

THE EFFECTS OF VARIOUS NUTRITIONAL FACTORS
ON THE COMPOSITION OF MILK

by

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INTRODUCTION

Milk has long been recognized for its high nutritional value. For many years, milk composition was considered unalterable, regardless of source and level of nutrients supplied to the cow. During the last decade evidence has accumulated showing that various feeding regimes cause definite changes in milk composition. The milk constituent most easily varied is fat; while protein is changed less readily; and lactose and minerals are more difficult to alter by feeding. A knowledge of nutritional factors affecting milk composition is important because the pricing structure of milk in the future will probably be based on constituents other than fat. Furthermore, the consumer is becoming increasingly aware of the various constituents in milk. Feeding practices which would consistently increase protein and other milk solids would appear to have a widespread beneficial effect.

The objectives of this study were: to investigate changes occurring in milk composition resulting from feeding a restricted-roughage, high-concentrate ration; to observe the effects of replacing the corn of a concentrate mix with lactose, a readily available carbohydrate, in an otherwise normal ration; to investigate changes in certain blood and rumen constituents which may be associated with the different rations; and to study the efficiency of conversion of feed protein to milk protein on the various dietary regimes.

REVIEW OF LITERATURE

The Effect of Level and Form of Dietary Fiber

The influence of nutrition on milk composition was suggested by Kellner as early as 1915. Abnormally low milk fat of a herd (2.10 and 2.45% on successive tests) was attributed to the low roughage content of the ration (brewer's grains, mangels, and potato slump). Powell (1938, 1939, 1941) was the first to report that fine grinding and restricted intake of roughage reduced the fat content of milk by as much as 40 to 60%, slightly decreased the solids-not-fat (SNF), and did not affect the milk yields. Loosli et al. (1945) confirmed these findings when they fed as little as 5 lb. of hay daily and enough grain to meet the energy requirements. However, the magnitude of the decrease in milk fat was not as great as reported by Powell, probably because the cows were in later stages of lactation and yielding less milk. Wisconsin workers (Stoddard et al., 1949; Tyznik and Allen, 1951) observed that a marked decline in milk fat to levels of 1 to 2% and no appreciable change in SNF resulted from feeding 3 to 6 lb. of hay daily and concentrates ad libitum. Reductions in milk fat and slight increases in SNF percentages have usually resulted from feeding rations containing less than 8 lb. of hay and concentrates fed at or above recommended standards (Balch et al., 1952, 1954a, b, and 1955b; Boyd and Mathew, 1962).

Grinding of the hay portion of the ration with or without pelleting has generally resulted in depressions in milk fat percentages (Keith, 1961; Jorgensen and Schultz, 1963; Porter et al., 1953; King and

Hemken, 1962). This effect is more marked if roughage intake is also at a low level (Powell, 1938; Balch et al., 1954a; Fosslund and Fitch, 1958; Ensor et al., 1959; Porter et al., 1953) or if high levels of concentrates are fed (Ronning, 1960; Balch et al., 1954a; Ensor et al., 1959; Broster and Tuck, 1961; King and Hemken, 1962). Failure by some workers to obtain a depression in percent milk fat when pelleted hay was fed may be explained by relatively coarse grinding (Rodrigue and Allen, 1960; Ronning, 1960; Putnam and Davis, 1961) or high intakes (Ronning et al., 1959; Palmquist and Ronning, 1961; Blosser et al., 1952; Bringe et al., 1958; Ensor et al., 1959) of the hay.

Depressions in the fat content of milk have occurred in cows grazing young succulent pasture, leafy oats, and pearl millet, when each was supplemented with concentrates (McClymont, 1950; Miller et al., 1963). A low intake of fiber was probably the cause of this decrease. When fairly mature oat pasture was grazed, no depression in milk fat was noted (McClymont, 1950).

Pelleting of the concentrate portion of the ration has resulted in decreases in the fat content of milk (Adams and Ward, 1956; Jorgensen and Schultz, 1963; Hawkins et al., 1963; Bishop et al., 1963). The depression was greater when hay was also pelleted (Jorgensen and Schultz, 1963) or forage was restricted (Bishop et al., 1963). Loosli et al. (1963) observed no difference in milk composition between concentrates pelleted at temperatures of 120 and 180° F. However, the pelleted concentrates depressed fat and increased protein when hay equivalent was fed at 0.5 and 1.0 lb. per 100 lb. body weight.

The type of grain in the concentrate also affects milk composition. Hawkins et al. (1963) noted a significant depression in milk fat on rations containing 35 and 49% pelleted corn. Small increases (non-significant) in milk fat were noted when pelleted oats was fed at similar levels. A decrease in the proportions of acetate to propionate in rumen fluid was noted when either corn or oats was pelleted, but there was an increase in rumen butyrate on pelleted oats. The relationship of rumen volatile fatty acids (VFA) to changes in milk composition will be discussed later. Balch et al. (1955b) showed that corn, fed with low levels of hay, was more effective in depressing the fat content of milk than a ration containing oats and barley.

Heat-treated concentrates have exerted a fat-depressing effect on milk. Ensor et al. (1959) fed 28 lb. pelleted hay plus 4 lb. heated corn or 6 lb. pelleted hay plus 18 lb. heated corn. Decreases in milk fat of 51 and 57%, respectively, were observed for the two rations after a 34-day feeding period. Shaw et al. (1959) cooked or heat-treated the high starch ingredients in a concentrate mix fed with only 6 lb. hay per day and observed decreases of 30 to 40% in the fat content of the milk produced. Balch et al. (1955b) fed 4 lb. hay daily plus one of three concentrate mixtures, containing 50% flaked corn (heat-treated), corn meal, or crushed oats and barley. In the last two weeks of the 12-week experimental treatment period, the adjusted mean fat percentages for the group of cows receiving flaked corn were 0.51 and 0.71 lower than those for the cows fed corn meal or the oats and barley mixes, respectively. Broster and Tuck (1961) observed decreases in the fat

content of milk when flaked corn was compared to corn meal with cows fed ground hay. King and Hemken (1962) observed slight (non-significant) decreases in milk fat when heated corn was compared to ground corn in rations where concentrates and roughages were fed at normal levels.

Feeding regimes which depress the fat content of milk also change the relative concentrations of VFA in rumen contents. Tyznik and Allen (1951) were first to report that the proportions of the ruminal VFA were altered (acetic decreased and propionic increased) by feeding high-concentrate, low-roughage rations to dairy cows. On normal diets acetic acid accounts, on a molar basis, for 60-65% of the total VFA, and propionic acid accounts for 18-22% (Rook, 1961). When fiber intake is low and grain high, the proportion of acetate may decrease to 35% and propionate may increase to 40% (Balch et al., 1955a; Balch and Rowland, 1957; Ensor et al., 1959; Shaw et al., 1959; Van Soest and Allen, 1959). The fall in milk fat is undoubtedly associated with this change (Rook, 1959 and 1961; Van Soest and Allen, 1959; Van Soest, 1963). It appears that the high levels of propionate produced on such rations has a marked antiketogenic effect, (Van Soest, 1963; Van Soest and Allen, 1959; Ensor et al., 1959) and thus reduces the availability of known milk fat precursors which are acetic acid and beta-hydroxybutyric acid.

Effect of Plane of Energy Nutrition

Field observations presented by Rowland in 1944 showed a decline in the SNF content of milk during the winter, but this was corrected in spring when cows went on pasture. It was suggested that

the low level of SNF was due to a low plane of nutrition. Two years later Rowland (1946) demonstrated higher SNF (8.68 vs. 8.50%) on a normal ration than one containing normal energy but 60% of the recommended protein. SNF was further reduced (8.34%) when cows were fed normal levels of protein and 75% of recommended energy. Decreased milk protein accounted for two-thirds of the decrease in SNF, while decreased lactose accounted for the other third. It is now widely recognized (Burt, 1957a; Rook, 1961; Elliot, 1962) that underfeeding of energy consistently results in a decrease in SNF content of milk.

An increase in the plane of energy nutrition of the cow is known to increase both yield and the SNF content of milk. A decrease in the fat content of milk may also occur but there is little effect on the yield of milk fat unless the fiber intake is restricted to very low levels (Burt, 1957a).

