THE EFFECTS OF DIFFERENT LEVELS OF PROTEIN ON THE PRODUCTION AND COMPOSITION OF MILK

by

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INTRODUCTION

Sorghum grain is grown extensively in certain parts of Kansas, especially the western two-thirds of the state. On account of its drought resistance sorghum is better suited climatically than corn. During a dry year sorghum often produces a much higher yield of grain than corn. The nutritive value of sorghum also compares quite favorably with that of corn.

Home produced grain is generally cheaper than grain purchased commercially as the farmer is not required to pay for handling or profit charges. Greater dependence on rations prepared from home grown grain, and supplementing them only to the extent essential, would by reducing cost of production increase the margin of profit.

Feeding trials at several stations have shown that home produced grain like corn, oats or barley could be used either alone or with a little supplementation with protein concentrates like soybean oil meal, when good quality legume hay is available for feeding *ad libitum*. Sorghum grain is used extensively for dairy cattle feeding, but not much experimental work appears to have been done with the feeding of this grain to dairy cows.

Cave and Fitch (1925) at the Kansas Agricultural Experiment Station demonstrated that there was no particular difference in the efficiency of corn chop or ground sorgo seed in maintaining body weight or milk production when both were supplemented with protein. Similar results have been reported from the Arizona

(1928), Nebraska (1940) and South Dakota (1943) Agricultural Experiment Stations.

This experiment was undertaken to study the efficiency of sorghum grain in milk production when used as a single grain or when supplemented with soybean oil meal. The effect of the three rations supplying three levels of protein, on the composition of milk in regard to the percentages of butter fat, total solids, protein and ash was also studied.

REVIEW OF LITERATURE

Sorghum Grain in Dairy Cattle Feeding

Cave and Fitch (1925 a,b) conducted six trials from 1920 to 1925 to compare sorgo seed and corn as a grain feed for dairy cows. Basal rations consisted of a liberal supply of ground alfalfa and sorgo silage. The grain mixture was made up of 2 parts of wheat bran, one part of linseed oil meal and 4 parts of either corn chop or ground sorgo. Small differences in the efficiency of maintaining body weight and milk production were observed between ~~corn~~ corn chop and ground sorgo. Efficiency of sorghum for milk or fat production was found to be 97.6 and 95.8 per cent the efficiency of corn.

Cunningham (1928) conducted two trials. In one he compared grain sorghum with rolled barley, while in the second he compared rolled barley with ground corn. The basal ration consisted of alfalfa hay and corn silage, while grain mixtures consisted of 1 part of wheat bran and 2 parts of either ground sorghum, rolled barley or ground yellow corn. He found that grain sorghum was as effective as rolled barley and the latter as effective as ground yellow corn in dairy cattle feeding.

Burr (1940) reported that Sooner milo, a variety of grain milo, was equal to corn, pound for pound, when these grains did not form more than 52 per cent of the concentrate mixtures. Olson (1943) also found no significant difference between yellow corn and Sooner milo in maintaining body weight and milk production in the two trials conducted at the South Dakota Agricultural Experiment Station. Alfalfa formed the sole basal ration in the trial.

In a recent trial at Kansas State University, Fountaine (1961) found sorghum grain to be about 98 per cent as effective as corn when fed as the only concentrate.

Effect of the Level of Protein on Milk Yield

Kellner (1910) in summing up the results of numerous experiments, especially of German origin, said "In so far as it is possible by means of food to effect the action of the milk glands, the protein exerts a very profound influence in increasing the quantity of milk."

Protein in feed serves two separate physiological functions in ruminants. One function pertains to the requirement of the of the animal for maintenance, growth, and production while the other pertains to growth and development of microorganisms in the digestive tract so that cellulose is digested by bacterial fermentation. The minimum protein required for maximum production therefore depends upon which functional need for protein is greatest, as the same protein is used in both functions. Since the protein requirement for milk production is higher than the requirement for bacterial activity, the limiting effect on microorganisms is not present in normal rations.

The possible effect of excess protein in stimulating greater milk production was a subject of live interest in the early part of the present century. Several experiments were conducted at various experimental stations to see if more milk could be obtained by "protein stimulus."

Hayword (1902) found that rations having nutritive ratios between the limits of 1:3.4 and 1:11.3 had no effect on the quantity or quality of milk produced. Lindsey (1911) on the other hand observed increased flow of milk when rations contained an excess of digestible protein above the minimum protein requirement of the animal. Taylor and Husband (1922) also observed greater secretion of milk on a high protein ration.

Hill and associates (1922) made an extensive study of the influence of varying nutritive ratios on the yield and composition of milk. Four levels of protein (very low, low, medium and high) were fed in experiments conducted over short and long periods of time. Cows fed high protein rations averaged 3.5 per cent more milk than on low protein and 2 per cent more than on the medium protein rations in short alternation trials. The results paralleled those obtained in experiments conducted over long continuous periods.

Harrison et al. (1932, 1933) found no evidence of the stimulatory effect of protein on milk production. They compared rations containing 20 and 24 per cent protein with one containing 16 per cent protein. Henke and Goo (1935) in a double reversal trial found milk production to be about equal on rations containing 10.8 and 20.2 per cent digestible crude protein. Seshan (1937) also observed no difference in the production of milk on rations containing 20.7 and 29.1 per cent digestible crude protein. Similar results were obtained by McCandlish (1939) Mackintosh (1940) Wright (1940) and Inchausti et al. (1945).

Kajanoja (1954) found that protein supplied greatly in excess of the standard allowance reduced milk yield.

Morozov (1953) observed that raising the digestible protein from the standard of 90 gms to 135 gms per feed unit increased daily milk yield by 1 to 2 kilograms. He further observed that high yielding cows reacted more favorably to increased protein than cows with low milk yields.

Reid and Holmes (1956) using a balanced latin square change over design observed a slight but statistically insignificant, positive increase in milk yield on rations containing high protein. In subsequent trials, Holmes et al. (1956) keeping the starch equivalent of rations constant adjusted digestible crude protein to 10, 15, and 17 per cent. Feeding these three levels of protein led to no significant difference in milk yield or body weight. But when digestible crude protein was held constant at 16 per cent while starch equivalent of the rations were altered to 53, 67 and 75 per cent, the latter two gave significantly higher milk yields than the first with low starch equivalents.

Edey and Pearce (1957), Frens and Dijkstra (1959) and Leisner (1959) observed no increase in milk yield by the addition of protein supplied above minimum protein requirements.

