EFFECTS OF GROUND, STEAM HEATED AND PELLETED HAY, WITH AND WITHOUT PELLETED GRAIN, ON MILK PRODUCTION AND COMPOSITION

by

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INTRODUCTION

Modern methods of handling and processing roughages have changed feeding practices. The increase in the size of farm units and the use of labor saving equipment has forced the dairyman to use prepared feeds which in some cases have altered the composition of milk.

There are instances where milk production and composition have been affected by the physical form and amount of roughage fed. The fineness of grind of roughage as well as the amount and form of grain fed influences the degree of milk composition change.

Little work has been done to determine how particle size reduction of hay influences milk composition. The effects of heat and pressure changes during pelleting of hay have not been separated from effects of particle size reduction occurring during pelleting. The ration and physical form also have a marked effect on rumen volatile fatty acids. Since volatile fatty acids are precursors of certain milk constituents they have been studied in relationship to milk composition.

This research was undertaken because of a need for a better understanding of the effects of particle reduction, steam heating, and pelleting of hay as it influences rumen volatile fatty acid ratios, milk production, and milk composition.

REVIEW OF LITERATURE

Effects of Feed Processing on Milk Production and Composition

Powell (1938) was among the first to become concerned with changes in milk composition due to feeding. He reported that consecutive lactation records showed that the physical characteristics of the feed influenced the composition of milk. The milk fat test was depressed when the hay and grain in the ration were finely ground and compressed into cubes. He observed that when the long hay part of the ration was decreased to 5 lb, the milk fat test was lowered also. For example, a cow which received an all cubed ration had a fat test of 2.6%; when 5 lb of long alfalfa hay was fed, the test increased to 2.9%; but when she was placed on a normal long hay ration, her test increased to 3.8%. The milk fat test of a cow fed meal and chopped hay (0.5 to 1 in. in length) decreased, but not as much as when the hay was finely ground and cubed.

His conclusions, which hold today, were:

1. There is a direct correlation between the roughage intake, up to a definite maximum amount, and the composition of the milk.

2. It is not only the amount of roughage (fiber) consumed, but also the physical condition of the roughage that causes variations in milk composition. Hence, abnormal fat tests may result if the roughage is adequate in amount, but incorrect physically, or if the roughage is correct physically but deficient in amount.

3. Fine stemmed alfalfa hay chopped in lengths of 0.5 to 1 in. aids in raising the milk fat percentage over what it would be if all the roughage were finely ground.

4. Fifteen lb of silage is less effective in maintaining the normal fat test of milk than 5 lb of long alfalfa hay.

5. A cow maintained on a ration deficient in normal roughage for as many as three lactation periods will return to milk of normal composition when returned to a normal ration.

Even though a considerable amount of work has been done on this problem, the minimum amounts of roughage or the size of roughage particle that will maintain normal milk composition has not been determined. Powell found that the total solids and fat content of milk decreased as the amount of roughage fed was decreased.

Espe and Cannon (1939) did not observe a change in the milk fat percentage in a trial where only part of the roughage was finely ground. Alfalfa hay cut to 0.25 in. lengths was fed with corn silage and a grain mixture. Corn fodder which was finely chopped was fed in a second trial. This work was conducted to study the cost of grinding roughages rather than the direct problem of changes in milk fat content resulting from changes in the physical state of roughages fed.

Results of work conducted by Loosli et al. (1945) corresponded with those of Powell. They observed that a significant drop in milk fat percentage occurred when hay intake was reduced from 2 lb per 100 lb body weight to 5 lb of hay per cow per day with a corresponding increase in grain to furnish required energy. In three experiments, a low roughage intake adversely affected milk production as well as depressing fat test; however, the cows were in advanced lactation. The feeding of small quantities of roughage reduced to 1 in. lengths did not decrease the fat test further. The control cows received daily 12 lb of hay, 30 lb of silage and a small amount of grain mixture.

Porter et al. (1953) conducted an experiment to determine the relative value, for milk production, of alfalfa hay fed as the sole source of roughage for dairy cows when it was field-cured and field-baled, artificially dried and chopped, artificially dried and ground and artificially dried and pelleted (1.75 cm diameter). The cows were fed hay free choice and 1 lb of grain for each 4 lb fat-corrected milk (FCM) produced. Each form of alfalfa was fed for 40 days. A double change-over design was employed. No significant changes in milk fat test were observed.

The findings of Porter were similar to those of Morrow and LaMaster (1929) who found that physical preparation of the hay portion of the ration had no effect on the quantity or quality of milk produced. The palatability of the ground hay appeared superior to the unground hay. The digestibility of the ground and unground alfalfa hays was similar. The ground hay was dusty and expensive to produce.

A significant drop in milk fat test among cows fed 4 to 8 lb of long hay and those fed 8 lb of finely ground hay was observed by Balch et al. (1954). Grain was fed according to milk production. Additional starch equivalent requirements for cows receiving reduced quantities of hay were supplied by a more fibrous grain mixture. The milk from cows receiving 12 lb of hay daily did not decline in fat percentage. Differences in milk yield among treatments were not significant.

Balch et al. (1955a) compared the effects of starch from flaked maize with that of maize meal or of dredge corn (oats and barley) on milk fat depression. All groups were gradually changed to 4 lb of hay daily and 4 lb of concentrate mixture for each 10 lb of milk. The milk of the group receiving flaked maize tested 2.90% fat during the 8th and 9th week, and 3.57% during the control period of the 12th and 13th week. Higher tests were observed during the preliminary period. The ration containing maize meal reduced the fat test slightly while the fat test of those receiving dredge corn was not affected. These results demonstrated that the kind of starch in the diet can affect the composition of milk. The form of starch may affect the flora of the reticulo-rumen.

Ensor et al. (1959) fed lactating cows, according to production, various combinations of long or finely ground alfalfa hay with or without ground corn, heated ground and crimped corn, or glucose. A second trial was conducted employing Holstein-Friesian steer calves. Rumen fluid collected by a stomach tube was analyzed for volatile fatty acids. The milk fat test of cows on long hay or ground and pelleted hay did not change in 28 days, but all other groups showed a change. The greatest percentage of decrease in the fat test was in the milk of cows receiving 6 lb of ground and pelleted hay and 18 lb of heated corn. A 53% reduction in fat test occurred by the 17th day, with 57% reduction by the 34th day. The next greatest reduction occurred with the group receiving 28 lb of ground and pelleted alfalfa hay and 4 lb heated corn. This group decreased 53% in fat test by the 18th day and 51% by the 34th day.

Ronning et al. (1959) used a multitreatment, switch-back design to determine the effect of pelleted and chopped hay on milk production and fat test. They observed an increase in production when the pelleted hay was fed ad libitum; also the total dry matter intake increased. Grain was added only to meet the nutritional requirements not supplied by hay. The chopped hay was cut with a field chopper into 3/4 in. lengths. The pellets were prepared by grinding the hay and pelleting through a 3/8 in. round hole die. The pellets had a bulk density of 42 lb per cu. ft. A 7-day preliminary and 28-day observation period were used. No significant changes in fat test occurred. This would tend to substantiate the hypothesis that the starch form of the carbohydrate fraction of concentrates may be an important factor causing fat depression.

A study made by King and Hemken (1962) utilized excellent quality red clover hay, which was ground through a 1/8 in. screen and extruded into pellets through a 3/16 in. die. It was difficult to maintain milk production on pelleted hay as it was less palatable than long hay. Acceptability of pellets and milk fat depression both appeared to be related to the fineness of grind before pelleting. The protein and solids-not-fat (SNF) content of these milks were affected by the milk fat depressing rations, but to a lesser degree and the change was in an opposite direction to change in fat. This inverse relationship was most noticeable during periods of rapid change in fat content. Samples evaluated during the last 2 weeks of each period showed an increase of 5% for protein and a decrease of 33% for fat. The rumen volatile fatty acids were affected by rations. Acetic acid concentration decreased and propionic acid increased while cows were on pelleted hay rations. Although the ratio of acetic to propionic acid was narrow in rumen fluid of cows fed pelleted rations, production of acetic acid (meq/100 ml) was 14% greater in the rumen fluid of cows fed pelleted as compared to long hay rations. The other VFA were increased accordingly.

Brown et al. (1962) found significantly more milk produced by cows fed grain and a low roughage ration of 1.0 lb of alfalfa hay per 100 lb of body weight than by those fed grain and 2.5 lb of hay per 100 lb of body weight. The milks were not different in protein content. The composition of the milk fat was similar between the two roughage levels, even though total fat was lower in the low roughage group.

Although pelleting has often depressed the dry matter digestibility of rations composed of 50% or more of hay, it appears not to alter the net energy value. Minson (1963) also observed that wafering and pelleting of coarse ground hay (3/8 in. screen) appeared to have a negligible effect on milk fat percentage, but pelleting finely ground hay (1/16 in. screen) depressed fat test, especially in the presence of concentrates.

Feeding pelleted concentrates with 5 lb of hay and 15 lb of silage resulted in an increase in milk yield and a decrease in fat percentage when compared with concentrates in the form of meal (Bishop et al. 1963). There were very small differences in feed intake in favor of the meal, but the efficiency of utilization of TDN for the production of FCM was slightly better when pellets were fed.

