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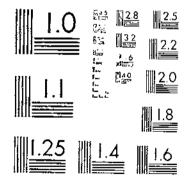
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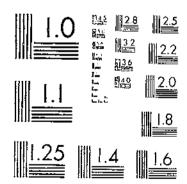
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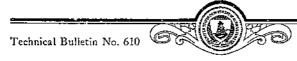
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MICROCOPY RESOLUTION TEST CHART NATIONAL BUREAU OF STANDARDS 1965 A

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March 1938

#### UNITED STATES DEPARTMENT OF AGRICULTURE WASHINGTON, D. C.

### FEEDING DAIRY COWS ON ALFALFA HAY ALONE '

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#### INTRODUCTION

During the last few years investigators have given much thought and study to the dairyman's problem of obtaining better quality in roughage and of utilizing roughages to a greater extent in feeding dairy cattle. This increased attention has been brought about partly by the economic situation, which has emphasized the necessity of keeping costs of milk production at a low level; and partly by a growing realization that extremely high milk production per cow, obtained by heavy grain feeding, is not necessarily the most economical production.

The Bureau of Dairy Industry has long recognized the important advantages of growing and feeding roughage crops on the dairy farm, and for a number of years the dairy-cattle feeding investigations carried on at the Bureau's regional experiment stations have been concerned with various phases of the problem of including more and better

<sup>&</sup>lt;sup>1</sup> Submitted for publication Aug. 27, 1937.

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roughage in the dairy ration. In its experiments (17, pp. 15-22) 3 at the Huntley, Mont., station, for example, the Bureau has shown the relative production of cows when fed roughage exclusively, and when fed roughage with grain. Graves and Shepherd 4 have shown the relative economy of milk production under different feeding systems when the crops (both grain and roughage) are home grown. The importance of cutting roughage crops (grasses and hays) at early stages of maturity in order to improve their nutritive value for milk production was shown in experiments with Sudan grass at the Woodward, Okla. station (4) and with pasture grasses at the Huntley station (7). Experiments are now under way to furnish information on other phases of roughage feeding.

In many irrigated sections of the United States alfelfa hav is grown in abundance, and is the crop, next to pasturage, in which nutrients for milk production can be produced at the lowest cost. In these regions dairy cows are fed rations consisting almost entirely of alfalfa Apparently, this heavy feeding of alfalfa hay, year after year, o detrimental effect on the animals' health. However, very few has no detrimental effect on the animals' health. definitely controlled experiments have been conducted to show the comparative effects on milk production and on the condition of the cows, of feeding alfalfa hay alone for extended periods as compared

with other systems of feeding.

Experiments by the Bureau have shown that cows will produce somewhat more milk when they have access to pasture during the pasture season and some other good roughage such as silage is added to the ration, than when they are restricted to alfalfa hay. these other feeds add some nutritive element that is not present in alfalfa hay or whether they simply provide a greater variety in the ration, and thereby stimulate a greater consumption of feed which

brings about this greater production, is not definitely known.

This bulletin gives the results of feeding 15 Holstein-Friesian cows throughout 26 lactation periods entirely on alfalfa hay. As a rule, alfalfa hay would not be fed exclusively throughout the year under commercial conditions. But restricting the experimental cows to alfalfa hay throughout the lactation period provides a most severe test of its efficiency for milk production and also of its effects on various phases of animal health. Feeding alfalfa hay alone also has an experimental advantage over feeding a ration in connection with pasturage, in that the amount of nutrients consumed can be measured more accurately.

The production of alfalfa has increased greatly in many sections in the last few years and will probably continue to increase for years This is because alfalfa is not only a cheaper source of nutrients for milk production than most other crops produced where it grows abundantly, but is also a soil improver and has an important

place in conservation of the land and in control of erosion.

The results of the experiment herein presented should be a useful

<sup>&</sup>lt;sup>3</sup> Italic numbers in parentheses refer to Literature Cited, p. 45.

<sup>&</sup>lt;sup>3</sup> Ibalic numbers in parentheses refer to Literature Cited, p. 45.

<sup>4</sup> Graves, R. R., and Shepherd, J. B. A study of certain phases of the economics of bary-cattle feeding. U. S. Bur. Deiry Indus., Roughage Feeding Ser. 1, BDIM-625, 1933. (Mimeographed.)

United States Department of Admiculture, Burkau of Damy Industry. Roughage feeding Ser. 2, BDIM-626. 1934. [Mimeographed.]

Graves, R. R., and Shepherd, J. B. A study of the effect of modified systems of farming on Milk production and net returns over cash outgo for purch-sed feeding Ser. 3, BDIM-627. 1934. [Mimeographed.]

contribution to our knowledge concerning one phase of the feeding of dairy cows that has heretofore received very little attention, and also of the efficiency of alfalfa hay for milk production.

#### REVIEW OF THE LITERATURE

The literature is rather extensive concerning experiments in which alfalfa hay has been fed as a part of various rations for dairy cattle. This review is confined to the comparatively few investigations wherein alfalfa hay, with or without mineral supplements, was the only feed used over periods long enough to bring out the advantages or disadvantages of such a system of feeding, as indicated by its effects on

the animals and on the economy of milk production.

Reed, Fitch, and Cave at the Kansas Agricultural Experiment Station (19) fed a group of six Holstein heifers on alfalfa hay exclusively from the age of 6 months through their first and second 10-month lactations. For the two lactations they averaged 4,124 pounds of milk and 150 pounds of butterfat, or an average of 1 pound of milk for each 2.24 pounds of alfalfa hay consumed and 1 pound of butterfat for each 61.6 pounds of hay consumed. Two of these heifers were later carried through a third lactation period under full-feed conditions, in which they received grain and silage and pasture in addition to alfalfa hay. On the full-feed ration the two heifers averaged 8,191 pounds of milk containing 298 pounds of butterfat. Both heifers increased very materially in body weight.

Two additional groups of heifers that were fed hay, grain, silage, and pasture produced approximately 40 percent more milk and butterfat during the first lactation than the group receiving alfalfa

hay alone.

The breeding records revealed that there was slightly less difficulty in bringing about conception in the animals fed exclusively on alfalfa

hay than in those fed on hay, grain, and silage.