Logan et al. (1953) used a balanced latin square change over design to study the effect of 4 rations having factorial combinations of high and low levels of protein and energy. The following table gives the nutrient level and production of milk obtained during the experiment.

	Rations			
	Normal Protein Low energy	High Protein High energy	Normal Protein High energy	High Protein Low energy
Intake as % of requirement				
D.C.P.	104	122	75	131
T.D.N.	90	105	96	86
Production in pounds				
F.C.M.	846	955	892	867
Body Weight changes	-26	17	-10	-16

They found the influence of the energy complement of the ration to be significant at the 1 per cent level and that of protein at the 5 per cent level. The interaction between level of protein and energy, however, was not significant. In a subsequent trial effects of the levels of protein in the rations were not significant.

Wright (1940), reviewing the minimum protein requirements, observed that rations to be efficient should not have a nutritive ratio wider than 1:9. Bartlett *et al.* (1940) compared two levels of protein in large scale field experiments. One level supplied 0.6 pounds of protein per gallon of milk while the other supplied two-thirds of this amount of protein. The starch equivalent was kept constant in both the rations. They found no measurable difference in milk yield or body weight by reducing the protein level below the standard. MacIntosh (1940) also found no detrimental effect on the yield or condition of cows by lowering the protein equivalent from 0.6 to 0.42 pounds per gallon of milk. On the other hand Ulvesli (1947) observed a drop in milk yield and loss of body weight, when the protein level was reduced below the standard. Kajanoja (1954) also noticed a reduction in milk yield when the minimum protein requirement was reduced even when starch equivalent was kept constant.

Lassiter *et al.* (1957) observed a drop in milk yield in cows fed rations containing 7.6 and 9.4 per cent crude protein compared to those cows fed rations containing 13.1 per cent crude protein. The cows were on a basal ration of timothy hay. Cows on 7.9 per cent protein in ration, lost on an average 57.5 pounds of weight over each thirty day period compared to 11.9 pounds of gain in weight in cows fed 11.9 per cent protein ration.

Frens and Dijkstra (1959) also noticed reduction in milk yield when the protein requirement for production was supplied at 10 per cent less than the standard recommended.

Composition of Milk

Waters and Hess (1895) reported an increase of fat, total solids and nitrogen in the milk, produced on a ration with a narrow nutritive ratio of 1:4 compared to one with a nutritive ratio of 1:6.6. Hayword (1902) on the other hand found no difference in the composition of milk on rations varying in nutritive ratios from 1:3.4 to 1:11.3. Lindsey (1911) observed little effect on the composition of milk with the variations ordinarily encountered in the digestible protein intakes. Taylor and Husband (1922) reported that with the exception of non protein nitrogen, which is not a product of the mammary gland, level of protein had no influence on the percentage composition of milk.

Hill and associates (1922) concluded from their extensive work that total solids and fat content of milk were not affected by rations varying in nutritive ratios from 1:5 to 1:11.6. The protein content of milk alone was positively influenced by an increase in the level of protein in the ration. Perkins (1932) also noticed little influence of the level of protein on the character of milk. The only variation he observed to be constant and progressive, with the increase in the level of protein in the ration was the percentage of non protein nitrogen in milk. Greatest variation was in percentage of urea. It increased several fold. Amino nitrogen, creatin, and creatinine nitrogen were also affected in the same direction as urea but the variations were smaller.

The above findings have been corraborated by several workers like Inchausti *et al.* (1945), Ulvesli (1947), Breirem *et al.* (1951), Venkatappaiah and Basu (1955), Holmes *et al.* (1956), Lassiter *et al.* (1957), Edey and Pearce (1957), Leisner (1959), Frens and Dijkstra (1959), and Logan *et al.* (1959).

Morozov (1953) observed that the fat content of milk increased by 0.25 to 0.35 per cent by raising the digestible protein of the ration from the standard of 90 gms to about 135 gms per feed unit.

Kajanoja (1954) observed that a very low protein intake reduced milk fat but had no perceptible influence on the protein content of milk.

Volatile Fatty Acids

Interest in the study of the formation of volatile fatty acids in the rumen is of recent origin. El - Shazly (1952 a,b) reported that the level of volatile fatty acids increased with the addition of a purified source of protein to the ration. Deaminative breakdown of amino acids by microorganisms led to increased concentration of ammonia which in turn increased concentration of isobutyric, valeric and isovaleric acids.

Gray *et al.* (1952) observed marked butyric fermentation *in vitro* when protein was added to the ration. Annison (1954) and Lewis (1955) also noted an increase of volatile fatty acids when amino acids were supplied for microbial activity. Bryant and associates (1955) and (1958) observed that certain branch chain volatile fatty acids, such as valeric acid, formed from bacterial breakdown of protein were essential for the growth of several species of cellulolytic ruminal bacteria. It thus indicated interdependence of mixed ruminal microflora in digestion of nutrients. Hungate and Dyer (1956), however, failed to demonstrate beneficial effect of the addition of valeric and isovaleric acids on the utilization of straw by ruminants. When valeric and isovaleric acids were fed to steers, appetite was stimulated but there was no significant gain in weight. Ruminal microbial activity was also not significantly different than in control. Huhtanen and Elliot (1956) also observed no stimulation of cellulose digestion _in vitro_ by the addition of valeric and isovaleric acids.

Balch and Rowland (1957) observed increased percentages of butyric and _higher acids_ with the increase of protein in the diet. Percentages of acetic and propionic acids, however, varied inversely. Davis and co-workers (1957) observed a definite increase in the production of total volatile fatty acids in response to increased protein feeding. When the values were compared on a percentage basis, acetic and _higher acids_ decreased while butyric acid increased with the level of protein in the ration.

Lassiter _et al_. (1958) fed valeric acid alone and in combination with isovaleric acid to study the effect on the performance of lactating cows. They found no significant difference in consumption of hay, production of milk, percentage of butter fat or gain in body weight.

Digestibility

Kellner (1910) while reviewing previous work on the effect of the level of protein on digestion, stated that complete digestion of all constituents of the feed is assured in ruminants if the total ration contains 8 to 10 parts of digestible nitrogen-free substance to each part of crude protein.