Significant increases (0.08%) in the SNF content of milk were observed by Burt (1957b) when dietary energy on high roughage rations was increased from 95 to 135% of recommended standards. Castle et al. (1958) fed normal levels of roughage and noted that a significant increase (0.11%) in SNF resulted from feeding 4 lb. of concentrates per gal. of milk compared to 2 lb. per gal. This change in SNF was almost entirely in the protein fraction. When the rate of concentrate feeding was increased from 2.6 lb. to 4.6 lb. per gal. of milk (Castle et al., 1959) there was a 0.15% increase ($P < .01$) in milk SNF (from 8.57 to 8.72%). The SNF in milk was 0.24% higher when the concentrate fed contained a starch equivalent of 79 rather than 63%. A direct relation

between the starch equivalent of a ration and SNF content of milk was reported in previous work by Holmes et al. (1956).

Holmes et al. (1957) fed cows a basal ration of grass products supplemented with concentrates at rates of 0, 2, 4 and 6 lb. per gal. milk produced and noted that SNF content of milk rapidly increased from 8.3 when no concentrates were fed to 8.6% when 4 or 6 lb. of concentrates per gal. of milk were fed. Later work by Holmes et al. (1960), in which varying levels of concentrates (1.25, 2.50, 3.75 and 5.00 lb. per gal. of milk) supplemented a ration of silage and hay fed ad libitum, showed that when concentrate consumption increased by 1 lb. of dry matter the consumption of hay and silage decreased by 0.18 to 0.22 lb. dry matter, respectively, but that the total fiber intake remained quite constant. The SNF content for the respective levels of supplementation (energy intake ranging from 83 to 116% of standards) were 8.42, 8.55, 8.63 and 8.71%. Spring grazing, undoubtedly due to an additional improvement in the plane of nutrition, raised the SNF to 8.91%.

In work by Castle et al. (1961), the daily addition of 60 lb. of fodder beet to a normal ration increased the daily dry matter intake from 29.1 to 35.4 lb. with resultant significant increases ($P < .01$) in both crude protein and casein contents of milk. These results were confirmed in a later experiment by Castle et al. (1963).

In a series of trials, Murdoch and Rook (1963) were unable to detect changes in composition or yield of milk with cows fed varying levels of silage or hay (made from the same sward) as long as total dry matter intakes were equal. When these feeds were offered ad

libitum, higher dry matter intakes were noted in the cows fed hay and there were subsequent increases in milk yields and the SNF content of milk.

Hotchkiss et al. (1960) fed four hay:concentrate ratios (75:25, 55:45, 35:65, 15:85 on a net energy basis) at each of three intake levels (high, medium, and low) for 12-week periods. The following significant ($P < .05$) effects were observed: 1) milk production was lower on the high hay ratio; 2) milk production and the protein and lactose content of milk were decreased by underfeeding; and 3) protein content of milk was higher on the high level of energy and at the two highest concentrate ratios.

Rook and Line (1961) imposed different planes of energy nutrition. One ration met the recommended energy standard, another provided 2.5 lb. of starch equivalent (S.E.) less than standard, and a third provided 5.0 lb. S.E. in excess of the standard. The results showed a slight decrease in fat content of milk on the highest level of energy and a significant increase ($P < .05$) in SNF. The latter effect was due mainly to an increase in milk protein. The increase in protein content was largely accounted for by an increased concentration of casein, but a significant increase also occurred in total albumin. There was a slight, but non-significant fall in milk lactose. The same workers compared high and low energy rations with cows in late lactation and noted similar changes in milk composition. Blood plasma glucose was slightly increased (significant at 8 hr. after feeding only) on the higher planes of nutrition, but the total blood plasma VFA and alpha-amino nitrogen were increased only at an extremely high level of energy.

Studies were conducted at the Virginia Station (Huber et al., 1964) in which cows grazing medium-quality pasture were supplemented with 1) ground-shelled corn, ad libitum; 2) ground-shelled corn plus corn silage, ad libitum; 3) ground-shelled corn (1 lb. per 6 lb. milk) plus corn silage ad libitum; and 4) corn silage ad libitum. Cows fed corn plus silage (rations 2 and 3) had the highest milk yields while SNF content of milk decreased as level of corn decreased (9.16, 8.92, 8.66 and 8.42% for consecutive groups). The milk protein accounted for most of the change in SNF. The fat content of milk was lower on high-corn rations (2.53, 3.23, 3.50 and 3.59%, respectively). The differences between the all corn and all silage groups for percent protein, SNF and fat in milk were all significant (P .05). Other pasture supplementation studies were conducted at the Virginia Station (Huber and Boman, 1965), in which high (22.6%) and low (8.3%) protein concentrates were fed at the rate of 1 lb. per 1.75, 3.5 and 7.0 lb. of milk to cows grazing medium-quality pastures. Milk fat was significantly (P .01) depressed at the highest level of feeding. Significant linear increases (P .01) in protein, lactose and SNF percentages were noted as the level of energy supplementation increased. The electrophoretic fractionation of blood serum proteins showed a trend toward greater decreases in albumin on low than on high protein.

The biological mechanisms through which an increase in energy intake results in an increase in the protein and hence, the SNF content of milk are not yet understood. It appears, however, that alterations in the ruminal production of VFA may be involved. The proportion of

propionic acid is consistently increased and acetate decreased when the plane of energy nutrition is increased, particularly on rations where forage intake is low (Van Soest and Allen, 1959; Huber et al., 1964; Huber and Boman, 1965). It has been established from infusion experiments (Rook and Balch, 1961; Storry and Rook, 1961 and 1962) that propionic acid definitely increases the secretion of protein and SNF in milk. This may result from propionate being converted to glutamate via the Krebs cycle (Rook and Line, 1961).

The Effect of Level of Protein

Hills et al. (1922) reported that total solids and fat in milk were unaffected when the concentrate contained 6.5, 10, 16 and 22% digestible protein, but albuminoid content of the milk was slightly increased as ration protein increased. The increased protein levels in the ration resulted in small (but non-significant) increases in milk production. Similar results were obtained by Harrison and Savage (1932). Other workers (Perkins, 1930; Cary, 1935) found that increased levels of dietary protein resulted in greater milk yields on rations of higher than normal energy intake. Work at the Virginia Station (Huber and Boman, 1965) showed significantly higher ($P < .05$) milk yields on a high protein (22.6%) compared to a low protein (8.3%) concentrate. Dietary protein had no significant effect on milk composition.

In a review, Rook (1961) stated that increases in the protein content of the ration above the recommended standards have had no effect on the yield; and composition was unaltered, except to cause small increases in the non-protein nitrogen (NPN) content. It was also reported

that moderate reductions in dietary protein below normal levels caused a slight decrease in milk yield and a decrease in milk proteoses, globulins and NPN. Other major milk constituents were not affected. On the other hand, Rowland (1946) observed that when only 60% of the recommended protein requirements were fed in rations providing normal levels of energy, there was a reduction of 0.18% in the SNF content of the milk.

The Effect of Dietary Fat

Woodward (1923) fed cottonseed meal, linseed oil meal, or gluten feed to replace 75% of the ordinary grain-concentrate for 10-day periods. Milk fat content was increased by the cottonseed and linseed oil meals but not by the gluten feed. Linseed oil (1 lb. daily) had the same effect as linseed oil meal; therefore, it was concluded that the oil and not the protein (as previously thought) was responsible for the increase in fat percentage associated with certain protein supplements. Forty-day feeding periods revealed that the increased fat percent caused by the oil meals was temporary and that after 10 days the percent fat returned to normal. Allen (1934) reported increases in milk fat percent associated with the feeding of fats and oils during 6-day periods. The degree of milk fat increase was proportional to the amount of fat fed. The earlier work has not always been confirmed by more recent studies.

Stull et al. (1957) fed a concentrate containing 7% rendered beef tallow and noted increased blood serum lipids and milk production, but not fat percentages. Peters et al. (1961) fed a concentrate composed of 6% stabilized prime tallow to Holstein and Jersey cows and observed a significant increase ($P < .05$) in the fat content of milk com-

pared to a more fibrous control concentrate in which no fat was added. Decreases ($P < .05$) in SNF resulted from the addition of tallow to rations for the Holsteins but not the Jerseys. In the same study, a concentrate containing 6% methyl esters of fatty acids significantly lowered ($P < .05$) milk SNF and lactose in Holstein cows. Horton *et al.* (1956) fed concentrates containing 4, 8 and 12% fat (the 8 and 12% levels contained 4 and 8% stabilized animal fat, respectively) and observed no significant increases in yield or fat content of milk.

Levels of 3 to 4% fat in concentrates, fed with quality forages, are usually present in rations producing maximum milk and fat yields; however, the level of dietary fat has had no consistent effect on milk fat percentages. Rations containing more than two lb. edible fat may cause digestive disturbances, loss in appetite, and decreased milk yields (Smith, 1959; Rook, 1961).