Woll (20) at the California Agricultural Experiment Station fed three heifers (one Holstein and two Jerseys) through two lactations on alfalfa hay and green alfalfa. They consumed 1.7 pounds of alfalfa-hay equivalent for each 1 pound of milk produced in the first lactation, and 1.6 pounds of hay equivalent in the second lactation. The hay consumption per pound of milk was somewhat lower than that reported by the Kansas station. There was no evidence that the exclusive feeding of alfalfa affected the breeding or fertility of the cows.

A later report by Woll and Voorhies (1), comparing production on alfalfa hay with that on a mixed ration that included full-grain feeding, gave the following summary: The average production on the alfalfa ration was 6,491.5 pounds of milk and 258.86 of butterfat, and on mixed ration, 7,336.8 pounds of milk and 323.37 of butterfat. The animals on the alfalfa ration produced 88.4 percent as much milk and 80.0 percent as much butterfat as those on the mixed ration that included full-grain feeding.

Headley (12) of the Nevada Experiment Station fed four grade Holstein cows for 4 years on selected alfalfa hay alone. They averaged 8,644 pounds of milk containing 304 pounds of butterfat per cow per year, and consumed 1.6 pounds of hay for each pound of milk produced. Their body weights remained practically stationary, averaging 1,355 pounds per cow per year. Four similar grade Holstein cows that were

allowed selected alfalfa hay at will were fed an average of 2,160 pounds of grain in addition, which was approximately at the rate of 1 pound to each 5 pounds of milk produced. Their production for the 4 years averaged 10,352 pounds of milk and 359 pounds of butterfat per cow per year. The cows on alfalfa hay alone produced 83 percent as much milk and a little less than 85 percent as much butterfat as the cows that were fed alfalfa hay and grain. The grain feeding apparently had little effect on the amount of hay consumed. A third group of cows fed the alfalfa hay ration and the grain and hay ration in alternating years averaged 9,163 pounds of milk and 326 pounds of butterfat. Their average hay consumption was only slightly less than that of the first group. Their body weights increased, especially during the years when grain was fed. There was some indication that the cows fed continuously on alfalfa hay alone were more inclined to breeding trouble, but the small number of animals does not warrant definite conclusions.

In comparing the feeding value of alfalfa hay produced in central Oregon and in the Willamette Valley, the Oregon Agricultural Experiment Station (18) fed two groups of three cows each on alfalfa hay exclusively for 342 days. Little difference was found in the two hays. The six cows consumed an average of only 9,936 pounds of hay during this period or less than 30 pounds per cow per day. Their production was very low, however, averaging only 3,953 pounds of milk containing 148 pounds of butterfat. It was stated that

this compares very unfavorably with the production of 300 to 450 pounds of butterfat per year claimed by many dairymen feeding only alfalfa hay. This discrepancy can hardly be due to better cows, as several of the cows used in the test have demonstrated their ability.

Later, in referring to the same experiment, Hang and coauthors (11) state that "the milk production of the animals restricted to alfalfa hay was approximately one-half that to be expected on the regular herd ration." They concluded that the intake of total digestible nutrients was not adequate for more than very moderate milk production. The body weights of the cows were not given. If the Savage standard of total digestible nutrients required for a body weight of 1,000 pounds is used, the consumption of 9,936 pounds of alfalfa hay of average nutrient content, would be enough for maintenance and the production of approximately 7,300 pounds of milk testing 3.7 percent of fat and containing 270 pounds of butterfat. This, however, is 3,346 pounds more milk than they actually produced.

Metabolism studies with some of the above-mentioned cows on alfalfa hay alone showed that early in the lactation period the cows were usually in positive calcium balance and were always in negative phosphorus balance. Feeding disodium phosphate changed the negative phosphorus balances to slightly positive balances. The hay contained 1.6 percent of calcium and 0.153 percent of phosphorus. A later report by Hang and others (10) showed that cows on alfalfa hay alone gave negative calcium and phosphorus balances and that the supplemental feeding of bonemeal resulted in distinctly positive calcium and phosphorus balances. They point out, however, in a general review of their work that the rapid decline in milk flow of cows fed largely on alfalfa hay is suggestive of a lack of specific nutrients rather than of total digestible nutrients. They question the biological

value of the proteins of alfalfa hay (when fed alone), especially the lack of the amino acid cystine as reported by Haag (9) in work with rats. A preliminary feeding trial indicated that wheat bran, a fairly good source of cystine, was effective as a supplement to alfalfa hay for

dairy cows.

Huffman and coworkers (14, 15) at the Michigan Agricultural Experiment Station and Eckles and coworkers (5) at the Minnesota Agricultural Experiment Station have published results that apply to certain phases of this experiment. Their publications also include a complete review of the literature covering phosphorus deficiencies and

requirements of dairy cattle.

Some investigators have reported undesirable effects on the milk (and its hyproducts) produced by cows fed exclusively on alfalfa hay. Richardson and Abbott (3) at the California station found indications that from 6 to 8 weeks on straight alfalfa feed caused cows to produce butterfat that made up into a typical sticky butter. Adding silage to the ration removed this condition, but it required about the same length of time for the butterfat to become normal.

Roadhouse, Regan, and Mead (2) of the same station showed that alfalfa in the form of bay or pasture, or when cut and fed in the green form, produced a marked flavor in the milk if fed within 5 hours before

milking. The hay produced the least noticeable flavor.

#### EXPERIMENTAL PROCEDURE

#### EXTENT OF THE DATA AND HISTORY OF COWS USED

The Bureau of Dairy Industry maintains seven field experiment stations, located in as many different regions, for the purpose of conducting breeding and feeding experiments of regional and Nationwide interest and importance. The data for the study reported herein are from the results of work at the stations at Mandan, N. Dak., Huntley, Mont., Woodward, Okla., and Ardmore, S. Dak.<sup>5</sup>

The breeding experiments at these stations require that all females be raised to producing age under similar environmental conditions, and tested under full-feed conditions to determine their inherited capacity for milk and butterfat production. After completing these tests, the cows are available for use in various other feeding experi-

ments.

Since all cows are raised, handled, and tested under similar conditions at all stations, comparable production records under full-feed conditions are normally available. But comparable records to show the relative level of production by the same cows when they are fed other rations must be obtained by further feeding experiments.

For the purpose of this study, 15 registered Holstein-Friesian cows that had completed 365-day production records under full-feed conditions were subsequently fed for yearly lactation records on a ration restricted to alfalfa bay. Table 1 gives the herd number, the previous history and breeding record, and the age of each of these cows at the time they were entered in the alfalfa hay feeding experiment, as well as their breeding records during their two or three consecutive lactations on the alfalfa hay rations.

