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LIBERAL versus LIMITED GRAIN FEEDING FOR MILK PRODUCTION

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SUMMARY

1. Nineteen Jersey cows were fed in each of two groups with the same kind of forage but different rates of grain feeding. Opportunity was given for those cows getting less grain to eat more hay.

a. The group fed grain liberally ate 1 lb. for each 3.06 lb. of 4 percent FCM.

b. The group fed limited grain ate 1 lb. for each 4.39 lb. of 4 percent FCM.

Both groups were fed according to a schedule which allowed a higher ratio of grain to forage when production was higher.

2. Sixty-two lactations were completed by the group fed grain liberally and 60 by the limited grain group with an average production of 8,285 ± 1,339 lb. of 4 percent FCM by the former and 8,618 ± 1,439 lb. by the latter.

3. A multiple regression analysis separating the effects due to pasture vs barn feeding, stage of lactation, and rate of grain feeding showed the greater production on limited grain feeding to be highly significant. Pasture caused an increase of 1.6 lb. of 4 percent milk daily over that obtained from winter feeding. The daily decline during lactation was 0.07 lb. of 4 percent milk per day.

4. There were no significant effects of rate of grain feeding on services per conception.

5. Rate of grain feeding did not cause a difference in butterfat percentage.

6. Limited grain feeding did not appear to provide sufficient energy for 2-year-old heifers when fed with the quality of forage used.

LIBERAL versus LIMITED GRAIN FEEDING FOR MILK PRODUCTION

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Economic reasons have forced dairymen to look for systems of feeding that result in production of milk with a greater margin of income over cost of feed. In earlier years hay and corn stover were the principal forages fed. With low quality forages, grain gave marked increases in production. When alfalfa and other legumes were produced more generally the amount of grain was reduced as legumes furnished more of the necessary protein and other nutrients.

In 1940 Sherwood and Dean (**20**) found that grade Jersey cows fed 5 lb. of grain produced 22 percent more milk than those fed alfalfa only. The amount of grain was not varied to determine an optimum proportion of forage and grain. Earlier Lush (**15**) had fed Jerseys and Holsteins while on pasture, at 3 levels—those on forage alone produced 63 percent as much as those fed grain at a ratio of 1:3 lb. of milk. Those fed grain at a ratio of 1:4.5 lb. of milk produced 91 percent as much as those fed at a ratio of 1:3. The variability within groups was great. The comparisons made during the 3 years suggest that pasture was not adequate.

Lindsey and Archibald (**14**) conducted an experiment comparing two systems of feeding;—(1) High roughage and low grain and (2) Low roughage and high grain. The low grain group was fed 1 lb. of grain to 4.5 lb. of milk, 35 lb. of corn silage and hay ad lib. The high grain group was fed 1 lb. of grain for each 2.5 lb. of milk, 20 lb. of corn silage and hay ad. lib. Soiling crops supplemented pasture. The low grain group produced 87 percent as much milk as the high grain group. That 35 lb. of corn silage would contain a large grain equivalent should be noted. The ration of the high grain group is estimated to contain about 10 percent more total digestible nutrients than that of the low grain group. In conclusion, high nutrient intake may have caused the greater milk production.

Autrey and others (**1**) devised two well-designed experiments studying the proportion of grain to forage. The first was a double switch-back trial where three groups of five Holstein cows each were

[1]This experiment was planned by Charles F. Monroe before his retirement from the station in 1951 and completed since his decease in 1956

fed: (1) forage alone, (2) forage with grain at a ratio of 1 lb. of grain to 8 lb. of milk and (3) a check group fed the same forage and grain at a ratio of 1:4. The groups 1 and 2 were on the double reversal while group 3 was fed continuously.

In the second experiment there were three groups of six cows each, assigned to rations so that each cow had all three rations and each ration was preceded by each other ration an equal number of times. This experimental design equalizes carryover effects. The three rations were (1) alfalfa and corn silage, (2) alfalfa, corn silage, and grain at a ratio of 1:7, and (3) the same forage but grain at a ratio of 1:3.5. In both experiments the dry matter intake increased as the proportion of grain in the ration increased. The cows receiving no grain consumed 21.8 less total digestible nutrients than Morrison's optimum standard and lost 0.43 lb. of body weight. On limited grain they consumed 10.8 percent less than requirement by this standard but gained 0.11 lb. per day. The daily production on forage alone was 30.3 lb., on limited grain 34.3 lb. and on grain at a ratio of 1:3.5, 37.2 lb. daily.