Unsaturated oils have consistently depressed milk fat percentages (Rook, 1961). Petersen (1932) fed 5 oz. of cod liver oil with a basal ration and observed decreases in milk fat of 30 to 40% compared to the basal ration. Shaw and Ensor (1959) orally administered 300 ml. cod liver oil, oleic acid, or linoleic acid to three cows on a normal hay-grain ration and to three cows on a ground and pelleted hay ration in which milk fat had been depressed. All of the additives to the normal hay-grain rations resulted in marked decreases in the fat content of milk and in the molar proportion of rumen acetic acid. Increases in the total concentration of ruminal VFA and in the molar proportion of propionic acid were also noted. The linoleic acid had the greatest effect. In the cows on ground and pelleted hay where fat

had already been depressed, the additives caused a further increase in the total VFA in rumen fluids but no additional decrease in milk fat was noted. Linoleic acid and cod liver oil resulted in further decreases in the molar proportion of rumen acetate and increases in the molar proportion of rumen propionate. The pattern of milk and rumen changes affected through feeding unsaturated fats and oils is similar to that shown on restricted roughage diets.

The Effect of Addition of Volatile Fatty Acids and Their Salts

Stoddard et al. (1949) reported that acetic acid given by stomach tube increased the percent milk fat in cows fed a low-roughage, high-concentrate ration in which fat had been previously depressed. Propionic acid (administered in the same manner) seemed to have no effect on milk fat. Tyznik and Allen (1951) fed sodium acetate to cows on low-roughage, fat-depressing rations and observed that the percent fat had increased by 24 hr. after feeding the acetate. Fat percentages had returned to normal by the time cows were eating 1 lb. of acetate daily.

Balch and Rowland (1959) fed or intraruminally infused sodium salts of VFA and found that addition of sodium acetate to normal diets did not increase fat percentages. When 0.5 to 1.5 kg. of sodium acetate was fed to cows in which milk fat had been depressed by low-hay, high-concentrate diets, there was usually an appreciable improvement in fat percentages. The daily administration of 414 gm. of sodium propionate did not restore fat percentages lowered by diets low in hay. Butyrate, in a test with one cow, appeared to give results similar to

acetate. Van Soest and Allen (1959) found that sodium acetate increased while sodium propionate decreased the percent fat in milk of cows fed fat-depressing rations. Rook and Balch (1961) infused acetic acid intraruminally and found that it increased the yield of milk and of all milk constituents. More specifically, increased fat percentages were noted. In contrast, propionic and butyric acids affected milk composition by not yield. Propionic acid decreased percent fat and increased the protein. Butyric acid increased only the fat percentage.

Acetic, lactic, propionic and butyric acids were repeatedly infused into the rumen by Storry and Rook (1961). Propionic caused increased protein and SNF in milk and decreased fat. Butyric decreased the lactose and increased the fat, protein and SNF. Lactic increased the protein, while acetic increased fat, protein and lactose. The effects of propionic and butyric were confirmed in a later experiment (Storry and Rook, 1962).

The Effect of Spring Grazing

In English work, the transfer of cows from winter feeding to spring grazing resulted in an increase in milk SNF; sometimes by as much as 0.3 to 0.4 percentage units. Slight decreases or no change in the fat content were also reported (Castle and Watson, 1961; Holmes et al., 1960; Rook et al., 1960). The depressed fat percentages may have been due to a reduced fiber intake as suggested by Waita et al. (1956). Castle et al. (1960) substantiated the above theory by feeding 4 lb. of poor quality hay daily to cows grazing pasture. It was noted that

the fat content was increased over those cows receiving no additional hay.

Various theories have been proposed to explain the increase in SNF content. One is that estrogenic substances in spring grass enhance the secretion of SNF (Bartlett et al., 1948). However, this was discounted by Pope and McNaughton (1959). Waite et al. (1956) proposed that the soluble carbohydrates in spring grass were responsible for the increased SNF content of milk. The most tenable theory, discussed by Rook (1961), is that increased TDN intake and improvement in the plane of energy nutrition promote the secretion of milk SNF. Numerous experiments (Castle and Watson, 1961; Holmes et al., 1960; Waite et al., 1959; Rook et al., 1960) have shown that the increased milk SNF noted during spring grazing was dependent upon the previous plane of energy nutrition. Greater increases in SNF (mainly protein) were noted for cows that had been on relatively low planes of energy nutrition prior to grazing. Cows receiving high levels of energy before grazing responded very little, if at all (Rook et al., 1960).

At comparable energy intakes spring grass fed indoors did not result in significantly higher milk protein than a normal winter ration (Waite et al., 1959), but a marked increase in SNF was further noted in cows allowed to graze the same sward. This increase was attributed to an increased intake of energy and not to any particular component of the grass. Using cows with rumen fistulas, Bath et al. (1962) were able to show a reduction in the proportion of acetate and an increase in the proportion of propionate in rumen fluid of cows grazing or being fed spring

grass ad libitum. This change in rumen acids explains the increase in the SNF content of milk from cows grazing spring grass; since propionic acid, in infusion experiments (Rook and Balch, 1961; Storry and Rook, 1961, 1962), increased the percent protein and SNF in milk.

The Effect of Feeding Inorganic Salts (Buffers)

Emery and Brown reported in 1961 that the addition of 1 lb. of potassium or sodium bicarbonate to fat-depressing (high-grain, low-forage) rations resulted in a significant increase in the fat test. Using three mature, non-lactating cows, equipped with rumen fistulas, these same workers fed 1 lb. of sodium bicarbonate with the high-grain, low-forage ration and observed an increase in rumen pH to normal levels. The rumen VFA pattern remained typical of the high-grain, low-forage ration. Restoration of percent milk fat to near normal levels was noted by Loosli et al. (1963) when 1 lb. of sodium bicarbonate was added to a ration in which roughage was restricted and high levels of a pelleted concentrate were fed. One problem was getting cows to consistently eat the bicarbonate-treated grain. Miller et al. (1963) could not prevent the fat depression associated with grazing pearl millet by feeding potassium bicarbonate (1 lb. per day) or magnesium carbonate (0.42 lb. per day).

More recent work by Emery et al. (1964) showed no restorative effects on milk fat when calcium carbonate (0.6 lb. per day) was added to a ration of 2 lb. hay and concentrates ad libitum. However, the addition of 1 lb. sodium bicarbonate to the same ration significantly increased ($P < .05$) the fat percentages from 2.35 to 3.66 and from 2.28 to

3.14 in two trials. Rumens liquor was sampled by stomach tube and, contrary to earlier work (Emery and Brown, 1961), a marked increase in the molar proportions of acetate and butyrate and a decrease in propionate resulted from feeding sodium bicarbonate. Similar changes in rumen VFA have been reported in beef cattle (Lassiter et al., 1963; Wise et al., 1961) when sodium bicarbonate was added to the diet. Lassiter et al. (1963) have also noted increases in the total numbers of anaerobic bacteria in the rumen of cattle given drinking water that contained 0.5% sodium bicarbonate.

EXPERIMENTAL PROCEDURE

This study was divided into two trials using 32 lactating Holstein cows from the Virginia Agricultural Experiment Station herd. In trial A (winter, 1962-63) 12 cows (averaging 7.3 mo. post partum) were divided into two groups. Groups were balanced for the protein and fat contents and the yield of milk during a 21-day standardization period. During standardization all cows received 1 lb. of commercial concentrate (16% crude protein) for each 3.5 lb. milk, about 30 lb. of corn silage per day, and orchardgrass hay ad libitum (10-15 lb. per day). Treatments were: 1) a control ration consisting of a concentrate mix (table 1) fed at a rate of 1 lb. per 3.5 lb. milk produced during standardization, 40 lb. corn silage, and orchardgrass hay ad libitum; 2) a restricted-forage, high-concentrate ration consisting

Table 1. Composition of Concentrates Fed. Trials A and B.

<u>Ingredients</u>	<u>Concentrate Mixture^a</u>			
	<u>Control</u>		<u>Lactose</u>	
	<u>lb.</u>	<u>%</u>	<u>lb.</u>	<u>%</u>
Ground shelled corn	1400	70	-	-
Soybean meal (44%)	480	24	760	38
Lactose (fermentation grade)	-	-	1120	56
Molasses (dried)	80	4	80	4
Salt	20	1	20	1
Dicalcium phosphate	<u>20</u>	<u>1</u>	<u>20</u>	<u>1</u>
Total	2000	100	2000	100

^a Three lb. of vitamin A (5,000 I.U./gm.) and two lb. of vitamin D (15,000 I.U./gm.) were added to each ton of mixture.

of the same concentrate fed ad libitum, 10 lb. corn silage, and 5 lb. orchardgrass hay. Twelve days were allowed for adjustment to ration and a 63-day treatment period was employed.