Many of the feeding trials reported in the literature were of short duration. However, Ronning (1960) conducted a trial lasting 175 days. Ground alfalfa was fed which had been ground through a hammer mill with a 1/16 in. screen and pelleted into 1/4 in. pellets. Rations containing 30 and 45% concentrates decreased milk fat test more severely than diets containing lesser amounts of concentrates. The average fat test of all cows by 28-day observation periods without regard to quantity of concentrate fed with pelleted hay were as follows: Preliminary, 3.5%; Period I, 3.0%; II, 2.2%; III, 2.0%; IV, 2.1%; V, 2.2%; and Post trial, 3.7%.

Mechanism of Fat Depression. Tyznik and Allen (1951) fed eight milking cows 3 lb hay daily and all the concentrates they would eat. After about 2 weeks the milk fat test was depressed from 1 to 2 percentage units. The rumen contents were sampled and the fatty acids determined weekly. Proportionally, propionic acid increased, acetic acid decreased and butyric acid remained constant.

Jorgensen et al. (1965) found a number of physiological changes consistently occurring when a fat-depressing diet was fed. These included: 1) a reduction in rumen acetic acid; 2) an increase in rumen propionic and valeric acids; 3) a decrease in blood lipids; 4) a decrease in blood ketone bodies; 5) an increase in blood glucose levels; 6) an increase in bodyweight gains;

7) a reduction in milk production; 8) a decrease in the short-chain acids as well as the palmitic and stearic acid components of milk fat; 9) an increase in the unsaturated fatty acid components of milk fat.

Van Soest (1963) in a review of fat metabolism in the ruminant, suggested that the degree of fineness of grind of a roughage appears to be the main factor involved in the decrease of acetic acid and increase in propionic acid that results.

The effect of giving volatile fatty acids to cows was explored by Balch et al. (1959). The fat content of milk of cows on a fat depressing diet returned to normal when 0.5 to 1.5 kg of sodium acetate was fed daily. Cows fed normal quantities of roughage showed no change in fat test when sodium acetate was fed. The administration of sodium propionate had no effect on fat test. The response to sodium butyrate (one cow) was similar to that of sodium acetate in restoring a depressed fat test.

Tyznik and Allen (1951) fed 0.25 lb of sodium acetate daily to cows receiving a fat depressing ration and observed an increase in milk fat content within 24 hr. When 1 lb of sodium acetate was fed per day, the milk fat test returned to an approximately normal level. When acetate feeding was discontinued, the fat test of the milk immediately returned to the sub-normal, low-roughage level.

Stoddard et al. (1949) fed cows 6 lb of hay daily and all the concentrates they would consume. A very marked decrease in fat test was observed. A decrease in the Reichert-Meissl number and an increase in iodine number was observed when the fat test was depressed. When acetic acid was administered by stomach tube the fat test increased towards normal. Propionic acid administration did not cause an increase in fat test.

Balch et al. (1957) fed cows a variety of diets and analyzed rumen fluid. Cows were maintained on experimental rations for at least 10 days before they were sampled. Samples of rumen fluid were taken before each feeding and at hourly intervals thereafter for 24 hr. The greatest fluctuation in concentration of volatile fatty acids was evident with diets low in hay or hay which had been finely ground. The range was 5.6 to 20.0 and 7.0 to 21.0 meq/100 ml respectively. The fluctuation in concentration of volatile fatty acids was much less with diets containing adequate hay in natural form. The pH varied inversely with the concentration of total volatile acids. The percentage of butyric and higher acids increased with increases in the protein content of the diet. The ratio of acetic to propionic acid decreased as the ratio of fibrous to starchy concentrates in the ration decreased.

Balch et al. (1952) observed a drastic decrease in fat percentage of milk when a ration of 2 lb of long hay and 24 lb of concentrate was fed to Shorthorn cows. The milk fat remained low even after 5 lb of dried straw pulp was fed. This indicates that fiber alone is not the only factor involved in milk fat depression, but that roughage must provide a physical property of fibrousness which restores the milk fat percentage to normal. The cows produced only 38-49% of the fat they would have produced on the control ration. The solids-not-fat content of the milk increased when milk fat content decreased, but no marked decrease occurred in the volume of milk produced.

Acetic acid was only slightly depressed from 45.2 to 42.6 meq/liter, whereas propionic was increased from 15.7 to 20.6 meq/liter on a restricted roughage ration (Van Soest and Allen, 1959). The feeding of sodium acetate trihydrate (450 g/day) increased milk fat test while anhydrous sodium propionate (300 g/day) depressed milk fat test of cows on restricted roughage rations which had already depressed the milk fat test.

Jorgensen and Shultz (1963) investigated the effects of feeding normal levels of hay and concentrates in various forms. Rations containing pelleted hay or pelleted corn produced these changes: 1) decreased milk fat test; 2) decreased percentage of rumen acetic acid; 3) increased percentage of rumen propionic acid; 4) increased total concentration of rumen acids; 5) increased blood sugar concentration. The feeding of pelleted corn tended to increase blood ketone bodies, whereas feeding pelleted hay reduced them. Feeding pelleted hay once a day counteracted the ketogenic effect of pelleted corn, whereas feeding a combined pellet (50% hay and 50% corn) had the same ketogenic effect as pelleted corn. An increase in total rumen acids with more butyrate to be metabolized would suggest butyrate to be the ketogenic agent. The high ketone levels did not prevent depression of milk fat test. The depression in milk fat test was not corrected when 20 lb of long hay was fed daily with pelleted corn. The hay was prepared for pelleting by grinding through a hammer mill with a 1/4 in. screen. The ground material was heated (140 to 170 F) and compressed with the aid of steam. The pellets were 1/4 in. in diameter. The corn was prepared the same way, except a 3/8 in. die was used for pelleting.

Shaw (1959) was able to show that the variation in molar proportion of rumen volatile fatty acids was very small regardless of when the samples were taken. He found a slight decrease in milk fat percentage when pelleted alfalfa meal and ground corn were fed compared to long hay and grain. A severe drop in milk fat percentage and molar percentage of acetic acid was noticed by the 19th day of a feeding trial when a cow was fed pelleted alfalfa meal and steamed corn.

Palmquist *et al*. (1964) observed that the short-chain fatty acids of the milk fat were depressed less than the long-chain fatty acids, when concentrates and ground pelleted alfalfa hay were fed at different times rather than at the same time. The hay was ground through a 1/16 in. screen and made into 3/8 in. pellets.

Porter *et al*. (1953) observed a decrease in hay consumption when cows were fed finely ground hay or hay pellets. The particle sizes were determined by soaking 200 g samples in water and then drying before passing through U. S. standard sieves. The particle sizes of pelleted hay used in two experiments are shown in Table 1.

Table 1

Particle size of pelleted hay as determined by dry sieving

	16	20	30	40	50	Pan
	----------Per cent of sample retained---------					
Experiment I	6.7	17.0	18.7	16.7	14.6	26.8
Experiment II	0	0	5.7	12.1	16.3	65.9

There was no difference between field-cured, artificially dried-ground and artificially dried-pelleted hays in the first experiment. A decrease in milk yield and milk fat test occurred in the second experiment. This was attributed to the hardness and small particle size of the alfalfa hay pellets.

Pfost (1966) developed a wet sieving technique by which pelleted material can be measured without further particle reduction during sample preparation. This method makes it possible to determine the particle size of feedstuffs and relate it to nutritive value.

Card and Shultz (1953) studied the production of acetic, propionic and butyric acids in rumen fluid of lactating dairy cows fed a variety of rations. The results obtained with 28 cows fed widely different rations are shown in Table 2.

Table 2

Effect of different rations on rumen volatile fatty acids

	Acetic	Propionic	Butyric
	---------------	Molar %	---------------
Mixed hay alone	60.0	21.0	19.0
Mixed hay and grain	57.7	18.8	23.5
Pasture alone	55.6	17.9	26.5
Pasture plus grain	53.0	20.0	26.7
Grain alone	47.3	23.2	29.5

Analysis of variance of the data showed a significant difference ($P < .01$) in the percentage of each of the acids as affected by ration. Acetic acid was the most variable with a reciprocal change taking place in butyric acid. Propionic acid was the least variable.

Balch et al. (1965) observed less milk fat depression among heifers on ground hay diets when maize was ground instead of flaked. The rations were composed of 40% Italian rye-grass and 60% concentrates. No difference in milk fat was observed on long hay and either flaked or ground maize in the concentrates. The milk yield and SNF were not affected in any of these experiments.

Mechanism for Changes in SNF and Protein Contents of Milk. There is evidence (Rook, 1959) that rations deficient in either protein or energy will reduce the SNF content of milk. In some cases, feeding excess energy resulted in increased SNF content of milk, whereas excess dietary protein above normal requirements had no effect. Quantity of energy fed had an effect on milk yield, as well as on SNF content of milk. Cows in advanced lactation and those in good condition were affected less by fat depressing diets than other animals. The changes in SNF which occur in milk appear to be due to changes in the protein fraction.

Balch et al. (1955b) observed a milk fat depression to less than 2.0% on diets of 2 lb hay and 24 lb concentrates compared to 3.5% fat in milk during the control period. There were increases in SNF percentages during the experimental periods. The composition of milk fat was influenced by the diets low in hay, the main changes being in a decrease in Reichert-Meissl value and increase in the iodine value.