Ellett and Holdaway (1917) also observed digestibility closely agreeing with the average coefficients when rations had a narrow nutritive ratio of 1:2.4. Thus an excess of protein in the ration had no further stimulatory effect on the digestion of other constituents. But when the nutritive ratio was widened to 1:11, digestibility of protein decreased by 47 per cent, fiber by 54 per cent, N.F.E. by 24 per cent and fat by 19 per cent. Perkins (1925) also observed a depression in digestibility when rations had a nutritive ratio of 1:11. The greatest depression was observed in ether extract, its digestibility dropping from 76 to 36 per cent. Burroughs (1950) did not observe any improvement in cellulose digestion in good quality roughages like clover and alfalfa hay when they were supplemented with protein concentrates. Similar results have been obtained by Head (1953). He concluded that when roughages contained 1 per cent nitrogen (6.5 per cent protein), further supplementation of the ration with protein was of no benefit, this level of protein being adequate for the growth and activity of cellulose digesting organisms.

Glover and Dougall (1960) found digestibility of carbohydrates to be little affected by the change in the level of crude protein within the range of 6 to 30 per cent in the dry matter of the feed. It was only when the crude protein level fell below 5 per cent of dry matter of the feed that a marked difference in digestibility of carbohydrates was noticed.

EXPERIMENTAL PROCEDURE

Twelve cows, 9 Holsteins and 3 Jerseys of the Kansas State University dairy herd were used in the experiment. The cows were in peak production. They were placed on a preliminary period of a standard herd ration so that they could be grouped on the basis of milk production. The 12 cows were divided into 4 groups of 3 cows each by assigning the first three highest producers of 4 per cent F.C.M. to the first group, the next three to the second group, and so on, so that cows within each group were as far as possible equal in production. Cows of the same yielding ability generally show a similar rate of fall in milk yield so that such groupings give uniformity of production during the experimental period.

A balanced latin square change over design described by Cochran _et al_. (1941) was used. The design balances the treatments so that every cow receives each treatment once and each treatment is followed by every other treatment an equal number of times. Six cows with 3 subperiods therefore formed one balanced design. It was replicated twice. Three treatments (low, medium and high protein concentrates) were allotted by the random distribution of treatments, rows, and columns using a table of random numbers. The plan of the distribution of treatments is shown as follows:

Cows: Replication I	Cows: Replication II	Sub periods: 1	Sub periods: 2	Sub periods: 3
153C	370C	A	B	C
107B	360C	B	C	A
157C	46B	C	A	B
169C	143C	C	A	B
175C	155C	B	C	A
178C	165C	A	B	C

A - Medium protein concentrate
B - High protein concentrate
C - Low protein concentrate

Each subperiod consisted of four weeks. The first two weeks of each subperiod were allowed for adjustment. The change from one treatment to another was effected in about four days and the remainder of the two weeks were allowed for the adjustment of microbial flora. The record of the subsequent two weeks was utilized for statistical analysis.

Three concentrate mixtures (low, medium and high protein) were formulated by using grain sorghum as the main ingredient and supplementing it with soybean oil meal (ether extracted) at 0, 12 and 24 per cent levels. The percentage ingredients by weight in the concentrate mixture is given in Table 1.

Table 1. Composition of concentrate mixtures.

Ingredients	Low Protein	Medium protein	High protein
		pounds	
Sorghum grain	99	87	75
Soybean oil meal	-	12	24
Salt	1	1	1
Total	100	100	100

The concentrate mixtures were pelleted to facilitate handling and to provide uniformity in day to day feeding. This also reduced wastage in feeding. Physical analysis indicating the fineness and uniformity of modulus of the grain in the pellets is given in Table 2.

Table 2. Physical analysis of concentrate pellets.

Pellets	Fineness of Modulus	Modulus of uniformity
Low protein	2.26	0:5:5
Medium protein	2.32	0:5:5
High protein	2.31	0:5:5

The concentrate pellets were chemically analyzed at the Department of Flour and Feed Milling Industries, Kansas State Unive rsity. Chemical analysis of the pellets is shown in Table 3.

Table 3. Chemical composition of concentrate pellets.

Pellets	Moisture	Protein Nx6.25	Fat	Fibre	Ash
	%	%	%	%	%
Low protein	13.0	8.9	2.9	1.52	2.19
Medium protein	13.0	12.6	2.8	2.10	3.43
High protein	12.4	17.0	2.6	2.49	2.82

A sample of alfalfa hay was analyzed at the chemical service laboratory of the Kansas State University Agricultural Experiment Station. This analysis is given in Table 4.

Table 4. Chemical composition of alfalfa hay.

Nutrients	per cent
Protein (Nx6.25)	18.31
Ether extract	1.54
Crude fibre	30.29
Moisture	10.82
Ash	8.77
Nitrogen free extract	30.27
Total	100.00

The equalised feeding plan of Lucas (1943) was modified as follows:

Requirements of digestible protein and total digestible nutrients, based on Morrison's feeding standard (1956), were calculated for the average production of milk during the last three days of the standard feeding period. The initial concentrate requirement was based on the necessity to supply additional digestible protein and total digestible nutrients after allowing 2.5 pounds of alfalfa hay per 100 pounds body weight. In subsequent weeks, concentrates were fed at 98 per cent of the previous week irrespective of milk production. Alfalfa hay, however, was fed *ad libitum*, its level being adjusted so that a little weigh-back would be left over in the manger. Refused feed was weighed back each day and subtracted from feed offered to determine feed intake.

Cows were confined to stanchions except for short periods in the mornings, when they were allowed in vegetation free open lots for exercise, whenever weather permitted.

Cows were milked twice daily and milk yields were recorded to the nearest .1 pound. Milk samples from four consecutive milkings were collected once a week. The samples were composited in proportion to yield and analyzed for fat, total solids, protein and ash. The chemical analysis except for fat was done at the chemical laboratory of the Kansas State University Agricultural Experiment Station.

Cows were weighed on two successive days at the same hour of the day in the beginning and end of each experimental period. The average of the two consecutive weights was taken in calculating change in body weight.

After the end of the first experimental subperiod cow 370 C became sick and had to be hospitalized. Therefore, she was dropped from the experiment and her probable yield for subsequent periods calculated by the missing plot technique (Snedecor, 1959).