The animals were housed and fed in individual stalls using sawdust bedding. Refused feed was determined daily. Cows were weighed for 3 consecutive days after adjustment to ration and at end of treatment. Single weights were made at biweekly intervals during treatment. Milk weights were recorded twice daily. At weekly intervals, a daily composite of milk was sampled for composition analyses. Fat was determined by the Babcock method. A modified A.O.A.C. method (1960) as adapted by Stone et al. (1964) was used for determination of total solids, and total protein was analysed according to the Kofranyi Direct Steam Distillation Method (Kofranyi, 1950), as modified by Stone et al. (1964). Percent solids-not-fat and lactose-mineral were determined by difference.

At the end of standardization and at different times during treatment, rumen samples were taken by stomach pump at approximately 5 hr. after the morning feeding. A pH reading was obtained from a portion of the sample using a Coleman Metrion, Model 28, pH meter. A 10 ml. aliquot of the rumen fluid (strained through four layers of cheesecloth) was mixed with a 2% solution of H_2SO_4 and stored at 5° C. until analyzed for volatile fatty acids according to the method described by Bruno and Moore (1962).

Blood samples were obtained by jugular puncture at biweekly intervals, held at 38-40° C. in a water bath for 30 min. and centrifuged

for 30 min. at 2,000 rpm. The supernatant fluid (blood serum) was frozen and held at -20° C. until subjected to electrophoretic fractionation. Serum protein fractions were determined by paper electrophoresis using a Durrum-type cell. The buffer system was sodium-barbital-barbituric acid (ionic strength 0.075 and pH 8.6). Undiluted serum (0.010 ml.) was used. Separations were made for 16 hr. at a constant current of 2.5 ma. The strips were dried, stained with bromphenol blue, and analyzed with an integration scanner (Beckman Model RB Analytrol). Total protein and true protein (precipitated by $\text{Ba}(\text{OH})_2$ and ZnCl_2) of serum were determined by Macro Kjeldahl. Non-protein nitrogen was calculated by difference.

Significance of differences were determined using the analysis of variance technique as described by Snedecor (1956).

In trial B (winter, 1963-64) 20 lactating Holstein cows were used. Eight were in late lactation (averaging 9.4 mo. post partum), and 12 were in an earlier stage of lactation (averaging 3.2 mo. post partum). Cows were allotted to treatment on the basis of milk yield and protein and fat contents of milk during an 18-day standardization period. The standardization ration was similar to that in trial A.

The late lactation cows were randomly assigned to two balanced groups. One group received a control ration in which concentrate was fed at the same rate as in trial A. They were also fed 48 lb. per day of corn silage and orchardgrass hay ad libitum. In the second group hay was restricted to 2 lb. per day and concentrates were fed ad libitum. Two groups of early lactation cows received the same treatments as those

in late lactation, while a third group received a ration identical to the controls except that the corn in the concentrate mix was replaced by lactose and soybean meal was increased to equalize protein (table 1).

Trial B. consisted of a 7-day adjustment and a 70-day treatment period. Management of the animals and sampling procedures were similar to trial A, except composite samples from four milkings (48 hr.) were taken at 10-day intervals; and cows were weighed for two instead of three consecutive days after adjustment to and at end of treatment. Blood and rumen samples were obtained from only the 12 cows in the earlier stages of lactation.

Treatment was followed by a 7-day balance trial. Twelve cows (eleven in early and one in late lactation) were used. The late lactation cow replaced one in early lactation that died after 60 days on treatment. The rations were the same as those fed during treatment so no adjustment was necessary. Total manual collection was employed and separation of urine from feces was accomplished by attaching one end of a rubber tube (diameter, 3 in.) to the vulva with branding cement and rubber matting. The opposite end was connected to a 4-gal. collection vessel. The method used for separation of urine and feces is illustrated in figure 1.

Total feces voided were weighed daily, thoroughly mixed and 1% was saved for analysis. Samples for 7 days were composited and stored at 5° C. A similar sampling procedure was used for urine except 0.5% of the total volume was kept for analysis. Daily feed samples for the 7-day period were composited prior to analysis. A milk sample (48 hr.

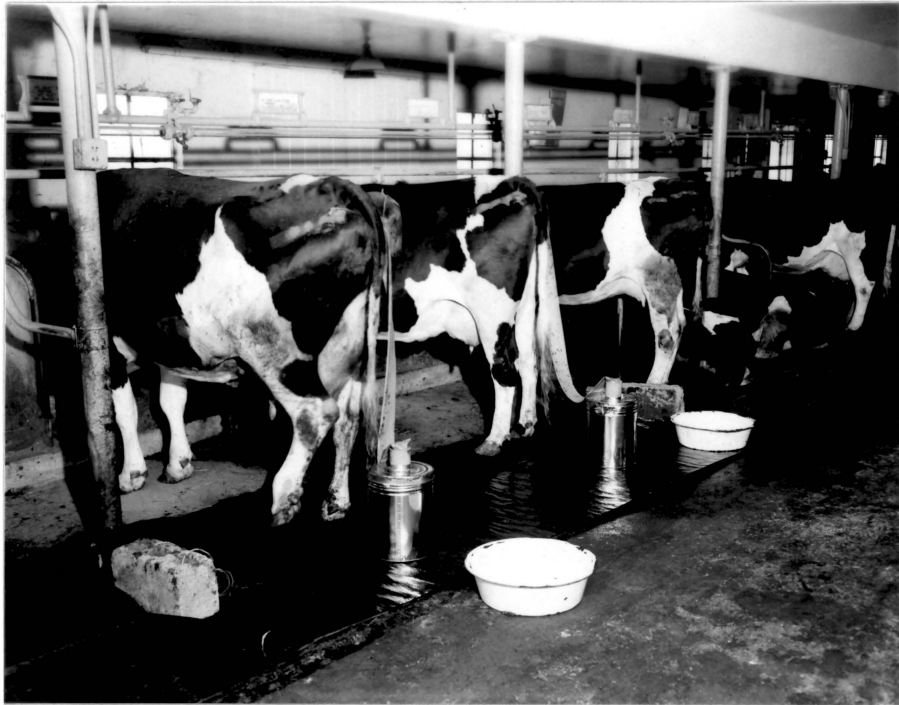
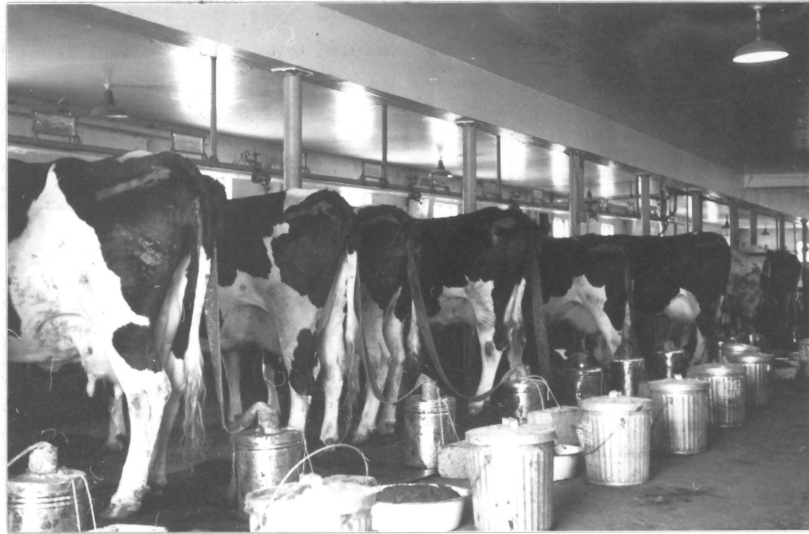


Figure 1. Technique Used for Separation of Urine and Feces. Trial B.

composite) was taken at the end of the trial and analyzed for its major constituents. Venous blood samples obtained at the end of the balance trial were analyzed for glucose according to the glucose oxidase method as described by Salomon and Johnson (1959). Urine was analyzed for nitrogen content by Macro Kjeldahl. Feed and fecal composites were subjected to proximate analysis. The determination of dry matter, crude protein, ether extract, and ash was according to A.O.A.C. methods (1960). Crude fiber was determined by the method of Whitehouse et al. (1945).