The increase in SNF which occurred on high energy intakes was attributed to the protein fraction (Huber and Boman, 1966). However, when relatively high fiber was fed, a variation in energy intake had less effect on SNF and protein. Pelleting or grinding of hay gave significant increases in milk protein (0.13%) and SNF (0.21%) when compared to long or chopped hay. It took longer for milk protein and SNF to respond to dietary changes than milk fat.

Rook and Line (1961) observed changes in milk composition when 6 lb of flaked maize was fed above a normal ration. The SNF content increased on the higher energy ration and fat content decreased slightly. The protein fractions contributed most of the SNF increase of animals on high energy ration. Lactose was increased only slightly on the higher energy ration.

Secretion of all the major fatty acids in milk was reduced when milk fat test was depressed on a low-hay diet (Storry and Rook, 1966). The change in proportion of rumen VFA when the cows were changed from a long-hay to a low-hay diet, was a decrease in acetic, an increase in both propionic and n-valeric acids. There was little change in n-butyric, but there was an increase in rumen lactic acid. When the animals were returned to high-hay diets, the proportions of acetic, propionic and valeric acids returned to normal in about 4 days. The recovery in milk fat content was not complete until the second to third week.

Blanchard et al. (1966) reported that the per cent of milk fat, SNF, and total solids slowly and consistently declined in lactations from 2 to 10 yr of age.

Digestibility of Hay. Blaxter and McGraham (1956) used sheep to determine the difference in utilization of energy from dried grass which was processed in three ways: coarsely chopped, medium ground and pelleted, and finely ground and pelleted. The medium was ground to pass through a 1/4 in. mesh sieve, and the fine was ground to pass through a 1/16 in. mesh sieve. There were no statistically significant differences in energy retention between the three hays at either a low (600 g/24 hr) or a high (1500 g/24 hr) level of feeding. Fecal losses of energy were smaller at the lower feeding level. Fecal losses of energy were considerably greater and methane losses were lower when pellets were fed than when coarsely chopped hay was fed. Determination of digestibility of the carbohydrate fractions of the grass showed that reduction in digestibility of the structural components of the cell was the major factor causing increased fecal losses. The digestibility of intracellular constituents was not greatly diminished.

Using Holstein heifers, Swanson and Herman (1952) studied the effect of feeding different forms of alfalfa hay on digestibility. Hay was processed in three ways: 1) ensilage cutter (coarse); 2) 1 in. hammer mill screen (medium); 3) 5/16 in. hammer mill screen (fine grind). Decreased rumination was directly related to the fineness of grind. The fineness of grind had no significant effect on digestibility. Apparently decreased rumination did not affect digestibility.

A study of the effects of different finenesses of grind on the digestibility and rate of passage of ground hay, as well as its effect on milk composition, was carried out by Rodrique and Allen (1960). The ration consisted of two parts of ground hay and one part concentrate by weight. The hay was ground in a hammer mill with a 1/16 in. screen by varying the speed. The fineness of grind was determined by dry sieving techniques. Results showed a noticeable decline in digestibility of fiber and/or cellulose as a result of grinding ($P < .01$). A close relationship was established between rate of passage of hay and digestibility of the total ration. The rate of passage increased as the fineness decreased. The distribution of particle size of ground hay is shown in Table 3.

Table 3

Distribution of particle size of ground hay used in the digestion trials as determined by U. S. standard sieves.

Sieve No.	Sieve Openings	Per cent Retained Series I Coarse Grind	Series II Medium Fine Grind	Series III Very Fine Grind
20	0.84 mm	8.0	6.0	0.0
40	0.42 mm	32.0	29.0	19.0
60	0.250 mm	27.0	24.0	21.0
80	0.177 mm	16.0	17.0	20.0
100	0.149 mm	5.0	6.0	9.0
Not Retained	Pan	12.0	18.0	31.0

Milk fat percentages were always lower when ground hay was fed, however, only in Series II was the difference significant ($P < .05$).

Rye grass ground through a hammer mill with a 0.049 in. diameter screen and pelleted with steam only, was less digestible than long hay (Campling _et al_. 1963).

EXPERIMENTAL PROCEDURE AND RESULTS

Experiment I. Effects of Hay Ground to Different Degrees of Fineness on Milk Composition and Yield

The purpose of Experiment I was to study the effect of grinding hay to different degrees of fineness on milk fat depression with the hope of ascertaining the maximum particle size reduction that may be achieved without depressing milk fat test.

Experimental Procedure. Twelve lactating cows (Holsteins, Ayrshires and Guernseys) were distributed among three groups. They were grouped as similarly as possible with regard to breed, stage of lactation, milk production, and milk fat test. The groups were assigned at random to three rations which were similar except that the hay was ground to three different degrees of fineness. The cows were housed and milked in a stanchion barn. The feed mangers were partitioned to prevent animals from eating each other's feed. They were bedded with shavings in the barn and attempts were made to prevent them from eating bedding. The cows were allowed to exercise daily in a dry-lot without access to feed or bedding. Water was available at all times. The same milker attended the cows throughout the experiment.

The following grain ration was fed to all cows throughout the experiment: corn, 500 lb; sorghum grain, 400 lb; wheat bran, 100 lb; soybean oil meal, 200 lb; steamed bone meal, 20 lb; salt, 20 lb. The grain was ground through a hammer mill without a screen. Sufficient baled alfalfa hay was procured for the entire experiment. The hay was prepared in three physical forms. One batch, designated as coarse grind, was prepared by chopping the hay with a Gehl chopper with a 1/2 in. screen. A portion of the coarse hay was ground with a Prater hammer mill, without a screen at 1760 rpm. This hay was designated as medium grind. A third portion of the coarse hay was ground with a Prater hammer mill employing the same speed but using a 4/64 in. hammer mill screen. This hay was designated as fine grind.

During a 10-day preliminary period the cows were fed baled alfalfa hay and the grain ration. Following the preliminary period all cows were fed the same grain ration, but the three groups were assigned at random to the three forms of hay. Grain was fed according to milk production (Table 8a, Morrison, 1956) and hay was fed at the rate of 2 lb per 100 lb of body weight. The duration of the experiment was 11 weeks.

The hay particle size distribution was analyzed by the wet sieve technique described by Pfost (1966). Samples of ground hay (before and after pelleting) were analyzed as follows:

1. Four 20-g samples were divided and placed in 250 ml beakers. One-half g of a nonfoaming detergent was added to each beaker which was then filled with distilled water. The samples were allowed to soak 24 hr.
2. The material was stirred gently for 5 min using an air-driven glass-rod stirrer.
3. The stirred samples were poured into the top sieve of a group of 5-in. diameter sieves having 9, 16, 32, 60 and 150 mesh (Tyler) openings.
4. The sieves were immersed in water and agitated vertically through 1.5 in. stroke at 35 strokes per min for 45 min. (The water level maintained provided a depth of 1 in. in the top sieve at the bottom of its stroke.)

5. After being agitated, the sieves were placed at the bottom of the stroke and allowed to set 15 min. Floating material was skimmed off, using a 1/16 in. mesh wire skimmer. This material was designated as "floater" size.

6. The screens were raised from the water and the material remaining on each screen was washed from the screen and deposited on 4 in. filter papers.

7. After the water cans had set 30 min, they were decanted and the sediment in the bottom was filtered to remove it for weighing.

8. All size fractions, together with their filter paper, were dried at 130 C for 5 hr in a forced-draft oven and weighed.

Individual milk weights were recorded at each milking. Fat tests were determined on individual 48-hr composite samples (according to production) collected on the last 2 days of the preliminary period, the first week and at 2 week intervals thereafter. Every 4 weeks, half of the composite sample was analyzed for protein, ash and total solids. Milk fat was determined by the Babcock method, protein and ash by procedures outlined in AOAC (1960).

Samples of rumen fluid for analysis of rumen volatile fatty acids (VFA) were obtained at the end of the preliminary period, the third week and at 2 week intervals thereafter. The samples were drawn with a 3/8 in. stomach tube and vacuum pump 8 hr after the morning feeding. The samples were cooled immediately in ice water and then were transferred to a freezer where they were stored. The samples were thawed just prior to analysis for VFA. After thawing the samples were centrifuged at 1000 g for 8 min. The supernatant was used for VFA determination. Concentrations of VFA were determined by a modification of the Keeney (1956) column chromatographic technique. The modifications were: 5ml rumen fluid were used instead of 2 ml; the silicic acid was alkaline so it is necessary to use HCl instead of NH_4OH in the glycol reagent to produce the desired color from brome creosol green; to obtain better separation of C_4 and C_5 acids the first solvent solution was comprised of 0.75% butanol in hexane instead of the recommended 1%; a 5% butanol solution was used as solvent to separate C_3 and C_2 acids; a solution of .01 N NaOH was used to titrate the fatty acids.

Results. The particle size reduction of the three hays used is shown in Table 4 and Figure 1. It is apparent that there were marked differences in the distribution of fine, medium and coarse particles in the three hays. Only 0.88% of the fine grind was retained on a 16 or larger sieve. The coarse grind was retained on a 16 or larger sieve to the extent of 66.88%. To compare fineness of grind between experiments conducted by different workers, it is necessary to define specifically particle size. The wet sieving technique of Pfost (1966) seems satisfactory for this purpose.