Since gross efficiency of milk production takes into account the digestible energy values of milk produced and total digestible nutrients consumed, this procedure was used in evaluating the results of the trial. In this method the digestible energy of milk is assumed to be 340 Kcal. per pound of F.C.M. (Gaines, 1928) and that of total digestible nutrients to be 2000 Kcal. per pound T.D.N. (Swift, 1957). Thus the formula for gross efficiency of milk production, unadjusted for change in live weight can be stated as:

$$\text{Gross efficiency} = \frac{100\text{x pounds F.C.M. x } 340}{\text{pounds T.D.N. x } 2000}$$

The adjusted efficiency of milk production further takes into account the change in live weight. Each pound of body weight change is taken as equivalent to 1952 Kcalories and the digestible energy value of milk is adjusted accordingly.

RESULTS

Experimental results of three levels of protein in concentrate feeding are classified as to their effect on (1) milk yield (2) composition of milk (3) consumption of hay (4) change in body weight and (5) efficiency of milk production.

Milk Production

The actual milk yield was converted to 4 per cent fat corrected milk yield by using Gaines (1928) formula: 4 per cent F.C.M. = 0.4 x pounds of milk plus 15 x pounds butter fat. Data on milk yield along with the analysis of variance of 4 per cent fat corrected milk yield are given in Table 5 in the Appendix. A summary of average production is presented in Table 6 while production trends are shown graphically in Appendix Figures 1 and 2.

Table 6. Average milk production per cow per day on three levels of protein feeding

	Low Protein	Medium Protein	High Protein
	lbs.	lbs.	lbs.
Milk yield	43.37	42.48	44.69
4% F.C.M.	41.87	42.30	42.01

Analysis of variance indicated that neither the direct nor residual effect of feeds were statistically significant and therefore were included in the error component of the variance. Variations from group to group, period to period and cows within groups were significant at the 1 per cent level. But variation due to treatment was not statistically significant. It is thus apparent that increasing the level of protein above that supplied by the low protein concentrate had no significant influence on milk yield or 4 per cent fat corrected milk yield.

Composition of Milk

The effect of the three levels of protein feeding on the composition of milk as regards percentage of fat, total solids, protein (nitrogen x 6.25) and ash is shown in Table 7 in the Appendix while the summary of it is given in Table 8. Figures 3 and 4 in the Appendix give graphically the trend in composition of milk.

Table 8. Average composition of milk on three levels of protein.

	Low protein	Medium protein	High protein
	%	%	%
Total solids	12.57	12.72	12.49
Fat	3.84	3.99	3.84
Protein	3.17	3.22	3.10
Ash	0.71	0.71	0.71

Analysis of variance of the percentage of total solids in milk indicated significant variations from group to group and cows within groups at the 1 per cent level. But variations from period to period and treatment to treatment were insignificant. Level of protein thus had no significant effect on the percentage of total solids in milk. A similar trend was also shown in the percentage of butter fat. Variations from group to group and cows within group were significant at the 1 per cent level. But variations due to level of protein and stage of lactation were not significant. Variations in the percentage of protein were similar except that variations of cows within groups were not significant at the 5 per cent level.

Analysis of variance of percentage of ash indicated a statistically significant decrease from period to period; the percentage of ash decreased as lactation advanced. The total of 12 observations during each of the experimental periods was 8.61, 8.52 and 8.42 from first to the third experimental period. Level of protein in the ration, however, had no significant effect on the percentage of ash in milk.

It is thus apparent that level of protein within the range of 9 to 17 per cent had no significant effect on the percentage of butter fat, total solids, protein (nitrogen x 6.25) or ash content of milk.

Consumption of Hay

Data regarding the effect of three levels of protein in the concentrate on the consumption of alfalfa hay are presented in Table 9 in the Appendix. Analysis of variance indicated that variations from group to group, period to period and cows within groups were significant at the 1 per cent level, but variations due to treatment were not significant. Increasing the level of protein above nine per cent in the concentrate rations thus provided no "protein stimulus" to increased consumption of hay. Mean consumption of alfalfa hay per cow per day was 30.1, 29.0 and 29.6 pounds on low, medium and high level of protein feeding respectively. Average consumption increased from 26.9 pounds during the first experimental period to 30.2 pounds during the second and 31.5 pounds during the third experimental period. The trend is shown graphically in Appendix Figure 5.

Live Weight Changes

Changes in live weight on the three levels of protein feeding are presented in Table 10 in the Appendix. The analysis of variance was carried out on the three complete sets of latin squares, the fourth set being omitted from the analysis on account of incomplete data on cow 370 C. Variations in live weight from period to period alone were significant. A level of protein above 9 per cent had no significant effect on live weight. Average gain in weight on the three levels of protein feeding was 9.2, 2.7 and 11.2 pounds, respectively. During the fourteen days of experimental period cows on an average gained 1.8 pounds in the first, lost 4.2 pounds in the second and gained 25 pounds in the third experimental period. The difference during the first and second experimental period, was not statistically significant.

Efficiency of Milk Production

Gross efficiency of milk production, without taking into account the change in live weight and after adjusting it for the body weight change, is presented in Table 11 in the Appendix while the summary of it is given in Table 12.

Table 12. Gross and adjusted efficiency of milk production.

Item	Low protein	Medium protein	High protein
	%	%	%
Gross efficiency	28.8	29.4	29.0
Adjusted efficiency	31.1	30.0	32.1

Analysis of variance indicated significant variations at the 5 per cent level from group to group and between cows within groups. But variations from period to period and treatment to treatment were not statistically significant. Thus, the level of protein above 9 per cent in the concentrate ration had no significant effect on the adjusted efficiency of milk production when cows were on <u>ad libitum</u> consumption of alfalfa hay. Total digestible nutrients required for the production of 100 pounds of fat corrected milk yield are given in Table 13 in the Appendix along with the analysis of variance. The average total digestible nutrients required per 100 pounds of fat corrected milk yield on low, medium and high protein rations were 60.4, 61.5 and 60.0 pounds, the differences being non-significant. But the T.D.N. requirement varied significantly from period to period, the averages being 54.3, 59.3 and 68.2 pounds, from the first to the third experimental period, the least significant difference being 5.2 pounds.

DISCUSSION

The productive ability of individual cows is a highly variable factor which introduces a source of variation in experiments. This variability may be eliminated by the use of a change over design in which all the experimental rations are fed to each experimental animal in turn. This, however, introduces a residual affect of the previous feed unless an adequate period is provided for adjustment. Usually two weeks are provided for adjustment to be completed. But the time required to overcome the residual effect varies with the nature of the treatment. Balancing the experimental design in such a way that each treatment is followed by every other treatment an equal number of times, helps in estimating the residual effect and freeing the treatment means by subtracting residual effect from it. However, when the residual effect is not significant nothing is gained by adjusting the means for residual effect (Cochran et al. 1941). The residual effect in the present trial was not significant. It was therefore included in the error component of the analysis of variance.