<sup>&</sup>lt;sup>5</sup> Dairy work at the Ardmore, S. Dak., station was discontinued in 1992.

Table 1.—History and breeding records of the 15 Holstein-Friesian cows for the period before they were fed the alfalfa hay ration, and observations during the experiment by lactation periods

Cow No.	Age a expe	t start of riment	History before use in experiment on alfalin hay alone	History by cor	secutive lactations on alfalfa hay ration	
-	Years	Months		First lactation	Second lactation	Third lactation
H-31	7	4	Had 2 lactations on limited grain, 1 on roughage alone, and 1 on full feed. Per-	Normal in all respects		
H-38.	ā	s	fect breeding record.  Had 1 lactation on full feed, 1 lactation on limited grain. Some breeding trouble.	Did not come in oestrus during lactation.  Developed vaginitis. Conceived later		
H-39	6	9	Breeding trouble. Inbred.	on full feed after treatment. Breeding rormal. Rather poor appe- tite for hay.	Breeding normal, but was bred too soon; record for 285 days. Appetite better. Milk developed alfalfa	
H-52	6	4	Breeding trouble. Aborted twin fetuses. 1 abnormal presentation.	Breeding trouble. Abnormal calf. Abnormal flavor and odor in milk for a short period.	flavor and odor, Breeding normal, Calved normally, Calf weak.	
H-53	6	3	Breeding normal, 1 dead calf, 1 abortion.	Normal in all respects	Normal in all respects.	
H-62	3	3	Normal in all respects	Developed vaginitis. Bred once, did not conceive or later come in oestrus.	·	
H-64			do	Sold as nonbreeder. Breeding normal, Bred too soon. Record for 308 days,	Accidentally bred at first heat period. Record for 265 days.	Bred 4 times before con- ceiving. Aborted.
			(lo	In oestrus at all times; did not conceive. Sold as nonbreeder upon completion of record.		
-W-44	3	9	Normal breeding record. Aborted first calf. Inbred.	Normal breeding record. Heavy con- sumption of hay with high refusal.	Normal breeding record. Went dry in 285 days.	Normal in all respects,
W-47	3,		Normal breeding record	Normal breeding record. Aborted a de- composed fetus that was carried 199 days. Low production.	Normal breeding record. Dry for 16 months previous to this lactation.  Low production.	
W-54 W-55	4 3	4	Normal in all respects	Normal in all respects Normal breeding record, Poor pro-	Did not show signs of oestrus until 6	
W-63 W-69	3 3	. a	Bred 4 times for first calf. Some mastitis Normal in all respects.	do		
270	9	4	Some breeding trouble as a younger cow. Extremely high producer. Raised at Beltsville, Md., shipped to Mandan, N. Dak., few months previous to start of experiment.	(10	Normal in all respects.	

Table 2.—Production records of the 15 Holstein cows when fed the alfalfa hay ration and when on full feed

			W	nen fed the n	lfalfa hay	ration					W	ben on full	feed		
Cow No.	Alfalfa hay con-		\ge	Period carrying	Milk	Butterfat	mnt	ated to urity	- 1	\ge_	Period carrying	Milk	Butterfat		lated to urity
	sumed		Month	calf				Butterfat	Year	Month	calr			Milk	Butterfat
H-31 H-31.	Pounds 16, 134		1	Days 248	Pounds 12, 225	Pounds 426. S	Pounds 12, 225	Pounds 426. 8	6	2	Days 224	Pounds 16, 677	Pounds 559. 5	Pounds 16, 677	Pounds 559.
H-38. H-39 1 H-39 2	16, 304 - 15, 795 12, 857 11, 490	- 5 6 8	8 9	211 0 169 251	11, 735 14, 400 10, 319 7, 527	411, 5 486, 4 386, 9 209, 6	11, 735 14, 544 10, 319 7, 527	411. 5 491. 3 386. 9 299. 6	3 2	0 10	147 195	15, 067 11, 587	501. 0 441. 8	18, 231 14, 368	606. 2 547, 8
H-52 . H-52 . H-53 .	15, 861 14, 984 16, 367	6 8 6	4 : 1 3	241 186	12, 557 10, 892 12, 359	468. 9 402. 9 509. 9	12, 557 10, 892 12, 359	468. 9 402. 9 509. 9	$\frac{2}{2}$	6	186 191	15, 396 13, 940	530. 7 522. 5	19, 861 17, 983	684. (
H-53 H-62 H-64 <sup>3</sup> H-64 <sup>+</sup>	17, 199 11, 954 11, 794 11, 530	7 3 4 5	8 - 11 - 10	197 0 246 220	10, 729 9, 996 10, 294 7, 108	396. 9 335. 8 370. 9 260. 3	10, 729 11, 096 10, 809 7, 179	396. 9 372. 7 389. 4 - 263. 0	$\frac{2}{2}$	6 7	114 192	16, 071 15, 215	529. 9 522. 0	20, 732 19, 475	683. 668.
H-64 W-21 W-4: W-44 <sup>5</sup>	11, 826 17, 092 16, 278 12, 155	6 7 3	8 11 9 11	40 0 206 199	9, 978 15, 109 11, 578 7, 641	375. 5 487. 5 401. 5 253. 6	9, 978 15, 109 12, 967 8, 023	375, 5 487, 5 449, 7 266, 3	$\frac{2}{2}$	5 6	213 188	15, 998 12, 520	499. 9 430. 3	20, 957 16, 151	654. 555.
W-44 W-47 W-47	14, 237 13, 533 11, 085	6 3 6	9	- 239 186 245	7, 876 8, 603 8, 181	278. 8 204. 7 254. 1	7, 876 9, 635 8, 181	478. 8 296. 5 254. 1	1	7	215	11, 893	348. 6	17, 810	522.
W-54 W-55 W-55	13, 164 13, 094 16, 466	4 3 4	4 8 10	205 219 155	9, 427 8, 285 12, 783	317. 6 258. 2 391. 0	10, 181 9, 362 13, 422	343. 0 292, 8 410, 5	2 2	2 5	201 205	17, 110 17, 947	548. 7 563. 5	23, 270 23, 511	746. 2 738. 2
W-63 W-69 270	13, 638 13, 386 14, 089 15, 158	3 3 9 10	7 5 4 4	259 268 188	11, 013 9, 936 11, 210 9, 713	380. 4 326. 6 437. 5 389. 4	12, 555 11, 526 11, 210 9, 713	433. 7 378. S 437. 5 389. 4	2 2 5	3 1 9	172	12, 719 16, 739 21, 763	444. 6 523. 2 800. 5	17, 171 23, 100 21, 981	722. 808.
A vernge 5		5	11		10, 702	375, 6	11, 125	389. 6	2	11	183	15, 376	517.8	19, 421	651.

