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Contributions of Acetate, Lactate, and Glucose to the Accumulation of Fat in Intramuscular and Subcutaneous Tissues of Beef Cattle

Stephen B. Smith and John D. Crouse

Introduction

The United States meat industry faces a dual challenge: it must reduce the fat content of meat in order to provide a nutritious product with a minimum of waste, while not affecting meat palatability. The positive effects of marbling (fat deposition within muscle) on tenderness and palatability, as well as a meat grading system that penalizes carcasses with little marbling, make it desirable that animals be produced with minimal amounts of fat stored in depots, such as the subcutaneous and perirenal depots, without markedly decreasing intramuscular adipose tissue. This can be accomplished only if the factors regulating lipid deposition in intramuscular adipose tissue and other fat depots differ substantially.

Previous studies have indicated that marbling scores are not affected by differences in diet to the extent observed for backfat thickness or total carcass fat. Therefore, the primary purpose of this study was to determine the relative contributions of acetate, lactate, and glucose as carbon precursors for fatty acid synthesis in intramuscular and subcutaneous adipose tissue. Additionally, the effects of age and diet on lipogenic activities in both depots were investigated because earlier studies have not demonstrated the interaction between age and diet on lipogenesis in either intramuscular or subcutaneous adipose tissue.

Procedure

Animals. At weaning (approximately 8 mo of age), 16 Angus steers were divided randomly into two groups and fed either a corn silage diet or a 70 percent ground corn diet. Cattle fed the ground corn diet were adapted gradually to the diet over a 30-day period. Four animals from each group, selected randomly, were slaughtered at 16 months of age, and the remainder at 18 months of age. Samples of muscle also were obtained at 12 months of age. However, the marginal intramuscular adipose tissue development at this age precluded obtaining quantities of adipose tissue sufficient for the in vitro incubations. Mean weights for the four groups of steers were 1,067 and 1,166 lb (16 mo, low energy and high energy, respectively), and 1,155 and 1,197 lb (18 mo, low energy and high energy, respectively). Intramuscular (marbling) and overlying subcutaneous (fat cover) adipose tissue was obtained at slaughter. Samples were used to make in vitro observations of adipose tissue lipogenesis. Key enzymes involved in adipose tissue lipogenesis were also assayed. Fat cell numbers and sizes were determined.

Results

Feed intake and carcass traits. Steers fed the low energy diet consumed 75 percent more feed than did steers fed the high energy diet. On a dry-matter basis, feed intake was not significantly different, although the animals on the ground corn diet consumed 14 percent more metabolizable energy.

In spite of greater carcass weights, cattle fed the ground corn diet did not display significantly greater longissimus dorsi (ribeye) surface areas or marbling scores. However, backfat thickness and kidney, pelvic, and heart fat were greater in cattle fed the ground corn diet, indicating that a large portion of the difference in carcass weights between the two groups was due to greater fat accumulation in the high energy-fed cattle. There were no significant age effects on any of the carcass characteristics.

Adipose cell size and soluble protein content. No differences in cell size, number distribution, or soluble protein content due to diet or age of steers were observed. Consequently, date were pooled across diet and age. Adipocytes obtained from intramuscular adipose tissue were substantially smaller than cells from the subcutaneous adipose tissue depot. Consistent with the smaller mean and peak diameters, intramuscular adipose tissue tended to have greater numbers of cells per gram tissue and significantly more soluble protein content than did subcutaneous adipose tissue.

Lipid synthesis. The nanomoles of lactate and glucose incorporated into the glyceride-glycerol moiety over the 3-h incubation period were similar. Some label from [U-14C]acetate was recovered in glyceride-glycerol; however, this does not represent a net synthesis of glycerol-3-phosphate from acetate; rather a net flow of tricarboxylic acid cycle intermediates to glyceride-glycerol. The incorporation of all three precursors into glyceride-glycerol was significantly greater in subcutaneous than in intramuscular adipose tissue. Furthermore, the incorporation of lactate and glucose into glyceride-glycerol increased with age in subcutaneous adipose tissue, regardless of diet.

Glyceride-fatty acid synthesis did not change with age in intramuscular adipose tissue, nor was it influenced by diet. Acetate and lactate incorporation into fatty acids was markedly greater in subcutaneous adipose tissue than in intramuscular adipose tissue. The highest acetate and lactate incorporation into fatty acids was observed in subcutaneous adipose tissue from steers fed the high energy diet. Conversely, glucose incorporation into fatty acids was significantly greater in intramuscular adipose tissue than in the subcutaneous depot. The lower incorporation of glucose into glyceride-fatty acids in the 18-month-old steers relative to the 16-month-old steers was likely because of the elevated acetate and lactate incorporation in these animals, causing increased dilution of the acetyl-CoA pool and increased competition for available enzyme A.

When the incorporation of lipogenic precursors into fatty acids was expressed as a percentage contribution to fatty acid synthesis, glucose was quantitatively the primary lipid precursor in intramuscular adipose tissue. Acetate provided 70 to 80 percent of the acetyl units to fatty acid synthesis in subcutaneous adipose tissue. Acetate's contribution to lipogenesis in intramuscular adipose tissue was substantially less (10 to 25 percent). Lactate contributed the same percentage acetyl units in both adipose tissue depots.

Feeding cattle a diet rich in grain typically results in animals with greater backfat thicknesses and percentage kidney, pelvic, and heart fat relative to animals fed corn silage or roughage diets. Changes in marbling scores generally are less dramatic than associated increases in backfat thickness in grain-fed cattle, and substantial increases in backfat thickness due to grain feeding have been observed even in animals that do not display increased marbling scores. The lesser sensitivity of the intramuscular adipose tissue depot to dietary manipulations relative to subcutaneous adipose tissue, suggests that lipogenesis in the two depots is not regulated in a coordinated manner.

When acetate and glucose also were present in the incubation media, lactate provided the same proportion of acetyl units to lipogenesis in intramuscular and subcutaneous adipose tissue...
The importance of acetate as a lipogenic precursor was greatly reduced in the intramuscular adipose depot; the basis for this major difference between depots is unknown.

In summary, several in vitro similarities exist between intramuscular and subcutaneous adipose tissue. However, the relative insensitivity of marbling scores and lipogenic activities in intramuscular adipose tissue to changes in age or diet, in conjunction with the greater importance of glucose as a lipogenic precursor in the intramuscular adipose depot, indicate that the potential exists to manipulate fat deposition in other depots without adversely affecting marbling scores, and hence palatability.