Dickson and Kopland (**6**) of Montana carried 10 Holstein cows on each of three planes of grain feeding: (1) alfalfa, beets, beet pulp, corn silage and pasture but with no grain, (2) The same forage but with grain at a ratio of 1:6, and (3) The same forage but with grain at a ratio of 1:3. Group 1 produced 77 percent as much milk as group 3 and group 2 produced 82 percent as much. They reported that feeding grain at 1:6 was more profitable than no grain, but feeding at the ratio of 1:3 was not as profitable compared to feeding at the ratio of 1:6 at prices current in Montana in 1934.

Kitchen **et al.** (**13**) fed three groups with the same three planes of grain feeding as above but with corn silage and hay as the forages. These forages are more typical of those now generally used. The three groups were fed silage varying from 25.1 to 27.9 lb. Grain averaged 3.8 lb. per day for the limited grain feeding (1-6) and 8.8 lb. for the liberal grain-fed group (1-3).

The differences in T.D.N. content of the silage and grain were reflected in hay intake, the forage-only group eating a fourth more hay. However, the additional hay consumption only partially compensated and the T.D.N. intake was greater in ratio to the amount of grain eaten. The group fed forage only gave 27.0 lb. of milk per day, the group fed grain at 1-6 produced 31.9 lb., the group fed grain at 1-3 gave 33.8 lb. The authors state that the extra milk produced by liberal over limited grain feeding cost $9.70 per hundredweight at current prices even after allowing for reduction in consumption of silage and hay.

Later Owen, Miles and Cowsert (**17**) reported that milk produced by feeding grain at a ratio of 1:3 was more profitable at $4.90 per hundredweight for milk than that produced by feeding grain at a ratio of 1:4.5 or 1:6. At $3.10, the price of manufactured milk, the milk produced by feeding grain at a ratio of 1:4.5 was more profitable. In these calculations the differences in value of forage consumed were disregarded.

Watson and co-workers (**22**) report that above the maintenance level they found little, if any, difference in digestibility of hay at different levels of intake.

In Washington where abundant rain makes forage growing desirable Hodgson and others (**11**) obtained 387 lb. of fat from Holstein cows fed forage alone which was only 61 percent of that obtained when grain was fed at a ratio of 1:3. Under contrasting conditions Wylie and Neel (**24**) fed two groups of seven Jerseys each, hay and silage in winter and pasture supplemented with hay and silage in summer. One group was fed grain at a ratio of 1:6 and the other at 1:3. This rate of grain feeding resulted in consumption of an average of 974 lb. and 1,836 lb. respectively. The cows receiving more grain received also 550 lb. more of hay and 650 more of silage; however, the group on lighter grain feeding had 75 percent more days on pasture. Thus the basic problem of the effect of the proportion of grain to forage was confounded by the difference in proportion of winter feeding and summer pasture. The group on heavy grain feeding produced only 2.5 percent more 4 percent fat-corrected milk.

Graves and co-workers (9) found that cows on pasture and on full grain were more persistent than those receiving less grain. Smith, Jones, and Haag (**21**) found that replacement of 13 to 25 percent of the T.D.N. of hay by grain permitted cows to produce at their expected level. An estimated one-eight part of 3 lb. of hay per hundredweight for a 1,000 lb. cow would be equivalent to 2.5 lb. of a grain mix with 75 percent T.D.N. This would be adequate grain for a Holstein cow milkiny 32 lb. at the ratio of 1 lb. of grain to each 5 lb. of 4 percent milk above 20 lb. Similarly a 25 percent substitution of grain for hay would provide for a cow producing 45 lb.

In contrast, the principle of diminishing returns was shown by Jensen **et al.** (**12**) to apply in milk production. Although their method of calculating maintenance requirements exaggerated the effects this principle was still in evidence.

In 1933, Forbes and co-workers (7) stated that associative effects of corn meal vary with the plane of nutrition. The net energy value of corn meal was approximately 50 percent greater when determined with

oat straw than with timothy hay. The variability between steers was but 2 percent. Later, in 1943, they stated "it is concluded that combinations of feedingstuffs affect apparent digestibility, not directly, but through the agency of microorganisms which grow at the expense of food nutrients and are then digested by the animal" (**8**).