<sup>Milked twice a day on the alfalfa hay ration; 3 times a day on full feed.
Bred too soon, milked for 285 days on the alfalfa hay ration; this record on hay was not used in the average.
Bred too soon, record for 305 days on the alfalfa hay ration.
Bred too soon, milked for 265 days on the alfalfa hay ration; this record on hay was not used in the average.
Record on the alfalfa hay ration for 285 days when cow went dry.
Average for 24 records on the hay ration; 15 records on full feed.</sup> 

At the Mandan station, cow H-64 completed three consecutive lactations on the alfalfa hay ration and cow 270 completed two. At the Huntley station, cows H-31, H-52, and H-53 each completed two consecutive lactations, and H-38 and H-62 each completed one lactation. At the Ardmore station, H-39 completed two consecutive lactations. At the Woodward station, W-44 completed three consecutive lactations, W-47 and W-55 two each, and W-21, W-54, W-63, and W-69 one lactation each.

The 15 cows completed a total of 26 lactation records on the alfalfa hay ration. All but 4 of the 26 records were for 365 days. Two of the records (second records of H-39 and H-64) were for less than 300 days, because the cows were accidentally bred too soon after calving, and are omitted from the calculations because they are not comparable. On the other hand, two other records, one for a little more and one for a little less than 300 days, were considered comparable with the 365-day records and are included in the calculations.

Table 2 gives the production records of the 15 cows for their 26 lactation periods on the alfalfa hay ration, also their production

records for their 15 lactation periods on the full-feed ration.

All the records on full feed with the exception of cow 270 were made in stanchions, and the cows were milked three times a day. Grain was fed at the rate of approximately 1 pound to each 3 pounds of milk produced, and the roughage part of the ration consisted of alfalfa hay, silage, and pasture.

Although the feeding and management conditions under which the full-feed records were made were not extreme, they were such as to enable these cows to produce somewhere near their inherent capacity. As will be shown later in the discussion of the feed and nutrient consumption, all these cows were capable of a high level of production under good feeding conditions.

Nearly all the cows made their full-feed records at an immature age, but they varied considerably in age when they were on the alfalfa hay ration. Because of such variations, and also because of the fact that some of the cows had been accustomed to roughage for long periods, it is necessary to present and discuss the results in more detail than if all the cows had been equal in age and production and had been accustomed to a ration of roughage only.

#### FEEDING THE ALFALFA HAY RATION

The cows were not all on the alfalfa hay ration simultaneously. Individual cows were started on the ration, independently of other cows, whenever they were available and always at a time when they could complete the entire lactation period on alfalfa hay. Each cow was started on the alfalfa hay ration at approximately 30 days before calving in order that she would be accustomed to the ration when her lactation began. After a cow had once started on the alfalfa hay experiment, she was fed alfalfa hay exclusively, throughout the entire lactation period and the dry period, until she was taken off the experiment. Of the 15 cows, 7 were on the experiment for 2 consecutive lactations, and 2 for 3 consecutive lactations.

At Woodward, Ardmore, and Hundley, the cows were kept in standiions while the hay was being fed. When the weather was favorable they were turned into an exercising lot where no feed was available. The hay was weighed out to the cows twice a day, and the amount not eaten was weighed back once a day. Cows W-54, W-63, and W-69 at the Woodward station were carried as a group for part of their lactation and the hay consumed and refused was prorated. At the Mandan station, cows H-64 and 270 were kept in a pen barn, each cow being kept in a small pen in order to obtain individual hay-consumption records. All cows either had frequent access to water in

the lots or drinking cups were provided in the stanchions.

After the cows became well accustomed to the hav ration, an attempt was made to offer them approximately 10 percent more hay than they were consuming. It was found, however, that when the amount offered was restricted too closely the amount they would The average amount rejected varied widely consume was lessened. for different cows. One of the cows consumed as high as 93.4 percent of the amount offered over the year and one consumed only 65.4 percent (table 9). However, the wide variations in percentage consumed by the different cows was probably due more to the palatability of the hay and to the individual preferences of the cows, than to The average the amount offered in excess of what they would eat. consumption for all cows was 84.7 percent of the amount offered. was noted with the majority of the cows that the refused hay was not confined entirely to the coarse stems. A portion of the weighback consisted of shattered leaves.

#### QUALITY OF ALFALFA BAY FED

The alfalfa hay used in these feeding experiments was produced in several different regions and varied in quality. The majority of the hay fed at Ardmore was produced locally under dry-land conditions, although some was purchased in northern Nebraska. All the hay fed at Huntley was produced locally under irrigation and was field cured, for the most part under good conditions. It was of excellent quality. Most of the hay fed at Woodward was produced locally under dry-land conditions and was of good quality and color; one year some of it was purchased near Garden City, Kans., and was of high quality. Most of the hay fed at Mandan, was/purchased in the vicinity of Huntley, although a small amount of locally grown hay was fed which was also of good quality.

No attempt was made to select the hay for any of the animals; it was fed as it came. It was the practice, however, to purchase only good-quality hay. Although poor-quality hay was fed occasionally for short periods the majority of the hay would have graded U.S. No. 1 alfalfa. Samples were taken occasionally and sent to Beltsville, Md., for chemical analysis. A total of 34 samples were analyzed, consisting of 4 from Ardmore, 16 from Huntley, 8 from Woodward,

and 6 from Mandan (table 11).

#### MINERAL SUPPLEMENTS FED

All cows had access to salt at will while they were on the alfalfa hay ration. In addition, a box containing special steamed bonemeal was so placed that each cow had access to it. It was observed that most of the cows ate little if any of the bonemeal. The amount consumed was measured for a time, but the consumption proved so small that measuring was discontinued. This is discussed more fully under Consumption of Calcium and Phosphorus.

#### MANAGEMENT OF COWS

All cows were milked three times a day, both when making their records on the alfalfa hay ration and under full-feed conditions, except cows H-39 and H-52, which were milked twice a day throughout

the first lactation period on the alfalfa hay ration.