After the 10-day preliminary period the cows were gradually changed to the ground roughage. Considerable difficulty was encountered in shifting the cows over to the finely ground hay. Cow 122C consumed all of her portion of the finely ground hay the first day but started leaving 6 to 10 lb of hay daily thereafter. In 10 days she appeared ketotic and was treated for ketosis. It was apparent that she would not survive on the finely ground hay ration so she was placed in the group receiving the medium grind. Cow 163C receiving the finely ground hay ate somewhat better than 122C but on the 9th day she developed ketosis. She was treated for ketosis and switched to the group

Table 4

Particle size distribution of hay used in Experiments I, II and III
(wet sieve analysis)

	Sieve Size (Tyler)						
	Floater	9	16	32	60	150	>150
	----------------Per cent retained on sieve-----------------						
Experiment I							
Coarse	15.65	16.27	34.96	22.94	3.30	.92	4.96
Medium	3.29	3.21	33.27	38.64	6.12	6.28	9.15
Fine	- -	.88	- -	54.78	21.07	7.95	15.28
Experiment II							
Conditioned	5.15	7.38	42.73	29.46	7.38	3.26	4.62
Pelleted	3.96	4.47	30.66	41.39	4.46	6.73	9.14
Experiment III							
Pelleted	2.50	7.42	30.67	40.17	3.72	6.75	8.70

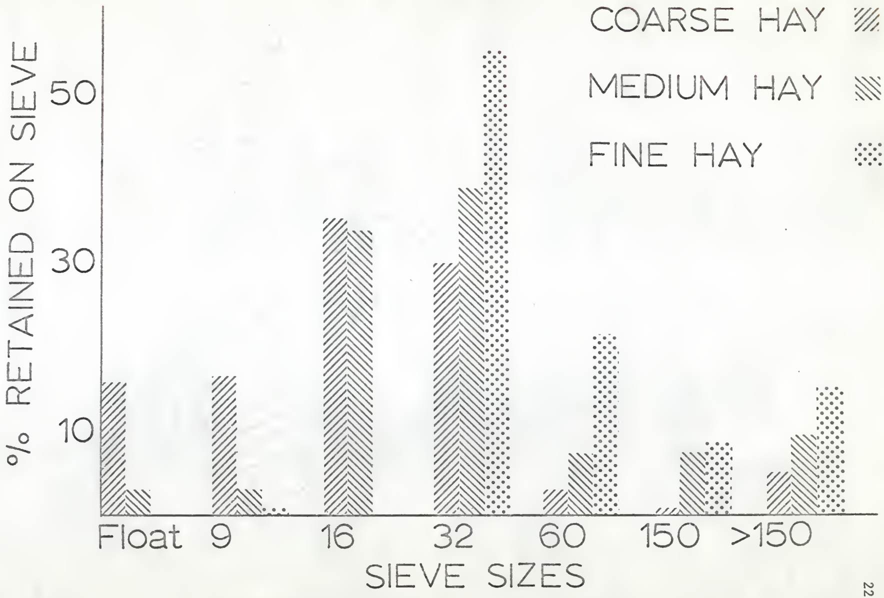

Figure 1. Particle size analysis of hay used in Experiment I.

receiving coarsely ground hay. The finely ground hay was consumed satisfactorily by cow 440B but there were certain days when she would leave part of her hay. At the start of the 10th week of the experiment she became severely ill and exhibited symptoms of ketosis. She was treated for ketosis and switched to the group receiving coarsely ground hay. Cow 4R consistently cleaned up her hay and completed the experiment without difficulty.

It is apparent (Table 5 and Appendix Table 1) that the finely ground hay depressed milk fat test during the first 6 weeks. From 6 to 12 weeks the test gradually increased. Feeding medium ground hay had no influence on fat test except during the 1st week when the test was lower. The cows receiving the coarsely ground hay increased in fat test (except for the 1st week). The increase was probably the result of advancing lactation. It was not possible to attribute a ration effect to changes in protein or SNF content of milk since cows in all three groups increased in protein and SNF. Apparently the increase was the result of advancing lactation also. The smallest percentage decline in milk production and greatest increase in body weight was in the group receiving the coarsely ground hay. The greatest percentage decline in production and smallest increase in weight was in the group receiving the finely ground hay.

The animals receiving finely ground hay craved fibrous material and it was necessary to use extreme care to avoid consumption of bedding. Rumen activity as determined by palpation of the left flank showed the feeding of finely ground hay decreased activity. Body weight of all cows remained reasonably constant or increased only slightly during the experiment (Table 5).

Table 5

Effect of fineness of hay grind on mean milk yield, composition of milk, and body weight change (Experiment I)

Group	Weeks	Milk	Fat	Protein	Solids-not-fat	Total solids	Weight change
		(lb)			(%)		(lb)
Fine Grind	0	22.1	4.6	3.5	9.4	14.0	
	1	23.2	4.3	- -	- -	- -	
	3	22.8	4.1	3.7	9.5	13.6	
	5	21.5	3.9	- -	- -	- -	
	7	20.5	4.3	3.8	9.3	13.6	
	9	18.9	4.1	- -	- -	- -	
	11	17.7	4.8	3.9	9.5	14.3	+ 5
Medium Grind	0	30.1	4.1	3.4	9.0	13.1	
	1	29.8	3.8	- -	- -	- -	
	3	28.7	4.2	3.6	9.1	13.3	
	5	28.0	4.0	- -	- -	- -	
	7	26.7	4.2	3.7	9.0	13.2	
	9	23.5	4.0	- -	- -	- -	
	11	23.3	4.3	3.9	9.4	13.7	+ 5
Coarse Grind	0	32.3	3.8	3.0	8.9	12.7	
	1	31.8	3.5	- -	- -	- -	
	3	31.4	3.9	3.2	8.9	12.8	
	5	30.9	4.0	- -	- -	- -	
	7	30.2	4.0	3.3	8.9	12.9	
	9	29.0	4.0	- -	- -	- -	
	11	27.8	4.0	3.5	9.2	13.2	+17

The finely ground hay decreased the percentage of acetic acid in the rumen (Table 6 and Appendix Table 3) and increased the percentage of propionic acid. Only a very slight depression in acetic and increase in propionic occurred in the cows receiving the medium ground hay. The VFA ratios of rumen fluid from animals fed coarsely ground hay were considered to be normal.

Discussion. As has been indicated by numerous workers previously (Powell, 1938; Ensor, 1959; King and Hemken, 1962; Ronning, 1960) finely ground hay will depress the fat content of milk. Also, as has been shown previously, the depression in fat test accompanies a reduction in the concentration of rumen acetic acid and an increase in concentration of rumen propionic acid. It is apparent from the data presented here that particle size reduction of the hay has an important bearing on these changes. Also, it is apparent that there is a minimum particle size reduction which apparently, under a given set of conditions, will not alter milk fat test or rumen VFA concentrations. The medium ground hay appears to approach this minimum particle size. The finely ground hay depressed milk fat test during the first 6 weeks and rumen acetic acid percentage during the first 7 weeks of the experiment. Thereafter both fat test and rumen acetic acid percentage increased. It might be conjectured that cows fed finely ground hay rations may be able to adapt to these rations in 7 weeks. This adaptation period has not been observed in other work possibly because the experiments have not been of sufficient duration to observe this effect. In previous studies at this station (Hand, 1960), cows receiving finely ground roughage rations exhibited signs of ketosis. This same condition was observed in three animals receiving the finely ground hay.

Table 6

Effect of fineness of hay grind on mean volatile fatty acid composition of rumen fluid (Experiment I)

		Weeks					
Group	VFA	0	3	5	7	9	11
		Molar %					
Fine Grind							
	acetic	68.3	61.6	62.8	59.2	62.7	63.0
	propionic	16.2	20.6	21.5	24.6	22.9	20.9
	butyric	13.1	14.4	13.0	13.1	12.2	13.6
	valeric	2.4	3.4	2.7	3.1	2.2	2.3
Medium Grind							
	acetic	68.5	64.0	64.0	65.5	65.3	66.4
	propionic	17.4	19.0	18.3	18.6	18.1	19.5
	butyric	11.9	13.9	14.4	12.8	13.3	11.8
	valeric	2.2	3.0	3.3	3.1	3.3	2.3
Coarse Grind							
	acetic	68.2	65.0	66.2	66.7	67.6	65.8
	propionic	18.0	18.0	16.8	17.9	17.7	18.6
	butyric	11.8	13.9	13.5	12.7	11.4	12.6
	valeric	2.0	3.1	3.4	2.7	3.3	3.0

It is not certain that this condition might be considered true ketosis. It is apparent that the condition should be studied in greater detail particularly because of the present interest in low-roughage, high-concentrate rations.

Experiment II. Effects of Steamed or Pelleted Hay on Milk Composition and Yield

The medium ground hay used in Experiment I appeared to approach the maximum particle size reduction which would not depress milk fat test, alter rumen VFA ratios, or depress rumen activity. Since the medium ground hay appeared to be on the border line of producing a depressing effect, it was decided to use a comparable particle size to determine the effect of heating and/or pelleting hay on milk fat test and rumen VFA ratio.

Experimental Procedure. Twelve lactating cows (Holsteins, Ayrshires, Jerseys and Guernseys) were assigned to three groups which were as similar as possible with regard to breed, stage of lactation, milk production and milk fat test.