Reid (**19**) pointed out the effect of forage quality (including stage of growth) upon production and emphasized the need for high quality forage where grain is fed in small amounts.

Castle and co-workers (**5**) studied the effect of level of concentrate feeding and type of roughage on milk production. In their experiment cows that were fed 4 lb. of concentrate per Imperial gallon (10.3 lb.) of milk produced more than those fed only 2 lb. per gallon. Likewise those fed dried grass produced more than those fed hay. It is noteworthy that the dried grass in place of hay, had nearly as much influence on milk production as the difference in ratio of grain feeding.

Later Castle **et al.** (**4**) reported another experiment in which two levels of grain feeding (4.6 and 2.6 lb. per Imperial gallon and two concentrate mixtures of high (79) and low (63) starch equivalent values) were fed with 7-10 lb. of hay, 4 lb. of artificially dried grass, 30 lb. of grass silage and 20 lb. of fodder beets. The greater milk production (3.8 lb.) from the higher rate of feeding was statistically highly significant. There was a 1 lb. greater production of milk on the concentrate mixture of the higher starch equivalent value, not statistically significant. The authors consider that the extra protein coupled with the extra starch value of the higher rate of concentrate feeding is probably responsible for the increased milk production. That the experimental periods were of 3 wk. duration and that there were but 2 cows per group should be noted.

In contrast to all the experiments reported above, Martin and co-workers (**16**) using 20 milking cows in two trials to test the effects of feeding hay at levels of 0.50, 1.17, 1.83, and 2.50 lb. per 100 lb. of bodyweight supplemented only by grain reported "There were no significant effects of level of hay feeding on body weight change. If total digestible nutrients or estimated net energy were held constant, there were no significant effects of level of hay feeding on milk production."

Bachtell, Allen and Monroe (**2**) in 1934 reported an experiment in which a ration of 18 lb. of hay, 24 lb. of corn silage and grain at a ratio of 1:4 was compared with one of 30 lb. of hay, 15 lb. of corn silage and grain at a ratio of 1:5. The protein of the grain mixtures was adjusted for protein differences of the roughage. The cows receiving grain at 1:4 produced 28.6 lb. of 4 percent F.C.M. daily which was 4 percent

more than the other group, regardless of the fact that care was used to provide a good grade of hay consisting of early cut clover, timothy and alfalfa.

Later Bachtell and co-workers (3) reported on a continuation of the previous project in which Holsteins were fed 20 lb. of corn silage and hay ad. lb. One group was fed an average total for the year (including the dry period) of 2,442 lb. of grain and the other only 1,639 lb., ratios of grain to milk of 1:4 and 1:6.5.

The cows fed 803 lb. **more** of **grain** ate only 473 less of hay, gaining an estimated 1 lb. of total digestible nutrients per day but produced 1.4 percent **less milk**. This comparison involves 22 lactations on moderate grain feeding and 21 on light grain feeding or about double the number involved in any of the other experiments reviewed here. The economic importance of this problem has since been emphasized by the development of grassland stimulated by the Soil Conservation Service and also by the relative prices of grain and good quality hay.

EXPERIMENTAL

To further test the effects of liberal and limited grain feeding on milk production an experiment was planned to be conducted at the Belmont County Experimental Farm at St. Clairsville, Ohio. The dairy barn provided 22 stanchions so that only 11 cows could be carried concurrently in each of the two groups.

Objective

This experiment was planned to measure the effects of level of grain feeding on entire lactations for the productive life of the cow.

Experimental Plan

Since the silo capacity was limited only 24 lb. of silage were to be fed daily. This silage was of a grass-legume mixture each year. After settling, the silo was refilled with corn. Both groups were fed daily from the same source so that both groups were affected alike by changes in kind of silage.

Grain was to be fed at two rates designated as liberal and limited. Hay was to be fed ad. lib. permitting the cows on limited grain to compensate by eating additional hay. The hay was fed in continuous mangers to the separated groups. Twice each month the hay was weighed in and refusal weighed back. Average amounts of hay consumed were charged against each animal of the respective groups. Some hay was purchased each year to supplement the farm grown hay that was fed. The experimental plan specified that all hay would be early cut and of

high quality. However, the hay produced on the farm had to be used even if rain damaged. Most of the hay purchased would not have graded higher than U. S. No. 3 alfalfa.