It was planned to have all the cows in milk for 365 days with a dry period of a month or 6 weeks between lactations. Unfortunately, some of the cows were accidentally bred too soon, and calved again in less than 300 days. Their records are included, but in some cases they are not used for comparisons.

#### RECORDS KEPT

Daily milk weights were kept, and once each month a sample of the milk was tested for butterfat. Daily weights were kept of the amount of hay fed and weighed back. The difference was considered as having been consumed. Body weights were taken for 3 consecutive days each month. The average monthly weight was calculated by averaging the weights for 2 consecutive months. average lactation-period weights are the average of the weights for the first and last month in lactation. Some of the cows were weighed a day or two previous to and immediately following calving. the others the nearest 3-day average weight previous to calving or following calving was considered as the precalving or after-calving weight.

Routine breeding and calving data were recorded at all times. Complete data were also available for all cows when under full-feed conditions. In addition, the men in charge of the cows noted any abnormal conditions they thought might be due to an exclusive ration of alfalfa hay. These observations will be referred to as the discus-

sion of the data proceeds.

#### PRODUCTION OF MILK AND BUTTERFAT

#### PRODUCTION ON ALFALFA HAY ALONE

The individual records of milk and butterfat production on the alfalfa hav ration by lactation periods, the ages at which the records were made, the number of days each cow carried a call, and the records calculated to a mature basis are given in table 2. records for the same cows under full-feed conditions are included for comparison, and are discussed in subsequent sections. The individual amounts of alfalfa hay consumed are also included in table 2, but are discussed in a later section on Feed and Nutrient Consumption. The production records are for 365 days, unless otherwise noted.

The second record made by cow H-39 on the alfalfa hay ration is not comparable because she was accidentally served by a young bull, and since the exact breeding date was not known, it was considered advisable to dry her off at the end of 285 days. It should be mentioned, however, that during the first 255 days, before drying-off was started, she produced 7,338 pounds of milk and 292 pounds of butterfat, as compared with 8,320 pounds of milk and 313 pounds of butterfat during the first 255 days of her first lactation on the alfalfa hay ration, although she conceived 34 days after freshening for the second record, whereas she conceived 191 days after freshening for the first record. She also consumed more hay during the 255-day period in the second lactation than in the first lactation. She was milked only twice a day for her first lactation record, however, and

three times a day for her second.

Cow H-64 was bred too soon after freshening for both her first and second lactation on the alfalfa hay ration. During the first lactation, she was bred 62 days after calving and it was necessary to dry her off at the end of 308 days, when she was still producing 16 pounds of milk a day. She calved again in 30 days. During the second lactation, she was accidentally bred 34 days after calving, and it was considered advisable to dry her off at the end of 265 days, when she was still producing 15 pounds of milk a day. She calved again in 51 days. This latter record is not included in the calculations because of its short duration.

Cow W-44, in making her second lactation record on the alfalfa hay ration, went dry in 285 days. This record is included in the calcula-

tions.

Although H-39 and H-52 were milked twice a day for their first lactation records on the alfalfa hay ration and three times a day for their second records, no correction has been made for this difference in number of milkings, with one exception noted on page 14. In the case of H-52, the record made on twice-a-day milking materially exceeds the later record made on three-times-a-day milking. However, the lactation in which she was milked twice a day followed a rather short and low-producing lactation following an abortion. Furthermore, as she was an uncertain breeder and had to be bred five times for a conception, she did not carry a calf in the lactation period when she was milked twice a day, whereas she carried a calf for 241 days during the lactation when she was milked three times a day.

Cows H-38, H-62, and W-21 also exhibited breeding troubles and did not carry calves during their lactation period on the alfalfa hay ration, as shown in table 2. H-38 failed to come in oestrus, H-62 developed vaginitis, and W-21 was in oestrus at all times. These breeding troubles are discussed later from the standpoint of possible relationship to exclusive alfalfa hay feeding. They are mentioned here because of the the effect of the number of days between freshening and conception, or conversely, the number of days they carried calves,

on production.

It is evident that the period before conception, or the number of days the calf was carried, did have a decided effect on production, when the records are compared from this standpoint. There were six comparable records made by cows that conceived on an average of 351 days after freshening and that carried a calf 40 days or less during a lactation period on the alfalfa hay ration. The 6 records averaged 2,020 pounds more in milk and 55 pounds more in butterfat than 18 records made by cows that conceived, on an average, within 145 days after freshening and that carried a calf more than 100 days. The 4 records made by nonpregnant cows (table 2) averaged 2,642 pounds more milk and 79 pounds more butterfat than the 20 records made by cows that conceived on an average of 163 days after freshening and that carried calves an average of 197 days. This is a 25-percent greater production in milk and 21-percent greater production in butterfat for the nonpregnant cows.

The 24 comparable lactation records on the alfalfa hay ration averaged 10,702 pounds of milk and 375.6 pounds of butterfat (actual basis) and were made at the average age of 5 years 11 months. A few cows made their records at immature ages, and when these are calculated to a mature basis the 24 records average 11,125 pounds of milk and 389.6 pounds of butterfat. It should also be noted that the 2 yearly records of cow 270 on alfalfa hay were undoubtedly affected by her advanced age. This cow was raised at Beltsville and sent to Mandan as a mature cow. She had the highest production record on full feed of any cow in the experiment. It was made in a box stall at the Beltsville station. When she was placed on the alfalfa hay ration, at 9 years 4 months of age, she was showing the effects of age to a marked degree, but otherwise appeared to be in good condition and completed 2 full-time yearly records on hay.

The highest comparable milk record made on the alfalfa hay ration was 15,109 pounds in 365 days, and the lowest was 7,641 pounds for a 285-day lactation period. The cow making the highest record consumed 17,092 pounds of hay and produced 1 pound of milk for each 1.13 pounds of hay consumed. The cow making the lowest record (W-44, second record) produced 1 pound of milk for each 1.59 pounds of hay consumed. Fourteen of the twenty-four milk records are above 10,000 pounds. The highest butterfat record is 509.9 pounds (H-53, first record) which is approximately twice as much as the lowest

butterfat record (W-47, second record).

#### COMPARISON BY CONSECUTIVE LACTATIONS

Table 3 was prepared to show the comparative production by nine cows that were on the alfalfa hay ration for two or more consecutive lactation periods. The number of days elapsing between treshening and conception is included because of its apparent effect on production.