The alfalfa hay used in Experiment I was used in Experiment II also. The coarsely ground hay used in Experiment I was reground with a Prater hammer mill (1760 rpm) having a 2 in. screen. The ground hay was then steam conditioned and pelleted employing a California pellet mill with a 3/4 in. round hole die. A second group of coarsely ground hay was reground through a 3/4 in. screen (Prater hammer mill, 1760 rpm) and steam heated in the conditioning chamber of the California pellet mill. This hay was not pelleted. The three groups of cows were assigned at random to the following roughage rations: medium ground hay, medium ground pelleted hay, and medium ground steam conditioned hay. The objective in hay preparation was to have all the hays with approximately the same particle size after processing. The procedures used above were established after trial and error. The steaming of hay was done to isolate the effect of heating which occurs during pelleting from other factors involved in pelleting such as pressure.

The cows were treated in a similar manner to that of Experiment I. Milk and rumen samples were obtained and analyzed as described in Experiment I. Grain and hay were fed as was done in Experiment I. The duration of the experiment was 10 weeks.

Results. The hay was processed so as to arrive at a finished product similar in particle size distribution to the medium ground hay of Experiment I. That this was essentially accomplished is evident from the data presented in Table 4. The pelleted hay had a slightly smaller particle size than the steam conditioned hay even though a larger particle size was used before pelleting.

After the preliminary period, some difficulty was encountered in getting the cows to consume the 3/4 in. hay pellets. It required approximately 1 week to get the animals to consume the pelleted hay readily. No difficulty was encountered in feed consumption or rumen activity in any of the groups. It is apparent from the data presented in Table 7 that the three forms of hay did not differ in their effect on fat or protein content of milk. Also total solids appeared not to be affected by the form of roughage fed. The mean milk yield increased the first 2 weeks in the groups receiving the steamed and control hays. Milk production declined and body weight increased to the greatest extent in the group receiving pelleted hay. Acetic acid declined slightly and propionic increased slightly in rumen fluid from cows on all three rations (Table 8). There appeared to be no difference in VFA ratios among rations.

Table 7

Effect of conditioning and pelleting hay on mean milk yield, composition of milk, and body weight change (Experiment II)

Group	Weeks	Milk	Fat	Protein	Solids-not-fat	Total solids	Weight change
		(lb)	----------------	----------------	(%)	----------------	(lb)
Pelleted	0	31.5	4.1	3.7	9.0	13.1	
	2	29.0	3.9	- -	- -	- -	
	4	28.6	3.9	3.6	9.1	13.0	
	6	27.1	4.0	- -	- -	- -	
	8	24.8	3.9	3.7	9.1	13.0	
	10	22.2	4.1	3.7	9.0	13.1	+65
Steamed	0	33.8	3.9	3.4	9.2	13.1	
	2	34.8	3.7	- -	- -	- -	
	4	34.8	3.9	3.3	9.0	12.9	
	6	33.0	3.9	- -	- -	- -	
	8	31.1	3.9	3.3	9.1	13.0	
	10	29.8	4.0	3.4	9.1	13.1	+ 9
Control (Medium grind)	0	35.1	4.0	3.6	8.9	12.9	
	2	37.5	3.8	- -	- -	- -	
	4	35.9	3.9	3.5	9.2	13.1	
	6	34.2	4.0	- -	- -	- -	
	8	31.9	4.0	3.7	9.3	13.3	
	10	30.0	4.2	3.9	9.6	13.8	+33

Discussion. The particle size of the hays used in the experiment reported here appeared to be on the borderline of producing a milk fat depressing effect. This conclusion is substantiated by the slight depression in rumen acetic acid which occurred in all three groups.

It would appear from the results of Experiments I and II that the degree of particle size reduction of ground hay has more influence on fat content of milk and ratio of rumen VFA than heating or pelleting treatments. Other workers have reported conflicting results concerning the effect of pelleted hay on milk fat depression. This is undoubtedly because sufficient attention was not paid to particle size of the pelleted hay. King and Hemken (1962) and Porter _et al_. (1953) concur with the results reported here inasmuch as they consider fineness of grind to be a more important factor affecting milk composition than pelleting _per se_. Also, Minson (1963) did not find pelleted coarsely ground hay to depress milk fat test. Huber and Boman (1966) observed an increase in milk protein and SNF content when pelleted hay was fed. This effect was not observed in this experiment. It is possible that particle size of the hay was finer in the experiment of Huber and Boman (1966) than that used here.

Experiment III. Effects of Pelleted Hay with or without Pelleted Grain on Milk Composition and Yield

Adequate data are unavailable concerning the relative effect on fat test depression of pelleted hay versus pelleted grain. The pelleted hay fed with ground grain in Experiment II appeared to be on the verge of depressing fat test. Consequently it appeared desirable to feed the pelleted hay ration with pelleted grain to determine the relative effect on milk fat depression of hay and grain pellets.

Experimental Procedure. Eight lactating cows (Holsteins, Ayrshires, Jerseys and Guernseys) were paired as similarly as possible with regard to breed, stage of lactation, milk production and milk fat test. Cows in each pair were grouped at random. Cows in one group received the pelleted hay used in Experiment II and the grain mixture used in Experiments I and II. However, in this case the grain ration was ground through a 4/64 in. hammer mill screen and then pelleted employing a California pellet mill and a 1/4 in. round hole die. Cows in the other group received the same pelleted hay with the same grain ration. The grain ration was also ground through a 4/64 in. hammer mill screen to provide a uniform grain particle size for both groups. The particle size of the grain ration was considerably smaller than that which had been fed in Experiments I and II.

Feeding and management was similar to that of Experiments I and II. Also, collection of milk and rumen samples and their analysis were similar to that of the first two experiments. The duration of Experiment III was 8 weeks.

Results. At first there was some reluctance by the cows to consume the grain in the meal form. However, after a few days they consumed their entire feed allowance. It is apparent from the data presented in Table 9 that milk fat was not depressed by the pelleted medium ground hay and ground grain ration. When the grain ration was fed in the pelleted form with the pelleted medium ground hay, the milk fat test appeared to be slightly depressed. The protein content of the milk from cows receiving ground grain increased during the 8-week experimental period. However, the milk of the cows receiving the pelleted

Table 8

Effect of conditioning and pelleting hay on mean volatile fatty acid composition of rumen fluid (Experiment II)

Group	VFA	Weeks 0	2	4	6	8	10
		---------	---------	Molar %	---------	---------	---------
Pelleted							
	acetic	67.6	65.8	64.7	65.0	63.6	65.0
	propionic	17.3	17.0	18.1	17.5	18.6	18.6
	butyric	12.3	14.4	13.7	14.2	14.0	13.4
	valeric	2.8	2.8	3.5	3.3	3.8	3.0
Steamed							
	acetic	65.8	64.2	64.6	66.1	64.9	65.4
	propionic	17.2	18.5	19.5	17.5	17.8	17.7
	butyric	13.7	13.9	12.9	13.8	13.5	14.3
	valeric	3.3	3.4	3.0	2.6	3.7	2.6
Control (Medium grind)	acetic	67.1	65.4	61.9	65.5	64.4	64.6
	propionic	17.6	18.4	19.0	17.7	18.4	19.2
	butyric	12.2	13.2	17.8	13.2	13.8	12.7
	valeric	3.1	3.0	1.3	3.6	3.4	3.5

grain did not change in protein content during this same period. Both groups declined in milk production and increased in body weight during the 8 week period. These changes were similar and apparently were not influenced by ration differences.

The ratio of acetic to propionic acid in rumen content of the cows receiving the ground grain became slightly narrower as the experiment progressed (Table 10). While this also occurred in the group receiving the pelleted grain ration, the narrowing of the acetic to propionic acid ratio was not so severe as that which occurred with the cows receiving ground grain. However, in neither case did the acetic acid reach the low levels or the propionic acid reach the high levels observed in Experiment I where finely ground hay depressed milk fat test. The VFA ratios of rumen fluid from the groups used in Experiment III appear very similar to those observed in Experiments I and II for the medium ground hay.

Discussion. Bishop *et al*. (1963) compared meal to pelleted concentrate ration fed with low or high levels of roughage. In both instances the pelleted concentrate depressed milk fat slightly but the differences were not statistically significant.

Hawkins *et al*. (1963) studied the effect on milk composition of feeding pelleted corn and oats at 19.75, 35, and 49% of the total ration. Molar ratios of VFA in rumen fluid were affected significantly by feeding rations containing 35 and 49% of pelleted corn or oats but not by rations containing 19.75% of these pelleted grains. Milk fat percentage was depressed by 35 and 49% pelleted corn rations but not by the 19.75% pelleted corn or pelleted oat rations.