A further source of variation is due to the characteristic drop in milk yield as lactation advances. This decrease in milk yield is not the same for cows with varying production capacities. The decrease is greater in high yielders than in low producers. Grouping the cows in such a way that cows within each group are as similar as possible would reduce the experimental error due to a decrease in milk yield. The rate of decrease in groups of varying production levels in the present experiment is shown in Table 13. The trend is also apparent from Figure two in the Appendix.

Table 13. Decrease in milk yield during the lactation.

	Group			
	I	II	III	IV
	lbs.	lbs.	lbs.	lbs.
Total milk yield*	403.0	358.6	232.4	519.9
Decrease -				
Expt. period 1-3	12.0	10.5	5.0	8.1
Expt. period 2-3	19.4	13.1	9.5	21.0

*Total of the average daily milk yields of 3 cows in the group over 3 experimental periods.

The rate of fall decreased from the high yielding cows in group IV to low yielding cows in group III, justifying the grouping according to milk yield. It is, however, difficult to secure cows which are nearly alike in production. This introduces variability within groups as is apparent from analysis of variance.

Milk Yield

Average daily four per cent fat corrected milk yield did not vary significantly when low, medium and high protein concentrates were fed to cows on a basal ration of alfalfa hay *ad libitum*. The low protein ration was made up of sorghum grain, while in the medium and high protein ration sorghum grain was supplemented with 12 and 24 per cent soybean oil meal. As there was no difference in milk yields it appears that sorghum grain alone can meet the requirements for milk production of cows on a basal ration of good quality alfalfa hay. Some of the cows in the present experiment were high producers. Cow 165C, 153C and 143C averaged 68.2, 66.4 and 63.1 pounds of fat corrected milk yield during the first experimental period. In the previous trials at this station by Cave and Fitch (1925), the high producers averaged 30 to 35 pounds, and sorghums constituted 57 per cent of the concentrate ration. In the experiments at Nebraska by Burr (1940) sorghums constituted 52 per cent of the concentrate ration. From results in the present trial it is indicated that sorghum grain alone can support milk production up to 60 pounds per day for cows fed on a basal ration of good quality alfalfa hay.

Protein supplied above the requirements for maintenance and milk production provided no "protein stimulus." This is in agreement with the findings of Harrison and Savage (1932), Wright (1940), Inchausti et al. (1945), Kajanoja (1954), Reid and Holmes (1956), Edey and Pearce (1957), Frens and Dijkstra (1959), and Logan et al. (1959).

Milk yield alone does not provide a true estimate of the ration effect unless the change in body weight is taken into account. The average gain in weight per cow during the entire experimental period of 14 days on the three rations was 9.2, 2.7 and 11.2 pounds, respectively. The differences between treatments were not statistically significant. The combined results of milk yield and change in live weight would indicate that sorghum grain is adequate to meet the requirements for maintenance and milk production up to at least 60 pounds per day, when on a basal ration of good quality alfalfa hay.

Milk Composition

The three levels of protein in the concentrate rations did not significantly alter the composition of milk as regards the percentage of total solids, fat, protein and ash. This is in agreement with the findings of Hill et al. (1922), Inchausti et al. (1945), Holmes et al. (1956), Lassiter et al. (1957), and Logan et al. (1959) as regards total solids, fat and ash components of milk but differs with the findings of Hill et al. (1922), Perkins (1932), Balch et al. (1954), Venkatappaiah and Basu (1955) that the protein content of milk varies with the level of protein in the feed, the increase being in non protein nitrogen. Increased protein intake raises the non protein nitrogen in the blood (Perkins 1960). As the blood rich in non protein nitrogen passes through the mammary glands the percentage of non protein nitrogen in milk increases. Non protein nitrogen of milk, not being a secretory product of the mammary gland (Taylor and Husband, 1922), is dependent on its concentration in the blood. It is possible that conditions of this experiment were not sufficiently critical to measure very small differences in the protein content of milk.

Consumption of Hay

There was no significant difference in the consumption of hay with three levels of protein intake. That the protein supplied above the body requirements provided no stimulus to appetite is in agreement with the findings of Seshan (1938), Reid and Holmes (1956), Lassiter _et al_. (1957), and Logan _et al_. (1957). The consumption of hay, however, varied significantly from one experimental period to another. The average consumption of alfalfa hay per cow per day during the three experimental periods was 26.9, 30.2 and 31.5 pounds. It is possible that cows may have increased the consumption of hay to compensate for the reduction of two per cent in concentrate feeding in each subsequent week. This decrease in concentrate feeding was more than the actual decrease in milk yield.

Efficiency of Milk Production

The variations in the efficiency of milk production on the three experimental rations were not statistically significant, the average values being 31.1, 30.0 and 32.1 per cent on low, medium and high protein rations, respectively. The efficiency of milk production, however, varied significantly from group to group and cows within groups. Individual variations are so characteristic that in spite of different criteria in grouping of the animals, variations are bound to remain. Grouping can only help in minimizing the variations.

SUMMARY

The experiment was conducted to study the efficiency of grain sorghum for milk production when used as a single grain or when supplemented with 12 and 24 per cent soybean oil meal on a basal ration of good quality alfalfa hay fed _ad libitum_.

The results from the feeding of the three concentrate rations to 12 cows, 9 Holsteins and 3 Jerseys, in a balanced, 3 x 3 latin square, change over design, were studied in regard to production and composition of milk, consumption of hay, change in body weight and efficiency of milk production. Each period consisted of four weeks of which the first two weeks were allowed for adjustment and the subsequent two weeks used as the experimental period.

The 4 groups of 3 cows each averaged 61.9, 49.6, 43.6 and 28.0 pounds of four per cent F.C.M. per cow per day during the first experimental period.

Neither milk production nor body weight changes varied

significantly among the treatments. The 4 per cent F.C.M. averaged 41.9, 42.3 and 42.0 pounds per cow per day while the gain in weight per cow over the experimental periods of 14 days averaged 9.2, 2.7 and 11.2 pounds on the three experimental rations. The combined results of milk yield and body weight change indicate that sorghum grain alone is adequate to meet the requirements for maintenance and milk production of at least 60 pounds per day when cows are on a basal ration of good quality alfalfa hay.

