MILK FAT RESPONSE TO CHOPPED AND GROUND HAY WHEN ADDED TO OR ENSILED WITH CORN SILAGE AND FED IN COMPLETE RATIONS TO DAIRY COWS

by

Charles W. Talbott

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APPROVED:

J. H. Herbein, Chairman

C. E. Polan

R. E. James

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INTRODUCTION

During the early stages of lactation the nutrient requirements of the cow may exceed 4-5 times that of her requirements at maintenance (NRC, 1978). In an effort to support the energy demands of high milk production, the cow's metabolism changes in order to maintain her altered physiological state. High concentrate roughage-restricted (HCRR) diets are fed at this time in order to maximize energy intake, but may frequently result in acute or sub-clinical metabolic disorders. As lactation progresses the energy status of the cow changes. Careful selection of ration components at this stage is critical in order to provide an optimal rumen fermentation and endocrine-metabolite relationship, favorable for milk fat synthesis and not body weight gain. The association between fiber length and normal milk fat levels has been extensively reviewed (Rodrigue and Allen, 1960; O'Dell et al., 1968; Chalupa et al., 1969; Miller et al., 1969). This relationship is basic to understanding the nutritional benefit derived from feeding HCRR diets supplemented with hay. Metabolic disorders and milk fat depression are common symptoms of inadequate intake of effective fiber and represent financial consequences due to decreased production and lower milk prices. With conventional feeding programs where forages are fed separately, there is no guarantee of hay intake. For example, hay computed at 5 lbs/cow/day in a ration formulated for 100 cows is "exactly" 7-10 bales distributed in a hay rack and fed free choice. Generally this assumption is unrealistic as some cows overconsume or underconsume hay while the majority of effective fiber is trampled or used as bedding.

In the past numerous feedstuffs have been added to ensiled roughages to improve their quality. By ensiling chopped or ground hay with corn silage, fiber availabilty in the ration could be increased. The added dry matter from the hay could also improve the quality of the corn silage by absorbing some of the nutrients lost during the fermentation process or seepage. The following study was proposed to investigate responses in milk fat content by ensiling ground or chopped hay with corn silage and feeding in a total mixed ration (TMR) for lactating dairy cows. Hay replaced corn silage at a rate of 12.5% total forage dry matter, which represents approximately 3 lbs/cow/day on an as-fed basis. This feeding level would typify numerous feeding programs in Virginia where corn silage is supplemented with small amounts of hay.

LITERATURE REVIEW

Fiber Length and Fat Composition

Various terms have been used to describe the ability of fiber to maintain normal milk fat levels. Harris (1975) uses an effective fiber index to predict this measurement. A good indication of effective fiber is obtained when the fiber source has been submerged in water and maintains a length of 1/4" to 1/2". He submits that any finely ground and pelleted forage contains less than 10 percent effective fiber; 17 percent is minimum for normal fat levels. A good example of forage processing and effective fiber is demonstrated in a study by Miller et al., (1969). Field chop (1.27cm) or rechopped field chop (<.64cm) corn silage was offered as the only roughage source to two groups of lactating cows. Cows receiving the rechopped forage had depressed milk fat percentage and fiber digestibility. They concluded that a minimum knife setting of 1-1.3 cm is necessary to maintain normal fat levels.

Jorgensen et al. (1978) quantitatively associate the theoretical length of cut (TLC) of fiber with normal milk fat levels and the actual time the cow spends chewing a particular forage. Two groups of high producing cows were fed rations with a 33:67 forage to concentrate ratio and differing only in the TLC of the roughage. The group fed the finely chopped roughage (< .48 cm) was significantly lower in milk fat and higher in body weight gains than the cows fed the medium chopped roughage (.64 cm). Chewing time was also lower ($P < .05$) for the cows fed the finely chopped roughage (7.4 hr/24 hr) as compared to the group fed the medium chopped roughage (9.4 hr/24 hr). Jorgensen maintains the critical TLC of a forage for normal fat levels is .64 cm, and when chewing time is reduced to less than 9.4 hr/24 hr period, energy output in the form of milk is replaced by a higher retention of energy into body weight.

As early as 1939, Powell reported the association of roughage intake and milk composition. Since then numerous experiments have well established the relationship between particle size and normal milk fat levels. Rodrigue and Allen (1960) noticed a significant depression in content of milk fat and cell wall digestibility when substituting rations containing finely ground hay for long stem hay. They concluded the depressed fat levels were attributed to a decrease in cellulose digestion resulting from a higher rate of passage for the ground hay. Finely ground feeds tend to reduce salivation and rumination, raise rumen propionate levels, decrease rumen pH and lower microbial cellulolytic activity (Bailey and Balch, 1961). O'Dell et al. (1968) reported that cows fed ground and pelleted alfalfa produced less milk fat when compared to a baled alfalfa-fed group. A slight increase in fat levels was observed when a .64 cm ground hay that was not pelleted was compared to the ground and pelleted hay. They concluded that the pelleting process further reduces forage particle size. In all cases, cows receiving the alfalfa pellets showed a greater daily weight gain, reduction in rumination and displayed mild symptoms of bloat. When the fat depressing pellets were fed at more frequent intervals the decline in fat levels was less severe.

By altering TLC in corn silage alone, Sudweeks et al. (1979) observed significant differences in mean rumen volatile fatty acid (VFA) production and acetate:propionate ratios (APR) in sheep. Murdock and Hodgson (1977) reported depressed milk fat and APR when alfalfa cubes were fed to lactating cows in place of long stem alfalfa hay.

Nutritional Benefits from Adding Hay

The addition of hay to the diet tends to maintain milk fat levels and correct conditions conducive to rumen disorders. Waugh et al. (1955) fed *ad libitum* corn silage with long stem hay at a rate of .00, .24, .47, and .83 lb/100 lb of live weight. He observed maximum milk, fat, and fat corrected milk(FCM) production with the group consuming the .47 lb level of hay and a significant increase in dry matter intake (DMI) at the higher level of hay fed. Chalupa et al. (1969) corrected milk fat depressions caused by pellet feeding with baled hay supplemented at 2.09 kg dry matter/day. In a study encompassing four years, Holter et al. (1973) determined the long term effects on milk production and composition, intake and general herd health, when feeding liberal amounts of concentrate and ad libitum corn silage, alone or with grass hay at two different rates (.5 or 1.0 kg/100 kg body weight daily). Milk fat percent (3.58 and 3.70 percent, respectively) was significantly higher for the rations containing hay than with the corn silage alone treatment (3.33 percent). Solids corrected milk and DMI was highest ($P < .05$) with the .5 percent added hay. Coarse dry feeds such as hay elicit more saliva secretion than high moisture feeds (Bailey and Balch, 1961). This is particularily important in HCRR diets which yield fermentation products high in propionate and lactate.

The pH of the rumen lowers as this condition is exaggerated due to excess production of lactic acid; rumination is depressed and cows go off feed (Thorley, 1968). The added buffering capacity when hay is supplemented in the diets increases the pH by promoting rumination and thereby helps maintain feed intake. Hodgson and Thomas (1975) cited the relationship between the buffering capacity of the rumen, dilution rate and rumen fermentation patterns. With HCRR or ground hay diets high propionate levels were correlated with low dilution rates. When Harrison et al. (1975) infused artificial saliva into sheep rumen, they observed an increase in rumen turnover with a significant depression in rumen propionate levels.

Rumen Fermentation and Fat Composition

Various methods have been developed which correlate milk fat depression with rumen fermentation products. Jorgensen et al. (1978) report that when the APR is above 2.5 normal fat tests are observed. Blaxter (1962) showed that when the molar percent of acetate was less than 60, a depression in milk fat was likely. A more precise method of energy partitioning is described by Orskov's (1975) nonglucogenic ratio (NGR). The ratio is defined by comparing the nonglucogenic rumen metabolites (acetate + 2 butyrate + valerate) to the glucogenic rumen products (propionate and valerate). Valerate is included in both the numerator and denominator because upon oxidation of valerate, one mole of propionate and one mole of acetate is produced. An NGR of 2.25-3.00 provides optimum energy utilization for growing or fattening animals, while ratios of 3-3.5 changes the partitioning of energy from adipose tissue synthesis to milk fat synthesis.

Forage:Concentrate Ratio

The limiting nutrient for high producing cows is usually energy (Balch,1976). Bauman and Currie (1980) report that the mammary gland may require up to 80 percent of total glucose turnover during peak lactation. Increased energy availability is partially met by a series of coordinated hormone responses which increases the gluconeogenic rate of the liver and alters the partitioning of energy to the mammary gland in preference to other tissues. This becomes evident when high producing cows do not generally reach positive energy balance until 90 days into lactation and milk production has decreased to 80 percent of peak production. Futhermore, the cow attempts to satisfy her carbohydrate or glucose needs by consuming more feed (Forbes,1977), and mobilizing her fat stores. Moe and Tyrrell (1972) computed that the efficiency of converting body tissue energy into milk fat was nearly as efficient as the direct use of dietary metabolizable energy (ME) for milk production. During the first 10 weeks of lactation, they observed that cows in negative energy balance mobilized an equivalent of 50 kg of lipid stores or 9 kg of milk daily(Moe and Tyrrell,1972).