Table 3.--Comparative milk and butterfut production and number of days between freshening and conception for cows fed the alfalfa hay ration for two or more consecutive luctation periods

	Fig	st <b>lact</b> ati	ion	See	ond lagte	tion	Th	ird laeta	tion
Cow No.	Milk	Butter- fst	Days he- tween fresh- ening and concep- tion	Mdk	Butter- fat	Days be- tween fresh- ening and concep- tion	Milk	   Butter-   fut 	Days be- tween fresh- ening and concep- tion
H-31, H-30, H-52, H-53, H-64, W-44, W-47, W-55,	Pounds 12, 225 10, 319 12, 557 12, 359 10, 281 11, 578 8, 603 5, 285 11, 210	Pounds 126.8 136.9 1408.9 500.9 401.5 264.7 258.2 437.5	Days 117 196 365 179 62 159 130 146	Pounds 11,735 27,527 10,892 10,729 10,718 7,108 7,611 8,181 12,783 9,713	Paunds 411, 5 2 299, 6 402, 9 396, 9 1 260, 3 2 253, 6 251, 1 391, 0 389, 4	151 34 124 168 34 161 120 210	Pounds 9,978 7,876	Pauadx 375.5 278.8	Days 325 126
Average of 7.	10, 974	395.4	171	10, 230	357.0	159			

<sup>1</sup> Milked twice a day,

<sup>2</sup> Bred too soon; milked for 285 days; records not used in averages.

Bred too scon; record for 308 days.
 Bred too scon; milked for 265 days; records not used in averages.

Record for 285 days; cow went dry.

One cow (W-55) on the alfalfa hay ration for two consecutive 365-day lactations produced 4,498 pounds more milk and 133 pounds more butterfat in the second lactation than in the first. She carried a calf only 155 days in the second lactation, however, and 219 days in the first, which may account in part for the higher production in the second lactation.

The records of cows H-39 and H-64 are omitted from the average because of abnormal factors other than feed. The other seven cows averaged 10,974 pounds of milk and 395.4 pounds of butterfat in the first lactation with an average of 171 days between freshening and conception, compared with 10,239 pounds of milk and 357.0 pounds of butterfat in the second lactation, with an average of 159 days between freshening and conception. The average production for the second consecutive lactation on the alfalfa ration was 10 percent less in butterfat and 6.6 percent less in milk than that for the first lactation.

The third consecutive lactation records made by the two cows (H-64 and W-44) are not comparable with their first and second records. The fact that both cows had a short second lactation may be partly responsible for the increased production during the third lactation, though there are many other factors than variations in the ration that may be responsible for differences in amount of production from lacta-

tion to lactation.

## COMPARATIVE PRODUCTION ON ALFALFA HAY ALONE AND ON FULL FEED

The individual milk and butterfat production records made by the 15 cows, both under full-feed conditions and on the alfalfa hay ration, are shown in table 2. Since all the records on full feed except two (H-31 and 270) were made at immature ages, it was necessary to calculate them to a mature basis in order to afford a fair comparison with the records on alfalfa hay. The correction factors used were those published by Fohrman (6). The average production (mature basis) on full feed was 19,421 pounds of milk and 651.5 pounds of butterfat This is an increase of 8,290 pounds of milk and 261.9 pounds of butterfat, as compared with the average production (mature basis) for the 24 comparable records made on the alfalfa hay ration. average production (mature basis) on the alfalfa hay ration was 57 percent as much in milk and 60 percent as much in butterfat as the average under full-feed conditions. If the actual records are used as a basis for comparison, the average production on the alfalfa hay ration was 70 percent as much in milk and 73 percent as much in butterfat as the average under full-feed conditions.

The 15 cows carried their calves for an average of 164 days per lactation when making the 24 records on the alfalfa hay ration, and for an average of 183 days under full-feed conditions. Any difference in this respect would be in favor of the records made under full-feed

conditions.

The 20 records (mature basis) made by the cows that became pregnant during lactations on the alfalfa hay ration averaged 10,685 pounds of milk and 376.5 pounds of butterfat, and they carried calves for an average of 197 days. The 12 records made by the same cows under full-feed conditions (mature basis), when they carried calves for an average of 189 days, averaged 19,282 pounds of milk and 652.3 pounds of butterfat. On this basis of comparison, the average production

on the alfalfa hay ration was 55 percent as much milk and 58 percent

as much butterfat as the average under full-feed conditions.

By comparing the records of those cows that conceived within a period of 30 days of each other in each group following calving, it is found that 11 records made on the alfalfa hay ration averaged 10,707 pounds of milk and 373.8 pounds of butterfat, with an average period of 155 days between freshening and conception. (In this case the first record of cow H-39, when she was milked twice a day, was increased by 20 percent so that it would conform to a three-times-a-day basis.) Seven records made on full feed by the same cows averaged 18,543 pounds of milk and 620.5 pounds of butterfat, with an average period of 162 days between freshening and conception. On this basis of comparison, the average production on the alfalfa hay ration was 58 percent as much milk and 60 percent as much butterfat as the average under full-feed conditions. The average percentage by months in lactation for these two groups is discussed on page 17.

Another point of interest in considering the two systems of feeding is the higher ratio of production on alfalfa hay at the Huntley station as compared with the records made at the Ardmore, Mandan, and Woodward stations. Cows H-31, H-38, H-52, H-53, and H-62 made their records at the Huntley station. Their eight records on the alfalfa hay ration (mature basis) averaged 12,017 pounds of milk and 435.1 pounds of butterfat, and they carried their calves for an average of 135 days. Their five records made under full-feed conditions averaged 18,697 pounds of milk and 641.6 pounds of butterfat (mature basis) and the average number of days each carried a calf was 172. These records indicate that they produced 64.3 percent as much milk and 67.8 percent as much butterfat on the alfalfa hay ration as on the full-feed ration. However, cows H-38, H-52 (first record), and H-62 were not pregnant during their lactations on the alfalfa hay ration. On eliminating these three records and the full-feed records of H-38 and H-62, comparison of the five records of H-31, H-52, and H-53 on the alfalfa hay ration (when they carried calves for an average period of 216 days) with their three records on full feed (when they carried calves for 200 days) shows that they produced 64 percent as much milk and 67 percent as much butterfat on alfalfa hay as they produced under full-feed conditions.

The records made on the alfalfa hay ration at the Mandan station are those for cows H-64 and 270. The first lactation on the alfalfa hay ration by H-64 was of short duration, and she carried a calf only 40 days during her third lactation, while her full-feed record was made at Huntley. The full-feed record of cow 270 was made at Beltsville. Although not entirely comparable, the four records (mature basis) made on the alfalfa hay ration averaged 10,428 pounds of milk and 398 pounds of butterfat, which is 50 and 54 per-

cent, respectively, of the production on full feed.