Grain

The grain mixture fed to both groups was composed of:

	Lb.
Ground ear corn	650
Ground oats	200
Soybean oil meal	150
Salt (mineralized)	10
Bonemeal	10
Total	1,020

A composite sample of grain for the year of 1954 analyzed 14.84 percent total protein.

The rate of grain feeding followed was according to the following table:

Milk Production, Daily		Grain Feeding	
lb., actual	lb., 4% F.C.M.	Limited	Liberal
40	47	11	15
35	42	9	14
30	36	8	12
25	30	6.5	10
20	24	5	8
15	18	3	6
10	12	2	4
Dry	Dry	2	4

Experimental Animals

The herd consisted entirely of Jerseys. The animals of milking age when the experiment began in September 1950 were divided on the basis of age, weight, stage of lactation and both current and past production. As 2-yr. old heifers calved they were assigned alternately to the groups without regard to their relationship to other members of the group. Heifers were bred to calve at 24 months. Many cows were re-bred to calve at 11 months, particularly those cows that were known to have short lactation periods.

The limited trouble experienced in getting heifers in calf was unrelated to this experiment.

The herd was brucellosis and tuberculosis free. In the summer of 1956 leptospirosis infected the herd. Four cows died and several responded with low production. The animals were carried on experiment for their entire lactations but any records were discarded where the lactation curves indicated that the animals were adversely affected.

The experiment was terminated in early 1957 as individual lactations were completed.

Pasture Seasons

Both groups ran together on pasture. With few exceptions the cows were turned on pasture May 1 and taken off November 1. When shortage of pasture made supplementary feeding necessary both groups were given hay or silage alike. They then had opportunity to adjust for requirements of digestible nutrients by varying the amount of grazing. The same rate of grain feeding was followed when on pasture or winter feeding. The same grain mixture was used in summer even though this resulted in excess estimated protein during the early part of the grazing season.

RESULTS

Number of Lactations

During the period from September 1951 to March 1957, 62 lactations were completed by cows fed grain liberally and 60 by those fed limited grain. Twenty-three other lactations were discarded because some uncontrolled variable made them unsatisfactory.

Production and Consumption Data

Table 1 presents the data on production and feed consumption for the two groups of 19 cows each. The average age of those fed grain liberally was 4 years and 10 months as compared with 4 years and 5 months for those fed limited grain. The average length of lactation periods was 292 and 293 days respectively.

The 62 lactations completed by the 19 cows fed grain liberally averaged 7,065 lb. of milk and 365 lb. of fat equivalent to 8,285 $\pm$ 1,339 lb. of 4 percent fat-corrected milk (FCM). When the individual records are converted to a mature basis they averaged 8,921 lb. The 60 lactations completed by the 19 cows fed limited grain averaged 7,283 lb. milk and 380.9 lb. fat equivalent to 8,618 $\pm$ 1,439 lb. of 4 percent FCM and equivalent to 9,310 lb. of 4 percent milk when calculated to a mature basis. The variability within groups was large and the "t" test shows the differences between groups not significant. The average daily production of 4 percent milk on a mature basis was 30.6 and 31.8 lb

TABLE 1.—Data on Milk Production and Feed Consumption for Cows Fed Liberal and Limited Grain

Groups	Grain Feeding	
	Liberal	Limited
No. of cows	19	19
No. of lactations	62	60
Av. age—yrs. and mos.	4–10	4–6
Av. days per lactation	292	293
Actual milk/lactation, (lb.)	7,065.0	7,283.0
Actual fat/lactation, (lb.)	365.0	380.9
Actual milk/day, (lb.)	24.2	24.9
Butterfat, (%)	5.2	5.2
Actual 4% FCM, (lb.)	8,285 ± 1,339δ	8,618 ± 1,439δ
4% milk, calculated to a mature basis		
Per lactation, (lb.)	8,921 0	9,310.0
Per day, (lb.)	30 6	31 8
Feed consumed during lactation		
Silage, (lb.)	3,439.0	3,132.0
Hay, (lb.)	3,192.0	3,252.0
Grain, (lb.)	2,703.0	1,961.0
Pasture days	134	154
Weight change, (lb.)	+47	+34
Feed cost/100# 4% FCM* ($)	2.53	1.78

*Calculated at $25.00 per ton for hay, $8 00 for meadow crop silage and $46.50 for grain mix, for winter feeding only

δStandard deviation

respectively. Since the average butterfat percent is the same for both groups there is no evidence of effect of either grain or roughage on fat content on these planes of feeding.