High producing early lactating cows are fed rations containing as much as 70 percent concentrate in an attempt to provide the energy necessary to meet their levels of production. As the proportion of concentrates in the diet increases, milk fat percentage and the ratio of acetate plus butyrate to propionate decreases (Sutton,1976). Forage:concentrate ratios effect the fat composition of milk by altering rumen fermentation products. In a classic study by Balch and Rowland (1957) ten experiments were conducted using fistulated milking shorthorn cows fed various amounts of forage and concentrates differing in type and texture. Fluctuations in rumen pH reflected the changes in concentration of VFA produced from the various diets. Low ratios of acetate:propionate were observed with the low or ground hay diets and coincided with a marked decrease in rumen pH. The low APR was still observed by feeding the ground hay in place of long stem hay without changing the forage:concentrate ratio. They also observed a decrease in rumination and subsequent decrease in saliva or buffering capacity with the rations containing the low fiber-high starch diets. Balch predicted that the failure to buffer the rumen environment with the low or ground hay diets led to an acidic environment unfavorable for cellulose digesting organisms that produce acetic acid.

Jorgensen and Schultz (1966) fed four different concentrates to mid-lactating cows with forage:concentrate ratios of 25:75 to 20:80. In all rations, acetate was depressed and propionate levels were increased. Milk fat depression was also observed in all rations; least decline was evident in the 25:75 ratio with the more fibrous corn and cob meal concentrate. Progressive decrease in DMI was reported as the amount of concentrate in the diet increased.

Ration Composition and Milk Fat Depression

Several earlier studies (Balch et al.,1955; Book,1962) support the concept that milk fat depression results from deficiencies of acetate production when ground or restricted roughage diets are fed. However, work done by Van Soest and Allen (1959) shows that absolute concentrations of rumen or blood acetate are not significantly lower on these diets. From this same study positive correlations of decreased blood ketone levels were observed with depressed milk fat, and negative correlations with rumen propionate were observed. Chalupa et al. (1969) reported lower fat levels with rations containing ground or pelleted forage as the sole roughage source. They also observed increased molar percentage of propionate and valerate. In addition milk fat contained decreased proportions of short chain fatty acids ($C < 12$). When corn silage or baled hay was substituted for the pellets, milk fat depression was alleviated and concomittant changes in rumen VFA and fatty acid composition in the milk was reported. Bensadoun et al. (1963) fed three rations containing chopped hay, pelleted ground hay, or a grain-hay pellet to sheep. When compared to the rations containing chopped hay, APB levels were lower for the pelleted rations with significant increases in plasma glucose concentrations. Propionate acts as an antiketogenic agent in depressing milk fat levels (Van Soest and Allen, 1959). Propionate is converted to lactate in the gut wall or glucose via gluconeogenesis in the liver. High concentrate roughage-restricted diets produce elevated blood glucose and insulin levels in lactating cows upon postprandial examination (Jenny and Polan, 1975). In an earlier study by Jenny et al. (1974) feeding high concentrate rations, milk fat depression was significantly correlated with high blood insulin levels.

McClymont and Vallance (1962) were among the first to propose that insulin may be involved with fat depression based on their results from intravenous glucose infusions.

They noticed a significant decrease in the free fatty acid fraction of arterial and mammary blood when glucose (2-3 mg/100 ml plasma) was infused intravenously. They concluded that insulin secretion depresses the rate of release of free fatty acids from the adipose tissue. Rao et al. (1973) stimulated lipoprotein lipase activity in adipose tissue of lactating cows when insulin and/or glucose was infused prior to tissue extraction; there was no alteration in response of this enzyme in the mammary gland. They maintain that when glucose and insulin stimulate lipoprotein lipase activity in adipose tissue, there is a reduction in the availability of fatty acids to the mammary gland due to a greater enzymatic hydrolysis of lipoproteins and uptake of triglycerides into the adipose tissue. Contrary to this finding, Yang and Baldwin (1973) observed no significant effect on basal lipolytic rates when insulin was added to isolated adipocytes, but reported a decrease of 20 percent in lipolytic rates with epinephrine stimulation. It appears that epinephrine stimulates lipolysis by increasing cAMP activity, which is necessary for the activation of lipoprotein lipase in the adipose tissue (Bauman, 1976). Insulin, however, is capable of activating the enzyme adenyl phosphodiesterase which catalyzes the hydrolysis of cAMP (Loten et al., 1970). This further reduces the conversion of inactive lipase to activated lipase.

Insulin may also affect re-esterification of fatty acids by increasing the uptake of glucose into the adipose tissue, thus supplying the necessary substrate for glycerol synthesis. Opstvedt et al. (1967) reported higher L-α-glycerolphospate dehydrogenase concentrations in cows fed HCRR diets. He proposed this would result in higher α-glycerolphosphate levels which would increase rates of fatty acid synthesis and re-esterfication in adipose tissue.

The rate of fat mobilization and fatty acid esterfication in ruminant adipose tissue appears to be affected by the animal's physiological state as well as the diet. The changes in fat mobilization to synthesis are closely related to the energy status of the animal (Benson et al., 1972). Jenny et al.(1974) reported no differences in serum glucose or insulin levels with cows in early lactation fed high or low concentrate rations. The inability of cows in early lactation to consume enough energy to support the metabolic demands of high milk production is characterized by a period of negative energy balance. As a result of carbohydrate insufficiency, low blood insulin may be advantageous at this time. By reducing competition with peripheral organs that require insulin for glucose uptake, glucose availability to the mammary gland may be enhanced. Furthermore, hypoinsulinemia would promote mobilization of lipid stores necessary for normal fat synthesis.

Complete Rations with Hay

Energy is a primary expense in dairy cow rations, and in Virginia corn silage yields the highest energy/acre in relation to production costs. However several articles have reported possible problems encountered with feeding programs consisting solely of corn silage based rations. Holter et al. (1973) reported a higher tendency for ketosis in early lactation with corn silage as the only roughage source. Trimberger et al. (1972) cited increased incidences of displaced abomasum, ketosis, off feed and other postpartum complications when cows receiving liberal concentrate and corn silage based rations were compared to those receiving comparable amounts of hay. They also reported that cows tended to gain excessive body flesh in late lactation and in the early dry period on the all corn silage treatment.

Lofgren and Warner (1970) observed a significant correlation between percent intake of ADF and fat test change ($r = .72$). Rock et al. (1974) reported an increase in milk fat test of .067 units for each unit increase in ration ADF dry matter composition. The N.R.C. (1978) recommends a minimum of 21 percent ADF in the total ration in order to maintain normal milk fat levels. If a high energy (23 percent ADF) corn silage is fed in a 60:40 forage:concentrate ratio, the total ration would contain a minimum of 16.6 percent

ADF. However if 6 lb of the dry matter from the corn silage were substituted with hay (40 percent ADF) the ration would be in excess of 19 percent ADF. Until there is a better method of administering hay intake, problems associated with postpartum stress and excess conditioning in late lactation appear unavoidable. Therefore, data is needed to establish the nutritional benefits derived from adding chopped or ground hay in complete rations to lactating dairy cows.

High quality forages are mandatory for optimum cow performance and instrumental for reducing feed costs from excessive grain feeding. The net result of feeding high quality roughages is higher milk production (Donker and Naik, 1979). Moe et al. (1971) have shown that direct conversion of feed ME to milk synthesis is more efficient than via tissue metabolism. Therefore, maximum intake of total digestible nutrients (TDN) in early lactation is necessary to help cows reach positive energy balance earlier. Journet and Remond (1976) compared various forage based diets of similar nutrient composition to determine which forage best met the energy needs of post partum cows. Cows fed the diets containing corn silage reached positive energy status sooner than cows fed equal proportions of alfalfa hay or long grass roughages.

In the past, numerous feedstuffs have been added to improve the quality of ensiled roughages. Formic acid or propionic acid are a form of additive used to help direct the course of fermentation and preserve the quality of ensiled roughages (Thomas, 1978). Grains high in starch (i.e., corn, barley, and milo) are generally added to aid in fermentation and add dry matter in roughages containing excessive moisture. Miller and Clifton (1965) reported the problems associated with high moisture silages and nutrient losses due to seepage. Bullis et al. (1959) observed that forages preserved with chopped alfalfa hay were higher in protein, fiber, and fat than the same forages preserved with molasses and dried beet pulp; the latter roughages were higher in NFE and TDN. By ensiling chopped or ground hay with corn silage, fiber digestibility could be increased. Hemicelluloses are hydrolyzed by plant enzymes during ensiling(McDonald et al., 1968). Presently, limited data is available to conclude that cellulose digestion is enhanced by plant enzymes during fermentation.

