results showed the small scale calves to have wider muscle fibers than large scale calves and that the small scale calves matured earlier and at a faster rate in fiber diameter. In addition, most of the absolute increase in muscle fiber diameter occurred post-weaning. Finally, it was observed that at 30 days of age the test animals had already attained 46-47 percent of their respective 14 month muscle fiber diameter.