The level of protein in the ration had no significant effect on the composition of milk as regards percentage of total solids, fat, protein (Nx6.25), and ash. There was no significant difference in the consumption of hay with the increase in the level of protein in the ration. The consumption of hay, however, increased significantly from period to period, possibly to compensate for the more than proportionate weekly decrease of 2 per cent in the concentrate feeding than the actual fall in milk yield as lactation progressed.

Efficiency of milk production averaged 31.1, 30.0 and 32.1 per cent on the low, medium and high protein rations, respectively. The differences were not significant.

From the results it may be concluded that grain sorghum can be used as a single grain on a basal ration of good quality alfalfa hay to meet the requirements for maintenance and milk production of 60 pounds of four per cent fat corrected milk yield.

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APPENDIX

Table 5. Average milk yield per cow per day

Cows	Low protein Milk yield	Fat	F.C.M.	Medium protein Milk yield	Fat	F.C.M.	High protein Milk yield	Fat	F.C.M.
	lbs.	%	lbs.	lbs.	%	lbs.	lbs.	%	lbs.
46B	20.9	4.4	22.1	20.5	4.3	21.9	17.3	4.7	19.2
107B	42.1	3.0	35.5	31.8	3.4	28.8	44.7	2.9	37.1
143C	64.0	3.9	63.1	60.8	3.7	57.8	52.3	3.9	51.7
153C	57.8	3.5	53.2	60.8	4.2	66.4	63.7	3.6	59.5
155C	56.4	3.4	51.2	48.3	3.6	45.0	59.6	3.4	54.4
157C	44.3	4.2	45.3	42.9	3.9	41.9	37.4	3.7	35.4
165C	67.9	3.2	59.8	63.1	4.6	68.2	74.2	3.5	68.6
169C	45.0	3.9	44.0	42.0	3.8	40.8	38.3	3.8	37.0
175C	40.9	3.3	35.3	34.3	3.5	31.8	43.1	3.2	38.1
178C	43.2	3.3	38.6	56.3	3.1	48.7	52.9	2.8	43.4
360C	27.3	5.3	32.4	24.9	5.2	29.2	30.2	5.1	35.2
370C	17.8*	5.2*	21.1*	24.0	4.7	26.7	22.6*	5.1*	24.7*

* missing values.

Analysis of Variance

Effect of level of protein on the production of 4 per cent F.C.M.

Source of Variation	D.F.	M.S.	F
Groups	3	1567.43	376.8**
Cows within groups	8	216.56	52.1**
Periods	2	207.91	50.0**
Group x periods	6	5.31	N.S.
Unadjusted direct	2	0.49	N.S.
Adjusted direct	2	0.39	N.S.
Carry over	2	0.08	N.S.
Error	6	4.16	

** $P<0.01$
N.S. Not significant

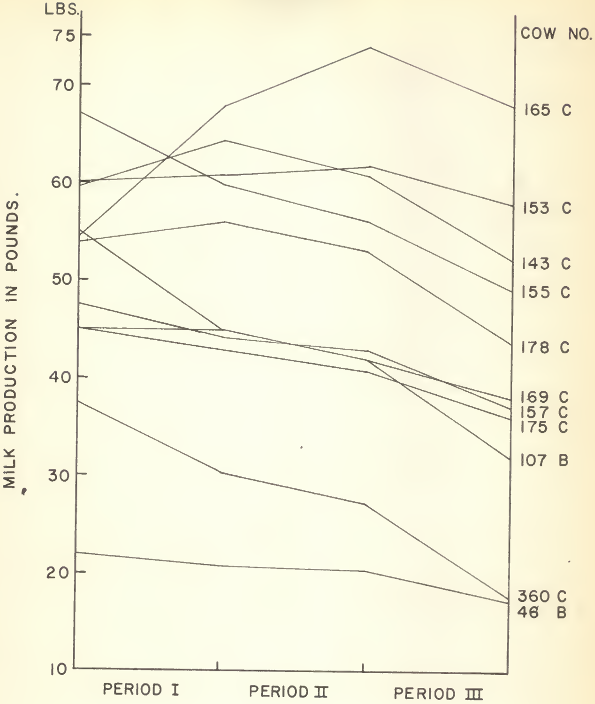

FIG. 1. TRENDS IN THE DAILY PRODUCTION OF MILK YEILD BY PERIODS.

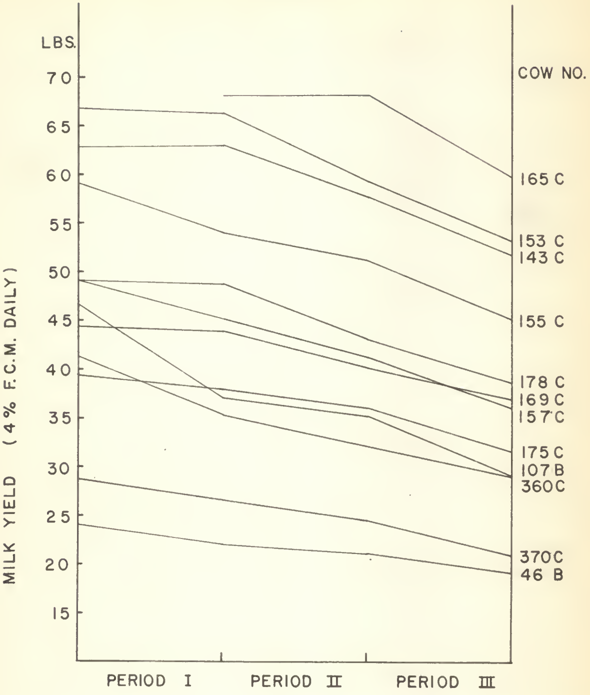

FIG. 2. TRENDS IN THE PRODUCTION OF 4% F.C.M. BY PERIODS.

Table 7. Composition of milk (Total solids, ash and proteins).

