MAMMARY AND ADIPOSE LIPID SYNTHESIS AS INFLUENCED BY PARTICLE SIZE OF ALFALFA HAY

R. J. Grant and V. F. Colenbrander

Purdue University, West Lafayette, IN 47907, USA

Introduction

Forages of reduced particle size depress milk fat secretion in dairy cows through metabolic mechanisms not clearly understood. However, consumption of finely chopped alfalfa silage has been associated with elevated blood glucose and insulin levels in support of the glucogenic theory for milk fat depression (Grant and Colenbrander, 1987).

This theory proposes that serum insulin plays a substantial role in the homeorhetic control of lipid metabolism in ruminants. Evolved from infusion and high concentrate feeding experiments, this theory postulates an insulin response to increased plasma glucose levels which results in a reduction of milk fat secretion (Emmanuel and Kennelly, 1984). Insulin may stimulate acetate uptake by adipocytes and enhance activity of lipoprotein lipase, thus favoring a concomitant increase in adipose lipogenesis (Bassett, 1975). Elevated activities of enzymes associated with adipose tissue lipogenesis have been observed when dairy cows consumed diets of high grain content (Opstvedt and Ronning, 1967).

Although many experiments have considered the effect of reduced particle size of hay upon milk fat synthesis, few studies have simultaneously measured ruminal, blood, and adipose tissue metabolites to evaluate the validity of the glucogenic theory under these dietary conditions. Forages which are sufficiently reduced in particle size depress rumination activity, elevate ruminal propionate concentration, and may induce milk fat depression by altering serum insulin levels (Grant and Colenbrander, 1987).

The objective of this experiment was to examine the effect of particle size of hay upon milk fat secretion, and ruminal, blood, and adipose tissue metabolites within the framework of the glucogenic theory.

Materials and Methods

At three weeks postpartum, nine multiparous Holstein cows were assigned randomly to a total mixed ration (TMR) containing alfalfa hay (55%, dry basis) of either 0.9 mm (fine) or 2.3 mm (coarse) mean arithmetic particle size in a switchback design with five week periods. Both TMR were isonitrogenous at 16.5% crude protein and contained 32% neutral detergent fiber (NDF). An individual feeding system allowed continuous access to TMR.

Milk production and composition, feed intake, bodyweight, and efficiency of 4% fat-corrected milk (FCM) production were measured during weeks one through five. Three cows were ruminally fistulated to allow quntitation of volatile fatty acid (VFA) concentrations and pH during five week. Blood samples were drawn from the tail vein every three hours for twelve hours once during week five of each period. Sampling began at 08:00 h, prior to morning feeding, with feeding again at 16:00 h.

Adipose tissue samples were obtained by biopsy during the fifth week of each experimental period and the activity of glycerol-P dehydrogenase in the prepared adipose sample was determined (Baldwin and Milligan, 1966).

Data were analyzed by analysis of variance using a model for the switchback design.

Results

Particle size of hay had no effect upon daily dry matter intake (22.7 kg), forage NDF intake (7.3 kg), or actual milk production (28.1 kg) ($p > .05$). Milk fat percentage (2.9, 3.7), FCM production (kg) (23.9, 26.7), and efficiency of FCM production (1.05, 1.20) were reduced significantly ($p < .10$) with decreasing forage particle size, while bodyweight (kg) (604, 597) was increased ($p < .04$).

Reduced particle size of hay was associated with depressed ruminal pH (5.86, 6.43), and acetate : propionate ratio (2.80, 3.75) ($p < .05$).

Ruminal concentration (mMol) of acetate (54.9, 46.3) and propionate (17.9, 13.3) increased ($p < .08$) with decreasing particle size of hay.

Table 1 illustrates the effect of particle size of hay upon specific hormones, enzymes, and metabolites instrumental in evaluating the validity of the glucogenic theory given these production and ruminal characteristics.

TABLE 1. EFFECT OF HAY PARTICLE SIZE UPON KEY BLOOD AND ADIPOSE METABOLITES

Item	Ration		MSD[1]
	Fine	Coarse	
Plasma glucose			
12 h mean (mg/dl)	52.6[a]	42.8[b]	2.1
Serum insulin,			
12 h mean (ng/ml)	0.38[a]	0.31[b]	0.05
Serum total			
cholesterol (mg/dl)[2]	160.2	195.0	38.0
Plasma glycerol (μM)	50.1	59.7	4.6
Glycerol-P dehydrogenase,			
nmoles/g tissue/min	28.9	22.4	3.4
nmoles/mg protein/min	4.7	3.9	0.9

[a,b]Means within rows with unlike superscripts differ ($P < .05$).
[1]Mean standard deviation.
[2]Includes cholesterol contained in HDL, LDL, and VLDL.

Discussion

Ration NDF level averaged 32%, thus both the fine and coarse TMR contained adequate fiber concentration to theoretically avoid metabolic disorders. However, the physical form of this fiber dramatically influences milk fat secretion. In this experiment, cows consumed nearly identical amounts of NDF regardless of particle size, yet cows fed the fine TMR exhibited milk fat depression. This response was due to the particle size of hay and not the concentration of fiber in the ration.

Cows fed the fine TMR had lower efficiencies of FCM production and higher body weights. These results imply that a metabolic adaptation favoring adipocyte lipogenesis over milk fat synthesis might be occurring as reported with high concentrate diets (Opstvedt and Ronning, 1967). The glucogenic theory suggests that serum insulin levels play a central role in regulating this balance of lipid synthesis for adipose storage or milk fat secretion (Emmanuel and Kennelly, 1984).

In our study, a ruminal pH below 6.0 was associated with an increased ruminal concentration of propionate when cows consumed the fine TMR. Grant and Colenbrander (1987) observed a similar shift in the ruminal environment accompanied by a dramatic decline in rumination time for cows fed finely chopped alfalfa silage as 55% of a TMR (dry basis). Increased ruminal propionate concentration should yield higher entry rates into portal blood and thus increase propionate availability as a substrate for hepatic gluconeogenesis.

Consequently, elevated plasma glucose levels could elicit an insulin response leading to enhanced adipocyte lipogenesis at the expense of mammocyte lipid secretion. In our study, both blood glucose and insulin levels increased proportionally with decreasing particle size of hay in the TMR. No significant differences were observed for blood levels of serum total cholesterol of plasma glycerol, two indices of the rate of adipose lipolysis. Furthermore, the activity of glycerol-P dehydrogenase, an enzyme which catalyzes the conversion of dihydroxyacetone-P to glycerol-3-P, was not significantly affected by particle size of hay. However, trends in the data agree with those predicted by the proposed lipogenic actions of insulin upon adipose tissue in ruminants (Bassett, 1975). Perhaps maximal changes in enzymatic activity in response to reduced particle size had not yet been achieved in this study at five weeks.

In summary, cows fed finely chopped alfalfa hay as the sole forage in the TMR have lower ruminal pH and increased propionate concentration associated with elevated blood glucose and insulin levels. These results suggest that insulin secretion in response to decreased forage particle size may enhance adipose lipogenic activity at the expense of milk fat synthesis. This conclusion supports the glucogenic theory for explaining milk fat depression in dairy cows consuming equal and adequate levels of forage fiber reduced in particle size. (Key Words: Forage Particle Size, Insulin, Glucogenic Theory)

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