Statistical tests were determined using the analysis of variance technique (Snedecor, 1956) and significance of differences between treatment means was tested according to Duncan (1955).

RESULTS

Trial A

Feed Intake. Daily intakes in the control group averaged 9.4 lb. concentrates, 10.5 lb. hay, and 37.6 lb. corn silage. Average daily consumption of the restricted-roughage, high-concentrate group (hereafter referred to as the high-energy group) was 34.4 lb. concentrates, 4.5 lb. hay, and 9.7 lb. corn silage.

Milk Composition. The percent of the major milk constituents and the change between standardization and treatment in milk composition are presented in table 2. Fat and total solids contents of milk were markedly decreased on the high-energy ration. Percent protein, SNF, and lactose-mineral in milk were apparently unaffected by treatment.

Table 2. Effect of a High-energy Ration on Milk Composition. Trial A.

	<u>Ration</u>			
	<u>Control</u>		<u>High-energy</u>	
	<u>%^a</u>	<u>Change^b</u>	<u>%</u>	<u>Change</u>
Fat	3.74	0.07	3.28	-.39 ^x
Protein	3.51	0.32	3.45	0.17
Lactose-mineral	5.56	-.02	5.49	-.04
SNF	9.07	0.32	8.95	0.24
Total solids	12.80	0.39	12.25	-.22 ^y

^a Average for 63-day treatment period (6 cows/group).

^b Average change from the standardization period. Statistical treatment of milk composition data is based on these values.

^x Difference between mean changes approaches significance ($P < .05$).

^y Difference between mean changes approaches significance ($P < .10$).

Yields of Milk and Milk Constituents. Although milk composition was only slightly affected by treatment, yield of milk and all of the major milk constituents was higher on the high-energy ration (table 3). For yields of milk, protein, lactose-mineral, SNF, and total solids, differences were highly significant ($P < .01$). Due to increased milk yields on high-energy, despite the depression in percent fat, the yield of fat was also greater ($P < .10$).

Table 3. Effect of a High-energy Ration on Yield of Milk and Milk Constituents. Trial A.

	Ration			
	Control		High-energy	
	<u>lb./day^a</u>	<u>Change^b</u>	<u>lb./day</u>	<u>Change</u>
Milk	29.3	-8.4	39.6	0.9**
Fat	1.10	-.28	1.30	-.10 ^x **
Protein	1.03	-.17	1.37	0.11**
Lactose-mineral	1.63	-.66	2.17	0.06**
SNF	2.66	-.48	3.55	0.03**
Total solids	3.75	-.94	4.85	0.05**

^a Average for 63-day treatment period.

^b Average change from standardization period. Statistical treatment of yield data is based on these values.

^x Difference between mean change, significant ($P < .10$).

** Difference between mean change, significant ($P < .01$).

Rumen Fluid. Ration effects on rumen VFA concentrations and pH are presented in table 4. The high-energy ration caused a decrease in the acetic/propionic ratio ($P < .05$). Greater increases in rumen propionic acid were noted on high-energy, but these differences were significant at only the 25% level of probability. Mean pH values were significantly less ($P < .01$) on the high-energy ration.

Table 4. Effect of a High-energy Ration on VFA Concentrations and pH of Rumen Fluid. Trial A.^a

Rumen fluid VFA (meq./100 ml.)	Ration	
	Control	High-energy
Acetic	5.13 (1.34) ^b	5.91 (1.67)
Propionic	1.01 (0.33)	1.98 (0.94)
Butyric	0.86 (0.20)	1.21 (0.45)
Valeric & others	0.19 (0.20)	0.41 (0.36)
Total	7.39 (2.06)	9.51 (3.21)
Acetic/propionic ratio	4.29 (-.03)	3.14 (-1.11) [*]
Rumen pH	7.15 ^c	6.22 ^{**}

^a Average values for 3 cows of each group at 94 days treatment and 3 and 2 cows, respectively, on the high-energy and normal rations at 46 days treatment.

^b Values in parentheses denote average change between standardization and treatment. Statistical treatment for rumen VFA is based on these values.

^c Mean value at ninth wk. of treatment (6 cows/group).

^{*} Difference between mean changes, significant ($P < .05$).

^{**} Difference between treatment means, significant ($P < .01$).

Blood Changes. Effects of ration on blood serum protein concentrations and the various blood serum protein fractions are presented in table 5. There were no consistent changes in the various fractions, which could be related to feeding. The small difference in beta globulin was significant only at the 25% level of probability.

Body Weight Changes. There were no treatment differences in body weight change. An average increase of 1.57 lb. per day was noted for both groups.

Table 5. Ration Effects on Blood Protein Concentration. Trial A.^a

Serum protein (gm./100 ml.)	Ration	
	Control	High-energy
Total protein	7.16(-.43) ^b	7.35(-.40)
True protein	6.77(-.38)	6.84(-.47)
NPN X 6.25	0.39(0.07)	0.51(0.08)
Serum protein components (% of total protein)		
Albumin	56.1 (2.42)	54.5 (3.97)
Alpha globulin	8.8(-3.93)	9.4(-4.47)
Beta globulin	9.3(-1.20)	10.0 (-.15) ^x
Gamma globulin	25.7(-2.72)	26.7 (-.73)

^a Average values for last wk. of 9-wk. treatment.

^b Values in parentheses denote change from standardization to ninth wk. Statistical treatment is based on these values.

^x Difference between mean change, significant ($P < .25$).

Trial B

Feed Intake. Average daily intake, during the 70-day treatment period, for the control group in late lactation was 10.8 lb. concentrates, 11.9 lb. hay, and 48.4 lb. corn silage; whereas the low-roughage group consumed 30.4 lb. concentrates, and 2 lb. hay. Intakes of early lactation cows on the control ration averaged 15.3 lb. concentrates, 11.2 lb. hay, and 45.7 lb. corn silage; while the low-roughage group ate 29.9 lb. concentrates, and 2 lb. hay; and the lactose group consumed 13.6 lb. concentrates, 11.0 lb. hay, and 44.2 lb. corn silage.

When cows were restricted to 2 lb. hay per day, diarrhea, anorexia, feed-lot bloat, and a decrease in rumination were observed. No physiological disturbances were noted for cows on the control or lactose treatments. It should be noted that the concentrate containing lactose was readily eaten by the animals.

Milk Composition. The effects of ration on milk composition for the late and early lactation cows are presented in tables 6 and 7, respectively. The percent fat was decreased and the percent SNF was increased ($P < .01$) by the low-roughage ration in the late lactation cows. Protein, lactose-mineral, and total-solids were not significantly affected. In the early lactation cows protein percentages were not significantly changed. Milk fat and total solids contents were significantly decreased ($P < .05$) by the low-roughage ration compared to the ration containing lactose. Percent SNF was significantly higher ($P < .05$) on the low-roughage ration compared to the control. Lactose-mineral content of the milk was increased ($P < .05$) by the low-roughage ration when compared to the lactose and control.

Table 6. Ration Effects on Milk Composition for Late Lactation Cows. Trial B.

	Ration			
	Control		Low-roughage	
	% ^a	Change ^b	%	Change
Fat	3.93	0.26	3.15	-.60*
Protein	3.71	0.36	3.92	0.53
Lactose-mineral	5.35	-.25	5.46	0.10
SNF	9.06	0.11	9.38	0.62*
Total-solids	12.99	0.37	12.56	-.05

^a Average for 70-day treatment period.

^b Change from standardization. Statistical treatment is based on these values.

* Difference between mean change, significant ($P < .05$).

Table 7. Ration Effects on Milk Composition for Early Lactation Cows. Trial B.

	Ration					
	Control		Lactose		Low-roughage	
	% ^a	Change ^b	%	Change	%	Change
Fat	3.59	-.14 ^x	4.03	0.60 ^x	2.60	-.61 ^y
Protein	3.25	0.28	3.49	0.38	3.30	0.37
Lactose-mineral	5.49	-.42 ^x	5.36	-.31 ^x	5.48	-.13 ^y
SNF	8.74	-.14 ^x	8.86	0.06 ^{xy}	8.78	0.24 ^y
Total-solids	12.33	-.01 ^{xy}	12.88	0.66 ^x	11.38	-.36 ^y

^a Average for 70-day treatment (1 cow in the low-roughage group died at 60 days treatment. Autopsy showed that the abomasum had been displaced. Milk composition data for this cow are averaged up to 55th day).

^b Change from standardization. Statistical treatment is based on these values.

^{x,y} Values sharing the same superscript are not significantly different ($P < .05$, except lactose-mineral between control and low roughage, $P < .01$).