One of the earlier reports on the concept of feeding complete rations was published by Olson (1965). This program has gained popular acceptance in the last decade because each mouthful provides a balanced supply of nutrients without dependence on the cow to select adequate quantities of available roughages and concentrates. In addition it tends to decrease fluctuations in rumen pH by combining the forage and concentrate intake uniformly. Kaufmann (1976) reported that a stable rumen pH is more conducive to higher cellulolytic activity. By routinely adding a chopped or ground hay source in a complete feed program, numerous nutritional and management advantages could be obtained. In high energy rations for early lactation, rumination and DMI could be promoted by assuring the intake of an effective fiber source such as hay. Coppock et al. (1974) compared *ad libitum* TMR feeding programs with wide forage to concentrate ratios and determined that cows do not regulate their intakes according to their energy needs. They suggested grouping cows by production levels and modifying the ration to control energy consumption. Particularily with high energy corn silage, added hay may adjust the ADF level to restrict the intake of cows in late lactation (while promoting the utilization of poorer quality hay) and prevent excess flesh. This program would eliminate feed preference and reduce hay wastage which characterize the conventional method of administering hay. Possible economic management advantages will be discussed in the epilogue.

MATERIALS AND METHODS

Experimental Design

Twenty-five multiparous cows in their second trimester of lactation were randomly assigned in a 5 x 5 latin square rotation to five silages: control (N), chopped added (CA), ground added (GA), chopped ensiled (CE), and ground ensiled (GE). Chopped (2-6 cm) or ground (< .5 cm) hay was added to corn green chop at 12.5% (total forage dry matter) before ensiling. Chopped or ground hay was also added to the control silage at the same rate prior to feeding. Supplement A (listed in Table I and formulated to contain 39% CP and 1.65 Mcal/kg NE_1, dry matter basis) and high moisture corn were added to the five silages to provide a total mixed ration (TMR) containing 14% crude protein and 1.67 Mcal/kg NE_1 (Table II). Normally a 612 kg cow producing 21 kg of fat corrected milk (FCM) requires 1.47 Mcal/kg NE_1 (NRC, 1978). By increasing the energy density of the ration to 1.67 Mcal/kg NE_1, milk production would not be limited theoretically, and an excess propionate fermentation may be expected to produce milk fat depression.

Table I. Composition of dairy supplement A.

Ingredient	Concentration[1]
	%
Dried Molasses	1.25
Wet Molasses	3.00
Distiller's Dried Grains	2.50
Wheat	5.75
Pellet Binder	2.00
Trace Mineralized Salt	1.75
Ground Limestone	2.50
Dicalcium Phosphate	3.50
$NaSO_4$	.75
Magnesium Oxide	.75
Vitamin Mix[2]	.50
Soybean Meal	75.75
Total	100.00

[1]Calculated on as-fed basis.

[2]12×10^6 IU A and D.

Table II. Percent dry matter supplied by the feed components for the five complete rations.

	N	CA	GA	CE	GE
			%		
Control corn silage	63.6	55.5	55.5		
Ensiled hay silage				63.6	63.6
Added hay (ground or chopped)*		8.1	8.1		
Supplement A	22.0	22.0	22.0	22.0	22.0
Ground H. M. corn	14.4	14.4	14.4	14.4	14.4

*Hay was added to ration prior to feeding.

Cows were housed in a stanchion barn throughout the experiment and water was available at all times. As cows became available for the experiment, four groups were formed containing five or ten cows in each group. Milk samples were collected on days 19 and 20 of each feeding period. Rumen and blood samples were taken at 1900 hr on day 21 prior to change of ration. A 10 ml jugular blood sample was collected 6 hr postprandial on day 21. Approximately 2 mg sodium fluoride and 200 U heparin were added to the tube to prevent glycolysis and clotting. The samples were centrifuged for 15 min at 6,785 x g using a Beckman J2-21 Centrifuge.[1] Plasma was aspirated and stored at -15°C until analyzed.

Ration Formulation and Analysis

Average quality baled orchard grass hay (9% CP and 36% ADF) was chopped with a field chopper at a knife setting of 2.54 cm. The same quality hay was also ground in a New Holland[2] tub grinder through a .64 cm screen. The corn silage was medium chopped averaging 1.27 cm theoretical length of cut (TLC). The chopped or ground hay was evenly distributed on top of the corn green chop prior to ensiling

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[1]Beckman Instruments, Inc., Fullerton, California.

[2]Sperry New Holland Corp., New Holland, Connecticut.

in 3.1 m x 9.1 m concrete upright silos. All rations were formulated to have a 64:36 forage:concentrate ratio on a dry matter basis. The concentrate mix, ground high moisture corn, and added hay (rations CA and GA) were mixed with the appropriate silage prior to each feeding. Cows were fed twice at 0700 and 1350 hr. Orts were collected and weighed daily at 0900. All rations were offered according to FCM production and body weight and adjusted to have 10% orts daily. Feed samples were collected biweekly for analysis[3] of nutrient composition. Body weights were recorded biweekly and dry matter intake (DMI) was expressed as kg/kg body weight$^{.75}$.

Milk Analysis

Milk samples were analyzed for % total solids, fat and protein content. A 2 ml aliquot of milk of known weight was dried for 3 hr in a 100°C forced-air oven. Dried samples were then weighed to obtain a dry milk weight and divided by fluid milk weight to determine percent total solids. Fat content was obtained by a light diffusion technique using a Milk Tester Automatic.[4] Protein analysis was determined by an amido black dye binding technique using a Foss Pro-Milk

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[3]Virginia Polytechnic Institute and State University Forage Testing Laboratory, Blacksburg, Virginia.

[4]Foss Electric, Hillerod Denmark.

Semiautomatic Tester.[5]

Determination of Plasma Glucose

Plasma samples were deproteinized prior to analysis using a modification of the Somogyi-Nelson Method (Reinhold, 1953). A one ml aliquot of plasma was combined with two ml of 5% zinc sulfate, two ml of 0.3 N barium hydroxide and five ml of distilled water. The sample was then centrifuged at 4,640 x g for 15 min. Deproteinized plasma samples were assayed in duplicate for glucose using a glucose oxidase procedure.[6] Color intensity was determined using a Beckman Model 35 Spectrophotometer. Concentration of plasma glucose was recorded in mg/dl.

Determination of Plasma Urea

Plasma urea nitrogen was determined according to the method of Coulombe and Favreau(1963). A 1.0 ml aliquot of plasma was added to a 9.0 ml tungstic acid reagent for deproteinization. Five ml of diacetyl monoxime and thiosemicarbazide (DAM-TSC) was added to 2 ml of the plasma/acid filtrate to form a red colored complex with urea. Concentration was determined by color intensity using a Beckman

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[5]Foss Electric, Hillerod, Denmark.

[6]Sigma Chemical Company, Saint Louis, Missouri.

Model 35 Spectrophotometer and expressed in mg/dl.

Determination of Rumen VFA

Fifty ml of rumen fluid was collected under vacuum using a stomach tube fitted with a 2 mm stainless steel filter. A 5 ml aliquot was pipetted into 1 ml of 25% metaphosphoric acid and stored at -15°C until analyzed. Volatile fatty acids(VFA) were analyzed by gas chromatography (Ottenstein and Bartley, 1971) using isocaproic acid as the internal standard for quantification.

Ration Digestibility Analysis

At the termination of the experiment, rumen fluid was collected from a fistulated cow fed a CA ration and *in vitro* dry matter digestibility was determined by Tilley and Terry (1963) technique.

Statistical Analysis

Statistical Analysis System[7] was used to analyze the data. Analysis of treatments was determined by general linear model procedures of SAS using the model:

Y = Ration, Day, Group, Cow (Group), Period (Group)

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[7]SAS Institute, Inc., Raleigh, NC, 1979.

Type (ensiled versus added), form (chopped versus ground) and all hay treatments versus the control were compared using orthogonal contrasts and estimates. Tukey's all-pairs comparison of the five rations were tested by Bonferroni F test. The model and experimental design used in this experiment are further described in Table III.

Table III. Statistical design, models, and expected mean squares for ensiled hay study.