The 11 records made on the alfalfa hay ration at Woodward (by the 7 cows, W-21, W-44, W-57, W-54, W-55, W-63, and W-69) probably form a better basis of comparison with the Huntley records because the full-feed records were also made at Woodward. These 11 records (table 2) average 10,803 pounds of milk and 353.8 pounds of butterfat, which is considerably less than the cows at Huntley produced on the alfalfa hay ration. The Woodward cows carried calves an average of 177 days while on the alfalfa hay ration, whereas the

Huntley cows carried calves only 135 days. The seven full-feed records of the Woodward cows, on the other hand, when calves were carried for an average of 195 days, averaged 20,286 pounds of milk and 648.5 pounds of butterfat, which is considerably higher in milk than the Huntley cows produced and somewhat higher in butterfat. On the alfalfa hay ration the Woodward cows produced 53.2 percent as much milk and 54.5 percent as much butterfat as they produced on the full-feed ration. As compared to the Huntley ratio of production on alfalfa hay versus full feed this represents a decided decline.

#### COMPARATIVE PRODUCTION BY MONTHS IN LACTATION

The two systems of feeding have been considered from the standpoint of total production for the lactation period. Table 4 was prepared to show the comparison in average daily milk production by months in lactation for the two systems of feeding. Figure 1 shows

the same data graphically. The milk yields shown are the actual yields made by each cow, unless otherwise indicated. The average daily production by months in terms of percentage of the maximum daily production is also shown.

On the alfalfa hay ration the cows reached their highest average daily production during the first month in lactation, produced slightly less during the

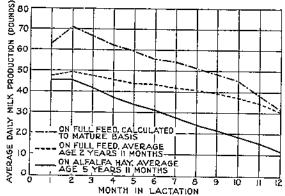


FIGURE 1.--Average daily milk production per cow, by months in lactation, on the alfalfa hay ration and on full feed.

second month, and declined steadily and rapidly from then on (table 4). On the full-feed ration the cows did not reach the peak of production until the second month in lactation, from which there was a more gradual decline (table 4). In the twelfth month they were still producing 62.1 percent as much milk as in their highest month. If the age-corrected figures are used instead of actual-yield figures, the rate of decline is much greater. This greater decline may be due to the fact that cows generally are more persistent in their early lactations (the actual records on full feed were for the most part for first lactations) and also that the great body of records from which the agecorrection factors were derived were made by cows that were not as persistent producers on an average as the cows in this experiment. In studying figure 1 it will be noted that while the plane of production (age-corrected basis) was much higher after the second month on full feed, the rate of decline on this basis was somewhat similar to that on the alfalfa hay ration.

Since the 15 cows varied considerably in the length of their open or nonpregnant periods while making their records on the two different rations, a comparison was made using only the records of 7 cows that were considered to have comparable open periods on both rations. An open period on one ration (clapsed time between freshening and

the next conception) was considered comparable with the open period on the other ration if the difference was less than 30 days. example, if a cow conceived 150 days after freshening on one ration and 170 days after freshening on the other, the difference between the two open periods is less than 30 days and her lactation records are used in the comparison indicated; but if a cow conceived 150 days after freshening on one ration and 200 days after freshening on the other, the difference between the two open periods is more than 30 days, and her records are not used in this comparison. This comparison therefore (table 4) includes 11 records by 7 cows on the alfalfa hay ration that were open for an average of 155 days, and 7 records on full feed when they were open for an average of 162 days. The rate of decline in milk yield by these 7 cows was considerably greater on both rations than the rate of decline by the entire group of 15 cows. The longer period of pregnancy for the 7 cows may have been responsible for this greater rate of decline. The rate of decline by the 7 cows was also relatively greater on the alfalfa hay ration than on the full-feed ration.

Table 4.—Average daily milk production by months in luctation, of the 15 cows when fed the alfalfa hay ration (average age 5 years 11 months), and when on full feed (average age 2 years 11 months)

#### COWS ON ALFALFA HAY RATION Average daily milk production by month in factation Eleventh tou No. Severith Pourth Eighth Second Ning Third Sixth 42.5 21. 9 23. 1 $\frac{24.4}{21.2}$ (39.7)42.4 41.9 36. S H-31.. . . pounds.. 25. S 35. 0 21. 3 31. 9 39 6 22. 9 20. 7 33. 4 16. 3 118.9 39. I 48. 7 35 3 $\frac{35.3}{40.2}$ 29.0 33. S 20. 2 48.3 31.2 137.3 47 2 41 0 46 7 41.6 39.6 42.9 39. 1 36. 3 41. 2 38, 5 21, 1 33, 3 31. 6 36. 2 18, 4 22, 5 42.0 51.320. 3 7. 7 3. 2 8. 6 31. 5 31 0 20. 0 32. 7 21. 1 28. 9 30. 2 do. 142.4 46.6 26, 4 21, 7 10, 3 21, 9 17, 0 36.6 25.8 31.8 40 2 33. 0 39, 8 27, 9 20, 3 36, 2 31, 7 46, 8 41, 7 32, 2 20, 9 29. 4 23. 2 $\frac{24.3}{20.3}$ $\frac{12.5}{15.2}$ H 53 43.6 p148. i 37. 0 39. 5 22.6 13.0 do.... 34.0 15. 1 40.231.0 -- [67, 2 --- [67, 0 33. 3 53 3 40.1 29, 4 55. 2 45. 7 44. 4 38. 5 44. 1 61.0 41.7 32, 8 31.3 W-21 .do 13. 0 151.6 15.6 40.8 22.1 36. 1 14. 3 19. 0 20, 2 12, 4 14, 9 26. 1 7. 2 9. 9 20.0 49 I 44, 9 5, 3 5. 1 50. 7 39. 1 47. 4 39. 3 W-11 do $\frac{41.4}{31.2}$ 21. 9 4.0 140.8 140.9 145.7 40.8 20. 2 26. 2 24. 7 24. 6 24. 7 24. 6 25. 2 24. 7 24. 9 3.57 20.12 31.1 37. 9 30. 2 15.5 ā. 5 W-47 do 33. 4 30. 7 17. 6 22, 2 19, 9 3.6 13 1 150. 1 37. 5 26 5 29 U 22.6 19.1 $\frac{20.7}{13.1}$ W 54 do 21, 6 13, 4 22, 2 15, 6 32, 3 29, 7 30, 7 35, 2 23, 3 41.3 39.0 47.7 44.3 53.7 32.1 39. 4 39. 3 6. 7 34, 1 . 0 33, 5 W-55. do (10.9 32.3 29, 0 32, 5 30.0 53.0 W~83 da 38.8 32.6 29.3 25.024. 1 18.7 27. 9 26. 4 22. 0 28.8 37 1 28.9 24, 3 22, 9 22, 4 W-69. 34, 4 29, 2 18, 8 11.3 4, 3 do 40.9 31.7 14. 4 20. 7 12.8 20.3 45.4 40.0do 110.5 15. 0 20 2 28 3 Average of 24 records 45.5 [ 45.5 41.8 21.6 37.0 33.7 30, 5 | 27.4 21.0 11.6 ununds Relation to maximum daily production (2) records) \_\_nercept \_ records) .percept . A verage of 11 records ( 100.0 99, 5 91.7 81. I 73.966, 8 60.1 52. 6 47, 4 11.0 34.2 25.4 0.236.8 28, 5 21.4 21, 1 18.1 15, 2 12.0 8.7 45.5 46, 1 32.3 pounds Relation to maximum daily production (1) 98, 7 [100, 0 ] 89, 4 ] 78, 8 ] 70, 0 61.8 52.9 45.5 39.3