Table 9

Effect of pelleted hay with ground or pelleted grain on mean milk yield, composition of milk and body weight change (Experiment III)

Group	Weeks	Milk	Fat	Protein	Solids-not-fat	Total solids	Weight change
		(lb)	---------------	------	(%)	---------------	(lb)
Hay pellets plus ground grain	0	33.8	3.8	3.4	9.1	12.9	
	2	32.7	3.5	- -	- -	- -	
	4	32.6	3.8	3.6	9.1	12.9	
	6	30.4	3.9	- -	- -	- -	
	8	27.2	3.8	3.9	9.6	13.4	+30
Hay pellets plus grain pellets	0	31.1	4.0	3.4	9.2	13.2	
	2	31.8	3.5	- -	- -	- -	
	4	31.0	3.5	3.5	9.3	12.8	
	6	28.6	4.0	- -	- -	- -	
	8	26.5	3.4	3.5	9.3	12.7	+41

Jorgensen and Shultz (1963) compared the feeding of 16 lb of ground corn with 16 lb of pelleted corn to cows receiving alfalfa hay ad libitum. The pelleted corn ration depressed milk fat test slightly. The reduction was from 3.8% to 3.3%. This reduction was statistically significant. Jorgensen and Shultz (1965) found a pelleted corn ration depressed milk fat significantly when compared with ground corn and when both concentrates were fed with 8 lb of alfalfa hay per cow per day. It would appear from the data presented in the literature that the feeding of pelleted concentrates can depress milk fat test. The extent to which they depress test depends on the quantity of concentrate and roughage fed. The effect is apparently more severe when large quantities of pelleted concentrate are fed with small quantities of roughage or when large quantities of concentrate are fed with pelleted roughages. The objective of the study reported here was to determine the relative effect of pelleted concentrate and pelleted roughage on depression of milk fat test. It would appear from the results of Experiments I, II and III that the feeding of pelleted concentrate is only a minor factor in milk fat depression if sufficient roughage of adequate particle size is fed. Furthermore, it appears that the degree of particle size reduction of ground hay has more influence on milk fat depression than heating or pelleting treatments of hay.

Table 10

Effect of pelleted hay with ground or pelleted grain on mean volatile fatty acid composition of rumen fluid (Experiment III)

Group	VFA	Weeks 0	2	4	6	8
		Molar %				
Hay pellets plus ground grain						
	acetic	64.5	65.0	65.3	64.5	63.7
	propionic	18.4	18.1	18.8	22.4	21.8
	butyric	13.7	12.8	11.8	11.1	11.8
	valeric	3.4	4.1	4.1	2.0	2.7
Hay pellets plus grain pellets						
	acetic	65.4	65.0	65.9	67.4	65.4
	propionic	16.4	18.6	15.9	16.9	19.1
	butyric	13.7	12.6	13.8	13.3	12.4
	valeric	4.5	3.8	4.4	2.4	3.1

SUMMARY

Three feeding experiments were conducted to evaluate the effects of grinding, steam heating or pelleting hay on rumen volatile fatty acid ratios, milk yield and composition. The effects of a pelleted versus unpelleted grain ration were studied also.

Twelve lactating cows were distributed among three groups. The groups were assigned to three rations which were similar except that the hay fed was ground to three different degrees of fineness: coarse grind (1/2 in. screen in Gehl chopper); medium grind (Prater hammer mill without screen); and fine grind (Prater hammer mill with 4/64 in. screen). The particle size distribution of ground hay was determined by wet sieving. The per cent hay retained on Tyler sieves of size 16 or larger was: coarse, 66.88; medium, 39.77; and fine, 0.88.

The finely ground hay depressed milk fat test during the first 5 weeks when it decreased from 4.6 to 3.9%. From 6 to 11 weeks the test gradually increased. The medium and coarse ground hay did not depress milk fat. It was not possible to attribute a ration effect to changes in protein or solids-not-fat content of milk or production of milk. The changes that occurred appear to be normal changes associated with advancing lactation. The finely ground hay decreased the percentage of acetic acid (68.3 to 59.2%) and increased the percentage of propionic acid (16.2 to 24.6%). These changes occurred within the first 7 weeks. Only a slight depression in acetic and increase in propionic occurred in the cows receiving the medium ground hay. The coarse ground hay did not influence rumen volatile fatty acid ratios. The majority of animals receiving the finely ground hay developed digestive disorders.

A second experiment employing 12 cows was conducted to determine the effect of heating and/or pelleting hay on milk composition. The cows were distributed among three groups and fed either medium ground hay, medium ground hay conditioned with steam (80 C), or medium ground hay steamed and pelleted (3/4 in. round hole die). All hays had approximately the same particle size after pelleting or other treatments. Steam heating or pelleting hay did not influence milk yield, milk composition or rumen VFA concentration.

In a third experiment, the pelleted hay used in the second trial was fed with either a pelleted (1/4 in. round hold die) or unpelleted concentrate ration. Eight cows distributed among two groups were used.

The group receiving the unpelleted concentrate declined 0.3% in milk fat test while those receiving the pelleted concentrate decreased 0.5%. Protein content of the milk increased in the group receiving ground grain. Both groups declined in milk production and increased in body weight during the 8 week period. These changes were similar and apparently were not influenced by ration differences. No major differences occurred in the other parameters studied.

It would appear from the results of these three experiments that the feeding of pelleted concentrate is only a minor factor in milk fat depression if sufficient roughage of adequate particle size is fed. Furthermore, it appears that the degree of particle size reduction of ground hay has more influence on milk fat depression than heating or pelleting treatments of hay.

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Appendix Table 1

Milk composition
(Experiment I)

Group and Milk Constituent	Animal	Weeks 0	1	3	5	7	9	11
		-%						
Fine Grind								
Fat	440B	5.0	4.7	4.5	4.2	4.9	4.4	5.4
	4R	4.3	3.8	3.7	3.6	3.6	3.8	4.2
	Mean	4.6	4.3	4.1	3.9	4.3	4.1	4.8
Protein	440B	3.8		4.0		3.9		4.1
	4R	3.3		3.5		3.6		3.7
	Mean	3.5		3.7		3.8		3.9
Total Solids	440B	14.6		14.1		14.2		15.0
	4R	13.4		13.1		13.0		13.6
	Mean	14.0		13.6		13.6		14.3
Medium Grind								
Fat	484B	4.2	4.2	4.3	4.3	4.8	5.2	4.7
	214C	4.0	4.1	4.1	4.0	4.0	4.5	4.6
	299B	4.8	3.3	3.7	4.0	4.0	4.2	4.2
	127C	3.4	3.6	4.0	3.7	3.7	4.6	3.8
	122C	3.9	3.9	4.8	4.1	4.2	4.5	4.0
	Mean	4.1	3.8	4.2	4.0	4.2	4.0	4.3
Protein	484B	3.2		3.4		3.6		3.8
	214C	3.3		3.4		3.6		3.8
	299B	3.2		3.8		3.8		4.0
	127C	3.4		3.6		3.5		3.7
	122C	3.6		3.7		3.9		4.1
	Mean	3.4		3.6		3.7		3.9
Total Solids	484B	13.2		13.3		13.8		14.1
	214C	13.0		13.3		13.1		13.9
	299B	13.5		13.2		13.2		13.7
	127C	12.3		12.9		12.5		12.8
	122C	13.5		14.8		13.6		13.9
	Mean	13.1		13.3		13.2		13.7

Appendix Table 1 Cont.

Group and Milk Constituent	Animal	Weeks 0	1	3	5	7	9	11
		--------------------			%			--------------------
Coarse Grind								
Fat	34B	5.1	3.8	5.3	5.1	5.0	5.0	5.0
	209C	4.0	3.7	3.8	4.2	4.0	4.3	4.4
	163C	3.2	3.0	3.1	3.3	3.1	3.2	3.4
	160C	3.6	3.2	3.4	3.3	3.7	3.5	3.3
	Mean	3.8	3.5	3.9	4.0	4.0	4.0	4.0
Protein	34B	3.4		3.5		3.6		3.9
	209C	2.8		3.4		3.5		3.8
	163C	2.8		3.0		3.1		3.1
	160C	2.8		3.0		3.0		3.1
	Mean	3.0		3.2		3.3		3.5
Total Solids	34B	14.3		14.6		14.3		14.4
	209C	13.0		12.7		12.9		13.8
	163C	12.0		11.8		11.9		12.4
	160C	11.7		12.2		12.4		12.2
	Mean	12.7		12.8		12.9		13.2

Appendix Table 2

Milk production and body weight (lb)
(Experiment I)

Group	Cow No.	Weeks 1	3	5	7	9	11	Body Weight Beginning	End
		---lb---						---lb---	
Fine Grind	440B	189.5	360.4	344.9	323.5	293.7	269.3	1103	1132
	4R	135.6	279.7	258.5	250.2	234.8	227.4	946	926
Medium Grind	484B	166.6	334.6	313.0	277.8	241.8	238.5	795	811
	214C	180.6	338.9	332.7	316.5	278.5	258.2	822	822
	299B	160.3	345.1	307.6	295.3	270.1	266.2	1113	1138
	127C	291.8	550.8	545.1	542.6	465.7	486.9	1258	1278
	122C	243.4	439.9	460.6	437.8	385.6	381.5	1296	1262
Coarse Grind	34B	226.5	461.3	449.8	436.8	386.5	368.7	945	979
	209C	144.9	301.2	288.4	265.8	256.2	240.1	968	980
	160C	270.9	492.7	513.9	497.9	505.4	490.2	1220	1230
	163C	248.2	504.5	477.2	492.1	467.0	460.1	1111	1121

Appendix Table 3

Effect of fineness of hay grind on rumen volatile fatty acids
(Experiment I)

