Effect of Diet Upon Activities of Several Enzymes in Abdominal Adipose and Mammary Tissues in The Lactating Dairy Cow

A number of investigations have suggested that the milk fat depression observed when cows are fed high concentrate:low roughage diets might be due, in part, to alterations in the metabolism of either adipose tissue, mammary tissue or both (1, 6-8). Since metabolic changes are often due to or reflected in changes in enzyme activities, a study was undertaken on the effects of feeding all-hay and all-concentrate diets upon the activities of several enzymes of carbohydrate and fat metabolism in adipose and mammary tissue.

Experimental Procedure

This preliminary study was made with samples obtained from eight lactating Holsteins and one lactating Jersey. One of the Holsteins and one Jersey were fed all-hay or all-concentrate rations in isocaloric amounts in an incomplete double-reversal trial. The all-hay ration was offered ad lib. and the concentrate in amounts to provide 68% of the dry matter intake on hay (7). This experiment had to be limited, because the Jersey stopped lactating in the last period. Of the other Holsteins, three were fed only alfalfa hay ad lib. and four only concentrate ad lib. for 3-4 wk, then slaughtered for another purpose. Biopsy samples of abdominal adipose and mammary tissues were collected from pair-fed animals at the time that the milk fat per cent on concentrate has dropped to 60-70% of its original value. Tissue samples were prepared and the enzyme assays carried out according the methods described earlier (2).

Data from the terminal studies and the incomplete double-reversal study were consistent and were combined for statistical analysis.

Results and Discussion

The all-concentrate-feeding regime depressed milk fat percentages to 60-70% of control values, but had no consistent effect on milk yields as compared to all-hay feeding. Liveweight gains were markedly higher on concentrate than hay when both were fed ad lib., but were only slightly higher when concentrate was restricted.

Results of the enzyme studies are presented in Table 1. The specific activities of glucose-6-P dehydrogenase, 6-P-gluconate dehydrogenase, glyceraldehyde-3-P dehydrogenase, a-glycerol-P dehydrogenase, and fatty acid synthetase were depressed when the cows were fed all-concentrate diets. Although the milk fat depression was greater when the concentrate was fed ad lib. than when it was restricted, the activities of these enzymes were not consistently affected.

| Table 1 Effect of diet on activities of several enzymes in abdominal adipose and mammary tissues |
|------------------|------------------|------------------|------------------|
| **Treatment**    | **Abdominal adipose** | **Mammary** |
| **Tissue**       | **Hay** | **Concentrate** | **Hay** | **Concentrate** |
| **Determination** | **X** | **S<sub>2</sub>** | **X** | **S<sub>2</sub>** | **X** | **S<sub>2</sub>** | **X** | **S<sub>2</sub>** |
| Extractable protein<sup>a</sup> | 19.7 (6) | 4.9 | 15.4 (7) | 7.1 | 54.2 (5) | 8.9 | 55.3 (6) | 10.0 |
| Hexokinase<sup>b</sup> | 0.15 (5) | 0.11 | 0.14 (6) | 0.07 | 0.10 (2) | 0.02 | 0.07 (5) | 0.03 |
| Glucose-6-P dehydrogenase | 0.15 (5) | 0.09 | 0.61 (7) | 0.13 | 0.14 (5) | 0.01 | 0.12 (5) | 0.04 |
| 6-P-Gluconate dehydrogenase | 0.09 (5) | 0.05 | 0.17 (7) | 0.02 | 0.31 (5) | 0.16 | 0.24 (5) | 0.12 |
| PPMA<sup>c</sup> | 0.02 (6) | 0.01 | 0.03 (6) | 0.01 | 0.04 (3) | 0.02 | 0.03 (4) | 0.00 |
| P-Glucose mutase | 0.02 (4) | 0.01 | 0.03 (4) | 0.01 | 0.05 (4) | 0.11 | 0.03 (5) | 0.09 |
| Fructose-1,6-diP aldolase | 0.07 (4) | 0.04 | 0.09 (5) | 0.04 | 0.08 (5) | 0.02 | 0.16 (5) | 0.04 |
| Glyceraldehyde-3-P dehydrogenase | 0.07 (4) | 0.02 | 0.02 (5) | 0.12 | 0.12 (4) | 0.03 | 0.14 (4) | 0.02 |
| a-Glycerol-P dehydrogenase | 0.02 (4) | 0.01 | 0.07 (5) | 0.02 | 0.08 (3) | 0.02 | 0.07 (6) | 0.03 |
| Fatty acid synthetase | 0.07 (4) | 0.02 | 0.02 (5) | 0.12 | 0.12 (4) | 0.03 | 0.14 (4) | 0.02 |
| Citrate cleavage enzyme | 0.03 (5) | 0.01 | 0.10 (4) | 0.05 | 0.03 (3) | 0.02 | 0.02 (6) | 0.01 |
| Malate dehydrogenase | 0.50 (5) | 0.15 | 1.18 (7) | 0.54 | 1.56 (3) | 0.60 | 1.11 (5) | 0.32 |
| Isocitrate dehydrogenase | 10.8 (2) | 2.30 | 9.44 (4) | 1.18 |