A. Statistical arrangement and cow assignment.

	N	CA	GA	CE	GE
Period I					
Period II					
Period III					
Period IV					
Period V					

	Group I	Group II	Group III	Group IV
Date started:	Jan. 13	Jan. 27	Feb. 10	Feb. 17
Cow no.:	H-1071	H-1068	H-1167	H-1133
	H-1083	H-1148	H-1232	H-1252
	H-1086	H-1159	H-1249	H-1104
	H-1227	H-1210	H-1254	H-1244
	H-1235	H-1246	H-1233	H-1208
	SH-1301			
	CH-1313			
	H-1331			
	H-1335			
	H-1341			

B. Model and expected mean squares for analysis of rations.

$$Y = \mu + R_i + G_j + C_{(j)k} + P_{(j)k} + D_m + E_{(ijklm)n}$$

where R = ration treatments i = 1 through 5

G = groups j = 1 through 4

C = cows k = 1 through 5

P = periods m = 1, 2

E = residual component

Source	Expected Mean Square
Groups	$\sigma_e^2 + k_2\sigma_c^2 + k_1\Sigma G_j^2/3$
Cows (Groups)	$\sigma_e^2 + k_2\sigma_c^2$
Periods (Groups)	$\sigma_e^2 + k_3\Sigma\Sigma P_{jk}/16$
Treatments	$\sigma_e^2 + k_4\Sigma T_i^2/4$
Days	$\sigma_e^2 + k_5\Sigma D_m^2$
Residual	σ_e^2

RESULTS AND DISCUSSION

Ration Analysis

Rations were formulated to be isonitrogenous, with hay-containing rations to have equal energy densities. Mean nutrient compositions of the silages and complete rations are reported in Table IV. Crude protein averaged 13.96% and net energy of lactation averaged 1.67 Mcal/kg. There were no differences ($P < .05$) between ration means for the five treatments although, hay-containing rations averaged 22% ADF while the control ration averaged 20% ADF.

Fat Composition

When comparing all five ration treatments (Tukey's test), milk fat percentage was significantly higher ($P < .05$) for the chopped hay rations (added or ensiled) and the ground ensiled ration than with the control (Table V). Holter et al. (1973) observed similar responses when feeding *ad libitum* corn silage and concentrate with two different levels(.5 and 1.0kg/100kg body weight daily) of supplemented hay. They reported significantly higher milk fat (3.58% and 3.70%) from hay-containing rations than when corn silage was

Table IV. Mean nutrient composition of silages and complete rations.[1]

	DM	CP	ADF	TDN	NE_1	IVDMD
	- - - - - - - - - %	- - - - - - - - -			Mcal/kg	%
Silage						
Ensiled chopped hay	39.5	8.1	29.0	68	1.59	74.3
Ensiled ground hay	38.6	8.0	29.8	67	1.57	73.2
Control silage	37.6	7.1	27.8	68	1.59	75.3
Ration						
N	48.8	13.6	20.1	74.3	1.69	78.8
CA	50.7	14.1	21.9	71.9	1.64	75.2
GA	49.0	13.5	21.2	73.1	1.67	78.4
CE	50.0	14.4	23.0	72.3	1.65	77.7
GE	51.2	14.2	21.3	73.4	1.68	76.9
pooled SE	1.3	.6	1.0	1.3	.02	.7

[1]Means of six samples of each ration analyzed by Virginia Tech Forage Testing Lab.

Table V. Milk component means and contrasts for ration treatments.

Ration	Milk	Fat	FCM	Protein	SNF	SCM	Total Solids
	kg	%	kg	%	%	kg	%
N	25.5[1]	3.07[a]	22.0	3.44	8.61	22.0	11.7[a]
CA	24.6	3.31[bc]	21.9	3.38	8.56	21.7	11.9[b]
GA	25.0	3.18[ab]	21.8	3.39	8.75	22.1	11.9[b]
CE	24.1	3.38[c]	21.8	3.41	8.64	21.7	12.0[b]
GE	24.8	3.28[bc]	22.0	3.39	8.61	22.0	11.9[b]
pooled SE	.8	.05	.3	.02	.04	.3	.04
Contrasts[2]							
CA vs CE	.49	-.07	.12	-.05	.05	.06	-.11
GA vs GE	.25	-.09	-.16	.01	.12*	.06	.02
N vs others	.89	-.21*	.90	.05	-.02	-.31	-.21*
GA and GE vs CA and CE	1.03	-.12*	.06	.00	.07	.25	-.06

[1]Ration means with different superscripts (a,b,c) are significantly different ($p < .05$).

[2]Corresponding numbers represent estimated differences, * denotes significance ($p < .05$).

the only roughage fed (3.33%). They offered, however, 4 and 10 times the amount we offered in this experiment. Other workers (Waugh et al., 1955; Chalupa et al., 1969) have also reported improvement in milk fat content by supplementing hay at various rates.

Orthogonal contrasts and estimates are shown in Table V. The control was .21 percentage units lower ($P < .01$) than rations containing hay. Contrary to work done by Lofgren and Warner (1970), the correlation between ADF intake and milk fat percentage was not significant. Whether added or ensiled, milk fat levels were .12 units higher ($P < .02$) for rations containing chopped hay versus ground hay. This is in agreement with numerous workers (Rodrigue and Allen, 1960; O'Dell et al., 1968; Chalupa et al., 1969; Miller et al., 1969; Murdock and Hodgson, 1979) whose work associate roughage particle length and milk fat percentage. The ground hay used in our experiment was less than .64 cm that Harris (1975) suggests as a minimum length for effective fiber.

The significant fat response we observed with the ground ensiled ration could reflect a higher quality silage obtained by adding ground hay. Dry matter recovery (DMR) for the ground ensiled forage was 92% while the chopped ensiled was 87%. A higher DMR would indicate a greater resistance to nutrient losses during the ensiling period. Ground hay may have substantially reduced seepage losses by absorbing highly digestible organic acids, soluble carbohydrates, minerals, and soluble nitrogenous compounds associated with the effluent (McDonald, 1981). Miller and Clifton (1965) reported dry matter losses in the effluent ranging from 0 to 12% with crops varying in dry matter content. Furthermore, the smaller particle size of the ground hay might have allowed for tighter packing, which would reduce losses from excessive aerobic fermentation. As a result, acetate production may have been higher in the ground ensiled roughage and thereby readily absorbed in the rumen epithelium. Acid concentration of the silages was not monitored in this experiment.

Orskov (1975) describes the manipulation of rumen fermentation products as necessary for influencing the maximum partitioning of energy into milk synthesis. Addition of hay to the ration tended to increase the nonglucogenic ratio (NGR) of volatile fatty acids in a direction favorable to increased energy output as milk fat. Correlation coefficients for NGR and APR with percent milk fat (% MF) were low but significant [(NGR and % MF; $r = .21$ ($P < .02$); APR and % MF, $r = .16$ ($P < .08$)]. The purpose of this experiment was to administer hay at a level (1.4kg/day) that would exemplify a typical Virginia dairyman's feeding program. One point which needs to be stressed is that the maximum amount of hay fed in our experiment was 10 to 60 percent of the amount fed by other workers (Holter et al., 1973; Chalupa et al., 1969) reported in the review. The small but significant responses we observed appears appropriate to the level of hay fed and design of the experiment.

By orthogonal contrast (Table VII), the NGR of the control ration was .35 units lower ($P < .03$) than the ratio for hay-containing rations. We did not observe any apparent differences in weight gains with the control ration which had the lowest NGR. This may reflect the length of the feeding period, however, the two added hay rations produced higher body weight gains than the two ensiled hay rations (Table VI). The drier consistency of the added hay rations may have stimulated the cows to consume more water.

Another possible account for the fat response with the ground ensiled ration may be due to the experimental design. Even though the statistical model accounts for a period effect, the ground ensiled ration may not have supported as high a fat level if the ration had been fed for a longer duration. When feeding finely chopped corn silage (TLC < 1 cm) for three weeks, Miller et al. (1969) observed only 1% decline in fat content from the initial level. From the 5th to the 10th week, however, they reported a 13% depression.

Table VI. Mean body weights, feed intake, ADF intake and contrasts for ration treatments.

Ration	Body weight (kg)	DMI/ $BW^{.75}$ (kg)	ADF intake (kg)	DMI/ BW (%)
N	586[1]	$.170^{c}$	4.1	3.47^{c}
CA	588	$.161^{ab}$	4.2	3.29^{ba}
GA	590	$.163^{abc}$	4.1	3.26^{ba}
CE	580	$.158^{a}$	4.3	3.24^{a}
GE	583	$.166^{bc}$	4.2	3.40^{bc}
pooled SE	5	.003	.1	.01
Contrasts[2]				
CA vs CE	8.10*	.003	-.07	.00
GA vs GE	5.44	-.004	-.13	-.14*
N vs others	.23	.008*	-.13	.17*
GA and GE vs CA and CE	4.70	.009	-.28	.00

[1]Ration means with different superscripts (a,b,c) are significantly different ($p < .05$).

[2]Corresponding numbers represent estimated differences, * denotes significance ($p < .05$).

In our latin square rotation (Table III), the ground ensiled treatment followed the chopped ensiled treatment in all periods except one. Higher fat levels produced by the ground ensiled ration could be due to a carry over from the elevated response from the chopped ensiled treatment. A similar depression was also observed when the ground added treatment followed the chopped added treatment.