Cow	Low protein			Medium protein		
	Total Solids	Ash	Proteins	Total Solids	Ash	Proteins
	%	%	%	%	%	%
46B	13.22	0.75	3.22	13.19	0.75	3.38
107B	11.61	0.70	3.06	11.67	0.70	3.15
143C	12.69	0.67	3.01	12.49	0.67	3.18
153C	12.03	0.70	2.93	12.89	0.76	3.12
155C	12.12	0.69	3.12	12.29	0.69	3.24
157C	12.81	0.73	3.17	12.62	0.73	3.10
165C	11.68	0.71	2.79	13.60	0.74	3.37
169C	12.85	0.70	3.30	12.95	0.70	3.29
175C	11.94	0.71	2.98	11.82	0.69	2.98
178C	11.29	0.67	2.74	11.47	0.68	2.64
360C	14.86	0.74	3.86	14.09	0.72	3.99
370C	13.73	0.72	3.89	13.79	0.72	3.13

Cow	High protein		
	Total Solids	Ash	Proteins
	%	%	%
46B	13.43	0.77	3.47
107B	11.43	0.70	3.01
143C	12.49	0.64	3.12
153C	12.18	0.72	3.04
155C	12.15	0.70	3.10
157C	12.25	0.72	3.16
165C	11.99	0.70	2.86
169C	12.78	0.69	3.32
175C	11.79	0.70	2.92
178C	11.35	0.67	2.70
360C	14.63	0.75	3.23
370C	13.39	0.75	3.29

Analysis of Variance

Effect of level of protein in feed upon protein percentage of milk.

Source of Variation	D.F.	M.S.	F
Groups	3	0.4689	11.19**
Cows within groups	8	0.0994	2.37
Periods	2	0.0488	1.16
Treatments	2	0.0409	0.98
Error	18	0.0419	

** $P<0.01$

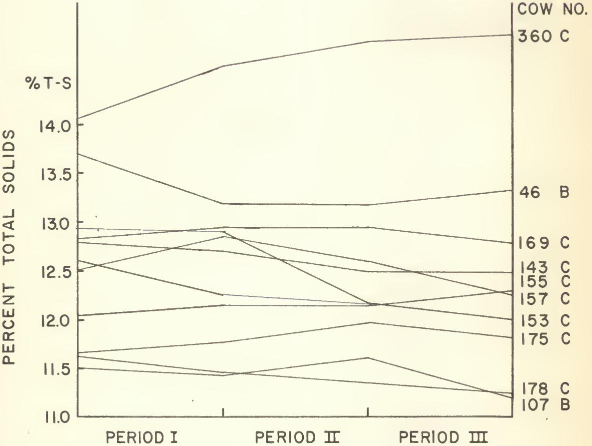

FIG. 3. TREND IN THE PERCENTAGE OF SOLIDS IN MILK BY PERIODS.

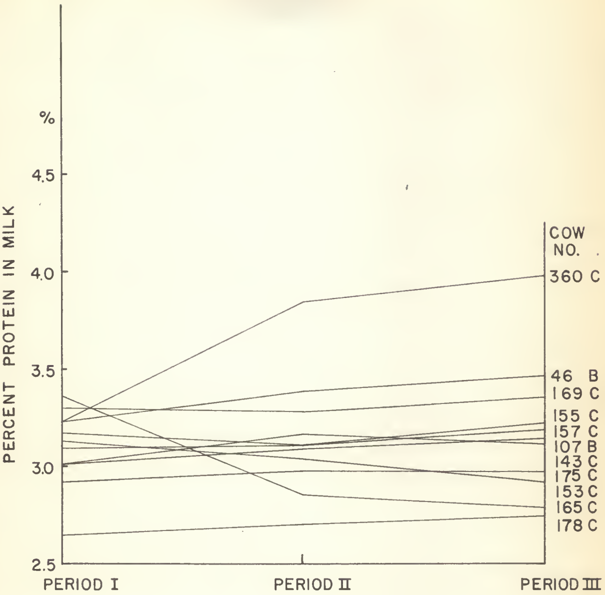

FIG. 4. TRENDS IN THE PERCENTAGE OF PROTEIN IN MILK BY PERIODS.

Table 9. Consumption of alfalfa hay.

Cow No.	Low protein	Medium protein	High protein
	lbs.	lbs.	lbs.
46B	12.6	18.0	20.7
107B	35.9	36.2	34.7
143C	29.8	33.8	32.4
153C	43.7	32.1	38.3
155C	37.7	42.2	35.8
157C	31.3	31.0	30.8
165C	37.7	26.6	31.9
169C	31.9	30.9	31.4
175C	36.4	38.1	31.0
178C	26.0	24.4	21.1
360C	22.4	22.6	21.2
370C	15.6*	11.8	19.5*

* missing values.

Analysis of Variance

Effect of different levels of protein on consumption of hay.

Source of Variation	D.F.	M.S.	F
Groups	3	537.3	82.7**
Periods	2	65.6	10.1**
Cows : groups	8	45.2	6.9**
Treatment	2	3.7	0.6
Error	18	6.5	

**$<$P 0.01

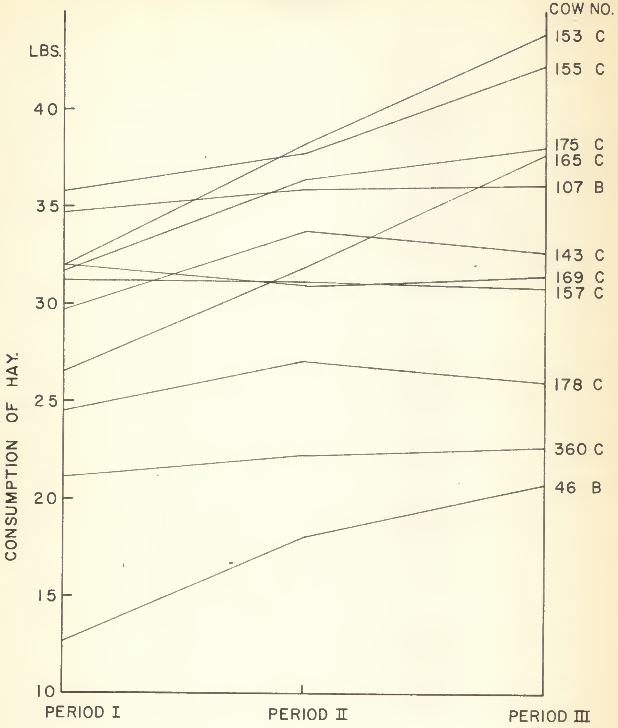

FIG. 5. TREND IN THE CONSUMPTION OF ALFALFA HAY BY PERIODS.

Table 10. Change in body weight during experimental periods.