<sup>a</sup> Milligrams extractable protein/gram of tissue. Numbers in parentheses indicate numbers of observations.
<sup>b</sup> Units of enzyme/milligram of protein × 10<sup>2</sup>. One unit of enzyme is defined as the amount required to convert 1 umole of substrate per minute at 25 degrees under standard assay conditions.
<sup>c</sup> Pentose phosphate metabolizing activity.
dehydrogenase, citrate cleavage enzyme, and 
maltate dehydrogenase, respectively, were 4, 2, 
3, 3, 5, 3, and 2 times higher in abdominal adipose 
tissue from the cows fed the all-concentrate ra-
tion than from cows fed the all-hay ration. The 
activities of most of these enzymes have been re-
lated to the capacity for fat synthesis (9) and, 
therefore, it would seem that the enzymatic capacity 
for fat synthesis in abdominal adipose tissue 
was higher in cows fed the all-concentrate ration 
than in cows fed the all-hay ration. No large 
differences in enzyme activities were observed 
between mammary samples from cows fed the 
all-hay and all-concentrate rations. However, the 
activities of many of the enzymes tended to be 
slightly lower in mammary tissue from the cows 
fed concentrate than from the cows fed hay. The 
activity of fatty acid synthetase in the mammary 
glands of the concentrate group, for example, 
was one-half that of the hay group.

A striking feature with the conditions of milk 
fat depression on high concentrate feeding is 
the simultaneous increased deposition of body 
fat as judged by increased body weight (7, 8). 
This switch from fat synthesis in the mammary 
gland to the adipose tissue might be due to 
impairment of the mammary gland to syn-
thetize fat (3, 8), and to improved ability of the 
adipose tissue for fat synthesis thereby de-
priving the mammary gland of milk fat precur-
sors in the blood (6), or to both (7). These data 
provide support for the suggestion that the 
enzymatic capacity of the adipose tissue for fat 
synthesis increases under conditions which de-
press milk fat per cent. They also indicate that 
the capacity of the udder for fat synthesis 
might be depressed slightly under these con-
ditions.

The marked increase in the activity of L-a-
glycerolphosphate dehydrogenase which occurred 
in the adipose tissue of the cows fed concentrate 
is of interest in view of the observations that 
long-chain fatty acyl Coenzyme A and fatty 
acids inhibit fat synthesis and that an increased 
supply of a-glycerol-P can relieve this inhibition 
by promoting esterification of the fatty acids 
(4, 5). One might theorize that in lactating cows 
fed normal rations the great drainage of glucose 
for lactose synthesis and a low activity of a-
glycerol-P dehydrogenase in adipose tissue might 
result in a deficit of L-a-glycerol-P. This would 
cause a buildup of fatty acids in adipose tissue 
which would cause, in turn, a decrease in fat 
synthesis and an increase in the rate of fatty 
acid release from adipose tissue. Presumably, 
these latter two effects would result in normal 
malate dehydrogenase. This would cause 
production of Low-Fat Milk. I. Effect of Glycerol 3-Phosphate on 
a-glycerol-P dehydrogenase in adipose tissue which would cause, in turn, a decrease in fat 
synthesis and an increase in the rate of fatty 
acid release from adipose tissue. Presumably, 
these latter two effects would result in normal 
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