Percent Total Solids and Solids Not Fat

Percent total solids were significantly higher ($P < .01$) in all rations containing hay when compared to the control (Table V). Estimates indicate that the control was .21 percentage units lower than the experimental rations. This predominately reflects the higher fat content of milk produced when hay-containing rations were fed. There were no differences in solids corrected milk (SCM) or milk protein content. Holter et al. (1973) reported higher SCM and percent milk protein when high quality hay was supplemented for corn silage at 1 kg/100 kg body weight. Their response may be influenced by the higher feeding level and quality of hay than fed in the present study. Several workers have cited an increase in milk production and milk protein content when casein and amino acids have been post ruminally infused (Broderick et al., 1970; Clark et al., 1973). Therefore, feeding low soluble protein (added hay rations) may have an advantageous response over high soluble protein (ensiled hay rations). Grieve et al. (1980), however, observed no improvement in milk protein content when feeding either dry (low soluble nitrogen) or ensiled (high soluble nitrogen) hay as the major roughage source. Prange et al. (1980) reported that nonammonia nitrogen flow to the duodenum was similar for both ensiled and baled alfalfa rations.

Percent solids not fat (SNF) for the ground added ration was .12 higher ($P < .03$) than the ground ensiled diet. Chalupa et al. (1969) reported higher SNF in ground and pelleted rations when compared to coarser forages. Grieve et al. (1980) also cited a higher lactose fraction produced from a dried versus ensiled roughage.

Milk Production and Dry Matter Intake

There were no differences in milk production or FCM among treatments (Table V). Other researchers (Chalupa et al., 1969; Holter et al., 1973; and Murdock and Hodgson, 1977) have reported similar responses when hay was substituted for pellets or corn silage in fat depressing diets. Increases in feed intake are generally associated with rations containing higher levels of ration digestibility (McCullough, 1973). Highest DMI (Table VI) was observed with the control ration, which also had the highest *in vitro* dry matter digestibility (Table IV). Cows receiving rations containing chopped hay were significantly lower in DMI than the control. Estimate of intake as a percent of the body weight was .02 units higher ($P < .02$) for the control ration than hay-containing rations. This may be expected as the added density and ADF from the hay would tend to depress intake (Campling and Freer, 1966; Rohweder et al., 1978).

Contrary to our findings other workers (Waugh et al., 1955; Holter et al., 1973) have cited increased DMI when hay was supplemented with corn silage based rations. Ruminal turnover or dilution rate is important in controlling feed intake. Fluid dilution rate depends upon salivary flow and is highly correlated with chewing indexes (Harrison et al. 1975; Sudweeks et al. 1975). Harrison et al. (1975) increased rumen dilution rates when artificial saliva was infused into sheep rumen. They observed however, that dilution rates were only increased with those animals that originally had low rumen turnover rates with the control ration. Increased intake response with supplemented hay may reflect the inability of a particular length of corn silage to initially provide adequate rumen stimulation and saliva production. We did not observe an increase in intake when hay was supplemented probably because adequate rumen stimulation was provided by the control silage (TLC, 1.27 cm).

Digesta does not leave the rumen until it is broken down into finer particles. Therefore, faster ruminal turnover must be accompanied by a greater rate of forage digestion (Mertens, 1977). Reducing particle size by grinding increases the surface area available for microbial attachment. Alwash and Thomas (1971) however, have shown that ground or pelleted feeds have shorter rumen retention times. This phenomenon enables higher intakes but depresses overall fiber digestion. The compromise in digestibility for intake may not be beneficial unless increased efficiency in digesting structural carbohydrates is improved. Grinding and ensiling may have improved fiber digestibility and feed efficiency as evident in the slightly higher FCM produced.

Mertens (1977) defines lag time as that period prior to fiber digestion when chemical or physical alteration of the plant structure must occur before bacterial attachment and enzymatic action can take place. Possible explanations for a lag period phenomenon include removing substances that inhibit fiber digestion, or prior hydration of fiber to allow enzyme penetration (Mertens, 1977). Even though rate of passage is increased by grinding the hay, a reduction in lag time due to ensiling may have facilitated utilization of the fiber source for acetate production. By taking an earlier postprandial rumen sample, we may have observed a higher acetate level with the GE ration.

Substitution of hay for corn silage may have also increased net utilization of energy for milk production. Rations containing hay averaged 1.66 Mcal/kg NE_1 while the control ration averaged 1.69 Mcal/kg NE_1. Tyrrell and Moe (1972) fed two different forage:concentrate diets averaging 1.66 Mcal/kg and 1.70 Mcal/kg to cows producing similar levels of milk as those used in our study. They reported 61% efficiency of milk synthesis from metabolizable energy from the lower concentrate diet (1.66 Mcal/kg) compared to 54% for the higher concentrate ration (1.70 Mcal/kg). The low efficiency was associated with depressed fat concentration in the milk.

Rumen Fermentation

Total VFA did not vary significantly among the ration treatments (Table VII). Normal ranges are from 60-120 µm/ml (Balch and Rowland, 1957; McClymont, 1951) and our treatments averaged 42.8 µm/ml. This value is lower than one might expect when feeding complete rations containing high quality corn silage. Balch and Rowland (1957) observed a 58% decrease in total VFA concentrations 6 hr after feeding. Therfore, discrepancy in the total amount may be due to time of sampling. Injection technique and method of sampling are also possible sources of error.

Table VII. Mean rumen volatile fatty acids and contrasts for ration treatments.

Ration	Total VFA	Acetate	Propionate	Butyrate	APR	NGR
	μm/ml	- - - - - - - molar %		- - - - - - -		
N	45.2[1]	54.9	33.8	9.5[a]	1.7	2.3
CA	43.9	57.0	30.8	10.7[b]	2.0	2.7
GA	43.4	55.6	32.5	10.3[b]	1.8	2.4
CE	37.0	56.1	31.4	10.8[b]	1.9	2.5
GE	44.8	55.3	31.4	11.5[b]	1.9	2.6
pooled SE	4.1	1.1	1.22	.5	.1	.1
Contrasts[2]						
CA vs CE	5.54	0.61	-.18	-.22	.02	.09
GA vs GE	-2.13	-0.11	1.43	-1.21	-.14	-.24
N vs others	2.89	-1.44	2.94*	-1.61*	-.21	-.35*
GA and GE vs CA and CE	8.19	-1.95	1.24	.60	-.19	-.20

[1]Ration means (±SE) with different superscripts (a,b,c) are significantly different ($p < .05$).

[2]Corresponding numbers represent estimated differences, * denotes significance ($p < .05$).

Acetate Production

Molar percent acetate was not significantly different between treatments and averaged 56 percent for all rations. Blaxter (1962) maintains that acetate proportion should be at least 60 percent to prevent milk fat depression. Several workers have implicated that an acetate deficiency rarely occurs. Jorgensen et al. (1965) found no improvement in milk fat levels when cows fed high grain rations were supplemented with 1 or 2 lbs of sodium acetate. The additive elevated blood acetate 4 to 5 times and raised APR levels to 3:1 without improving milk fat production. Davis (1967) showed that actual acetate production and turnover rates were similar for both high and low forage:concentrate diets. Even though acetate production is comparable for high and low grain rations, <u>de novo</u> milk fat synthesis is limited due to an increase in acetate uptake by adipose tissue for body fat synthesis (Davis, 1967; Bauman, 1976). When cows are changed from a milk fat depressing diet to a ration high in roughage, the APR returns to normal within 3 to 4 days, however, 2 to 3 weeks are required for fat test levels to recover (Satter and Binge, 1969). This lag period suggests that other factors other than an ample supply of precursors for milk fat may be contributing to depressed fat synthesis. Excess propionate production could be limiting fat synthesis by altering enzymes and shifting metabolism in favor of weight gain in place of milk fat synthesis.

Volatile fatty acids are synthesized at a faster rate in silage diets than dry hay diets (Sudweeks, 1977). The extra time needed for the rumen microbes to penetrate the dried hay may result in a delayed acetate release. Therefore, a higher postprandial acetate production may have occurred with the rations containing ensiled hay at an earlier observation.

Effective fiber is necessary to remove degenerate tissue and enhance metabolic activity in the rumen mucosa (Weigand et al., 1975). Nocek et al. (1980) showed that ration physical form also appears to influence rumen morphology and epithelial transport of VFA. They observed higher rates of acetate transport in calves fed rations containing chopped or ground hay when compared to feeding concentrates deficient in effective fiber. Additional fiber supplied by the hay-containing rations may have enhanced VFA transport across the rumen, resulting in lower rumen acetate levels observed. Determination of plasma acetate levels may have clarified this assumption.

Propionate Production

There were no statistical differences for molar percent propionate between the treatments(Table VII). However, an 8% reduction from the control level was observed in the rations which responded significantly higher in fat levels and may have contributed to this response. By orthogonal contrast molar percent propionate was 2.9 percentage units lower($P<.04$) for the rations containing hay when compared to the control. Numerous workers (Storry and Sutton, 1969; Palmquest and Conrad, 1971) have reported elevated rumen propionate levels associated with milk fat depression when feeding HCRR diets. Propionate is the predominate glycogenic precursor from rumen VFA, and it has been estimated that 16% to 60% of absorbed propionate is converted to glucose (Bergman et al., 1966; Judson et al., 1968; Leng, et al., 1967). McClymont and Vallance (1962) suggested that accelerated rates of gluconeogenesis from high concentrate diets cause increased rates of insulin secretion, depressing the rate of release of free fatty acids (FFA) deposited in the adipose tissue. Van Soest (1963) proposed that propionate acts as an antiketogenic agent in suppressing the mobilization of fat stores and reducing the plasma lipid concentration necessary for normal milk fat synthesis. Long chain fatty acids supply approximately 50% of the fatty acids found in milk (Emery, 1973). Insulin acts as an antilipolytic hormone in mid and late lactation cows, presumably by indirectly activating lipoprotein lipase by lowering cAMP levels (Jenny et al., 1974; Yang and Baldwin, 1973).