The greater variability in production of the animals fed limited grain suggested study of the lactation records of the 2-year olds that completed records also as 3-year olds, of which there were 12 in each group. The records as 2-year olds of those fed grain liberally were 6,948 lb. of 4 percent FCM and as 3-year olds 7,749 lb. as shown in Table 2 . The 2-year old and 3-year old records when calculated to a mature basis were 8,606 and 8,762 lb. respectively· these equivalents are practically the same on the mature basis, as they should be. When the 2-year and 3-year old records of those fed limited grain are averaged they are 7,090 and 8,204 lb. FCM respectively. When converted to a

mature basis these are 8,925 and 9,299 lb. respectively. The increase of 4 percent in production with greater maturity resulting from a year of production suggests that the limited grain feeding did not provide adequate energy for the 2-year olds to meet their needs. It might have been adequate, however, with better forage.

TABLE 2.—The Production as 2-year Olds and as 3-year Olds of Those Animals Fed Limited and Liberal Grain

	Level of grain fed	
	Liberal	**Limited**
4% FCM/lactation, (lb.)		
Actual Production		
2-yr. records	6,948	7,090
3-yr. records	7,749	8,204
Mature Basis		
2-yr. records	8,606	8,925
3-yr. records	8,762	9,299

The difference of 2 percent in production of the 2-year olds of the two groups is less than the difference in production of the entire groups; in both cases the groups fed limited grain produced more.

Multiple Regression Analysis

Since 20 days more of pasture were utilized the group fed limited grain, the need for removal of this variable was indicated. Therefore, the production of each group was separated and tabulated when on pasture and when on winter feed. From these data, regression lines were constructed and presented as Fig. 1. All regression coefficients were highly significant. The regression analysis of 4 percent age-corrected 4 percent milk also considered level of grain feeding and stage of lactation. The average daily 4 percent age-corrected milk was determined for each calendar month, or fraction thereof, for each lactation. The average production for the 1,291 observations was 30.92 lb. The multiple regression statistics appear in Table 3.[2]

The multiple correlation coefficient is 0.7177 which is highly significant.

[2]Thanks are due to Dr. C. R. Weaver, Station Statistician, for this analysis.

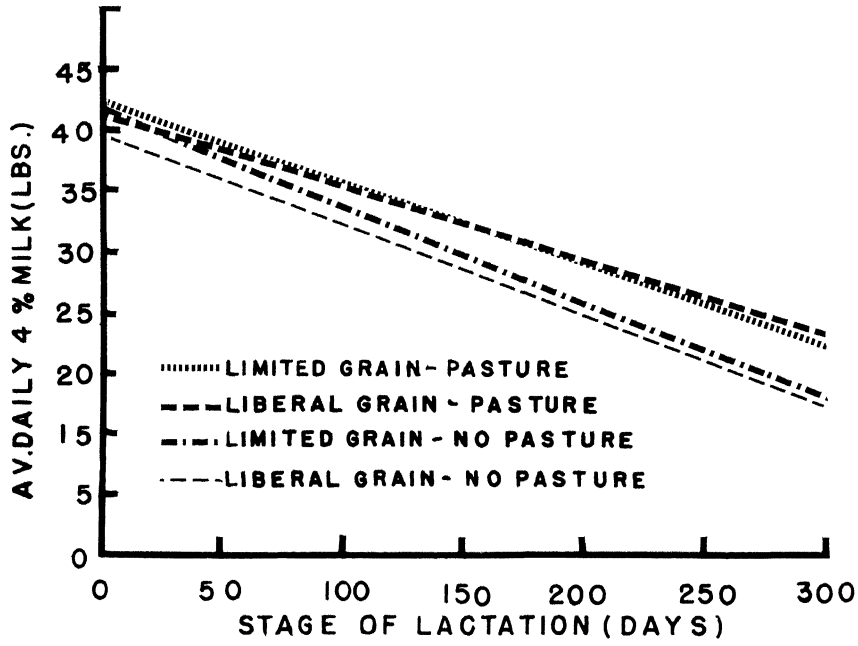

Fig. 1.—Chart shows regression lines for four groups. Average production for 1,291 observations was 30.92 pounds.