Group	Animal	VFA	Weeks 0	3	5	7	9	11
			--------------------Molar %--------------------					
Fine Grind								
	440B	C-2	67.1	61.1	61.0	59.5	61.5	63.6
		C-3	16.9	22.0	24.3	26.4	24.9	21.3
		C-4	13.5	13.2	11.5	10.8	12.0	13.0
		C-5	2.5	3.7	3.2	3.3	1.6	2.0
	4R	C-2	69.5	62.2	64.7	58.9	63.8	62.8
		C-3	15.6	19.2	18.8	22.7	20.9	20.6
		C-4	12.6	15.6	14.6	15.3	12.4	14.2
		C-5	2.3	3.0	1.9	3.1	2.9	2.4
Medium Grind								
	484B	C-2	70.7	64.8	64.9	65.3	65.5	66.9
		C-3	15.8	20.0	18.9	19.3	17.8	18.8
		C-4	10.0	12.3	13.4	12.6	13.5	11.2
		C-5	3.5	2.9	2.8	2.8	3.2	3.1
	214C	C-2	66.9	63.0	64.6	67.7	67.4	67.2
		C-3	15.9	18.5	18.4	17.2	16.3	19.4
		C-4	14.3	16.4	12.6	12.7	13.7	11.0
		C-5	2.9	2.1	4.4	2.3	2.6	2.4
	299B	C-2	68.9	64.5	63.6	65.4	67.5	67.4
		C-3	18.8	18.7	18.8	18.7	18.6	19.1
		C-4	10.6	12.8	15.4	12.7	11.5	11.6
		C-5	1.7	4.0	2.2	3.2	2.2	1.9
	127C	C-2	68.3	64.0	64.7	66.2	63.4	63.4
		C-3	17.2	18.3	18.2	16.9	19.1	19.7
		C-4	13.1	14.5	13.7	13.5	14.4	14.6
		C-5	1.4	3.2	3.4	3.4	3.1	2.3
	122C	C-2	67.6	63.7	62.5	63.0	63.7	67.1
		C-3	18.4	19.6	17.1	20.8	19.0	20.4
		C-4	11.6	13.3	15.8	12.7	13.3	10.6
		C-5	2.4	3.4	4.5	3.4	4.0	1.9

Appendix Table 3 Cont.

Group	Animal	VFA	Weeks 0	3	5	7	9	11
			--------Molar %--------					
Coarse Grind								
	34B	C-2	67.4	65.0	64.9	64.5	66.1	64.5
		C-3	19.1	17.6	17.0	18.7	18.1	20.6
		C-4	11.3	14.7	13.7	13.9	11.9	11.5
		C-5	2.2	2.7	4.4	2.9	3.9	3.4
	209C	C-2	69.0	66.3	66.6	66.9	67.5	67.1
		C-3	16.3	18.0	17.4	18.3	17.1	17.6
		C-4	13.1	12.6	12.9	12.1	11.9	12.9
		C-5	1.6	3.1	3.1	2.7	3.5	2.3
	160C	C-2	67.0	65.1	65.3	67.2	67.6	65.5
		C-3	18.3	18.5	15.7	17.7	18.0	17.8
		C-4	12.2	13.4	16.0	12.5	11.2	13.8
		C-5	2.5	3.0	3.0	2.6	3.2	2.9
	163C	C-2	69.9	63.4	68.1	68.2	69.1	65.9
		C-3	17.3	17.7	17.1	17.0	17.5	18.4
		C-4	10.8	15.0	11.6	12.1	10.7	12.4
		C-5	2.0	3.9	3.2	2.6	2.6	3.3

Appendix Table 4

Milk composition
(Experiment II)

Group and Milk Constituent	Animal	Weeks 0	2	4	6	8	10
		--------	--------	--------	%	--------	--------
Pelleted							
Fat	122C	4.5	4.2	4.3	4.2	4.1	3.8
	34B	5.0	4.8	4.9	4.9	4.8	5.7
	184B	3.2	3.1	3.0	3.2	3.1	3.2
	160C	3.6	3.4	3.4	3.6	3.5	3.4
	Mean	4.1	3.9	3.9	4.0	3.9	4.1
Protein	122C	4.4		4.3		4.7	4.7
	34B	3.8		3.7		3.8	3.7
	184B	3.3		3.3		3.3	3.2
	160C	3.2		3.2		3.2	3.2
	Mean	3.7		3.6		3.7	3.7
Total Solids	122C	14.3		14.3		14.5	14.2
	34B	14.1		14.0		13.8	14.4
	184B	11.5		11.4		11.4	11.5
	160C	12.7		12.5		12.3	12.5
	Mean	13.1		13.0		13.0	13.1
Steamed							
Fat	145C	3.5	3.2	3.5	3.4	3.5	3.5
	167C	3.6	3.8	3.8	3.8	3.9	3.8
	474B	4.7	4.4	4.8	4.8	4.6	4.7
	206C	3.7	3.5	3.5	3.7	3.7	3.9
	Mean	3.9	3.7	3.9	3.9	3.9	4.0
Protein	145C	3.5		3.4		3.4	3.5
	167C	3.2		3.1		3.2	3.2
	474B	3.6		3.3		3.5	3.5
	206C	3.4		3.3		3.3	3.5
	Mean	3.4		3.3		3.3	3.4
Total Solids	145C	12.8		12.4		12.5	12.6
	167C	12.5		12.6		12.6	12.9
	474B	13.9		13.9		13.9	13.9
	206C	13.1		12.5		12.7	13.0
	Mean	13.1		12.9		13.0	13.1

Appendix Table 4 Cont.

Group and Milk Constituent	Animal	Weeks					
		0	2	4	6	8	10
		%					
Control (Medium Grind)							
Fat	169B	3.4	3.3	3.4	3.1	3.3	3.3
	139C	4.1	3.8	3.9	3.9	3.8	4.5
	6B	4.7	4.5	4.8	4.6	4.7	4.2
	163C	3.7	3.5	3.7	4.3	4.1	4.8
	Mean	4.0	3.8	3.9	4.0	4.0	4.2
Protein	169B	3.9		3.4		3.3	3.3
	139C	3.8		3.7		3.7	3.5
	6B	3.5		3.1		3.1	3.3
	163C	3.5		3.8		4.4	5.1
	Mean	3.6		3.5		3.7	3.9
Total Solids	169B	12.1		12.1		12.0	12.4
	139C	13.4		13.2		13.2	13.8
	6B	13.9		13.6		13.6	13.2
	163C	13.1		13.4		14.5	15.8
	Mean	12.9		13.1		13.3	13.8

Appendix Table 5

Milk production and body weight (lb)
(Experiment II)

Group	No.	Weeks 2	4	6	8	10	Body Weight Beginning	End
		-----------------		lb		-----------------	------lb-------	
Pelleted	122C	393.2	383.2	342.7	280.0	206.1	1263	1390
	34B	324.4	307.4	297.2	260.3	185.4	979	1035
	184B	406.3	404.4	396.6	391.9	388.9	1505	1530
	160C	498.1	509.0	481.2	454.7	460.3	1230	1280
Steamed	145C	541.5	551.7	525.9	493.6	485.3	1115	1125
	167C	475.3	466.9	456.7	437.4	423.4	1055	1080
	206C	498.3	500.5	456.1	439.9	406.2	1028	1061
	474B	435.4	427.3	406.9	370.0	355.9	1017	986
Control (Medium grind)	169B	524.7	504.1	486.9	483.7	474.9	1160	1126
	139C	447.5	457.0	457.0	427.5	423.9	1327	1362
	6B	694.6	699.5	655.6	638.1	580.0	889	816
	163C	431.0	350.6	313.4	235.1	177.9	1120	1320

Appendix Table 6

Effect of conditioning and pelleting of hay on rumen volatile fatty acids (Experiment II)

Group	Animal	VFA	Weeks 0	2	4	6	8	10
			---	---	---	-Molar %-	---	---
Pelleted	122C	C-2	67.7	65.8	64.3	64.3	63.1	63.2
		C-3	17.2	17.9	17.6	18.7	17.7	20.3
		C-4	12.3	13.3	14.0	13.4	15.2	12.8
		C-5	2.7	3.0	4.1	3.6	4.0	3.7
	34B	C-2	67.9	62.2	64.2	65.4	64.2	65.0
		C-3	16.1	15.6	19.6	17.4	20.0	17.6
		C-4	13.1	18.7	12.7	14.2	12.5	14.3
		C-5	2.9	2.6	3.5	3.0	3.3	3.1
	184B	C-2	67.1	69.0	64.0	66.5	63.6	66.0
		C-3	16.8	16.8	17.8	17.3	18.7	18.7
		C-4	12.5	11.8	15.0	13.1	13.3	12.9
		C-5	3.6	2.4	3.2	3.1	4.3	3.4
	160C	C-2	67.6	66.1	66.5	63.9	63.5	65.6
		C-3	19.2	17.6	17.4	16.5	18.0	17.7
		C-4	11.4	13.7	13.1	16.3	14.9	13.8
		C-5	1.8	2.6	3.0	3.2	3.6	2.9
Steamed	145C	C-2	64.5	64.5	61.6	65.5	65.4	65.1
		C-3	18.4	18.9	25.6	17.0	18.1	16.7
		C-4	14.5	13.9	10.6	15.4	13.5	14.7
		C-5	2.6	2.7	2.2	2.1	3.0	3.5
	167C	C-2	67.7	65.2	65.9	68.0	67.0	65.1
		C-3	17.4	18.2	16.9	16.5	17.2	16.7
		C-4	11.2	12.8	14.0	11.7	12.1	14.7
		C-5	3.7	3.8	3.2	3.8	3.7	3.5
	206C	C-2	65.3	64.4	66.5	66.8	64.1	66.0
		C-3	16.0	18.0	17.9	18.1	17.7	17.4
		C-4	15.1	13.9	12.7	13.0	13.4	13.4
		C-5	3.8	3.7	2.9	2.1	4.8	3.2
	474B	C-2	65.6	62.8	64.5	64.2	63.1	65.0
		C-3	17.1	19.1	17.5	17.5	18.0	18.2
		C-4	13.9	15.0	14.2	15.2	15.0	14.5
		C-5	3.4	3.1	3.8	3.1	4.9	2.3

Appendix Table 6 Cont.