Although not significant, the reduction in propionate levels seems to have influenced milk fat alleviation. The effect may be more apparent by observing the APR and NGR trends. By examining the fatty acid content of milk, we may have obtained more evidence to support this interpretation of our fat response. When feeding all concentrate versus all hay rations, Opstvedt and Ronning (1967) reported significant increases in the amount of unsaturated to saturated fatty acids and a pronounced reduction of long chain fatty acids in the milk. Plasma insulin levels were not examined in this study.

Butyrate Production

Butyrate was higher ($P<.05$) in all rations containing hay and may reflect an interconversion of acetate to butyrate in the rumen (Sachan and Davis, 1967). By orthogonal contrast with the control, molar percent butyrate was 1.6 units higher ($P<.01$) for all rations containing hay (Table VII). Van Soest (1963) proposed one reason for depressed milk fat could result from a deficiency of β-hydroxybutyrate

(BHBA). Other workers (Miller et al., 1969; Jorgensen and Schultz, 1963; Opstvedt and Ronning, 1967) have reported similar increases in molar percent butyrate levels associated with significant fat responses. Butyric acid is converted to BHBA, a ketone body, in the rumen epithelium and liver. The utilization of ketone bodies by the mammary gland has been closely correlated with the secretion of milk fat. The extent to which a butyrate deficiency from HCRR diets limits milk fat synthesis has been questioned.

Palmquist et al. (1969) showed that the specific activity of C_4-C_{14} fatty acids in milk remained constant with injections of BHBA. From these results, they concluded that BHBA contributes only 8% of the total fatty acid carbons and postulated that a deficiency of BHBA is not a causative factor for depressed production of milk fat in HCRR diets. Luick and Kameoka (1967), however, indicated a partial breakdown of BHBA in the mammary gland to acetyl units, which would add to the acetate supply incorporated into milk fatty acids.

Interaction of propionate on conversion of butyrate to BHBA offers another possible explanation in determining how elevated butyrate levels may have contributed to a milk fat response. High propionate levels inhibit formation of BHBA from butyrate in the liver (Seto et al, 1959). This would suggest that lower propionate production from chopped rations or ground ensiled ration had less of an antiketogenic effect. By measuring blood ketone levels we may have been able to clarify this assumption.

Plasma Urea Nitrogen

Mean blood urea nitrogen (BUN) levels averaged 8.70 ± .43 mg/dl and are within the normal range for cows as reported by Schalm et al. (1975). By orthogonal contrast the chopped hay added diet was .14 mg/dl higher than when chopped hay was ensiled with corn silage (Table VIII). The majority of BUN is either excreted in the kidneys or recycled to the rumen via the blood stream or saliva for further microbial protein assimulation. Since energy and protein intake levels were similar for ration treatments, it appears the higher BUN level observed 6 hr postprandial for the chopped added diet indicates a slower release of ammonia-nitrogen from the less soluble added forage (Tagari et al., 1964). This agrees with work reported by Nocek et al. (1979) showing higher N solubility and lower residual N with fermented forages, i.e., corn silage compared to chopped orchard grass. High BUN levels have been positively correlated with rumen-NH_3 concentration and negatively correlated with N-retention (Tagari et al., 1964). This trend is not

Table VIII. Mean plasma glucose and urea nitrogen levels for ration treatments.

Ration	Glucose mg/dl	Urea nitrogen mg/dl
N	53.4	8.36
CA	52.0	9.30
GA	54.2	8.30
CE	53.0	8.18
GE	53.2	9.30
pooled SE	1.1	.45
Contrasts[1]		
CA vs CE	-.9	.14*
GA vs GE	.3	-.10
N vs others	.5	-.05
GA and GE vs CA and CE	2.1	.05

[1]Corresponding numbers represent estimated differences, * denotes significance ($p < .04$).

apparent with the results of our study. Nitrogen incorporation into milk protein (CA=.83 kgN, CE=.82kgN) was similar for both rations. A nitrogen balance study and several postprandial rumen fluid collections may have further clarified N utilization among the treatments.

Plasma Glucose Levels

There were no differences observed in levels of plasma glucose for the ration treatments. Although not significant, a tendency for higher milk production was observed with the higher plasma glucose (Table VIII) and rumen propionate levels. The liver and, to a lesser extent, the kidneys are responsible for supplying the majority of glucose for the ruminant. Acetate and butyrate do not contribute to a net synthesis of glucose (Bergman, 1973), however, they may spare glucose by providing the tissues with other substrates for oxidative energy (Head et al., 1964). Propionate and glucogenic amino acids are the major precursors for gluconeogenic pathways. The amount of propionate available for gluconeogenesis varies with the type and texture of the diet as well as the level of intake (Bensadoun et al. 1963).

Linzell (1960) has shown that mammary uptake of glucose increased ten-fold during lactation in goats. Bickerstaff et al. (1974) estimated that 60% of the glucose uptake in cows was incorporated into lactose synthesis. Lactose is considered to be the major osmole of milk (Linzell and Peaker, 1971), and therefore influences milk production by drawing water into the alveclar lumens.

SUMMARY AND CONCLUSIONS

The purpose of this experiment was to determine if chopped or ground hay (either added to or ensiled with corn silage) would elicit a milk fat response when fed in a TMR at a level that would typify numerous feeding programs throughout Virginia. Twenty-five mature cows in mid-lactation were randomly assigned in a 5 x 5 latin square rotation to five silages: control, chopped added, ground added, chopped ensiled and ground ensiled. Chopped or ground hay was added to corn green chop at 12.5% (total forage dry matter) before ensiling or added at the same rate with the control silage prior to feeding. Silages were supplemented to contain 14% CP and 1.67 mcal/kg NE_1 on a dry matter basis and fed as a TMR. Each cow received the assigned ration for three weeks.

The results indicate increased milk fat production when chopped hay (added or ensiled) or ground hay (ensiled) is included in corn silage based rations to mid lactation cows. Percent milk fat was significantly higher in CA, CE, and GE rations (3.31, 3.38 and 3.28%, respectively) when compared to N (3.07%). The NGR for the control ration was -.35 lower

There were no differences in milk production, FCM, SCM, SNF, percent milk protein, plasma glucose or BUN levels for the ration treatments. However, dry matter intake was significantly lower than the control when chopped hay (added or ensiled) was included in complete rations with corn silage. With no difference in FCM produced within ration treatments, an equal level of performance from the chopped hay rations could be expected, with considerable savings in feed intake and cost. Fourteen cents/cow/day could be saved when corn silage ($20/T), 39% protein supplement ($245/T), high moisture corn ($110/T) and orchard grass hay ($58/T) are fed in similar proportions as outlined in this experiment. Particularily when feeding HCRR diets to cows in early lactation, the added hay in a complete feed program would assure the intake of an effective fiber source to promote rumination and DMI. When feeding a high energy corn silage, this same program would adjust the ADF level to inhibit the feed intake of late lactation cows and prevent excess weight gains. By adding hay in a TMR, feed preference would be eliminated along with a substantial reduction in hay wastage.

REFERENCES

Alwash, T. and P. C. Thomas. 1971. Effect of the physical form of the diet and the level of feeding on the digestion of dried grass by sheep. J. Sci. Fd. Agric. 22:611.

Bailey, C. B. and C. C. Balch. 1961. Saliva secretion and its relation to feeding cattle. Brit. J. Nutr. 15:383.

Balch, C. C. 1976. Feed intake regulation: a limiting factor in animal production. Livestock Prod. Sci. 3:101.

Balch, C. C., D. A. Balch, S. Bartlett, M. P. Bertrum, V. W. Johnson, S. J. Rowland, and J. Turner. 1955. Studies of the secretion of milk of low fat content by cows on diets low in hay and high in concentrates. VI. The effect on the physical and biochemical processes of the reticulo-rumen. J. Dairy Res. 22:270.

Balch, D. A. and S. J. Rowland. 1957. Volatile fatty acids and lactic acid in the rumen of dairy cows receiving a variety of diets. Brit. J. Nutr.

Bauman, D. E. 1976. Intermediary metabolism of adipose tissue. Fed. Proc. 35:2308.

Bauman, D. E. and W. B. Currie. 1980. Partitioning of nutrients during pregnancy and lactation: A review of mechanisms involving homeostasis and homeorhesis. J. Dairy Sci. 63:1514.