TABLE 3.—Multiple Regression Analysis

	Regression b	Standard error S_b	t
Pasture	1.6055	0.0193	83.19*
Grain feeding	−1.0571	0.0190	55.64*
Lactation	−0.0711	0.00000061	116,557.38*

*Highly significant.

Effects of Feeding on Production

The greater production of 1.6 lb. of milk daily while on pasture accounts for only 32 lb. of the 333 lb. variation in yield between the two groups. That the cows of both groups produced more milk in summer than when on the same kind and ratio of grain in winter suggests that the forage fed in winter did not give a maximum response.

The data show the greater body weight increases of the group fed grain liberally during the lactation periods. Coupled with the lowered production of 1.057 lb. of milk per day from liberal grain feeding and consequent reduction in forage intake from eating more grain, these data suggest a change in energy utilization. This may have been associated with a shift in the proportions of acetic and butyric acids produced in the rumen. The research of Hibbs **et al.** (**10**) with dairy steers, showing greater efficiency in use of T.D.N. during fattening (from 52 to 72 weeks) on a roughage to grain ratio of 1:1.1 compared to a ratio of 1:2.2 is further evidence that high roughage feeding favorably affects ruminant performance.

The feed consumed during the lactation periods only has been tabulated (Table 1) to eliminate the effects of difference in the length of the dry interval before calving. If the cows fed limited grain had been on pasture only 134 days they would have had 480 pounds more of silage and possibly 450 pounds more hay per animal than they actually consumed. The estimated total digestible nutrient content of the calculated increased forage intake would have been only approximately one-half as much as that of the 742 lb. of grain (difference in consumption by the two groups).

Apparently with cows on a higher level of production the roughage would need to be of higher quality to realize maximum production on limited grain.

Feed Costs of Production

At current farm prices of $25.00 per ton for hay, $8.00 for meadow crop silage and $46.50 for grain mix, the feed cost of 100 lb. of milk produced in winter, when a record of total feed consumption was made, was $1.78 for those fed limited grain and $2.53 for those fed grain liberally. Costs cannot be determined for the pasture season due to lack of information on grass consumption.

Unpublished data from another project (**18**) show that very light grain supplement for cows fed green-chopped grass-legume increases dry matter intake while double that amount of grain did not further increase dry matter intake but substituted grain dry matter for grass dry matter without increasing milk production.

During the first winter of this experiment dairymen unfamiliar with the experiment and barn employees noted that those cows fed grain liberally carried more flesh and showed a glossier hair coat but thereafter this condition was not noticeable.

Breeding Response

A study has been made on services per conception for both groups, however, only the conceptions that occurred during the feeding experiment were considered. Thus the first calving was not included while the calving followed the use of the cow on experiment was included as service occurred while under this feeding regime. These data appear in Table 4.

TABLE 4.—Breeding Data for Cows Fed Liberal and Limited Grain

Group	Number Cows	Number Conceptions	Services per Conception	Cows Conceiving on 1st Service	Number of Cows Conceiving on Service Number										
				%	1	2	3	4	5	6	7	8	9	10	11
Liberal	19	57	1 63	73 6	42	5	4	2	3	1	--	--	--	--	--
Limited	19	58	1.84	75 8	44	2	5	3	--	2	--	--	1	--	1

The percentage conceiving on first service within the two groups is very similar. Fifty-one of each group conceived on or before the third service. Level of grain feeding does not appear to have influenced rate of conception.

Effect of Protein

The grain ration used in this experiment contained 14.8 percent total crude protein. Samples of the hay composited for entire years varied from 11.8 to 12.4 percent protein (air dry basis) while similar composites of grass-legume silage average 11.1 percent protein. Thus substitution of grain mixture for hay would increase the total protein content of the total ration. The fact that the cows on the limited grain produced more milk indicates that the protein was adequate for that level of milk production and suggests that some other factor is responsible for the significantly greater milk production.

Of the other experiments referred to above that of Martin, Stoddard and Allen (**16**) utilized a grain mixture of the lowest total protein content (11.7 percent) which when substituted for hay on an equal T.D.N. or estimated net energy content, neither increased nor decreased production.

Evidently a grain mixture of 12 percent total protein is adequate when forage quality is good except, perhaps, for very high milk production.

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