Yields of Milk and Milk Constituents. Milk and milk fat yields were significantly lower ($P < .01$) in the late lactation cows on the low-roughage ration (table 8). Yields of protein, SNF, and total-solids were also lower ($P < .05$) as was the yield of lactose-mineral (approaches significance $P < .05$). Trends for early lactation cows were similar to late lactation but due to large individual cow variations, none of the treatment differences were significant (table 9). However, by pooling the data for the early and late lactation groups, significantly lower ($P < .05$) milk yields were shown on the restricted-roughage ration compared to the control.

Table 8. Ration Effects on Milk and Constituent Yields for Late Lactation Cows. Trial B.

	Ration			
	Control		Low-roughage	
	lb./day ^a	Change ^b	lb./day	Change
Milk	35.21	-.72	27.06	-8.40 ^{**}
Fat	1.38	-.06	0.85	-.46 ^{**}
Protein	1.31	0.11	1.06	-.14 [*]
Lactose-mineral	1.88	-.12	1.48	-.43 ^x
SNF	3.19	-.01	2.54	-.56 [*]
Total-solids	4.57	0.05	3.40	-1.01 [*]

^a Average for 70-day treatment.

^b Change from standardization. Statistical treatment is based on these values.

^{*} Difference between mean changes, significant ($P < .05$).

^{**} Difference between mean changes, significant ($P < .01$).

^x Difference between mean changes approaches significance ($P < .05$).

Table 9. Ration Effects on Milk and Constituent Yields for Early Lactation Cows. Trial B.

	Ration					
	Control		Lactose		Low-roughage	
	lb./day ^a	Change ^b	lb./day	Change	lb./day	Change
Milk	48.44	-6.65	41.52	-11.85	43.52	-11.35
Fat	1.74	-.23	1.67	-.18	1.13	-.64
Protein	1.57	-.05	1.45	-.21	1.44	-.16
Lactose-mineral	2.66	-.60	2.23	-.79	2.39	-.70
SNF	4.23	-.65	3.68	-1.00	3.82	-.85
Total-solids	5.97	-.88	5.35	-1.18	4.95	-1.50

^a Average for 70-day treatment (1 cow of the low-roughage group died at 60 days treatment. Autopsy showed that the abomasum had been displaced. Yield data for this cow are averaged up to 55th day).

^b Change from standardization. Statistical treatment is based on these values. None of the differences between mean changes are significant ($P < .05$).

Rumen Fluid. Ration effects on ruminal VFA concentrations and rumen pH values are summarized in table 10. At 55 days the low-roughage ration resulted in a significantly greater increase ($P < .01$) in acetate concentrations than the control or lactose; and acetate was lower ($P < .05$) on the lactose than on the control ration. Propionate was significantly higher at 5 and 25 days on the low-roughage ration. The ratio of acetate to propionate was significantly lower ($P < .05$) on the low-roughage ration at 5 and 25 days, but not at 55 days.

At 5 days butyric and other VFA (valeric and lactic) concentrations were greater ($P < .05$) on the low-roughage than the control and lactose rations, but at 55 days the concentration of these acids was

Table 10. Effect of Ration on Concentrations of VFA and pH Values in Rumen Fluid. Trial B.^a

VFA (meq./100 ml.)	Day	Ration		
		Control	Lactose	Low-roughage
Acetic	5	7.04 (1.17) ^b	6.46 (0.57)	7.90 (2.74)
	25	7.34 (1.48)	6.22 (0.33)	6.96 (1.79)
	55	7.12 (1.26) ^x	5.82 (-.06) ^y	7.62 (2.46) ^z
Propionic	5	2.08 (0.48) ^x	1.82 (0.29) ^x	4.04 (2.78) ^y
	25	2.16 (0.56) ^x	1.91 (0.38) ^x	3.87 (2.61) ^y
	55	1.80 (0.20)	1.64 (0.11)	3.38 (2.12)
Butyric & others	5	1.80 (0.30) ^x	1.98 (0.57) ^x	3.22 (1.84) ^y
	25	2.14 (0.64)	2.72 (1.30)	3.12 (1.74)
	55	2.07 (0.58) ^x	2.93 (1.56) ^y	2.81 (1.44) ^y
Total	5	10.90 (1.96) ^x	10.25 (1.42) ^x	15.16 (7.36) ^y
	25	11.64 (2.68)	10.84 (2.02)	13.94 (4.10)
	55	10.99 (2.94) ^x	10.39 (1.56) ^x	13.81 (6.01) ^y
Acetic/propionic	5	3.38 (-.32) ^x	3.55 (-.32) ^x	1.96 (-1.87) ^y
	25	3.40 (-.28) ^x	3.26 (-.57) ^x	1.80 (-2.11) ^y
	55	3.96 (0.24)	3.55 (-.24)	2.25 (-1.06)
Rumen Fluid pH	5	6.81 (-.38) ^x	7.01 (-.11) ^x	5.96 (-1.35) ^y
	25	6.56 (-.62) ^{xy}	6.96 (-.15) ^x	5.84 (-1.48) ^y
	55	6.75 (-.44) ^x	7.06 (-.06) ^x	6.04 (-1.28) ^y

^a Each value is the average for four cows.

^b Values in parentheses denote average change from standardization. Statistical treatments are based on this value.

^{x,y,z} Values sharing the same superscript are not significantly different ($P < .05$, except acetic acid at 55 days, total VFA at 5 days and pH at 5 days which differed at $P < .01$).

greater ($P < .05$) on low-roughage and lactose than on the control ration. Total rumen VFA were highest on the low-roughage ration at 5 days ($P < .01$) and at 55 days ($P < .05$). Rumen pH values were lower at 5 and 55 days

($P < .05$) on the low-roughage than on the other rations. At 25 days the only significant difference ($P < .05$) in pH values was between low-roughage and lactose.

Blood Changes. Blood serum protein concentrations and the relative proportions of the protein fractions are presented in table 11. Treatment had no significant effect on total crude protein, true protein or NPN. Blood serum albumin values were significantly lower and

Table 11. Ration Effects on Blood Protein Concentrations. Trial B.^a

Serum protein (gm./100 ml.)	Ration		
	Control	Lactose	Low-roughage
Total protein	7.86(0.63) ^b	7.83(1.03)	8.18(0.46)
True protein	7.39(0.38)	7.34(0.68)	7.30(0.16)
NPN X 6.25	0.48(0.25)	0.49(0.36)	0.88(0.31)
Serum protein components (% of total protein)			
Albumin	54.4(-1.10) ^{x,y}	55.1 (4.20) ^x	45.0(-4.30) ^y
Alpha globulin	12.4 (-.48)	11.7 (-.10)	11.2 (-.48)
Beta globulin	9.6 (0.65)	9.8 (0.98)	12.2 (0.75)
Gamma globulin	23.6 (0.88) ^x	22.8(-5.20) ^y	31.6 (4.00) ^x

^a Concentrations at 56 days of treatment.

^b Values in parentheses denote change from standardization. Statistical treatment is based on these values.

^{x,y} Values sharing the same superscript are not significantly different ($P < .05$ for albumin and $P < .01$ for gamma globulin).

gamma globulin was significantly higher ($P < .05$) on low-roughage and control compared to the lactose ration.

Blood glucose was higher in cows on low-roughage than on lactose and control rations. Average concentrations of blood glucose for the lactose and control rations, respectively, were 72.5 and 64.8% of the level determined for the low-roughage group.

Body Weight Changes. Results of body weight changes for trial B are presented in table 12. In late lactation cows, the low-roughage ration resulted in higher average daily gains ($P < .05$) than the control. Treatment had no significant effect on body weight changes in early lactation cows.

Table 12. Effect of Ration on Body Weight Change. Trial B.^a

<u>Group</u>	<u>Ration</u>		
	<u>Control</u>	<u>Lactose</u>	<u>Low-roughage</u>
Late lactation	+0.71	-	+2.03*
Early lactation	+1.16	+0.49	+1.10

^aAverage daily change per cow after adjustment to ration until end of treatment period.

* Difference between mean changes, significant ($P < .05$).

Balance Trial. Results of nitrogen balance are presented in table 13. Nine of the twelve cows were in negative nitrogen balance but the differences due to ration were not significant ($P < .05$). Cows on the low-roughage ration voided a significantly greater proportion of dietary nitrogen in the urine ($P < .05$) and a lesser proportion in the feces ($P < .01$) than those on control and lactose. There were no significant differences in the proportion of dietary nitrogen secreted in milk.