Bensadoun, A, O. L. Paladines, and J. T. Reid. 1963. Effect of level of intake and physical form of the diet on plasma glucose concentration and volatile fatty acid absorption in ruminants.

Benson, J. D., E. W. Askew, R. S. Emery, and J. W. Thomas. 1972. Metabolism of fatty acids by adipose tissue and liver of cows fed normal, restricted roughage or MgO supplemented diets. J. Dairy Sci. 55:83.

Benson, J. D. and R. S. Emery. 1971. Fatty acid esterification by homogenates of bovine liver and adipose tissue. J. Dairy Sci. 54:1034.

Bergman, E. N., W. E. Roe, and K. Kon. 1966. Quantitative aspects of propionate metabolism and gluconeogenesis in sheep. Am. J. Physiol. 211:793.

Bergman, E. N. 1973. Glucose metabolism in ruminants as related to hypoglycemia and ketosis. Cornell Vet. 63:341.

Bickerstaffe, R., E. F. Annison, and J. L. Linzell. 1974. The metabolism of glucose, acetate, lipids, and amino acids in lactating diary cows. J. Agric. Sci., Camb. 82:71.

Blaxter, K. L. 1962. The energy metabolism of ruminants. Hutchinson, Scientific and Technical. London.

Broderick, G. A., T. Kowalczyk, and L. D. Satter. 1970. Milk production response to supplementation with encapsulated methionine per Cs or casein perabomasum. J. Dairy Sci. 53:1714.

Bullis, D.D., R. H. Kliewer, and I. R. Jones. 1959. Dried mollasses beet pulp versus chopped alfalfa hay as a preservative for oat and vetch silage. J. Dairy Sci. 42:1740.

Campling, R. C. and M. Freer. 1966. Factors affecting the voluntary intake of food by cows. 8. Experiments with ground, pelleted roughages. Brit. J. Nutr. 20:229.

Chalupa, W., G. D. O'Dell, A. J. Kutches, and R. Lauker. 1969. Supplemental corn silage or baled hay for correction of milk fat depressions produced by feeding pellets as the sole forage. J. Dairy Sci. 53:208.

Clark, J. H., H. R. Spires, and R. G. Derrig. 1973. Postruminal administration of glucose and Na-caseinate in lactating cows. J. Anim. Sci. 37:340.

Coppock, C. E., C. H. Noller, and S. A. Wolfe. 1974. Effect of forage-concentrate ratio in complete feeds fed ad libitum on energy intake in relation to requirements by dairy cows. J. Dairy Sci. 57:1371.

Coulombe, J. J. and L. Favreau. 1963. A new simple semimicro method for colorimetric determination of urea. Clin. Chem. 9:102.

Davis, C. L. 1967. Acetate production in the rumen of cows fed either control or low-fiber, high-grain diets. J. Dairy Sci. 50:1621.

Donker, J. D. and D. G. Naik. 1979. Predicting total digestible nutrients and estimated net energy of dairy cow rations from chemical components. J. Dairy Sci. 62:424.

Emery, R. S. 1973. Biosynthesis of milk fat. J. Dairy Sci. 56:1187.

Forbes, J. M. 1977. Development of a model of voluntary food intake and energy balance in lactating cows. Anim. Prod. 24:203.

Harris, B. 1975. Using nutrient requirement information for feeding dairy cattle. Dairy Information Sheet. OY 73-11. Univ. of Florida, Gainesville.

Harrison, D. G., D. E. Beever, D. J. Thompson, and D. F. Osbourn. 1975. Manipulation of rumen fermentation in sheep by increasing the rate of flow of water from the rumen. J. Agric. Sci. (Camb.) 85:93.

Head, H. H., J. D. Connolly, and W. F. Williams. 1964. Glucose metabolism in dairy cattle and the effect of acetate infusion. J. Dairy Sci. 47:1371.

Hodgson, J. C. and P. C. Thomas. 1975. A relationship between the molar proportion of propionic acid and the clearance rate of the liquid phase in the rumen of the sheep. Brit. J. Nutr. 33:447.

Holter, J. B., W. E. Urban, Jr., H. S. Kennett, and C. J. Sniffen. 1973. Corn silage with and without grass hay for lactating dairy cows. J. Dairy Sci. 56:915.

Grieve, D. G., E. E. Wheeler, Y. Yu, and G. K. Mocleod. 1980. Effects of dry or ensiled feeds and protein percent on milk production and nitrogen utilization by lactating cows. J. Dairy Sci. 63:1282.

Jenney, B. F. and C. E. Polan. 1975. Postprandial blood glucose and insulin in cows fed high grain. J. Dairy Sci. 58:512.

Jenny, B. F., C. E. Polan, and F. W. Thye. 1974. Effects of high grain feeding and stage of lactation on serum insulin, glucose, and milk fat percentage in lactating cows. J. Nutr. 104:379.

Jorgensen, N. A. and L. H. Schultz. 1963. Ration effects on rumen acids, ketogenesis, and milk composition. I. Unrestricted roughage feeding. J. Dairy Sci. 46:437.

Jorgensen, N. A., M. E. Finner and J. D. Marquandt. 1978. Effect of forage particle size on animal performance. Proc. Am. Soc. Ag. Eng. Summer. 78-1048.

Jorgensen, N. A., L. H. Schultz, and G. R. Barr. 1965. Factors influencing milk-fat depression on rations high in concentrates. J. Dairy Sci. 48:1031.

Judson, G. J., E. Anderson, J. R. Luick, and R. A. Leng. 1968. The contribution of propionate to glucose synthesis in sheep given diets of different grain content. Br. J. Nutr. 22:69.

Journet, M. and B. Remond. 1976. Physiological factors affecting the voluntary intake of feed by cows: a review. Livest. Prod. Sci. 3:129.

Kaufmann, W. 1976. Influence of the composition of the ration and the feeding frequency on pH-regulation in the rumen and on feed intake in ruminants. Livest. Prod. Sci. 3:103.

Leng, R. A., J. W. Steel, and J. R. Wick. 1967. Contribution of propionate to glucose synthesis in sheep. Biochem. J. 103:785.

Linzell, J. L. 1960. Mammary-gland blood flow and oxygen, glucose and volatile fatty acid uptake in the conscious goat. J. Physiol., Lond. 153:492.

Linzell, J. L. and M. Peaker. 1971. Mechanism of milk secretion. Physiological Reviews. 52:564.

Lofgren, P. A. and R. G. Warner. 1970. Influences of various fiber sources and fractions of milk fat percentage. J. Dairy Sci. 53:296.

Loten, E. G. and J. G. T. Sneyd. 1970. An effect of insulin on adipose tissue adenosine 3', 5'-cyclic monophosphate phosphodiesterase. Biochem. J. 120:187.

Luick, J. R. and K. Kameoka. 1966. Direct incorporation of β-hydroxybutyric acid into milk fat butyric and hexanoic acids in vivo. J. Dairy Sci. 49:98.

McClymont, G. L. and S. Vallance. 1962. Depression of blood glycerides and milk fat synthesis by glucose infusion. Proc. Nutr. Soc. 21:Xil.

McCullough, M. E. 1973. Optimum feeding of dairy animals for meat and milk. Second Edition. The University of Georgia Press. Athens.

McDonald, P. 1981. The biochemistry of silage. John Wiley and Sons, Chichester.

Mertens, D. R. 1977. Dietary fiber components: relationship to the rate and extent of ruminal digestion. Fed. Proc. 36:187.

Miller, C. N. C. E. Polan, R. A. Sandy and J. T. Huber. 1969. Effects of altering the physical form of corn silage on utilization by dairy cattle. J. Dairy Sci. 52:1955.

Miller, W. J. and C. M. Clifton. 1965. Relation of dry matter content in ensiled material and other factors to nutrient losses by seepage. J. Dairy Sci. 48:917.

Moe, P. W. and H. F. Tyrrell. 1972. Metabolizable energy requirements of pregnant dairy cows. J. Dairy Sci. 55:480.

Moe, P. W., H. F. Tyrrell, and W. P. Flatt. 1971. Energetics of body tissue mobilization. J. Dairy Sci. 54:548.

Murdock, F. R. and A. S. Hodgson. 1977. Cubed complete rations for lactating dairy cows. J. Dairy Sci. 60:1921.

National Research Council. 1978. Nutrient requirements of domestic animals. No. 3. Nutrient requirements of dairy cattle. 5th ed. Nat. Res. Pub. ISBN 0-309-02749-7.

Nocek, J. E., K. A. Cummins, and C. E. Polan. 1979. Ruminal disappearance of crude protein and dry matter in feeds and combined effects of formulated rations. J. Dairy Sci. 62:1587.

Nocek, J. E., J. H. Herbein, and C. E. Polan. 1980. Influence of ration physical form, ruminal degradable nitrogen and age on rumen epithelial propionate and acetate transport and some enzymatic activities.

O'Dell, G. D., W. A. King, and W. C. Cook. 1968. Effect of grinding, pelleting, and frequency of feeding of forage on fat percentage of milk and milk production of dairy cows. J. Dairy Sci. 51:50.