Cow No.	Low protein	Medium protein	High protein
	lbs.	lbs.	lbs.
46B	+ 9	- 7	+15
107B	+ 3	+33	- 1
143C	+ 3	-10	+22
153C	+25	-39	- 4
155C	-11	+43	+25
157C	+29	- 7	+25
165C	+32	-32	+10
169C	+12	+ 8	+11
175C	-32	+17	+ 8
178C	+22	+11	+ 5
360C	+16	+22	-12
370C	-	+ 8	-

Analysis of Variance

Variations in body weight.

Source of Variation	D.F.	M.S.	F
Groups	2	13.5	0.04
Cows within groups	6	272.2	0.87
Periods	2	2232.1	7.06**
Treatments	2	179.8	0.58
Error	14	311.6	

** $P<0.01$

Table 11. Gross and adjusted efficiency of milk production.

Cow	Low protein Efficiency Gross	Low protein Efficiency Adjusted	Medium protein Efficiency Gross	Medium protein Efficiency Adjusted	High protein Efficiency Gross	High protein Efficiency Adjusted
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
46B	31.8	37.1	26.7	22.7	20.8	27.5
107B	22.4	23.1	18.5	27.0	23.4	23.1
143C	36.9	37.6	32.8	30.4	30.9	36.3
153C	29.0	34.5	39.4	29.5	34.7	33.7
155C	27.1	24.7	22.9	31.8	28.9	34.4
157C	29.1	36.6	27.5	25.7	21.8	29.0
165C	33.7	41.0	40.4	32.7	38.7	41.0
169C	28.9	32.1	28.2	30.4	26.0	29.2
175C	23.6	15.1	20.5	24.9	27.0	30.7
178C	28.5	35.1	34.3	37.4	30.0	31.5
360C	26.3	31.6	24.3	31.7	28.1	24.2
370C	-	-	33.4	37.5	-	-

Analysis of Variance

Adjusted efficiency of milk production.

Source of Variation	D.F.	M. S.	F
Groups	2	77.5	4.47*
Cows within groups	6	65.3	3.77*
Periods	2	48.4	2.79
Treatments	2	9.9	0.57
Error	14	17.3	

* $P<0.05$

Table 13. T.D.N. consumed per 100 pounds 4 per cent F.C.M.

Cow No.	Low protein	Medium protein	High protein
	lbs.	lbs.	lbs.
46B	53.5	65.0	81.9
107B	75.9	92.0	72.7
143C	46.1	51.9	54.9
153C	58.7	38.6	49.1
155C	62.7	74.3	58.8
157C	59.6	61.8	75.6
165C	50.8	42.1	43.9
169C	58.5	60.2	65.4
175C	71.9	82.9	63.1
178C	59.4	49.5	56.6
360C	64.8	70.0	60.5
370C	-	50.8	-

Analysis of Variance

T.D.N. consumed per 100 pounds 4 per cent F.C.M.

Source of Variation	D.F.	M.S.	F
Groups	2	309.17	28.36**
Cows within groups	6	428.70	39.28**
Periods	2	445.37	40.86**
Treatments	2	5.20	0.48(N.S.)
Error	14	10.90	

** $P<0.01$

THE EFFECTS OF DIFFERENT LEVELS OF PROTEIN ON THE PRODUCTION AND COMPOSITION OF MILK

by

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Sorghum is grown extensively in western Kansas. On account of its drought resistance, sorghum often produces a much higher yield of grain than corn. Home produced grain is cheaper to feed than purchased grain. The experiment was therefore undertaken to study the efficiency of grain sorghum in the production of milk when fed as a single grain, or when supplemented with soybean oil meal. The effect of the rations on the composition of milk was also investigated.

Twelve cows, 9 Holsteins and 3 Jerseys, varying in yield of 4 per cent fat-corrected milk from 68 to 22 pounds daily were used in a balanced 3x3 latin square change over design. Cows were grouped according to milk yield into 4 groups so that cows within the groups were as similar as possible. The experiment was subdivided into 3 subperiods of 4 weeks each. The first two weeks were allowed for adjustment and the subsequent two weeks used as experimental periods. In this design every cow receives each treatment in turn and each treatment is followed by every other treatment an equal number of times. This arrangement helps in reducing the effects of highly variable individual productive ability and at the same time in estimating the residual effect so that the yields can be freed of the effects of previous feeds.

The basal ration consisted of good quality alfalfa hay. The concentrate rations were formulated by using grain sorghum as the main ingredient and supplementing it with 0, 12, and 24 per cent of soybean oil meal. The concentrate rations were pelleted to provide uniformity in feeding from day to day and to avoid wastage. The protein content of the pellets was 8.3, 12.6 and 17.0 per cent. Accordingly they were designated as low, medium and high protein concentrates. An equalized feeding design was followed with the exception that hay was fed *ad libitum*. The amount of concentrate fed was reduced by 2 per cent each week, this reduction being irrespective of the actual decrease in milk yield.

Milk yield and consumption of hay were recorded daily. Samples of four consecutive milkings were composited according to yield and analyzed once a week for the percentage of total solids, fat, protein (Nx6.25), and ash. Cows were weighed at the beginning and the end of each experimental period for two consecutive days, and the average taken in calculating change in live weight.

Results indicated statistically insignificant variations in the production of four per cent fat-corrected milk yield on the three experimental rations, the average daily production of 4 per cent F.C.M. being 41.9, 42.3 and 42.0 pounds. The variations in live weight were also statistically insignificant. The average gain in weight on the three experimental rations was 9.2, 2.7 and 11.2 pounds, in 14 days of experimental period. The combined results of milk yield and body weight change indicated that sorghum grain can support a daily milk yield of at least 60 pounds for cows fed a basal ration of good quality alfalfa hay.

The three levels of protein did not alter significantly the percentage of total solids, fat, protein and ash in the milk. The consumption of hay was also not altered significantly on the three levels of protein feeding. The average consumption of alfalfa hay per cow per day was 29.0, 29.6 and 30.1 pounds, respectively. The consumption of hay, however, varied significantly from period to period, the average consumption from the first to the third experimental period being 26.9, 30.2 and 31.5 pounds. It is possible that the cows may have increased consumption of hay to compensate for the more than proportionate decrease in concentrate feeding than the actual decrease in milk yield.

The average efficiency of milk production on the three rations was 31.1, 30.0 and 32.1 per cent, respectively, the variations being statistically insignificant. Efficiency of milk production, however, varied significantly from group to group and cows within groups indicating characteristic individual differences which can not be eliminated from an experimental design.