Table 13. Nitrogen Balance Data. Trial B.^a

	Ration		
	<u>Control</u>	<u>Lactose</u>	<u>Low-roughage</u>
Nitrogen intake (gm./day)	335.8	294.6	325.6
Nitrogen outgo (gm./day)			
Milk	96.6	85.0	84.5
Urine	132.9 ^x	119.6 ^x	177.1 ^y
Feces	<u>123.5^x</u>	<u>115.5^x</u>	<u>71.1^y</u>
Total	353.0	320.1	332.7
Balance (gm./day)	-17.2	-25.5	-7.1

^a Daily average values for four cows in each group.

^{x,y} Values sharing the same superscript are not significantly different ($P < .05$ for urine and $P < .01$ for feces). Statistical treatment of intake and balance data is based on actual values, but outgo is based on the proportion of total intake.

The effect of ration on apparent digestibility of the dry matter and the various dry matter constituents is summarized in table 14. Significantly higher ($P < .01$) coefficients of digestibility for dry matter, crude protein, nitrogen free extract, and ether extract were obtained on the low-roughage ration than on the control and lactose. Digestibility of crude fiber on the low-roughage ration was depressed ($P < .05$) compared to the other rations. The only significant difference between the digestion coefficients of the control and the lactose rations was a lowered ($P < .01$) digestibility of ether extract on the lactose ration.

Table 14. Effect of Ration on Apparent Digestibility Coefficients. Trial B.^a

Apparent digestibility (%)	Ration		
	<u>Control</u>	<u>Lactose</u>	<u>Low-roughage</u>
Dry matter	69.8 ^x	69.7 ^x	80.2 ^y
Crude protein	62.9 ^x	60.2 ^x	78.2 ^y
Ether extract	69.5 ^x	58.7 ^y	81.0 ^z
Crude fiber	62.5 ^x	57.5 ^x	44.0 ^y
Nitrogen free extract	74.8 ^x	76.3 ^x	85.6 ^y

^a Average during the 7-day digestion trial.

^{x,y,z} Values sharing the same superscript are not significantly different ($P < .01$, except the difference for crude fiber between low-roughage and lactose is significant at the 5% level of probability).

DISCUSSION

Feed Intake. Ad libitum intake of concentrates was higher in trial A for cows that were fed 5 lb. hay and 10 lb. corn silage than in trial B when the cows received only 2 lb. hay per day. It appears that serious restriction of forage to as low as 2 lb. of hay daily to dairy cows does not supply enough fiber for maximum intake of energy. Kesler and Spahr (1964) observed that cows reached their maximum intake of productive energy when concentrates made up 50 to 60% of the ration. Reductions in feed and total dry matter intake occurred when concentrates supplied more than 60% of the total dry matter.

It is thought that the primary causes for the lower intake were digestive disturbances (bloat, diarrhea, etc.) which occurred on the low-roughage ration. Emery and Brown (1961) also observed mild bloat when they fed 2 lb. hay daily with high levels of concentrates. There is also a possibility that the increased rumen concentrations of propionate and butyrate observed on this ration had a depressing effect on appetite. Fontenot and Theurer (1965) have demonstrated that intravenous injections of VFA will suppress appetite in fattening beef heifers. Propionate had the greatest effect, acetate exerted the least effect, and butyrate had an intermediate effect.

One early lactation cow on the low-roughage ration died of a displaced abomasum after 60 days treatment. It is possible that this ration could have been the cause of death. Reference has been made in the popular press (Woelffer, 1962) that the highest incidence of abomasal

displacement occurs in herds where heavy grain feeding is practiced.

Milk Composition and Yield. Milk fat was consistently depressed when roughage was restricted and concentrates were fed ad libitum. This effect was probably related to the increased propionate and decrease in the ratio of acetate to propionate in rumen fluid. Similar results have been reported by a number of other workers (Tyznik and Allen, 1951; Van Soest and Allen, 1959; Huber and Boman, 1965).

The failure of the low-roughage ration to produce a significant increase in percent protein in milk was not anticipated. However, other studies have not always shown increased milk protein on high-concentrate rations. The expected increase in milk protein content was probably masked by the late stages of lactation of the cows in trial A and by the digestive disturbances occurring in trial B when cows were restricted to 2 lb. hay.

Lactose was fed in trial B in an attempt to increase the concentration of rumen propionate and thus increase milk protein. Substances rapidly fermented in the rumen have been shown to increase the relative proportion of ruminal propionic acid (Annison and Lewis, 1959); and infusion of propionic acid into the rumen has resulted in increased synthesis of milk proteins (Rook and Balch, 1961; Storry and Rook, 1961 and 1962). No significant increases in milk protein or rumen propionic acid were observed, but there was a tendency toward a higher fat content of milk from cows fed lactose. The trend toward increased milk fat on the lactose ration was probably associated with a higher concentration of rumen butyrate on the lactose ration than the control, and lower

rumen propionate compared to the low-roughage ration. This is in agreement with the above mentioned infusion experiments in which butyric acid increased and propionic acid decreased milk fat percentages.

In trial B, percent SNF in milk was significantly increased on the low-roughage ration due to increases in both the protein and lactose-mineral fractions. The increase in lactose-mineral may have been due to the higher concentrations of blood glucose available to the mammary gland for the synthesis of lactose (Smith, 1959). Other studies at the Virginia Station (Huber et al., 1964; Huber and Boman, 1965) have shown increased lactose-mineral as the result of feeding high levels of concentrates.

The reduction in percent total solids on the low-roughage rations (in both trials) was primarily due to the lowered fat percentages.

In trial A significantly higher milk production resulted from feeding the low-roughage ration than the control. This in turn caused greater yields of all of the major milk constituents except fat. The higher milk yields on the low-roughage ration in trial A probably had a masking effect on treatment differences in percent solids-not-fat.

The lower milk yields on the low-roughage ration (compared to the control) in trial B were probably attributable to the digestive disturbances and the reduced intake as previously mentioned. The Pennsylvania workers (Kesler and Spahr, 1964) also noted that cows on low fiber (9.5%) rations were less persistent than those fed fiber levels of 13.1 and 17.7%.

Rumen Fluid. There was a definite trend toward increased concentrations of all individual VFA on the low-roughage rations compared to the controls. The significant reduction of the acetate to propionate ratio in trial A was partially responsible for the depression in milk fat percent. Rumen VFA changes were less marked in trial A than trial B as were changes in milk composition. This suggests a relationship between changes in rumen VFA and changes in milk composition. This observation is in accord with many other reports (Rook and Balch, 1961; Van Soest and Allen, 1959; Huber and Boman, 1965).

In trial A, part of the cows were sampled after 46 days of treatment and the remainder at 94 days. It was assumed that pooling the data from both sampling times was valid since the major changes in VFA concentrations should have occurred prior to 46 days. The results of trial B suggest a reversion toward normal in rumen VFA concentrations after 5 days on the low-roughage ration. There was a tendency for the acetate to increase and the propionate to decrease between 5 and 55 days of treatment. However, the reversion toward concentrations on a normal ration was by no means complete.

On the lactose ration, butyrate was consistently increased and there was a trend toward decreased acetate. The decrease in acetate did not result in a decrease in milk fat percentages because of the increased butyrate which has been reported to have ketogenic properties.

Rumen pH was consistently lower on the low-roughage ration than on the control in trials A and B and the lactose ration in trial B. Marked decreases in pH on similar rations were noted by other workers

(Emery and Brown, 1961; Emery et al., 1964). English workers (Balch, 1958; Balch et al., 1955a) observed that on high concentrate rations, intake is at a faster rate and less saliva is released into the rumen. This undoubtedly results in a decrease in the buffering capacity of the rumen and may partially explain the lowered pH on such rations.

Blood Changes. There were no significant treatment differences in blood serum concentrations of total protein, true protein, or NPN in trials A or B. The small increase in the proportion of serum beta globulin noted in cows on the low-roughage ration in trial A was not observed in trial B. However, there were decreases in the proportion of albumin and increases in the proportion of gamma globulin on the low-roughage ration in the latter trial. The higher proportion of gamma globulin in trial B suggests that a physiological stress may have occurred in feeding only 2 lb. hay daily and concentrates ad libitum. Other studies at this station (Huber and Boman, 1965) have shown no relationship between level of concentrate fed to lactating cows on pasture and changes in blood serum protein fractions. However, there was a trend toward greater decreases in the proportion of serum albumin of cows fed a low (8.3%) compared to a high (22.6%) protein concentrate. These studies suggest that concentrations of blood serum protein and protein fractions are quite homeostatic and are not drastically altered by widely differing rations.