Olson, H. H., A. Reed, and H. Benson. 1965. Comparison of ad libitum grain and restricted roughage feeding with conventional dairy cattle feeding practices. J. Dairy Sci. 48:1398.

Opstvedt, J., R. L. Baldwin, and M. Ronning. 1967. Effect of diet upon activities of several enzymes in abdominal adipose and mammary tissues in the lactating dairy cow. J. Dairy Sci. 50:108.

Opstvedt, J. and M. Ronning. 1967. Effect upon lipid metabolism of feeding alfalfa hay or concentrate ad libitum as the sole feed for milking cows. J. Dairy Sci. 50:345.

Orskov, E. R. 1975. Manipulation of rumen fermentation for maximum food utilization. World Review of Nutrition and Dietetics. 22:152.

Ottenstein, D. M. and D. A. Bartley. 1971. Improved gas chromatography separation of free acids C2-C5 in dilute solutions. Anal. Chem. 43:952.

Palmquist, D. L. and H. R. Conrad. 1971. Origin of plasma fatty acids in lactating cows fed high grain or high fat diets. J. Dairy Sci. 54:1025.

Palmquist, D. L., C. L. Davis, R. E. Brown, and D. S. Sachan. 1969. Availability and metabolism of various substrates in ruminants. V. Entry rate into the body and incorporation into milk fat of D(-) β -hydroxybutyrate. J. Dairy Sci. 52:633.

Powell, E. B. 1939. Relation of roughage to the fat content of milk. J. Dairy Sci. 23:472.

Prange, R. W., M. D. Stern, N. A. Jorgensen, and L. D. Satter. 1980. Sites and extent of nutrient digestion in lactating dairy cows fed ensiled or baled alfalfa. J. Dairy Sci. 63(Suppl. 1):135.

Rao, D. R., G. E. Hawkins, and R. C. Smith. 1973. Effect of glucose and insulin on lipoprotein lipase activity in adipose tissue and milk. J. Dairy Sci. 56:1415.

Reinhold, J. G. 1953. Glucose. Standard Methods Clinical Chemistry. 1:65.

Rock, C. G., C. E. Polan, W. E. Etgen, and C. N. Miller. 1974. Varying dietary fiber for lactating cows fed corn and barley silages. J. Dairy Sci. 57:1474.

Rodrigue, C. B. and N. N. Allen. 1960. The effect of fine grinding of hay on ration digestibility, rate of passage, and fat content of milk. Can. J. Anim. Sci. 40:23.

Rohweder. D. A., R. F. Barnes, and N. Jorgensen. 1978. Proposed hay grading standards based on laboratory analysis for evaluating quality. J. Anim. Sci. 47:747.

Rook, J. A. F. 1962. Variations in the chemical composition of the milk of the cow. Dairy Sci. Abstrs. 23:251.

Sachan, D. S. and C. L. Davis. 1967. Synthesis of D(-) β-hydroxybutyric Acid.-^{14}C. J. Dairy Sci. 50:1273.

Satter, L. D. and N. Bringe. 1969. Effect of abrupt ration changes on milk and blood components. J. Dairy Sci. 52:1776.

Schalm, O. W., N. C. Jain, and E. J. Carroll. 1975. Veterinary Hematology. 3rd ed. Lea and Febiger, Philadelphia.

Seto, K. T., T. Tsuda, and M. Umezw. 1955. The mechanism of the ketone bodies production with rumen epithelium. I. The ketone bodies production from volatile fatty acids with rumen epithelium and the influence of substances concerned with the citric acid cycle on their production. Tohokw. J. Agr. Res. 6:91.

Storry, J. E. and J. D. Sutton. 1969. The effect of change from low-roughage to high roughage diets on rumen fermentation, blood composition and milk fat secretion in the cow. Brit. J. of Nutri. 23:511.

Sudweeks, E. M. 1977. Chewing time, rumen fermentation and their relationship in steers as affected by diet composition. J. Anim. Sci. 44:694.

Sudweeks, E. M., L. O. Ely, and L. R. Sisk. 1979. Effects of particle size of corn silage on digestibility and rumen fermentation. J. Dairy Sci. 62:292.

Sudweeks, E. M., M. E. McCullough, L. R. Sisk, and S. E. Law. 1975. Effects of concentrate type and level and forage type on chewing time of steers. J. Anim. Sci. 41:219.

Sutton, J. D. 1976. Energy supply from the digestive tract of cattle. Page 121 in Principles of Cattle Production. H. Suan and W. H. Broster, ed. Butterworths, London.

Tagari, H. Y., Y. Dror, I. Ascarelli and A. Bondi. 1964. The influence of levels of protein and starch in rations of sheep on the utilization of protein. Brit. J. Nutr. 18:333.

Thomas, J. W. 1978. Preservatives for conserved forage crops. J. Anim. Sci. 47:721.

Thorley, C. M., M. C. Sharpe, and M. P. Bryant. 1968. Modification of the rumen bacterial flora by feeding cattle ground and pelleted roughage as determined with culture media with and without rumen fluid. J. Dairy Sci. 51:1811.

Tilley, J. M. A. and R. A. Terry. 1963. A two stage technique for the in vitro digestion of forage crops. J. Brit. Grassland Soc. 18:104.

Trimberger, G. W., H. F. Tyrrell, D. A. Morrow, J. T. Reid, M. J. Wright, W. F. Shipe, W. G. Merrill, J. K. Loosli, C. E. Coppock, L. A. Moore, and C. H. Gordon. 1972. Effects of liberal concentrate feeding on health, reproductive efficiency, economy of milk production, and other related responses of the dairy cow. New York's Food and Life Sci. Bull. No. 8. Cornell University.

Tyrrell, H. F. and P. W. Moe. 1972. Net energy value for lactation of a high and low concentrate ration containing corn silage. J. Dairy Sci. 55:1106.

Van Soest, P. J. 1963. Ruminant fat metabolism with particular reference to factors affecting low milk fat and feed efficiency. J. Dairy Sci. 46:204.

Van Soest, P. J. and N. N. Allen. 1959. Studies on the relationships between rumen acids and fat metabolism of ruminants fed on restricted roughage diets. J. Dairy Sci. 42:1977.

Waugh, R. K., H. S. Poston, R. D. Mochrie, W. R. Murley and H. L. Lucas. 1955. Additions of hay to corn silage to maximize feed intake and milk production. J. Dairy Sci. 38:688.

Weigand, E., J. W. Young, and A. D. McGilliard. 1972. Extent of propionate metabolism during absorption from the bovine rumenoreticulum. Biochem. J. 126:201.

Works, D. W., R. H. Ross, D. L. Thacker, and L. G. Williams. 1963. Chopped hay drying and storage. University of Idaho Press. Moscow, Idaho. Leaflet No. 58.

Yang, Y. T. and R. L. Baldwin. 1973. Lipolysis in isolated cow adipose cells. J. Dairy Sci. 56:366.

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MILK FAT RESPONSE TO CHOPPED AND GROUND HAY
WHEN ADDED TO OR ENSILED WITH CORN SILAGE
AND FED IN COMPLETE RATIONS TO DAIRY COWS

by

Charles W. Talbott

(ABSTRACT)

Twenty-five multiparous cows in their second trimester of lactation were randomly assigned in a 5 x 5 latin square rotation to five silages: control (N), chopped added (CA), ground added (GA), chopped ensiled (CE), and ground ensiled (GE). Chopped (2-6 cm) or ground (< .5 cm) hay was added to corn green chop at 12.5% of the total forage dry matter before ensiling (CE and GE). Chopped or ground hay was also added to the control silage at the same rate prior to feeding (CA and GA). Silages were supplemented to contain 14% crude protein and 1.67 Mcal/kg on a dry matter basis and fed as a total mixed ration. Hay-containing rations averaged 22% ADF, compared to 20% ADF in the control ration. Each cow received the assigned ration for three weeks and milk samples were collected on days 19 and 20 of each feeding period. Means ± S.E. for N, CA, GA, CE and GE were: percent milk fat 3.07 ± .08, 3.31 ± .09, 3.37 ± .08, 3.28 ± .08; percent total solids 11.7 ± .11, 11.8 ± .12, 11.9 ± .12, 12.02 ± .13, 11.94 ± .12; and dry matter intake per kg

metabolic body weight .170 ± .003, .161 ± .003, .163 ± .004, .158 ± .004, .166 ± .004, respectively. Percent milk fat was significantly higher in rations CE, CA, and GE when compared to N. Milk production and percent milk protein did not differ. The results indicate increased milk fat production when chopped hay (added or ensiled) or ground hay (ensiled) is included in corn silage based rations for dairy cattle. Whether chopped or ground, hay added at time of ensiling tended to stimulate milk fat production more than hay added just prior to feeding. The beneficial effect of increased hay fiber length on milk fat production was evident whether hay was ensiled with or added to corn silage.