Group	Animal	VFA	Weeks 0	2	4	6	8	10
			--------	--------	--------	Molar %	--------	--------
Control (Medium Grind)	169B	C-2	66.7	63.6	66.4	65.0	66.1	64.3
		C-3	17.6	19.2	18.8	18.7	17.2	19.5
		C-4	11.9	13.3	12.0	12.2	13.4	12.6
		C-5	3.8	3.9	2.8	4.1	3.3	3.6
	139C	C-2	67.8	66.9	64.0	67.3	62.7	66.0
		C-3	18.2	17.7	17.8	16.5	19.1	19.5
		C-4	11.2	12.3	14.2	13.4	14.5	11.8
		C-5	2.8	3.1	4.0	2.8	3.7	2.7
	6B	C-2	66.9	63.7	54.8	63.2	64.0	62.2
		C-3	16.9	18.1	20.8	18.5	18.8	19.2
		C-4	12.9	15.2	20.6	15.0	13.6	14.8
		C-5	3.3	3.0	3.8	3.3	3.6	3.8
	163C	C-2	66.9	67.3	62.4	66.6	64.8	66.0
		C-3	17.6	18.8	18.6	17.2	18.4	18.7
		C-4	12.9	11.9	14.6	12.3	13.8	11.5
		C-5	2.6	2.0	4.4	3.9	3.0	3.8

Appendix Table 7

Milk composition
(Experiment III)

Group and Milk Constituent	Animal	Weeks 0	2	4	6	8
		-----	-----	%	-----	-----
Hay pellets plus grain meal						
Fat	6B	4.2	3.7	4.1	4.5	4.1
	206C	3.9	3.6	3.6	3.6	3.5
	167C	3.8	3.6	4.1	4.1	4.3
	169B	3.3	3.0	3.5	3.4	3.2
	Mean	3.8	3.5	3.8	3.9	3.8
Protein	6B	3.3		3.7		3.5
	206C	3.5		3.5		3.8
	167C	3.2		3.4		3.4
	169B	3.6		3.7		3.9
	Mean	3.4		3.6		3.9
Total Solids	6B	12.2		13.5		13.4
	206C	13.0		12.9		13.0
	167C	12.9		13.0		14.5
	169B	12.4		12.2		12.6
	Mean	12.9		12.9		13.4
Hay pellets plus grain pellets						
Fat	139C	3.7	3.6	3.4	4.1	3.6
	145C	3.5	2.8	2.9	3.5	3.1
	474B	4.7	4.3	4.5	4.7	3.9
	160C	3.4	3.3	3.1	3.4	3.1
	Mean	4.0	3.5	3.5	4.0	3.4
Protein	139C	3.5		3.9		4.2
	145C	3.5		3.6		3.5
	474B	3.5		3.5		3.2
	160C	3.2		3.2		3.2
	Mean	3.4		3.5		3.5
Total Solids	139C	13.8		13.1		13.7
	145C	12.7		12.2		12.3
	474B	13.9		13.7		12.7
	160C	12.5		12.1		12.1
	Mean	13.2		12.8		12.7

Appendix Table 8

Milk production and body weight (lb)
(Experiment III)

Group	Cow No.	Weeks 2	Weeks 4	Weeks 6	Weeks 8	Body Weight Beginning	Body Weight End
		------------------------lb------------------------					
Hay pellets plus grain meal	6B	547.8	524.5	512.9	473.1	816	844
	206C	393.1	369.3	327.2	274.8	1061	1093
	167C	427.8	445.1	402.3	326.9	1080	1118
	169B	461.2	484.9	458.7	446.4	1126	1148
Hay pellets plus grain pellets	139C	455.7	453.9	438.8	391.2	1362	1426
	145C	500.2	512.8	496.4	466.8	1125	1180
	474B	365.7	318.8	242.6	213.0	986	984
	160C	459.3	450.3	423.9	415.5	1280	1329

Appendix Table 9

Effect of pelleting hay and grain on rumen volatile fatty acids (Experiment III)

Group	Animal	VFA	Weeks 0	2	4	6	8
			---Molar %---				
Hay pellets plus grain meal	6B	C-2	62.2	60.4	65.3	60.7	57.3
		C-3	19.2	24.1	18.0	26.8	29.5
		C-4	14.8	11.2	12.1	9.5	10.5
		C-5	3.8	4.3	4.6	3.0	2.7
	206C	C-2	66.0	64.3	65.8	67.4	66.7
		C-3	17.4	17.5	16.3	16.3	18.2
		C-4	13.4	14.2	13.1	13.2	12.3
		C-5	3.2	4.0	4.8	3.1	2.8
	167C	C-2	65.3	67.6	67.6	67.0	64.3
		C-3	17.6	15.1	15.0	17.8	19.1
		C-4	14.0	13.0	13.5	12.5	13.8
		C-5	3.1	4.3	3.9	2.7	2.8
	169B	C-2	64.3	67.5	62.7	59.0	66.7
		C-3	19.5	15.5	26.0	28.8	20.3
		C-4	12.6	12.9	8.4	9.3	10.3
		C-5	3.6	4.1	2.9	2.9	2.7
	Average	C-2	64.5	65.0	65.3	64.5	63.7
		C-3	18.4	18.1	18.8	22.4	21.8
		C-4	13.7	12.8	11.8	11.1	11.8
		C-5	3.4	4.1	4.1	2.0	2.7
Hay pellets plus grain pellets	139C	C-2	66.0	66.7	68.4	68.6	65.2
		C-3	19.5	16.6	16.3	15.7	20.3
		C-4	11.8	12.7	11.3	13.5	11.4
		C-5	2.7	4.0	4.0	2.2	3.1
	145C	C-2	65.1	61.6	64.7	65.5	63.9
		C-3	16.7	24.3	16.4	18.6	21.4
		C-4	14.7	10.6	15.4	13.7	11.8
		C-5	3.5	3.5	3.5	2.2	2.9
	474B	C-2	65.0	65.5	65.7	67.4	65.6
		C-3	18.2	16.1	15.3	17.1	16.9
		C-4	14.5	14.5	14.4	13.1	14.1
		C-5	2.3	3.9	4.6	2.4	3.4
	160C	C-2	65.6	66.1	65.0	68.2	66.8
		C-3	17.7	17.5	15.5	16.1	17.8
		C-4	13.8	12.7	14.0	13.0	12.2
		C-5	2.9	3.7	5.5	2.7	3.2
	Average	C-2	65.4	65.0	65.9	67.4	65.4
		C-3	16.4	18.6	15.9	16.9	19.1
		C-4	13.7	12.6	13.8	13.3	12.4
		C-5	4.5	3.8	4.4	2.4	3.1

EFFECTS OF GROUND, STEAM HEATED AND PELLETED HAY WITH AND WITHOUT PELLETED GRAIN ON MILK PRODUCTION AND COMPOSITION

by

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Feeding experiments were conducted to evaluate the effects of grinding, steam heating or pelleting hay on rumen volatile fatty acid (VFA) ratios, milk yield and composition.

Twelve lactating cows were distributed among three groups. The groups were assigned to three rations which were similar except that the hay fed was ground to three different degrees of fineness: coarse grind (1/2 in. screen in Gehl chopper); medium grind (Prater hammer mill without screen); and fine grind (Prater hammer mill with 4/64 in. screen). The particle size distribution of the ground hay was determined by wet sieving. The per cent hay retained on Tyler sieves of 16 or larger was: coarse, 66.88; medium, 39.77; and fine, 0.88. Feeding finely ground hay resulted in narrowing the acetic to propionic ratio of rumen fluid and depressing milk fat test during the first 6 to 7 weeks of an 11 week trial. The medium and coarse ground hay did not depress milk fat test or influence rumen VFA ratios. Changes in protein or solids-not-fat content of milk could not be attributed to ration differences. The majority of animals receiving the finely ground hay developed digestive disorders.

A second experiment employing 12 cows was conducted to determine the effect of heating and/or pelleting hay on milk composition. The cows were distributed among three groups and fed either medium ground hay; medium ground hay conditioned with steam (80 C); or medium ground hay steamed and pelleted (3/4 in. round hold die). All hays had approximately the same particle size after pelleting or other treatment. Steam heating nor pelleting the hay influenced milk yield, milk composition or rumen VFA concentration.

In a third experiment, the pelleted hay used in the second trial was fed with either a pelleted (1/4 in. round hole die) or unpelleted concentrate ration. Eight cows distributed among two groups were used. The pelleted grain ration decreased milk fat test slightly. No major differences occurred in the other parameters studied during the 8 week experiment except that protein content of milk increased in the group receiving ground grain.

It would appear from the results of these three experiments that the feeding of pelleted concentrate is only a minor factor in milk fat depression if sufficient roughage of adequate particle size is fed. Furthermore, it appears that the degree of particle size reduction of ground hay has more influence on milk fat depression than heating or pelleting treatments.