Higher concentrations of blood glucose obtained on the low-roughage ration were probably associated with the increased concentrations of rumen propionic acid, since the latter is assumed to be one of the important precursors of blood glucose in the ruminant (Shaw, 1956).

Body Weight Changes. High levels of concentrates have usually resulted in increased body weight gains as compared to normal hay:concentrate rations (Hooven and Flowman, 1963; Rumery and Plum, 1963) when milk yields were not stimulated. On the other hand when milk flow has been increased by the additional concentrates (Bishop et al., 1963; Brown et al., 1962) no significant effect on body weight was observed.

Failure of the low-roughage ration to cause greater gains in body weight than the control in trial A can be explained on the basis of the higher milk yields (39.6 vs. 29.3 lb. per day).

Late lactation cows in trial B receiving grain ad libitum and 2 lb. hay per day gained at a significantly faster rate than controls. This was probably due to lower milk production which resulted in more energy available for body weight gains.

Balance Trial. From the apparent digestion coefficients and nitrogen balance data it is evident that the low-roughage, high-concentrate cows were more efficient in the digestion of dietary protein; but they were not as efficient as the other two groups in conversion of digested protein to milk protein. Explanation of this phenomenon again appears to be the result of a physiological stress on the low-roughage ration, or a lower energy intake with consequent deamination

of the protein to be used for energy. Daily intakes of digestible dry matter averaged 1.58, 1.81 and 1.87 lb. per 100 lb. body weight on the low-roughage, control and lactose rations, respectively. These intake values for the low-roughage group were lower and approached significance ($P < .05$). No significant differences between treatment were noted in efficiency of conversion of TDN (above maintenance) to 4% fat corrected milk.

The increased apparent digestibilities of all dry matter constituents, except crude fiber, obtained in this experiment are in accord with previous work. Lassiter et al. (1957) with non-lactating cows and Putnam and Loosli (1959) with lactating cows demonstrated that the digestibilities of all components of dry matter (except crude fiber which was decreased) were increased, as the proportion of dry matter coming from roughage was decreased from 80 to 20%, or from 80 to 40%, respectively.

It is probable that most high producing cows in early lactation are in a negative nitrogen balance. Certainly these data would suggest that such is the case. It is felt that additional studies to establish the relationship between dietary components, stage of lactation and nutrient balances are needed.

SUMMARY

Two feeding trials were conducted to study the effects of source and level of concentrates and level of roughage on milk composition; changes in certain blood and rumen constituents; and efficiency of conversion of feed protein to milk protein. Trial A was for 63 days and employed two groups of six cows each. The control ration consisted of concentrates at 1 lb. per 3.5 lb. milk, 40 lb. of corn silage, and orchardgrass hay, ad libitum; while the low-roughage ration contained 5 lb. orchardgrass hay, 10 lb. corn silage, and concentrates ad libitum. Trial B was for 70 days and employed five groups of four cows each. Two groups were in late lactation and three in early lactation. One late lactation group served as the control and received the same ration as the controls in trial A, except 48 lb. of corn silage were offered. The other group received only 2 lb. hay and concentrates ad libitum. The first two early lactation groups received rations identical to the late lactation groups; while the third received a ration similar to the control except the corn in the concentrate was replaced by lactose. The twelve early lactation cows were subjected to a balance study at the end of the feeding trial.

Intake of concentrates and milk yields on the low-roughage rations were higher in trial A than trial B. Percent milk fat and the acetate/propionate ratio of rumen fluid were decreased by low-roughage; while rumen propionate was increased. No significant differences in milk protein were observed. Milk SNF and lactose-mineral were increased on low-roughage in trial B. Feeding only 2 lb. hay daily

resulted in bloat and diarrhea; while blood glucose and gamma globulin were increased. Lactose increased rumen butyrate and tended to increase milk fat percentages above the controls.

Digestibilities of all dry matter components, except crude fiber, were higher on low-roughage. Cows on low-roughage digested a larger proportion of the dietary protein, but were less efficient in the conversion of digested protein to milk protein.

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APPENDIX

Table 15. Average Daily Feed Intake of Individual Cows. Trial A.

<u>Ration</u>	<u>Cow</u>	<u>Concentrates (lb.)</u>	<u>Hay (lb.)</u>	<u>Corn Silage (lb.)</u>
High energy	Ginger	33.6	4.4	9.3
	Tilly	37.8	4.2	9.8
	Carolyn	29.5	4.5	9.7
	Gleanora	33.8	4.8	10.0
	Alice	38.9	4.7	9.6
	Terry	32.9	4.6	9.9
Control	Fatima	9.3	8.0	37.4
	April	5.3	7.9	36.6
	Angela	8.7	10.2	38.0
	Audrey	13.6	12.8	37.9
	Cindy	10.3	12.1	37.9
	Hilltop	9.1	11.9	37.9

Table 16. Average Daily Feed Intake of Late Lactation Cows. Trial B.

<u>Ration</u>	<u>Cow</u>	<u>Concentrates (lb.)</u>	<u>Hay (lb.)</u>	<u>Corn Silage (lb.)</u>
Low roughage	Chris	25.2	2.0	-
	Inherit	30.5	2.0	-
	Harari	33.7	2.0	-
	Globe	32.3	2.0	-
Control	Dagmar	12.9	10.1	47.8
	Genette	7.7	11.2	49.0
	Doreen	11.2	12.3	46.7
	Cecile	11.4	14.0	49.9

Table 17. Average Daily Feed Intake of Early Lactation Cows.
Trial B.

<u>Ration</u>	<u>Cow</u>	<u>Concentrates (lb.)</u>	<u>Hay (lb.)</u>	<u>Corn Silage (lb.)</u>
Low roughage	Grateful	27.5	2.0	-
	Intent	33.4	2.0	-
	Huntress	38.6	2.0	-
	Jubilee	21.7	2.0	-
Control	Joy	12.1	5.6	37.0
	Fatima	11.4	11.8	49.1
	Fox	20.5	13.1	48.0
	Gleanora	18.4	14.5	48.6
Lactose	Jan	10.2	6.7	35.2
	Candy	19.9	11.2	45.5
	April	10.6	9.7	48.8
	Cindy	13.6	16.5	49.6

Table 18. Proximate Analyses of Feeds Used in Balance Study.
Trial B.^a

	<u>Dry Matter (%)</u>	<u>Crude Protein (%)</u>	<u>Ether Extract (%)</u>	<u>Fiber Crude (%)</u>	<u>Ash (%)</u>	<u>NFE (%)</u>
Control concentrate	88.3	18.4	3.1	4.3	4.8	69.4
Lactose concentrate	96.0	14.9	0.5	2.7	4.2	77.8
Corn silage	27.3	8.8	2.7	22.4	4.4	61.7
Orchardgrass hay	89.5	12.4	2.0	29.9	7.7	48.0

^a Values are on a dry matter basis.

ABSTRACT

Two feeding trials were conducted to study the effects of source of concentrate and level of concentrate and roughage on milk composition; changes in certain blood and rumen constituents; and efficiency of conversion of feed protein to milk protein. Trial A (63 days) employed two groups of six cows each. The following rations were fed: 1) Control consisting of 1 lb. concentrate per 3.5 lb. milk, 40 lb. corn silage, and orchardgrass hay, ad libitum; 2) Low-roughage composed of 5 lb. orchardgrass hay, 10 lb. corn silage, and concentrates ad libitum. Trial B (70 days) employed two groups (four each) of late and three of early lactation. A control ration similar to that fed in trial A, except 48 instead of 40 lb. of corn silage, and a low-roughage ration of only 2 lb. hay and concentrates ad libitum, were fed to two groups in each stage of lactation. The remaining early lactation group received a ration comparable to the control except the corn in the concentrate was replaced by lactose. The twelve early lactation cows were subjected to a balance study at the end of the feeding trial.

Intake of concentrates and milk yields on the low-roughage rations were higher in trial A than trial B. Percent milk fat and the acetate/propionate ratio of rumen fluid were decreased by low-roughage; while rumen propionate was increased. No significant differences in milk protein were observed. Milk SNF and lactose-mineral were increased on low-roughage in trial B. Feeding only 2 lb. hay daily

resulted in bloat and diarrhea; while blood glucose and gamma globulin were increased. Lactose increased rumen butyrate and tended to increase milk fat percentages above the controls.

Digestibilities of all dry matter components, except crude fiber, were higher on low-roughage. Cows on low-roughage digested a larger proportion of the dietary protein, but were less efficient in the conversion of digested protein to milk protein.