<sup>&</sup>lt;sup>4</sup> Includes only the 11 records of caws 11/31/(2), H/39, H/52 (2), W/44 (first and second), W/47 (2), W-54, and W/55 (first), that conceived within a period of 30 days of their corresponding breeding records when on full feed.

Table 4.—Average daily milk production by months in lactation, of the 15 cows when fed the alfalfa hay ration (average age 5 years 11 months), and when on full feed (average age 2 years 11 months).—Continued

#### COWS ON FULL FEED

			-5 11 42									
			Averap	e daily	r milk	produc	etion b	y mon	ili in la	ctation	1	
Cow No.	First	Second	'Third	Fourth	Finh	Sixth	Seventh	Eighth	Nintli	Teath	Eieventh	Pwelfth
11-31	60. 0 47. 0 50. 6 48. 8 53. 2 39. 6 49. 0 46. 4 31. 6 52. 0 41. 6 48. 0 61. 2	03. 2 50. 0 35. 7 47. 4 45. 7 46. 2 47. 4 45. 7 34. 1 42. 3 46. 0 69. 3	55. S 42. 2 4 36. 4 2 4 50. 5 9 45. 9 40. 3 40. 9 40. 9 40. 9 40. 0 67. 9	54, 1 39, 4, 7, 8, 44, 8, 8, 14, 2, 4, 44, 8, 5, 7, 5, 1, 5, 0, 57, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,	47, 0 40, 0 33, 2 42, 4 42, 3 44, 7 45, 9 34, 8 35, 1 56, 4 36, 0 50, 9 61, 5	40.8 10.2 32.4 42.5 42.5 45.7 44.4 34.8 35.3 50.0 52.3 52.8 67.8	36, 0 38, 1 31, 9 35, 5 42, 3 43, 4 43, 4 43, 5 50, 6 50, 5 51, 6 51, 0 51, 0	31, 3 40, 5 30, 1 38, 9 42, 0 43, 5 38, 0 33, 2 36, 6 50, 6 33, 2 49, 8 57, 4	28, 5 38, 6 30, 0 36, 5 34, 6 42, 3 40, 0 34, 2 40, 0 34, 2 46, 8 31, 0 47, 0 56, 7	25, 3 4 7 8 25, 8 7 4 25, 8 3 1, 10 39, 0 7 4 4 1, 4 4 2, 10 34 1, 10 36, 2 2	22, 3 40, 0 27, 1 35, 1 35, 7 37, 3 37, 3 37, 3 31, 1 28, 1 28, 1 28, 1 36, 5 36, 1 31, 9 31, 9 31, 9	17, 4 39, 5 26, 2 33, 0 27, 7 36, 0 40, 6 28, 0 21, 1 28, 8 25, 6 21, 5 13, 5
Average yield factual basis; pounds		19.3	47.6	40.0	13.8	43. 5	41.6	40.7	39, 5	37. 2	31.8	30.6
Average yield (mature basis) pounds Relation to maximum daily yield (actua)	62.8	71.0	66, 5	62. 1	49, 5	55, 7	54.1	51.6	48.1	45. I	38, ä	31, 7
basis) percent . Relation to maximum daily yield (matura		100.0	96.4	93. 3	88.8	88. 2	81,4		80. 1	75, 5	į	62. E
Average yield for 7 = records (actual basis) pounds.	45.7	100.0 47.1	93. 7 45. 2	57 5 44.4	\$3. 8 42. 0	78. 5 40. 3	 	72.7 38.0	67, 7 36, 5	63. 5 34. 3	54. 2     34. 3	20, 2
Average yield for 72 records (mature bu- sis) pounds, Relation to maximum	60, 0	67.7	63. 5	59_3	56, S	53, 2	51.6	10.3	45, 9	43. 1	36.8	30, 3
daily yield (actual) :	97.0°	100.0	96-0	94.3	89, 2	85.6	84.0	80.7	77.5	72, 8	<b>6</b> 6 5	55, fi
percent	88.4	104. 0	93, 5	$S_T^\bullet, f_I$	83, 9	78, 6	70, 2	72.8	67.8	63. 7	51.4	11.8

 $<sup>^2</sup>$  Includes only the 7 records of cows (H/34, H/39, H/53, W/44, W/47, W-54, and W/55) that conceived within a period of 30 days of their corresponding records on alfalfa hay alone.

The lack of persistency in lactation, which is characteristic of the rows on the alfalfa hay ration, is one of the reasons why their total production on that ration is not higher in relation to their production on the full-feed ration. The greater relative decline on the alfalfa hay ration as the lactation advances may be indicated in another way; that is, the relative yield on the two rations may be compared by months in lactation. Comparing the records made by the seven cows that had comparable open periods on both rations (table 4) the milk yield on the alfalfa hay ration was 75.8 percent of the yield on full feed during the first month of lactation, 68.1 percent the second month, 64.9 the third, 62.1 the fourth, 56.8 the fifth, 53.6 the sixth, 47.3 the seventh, 42.8 the eighth, 39.4 the ninth, 35.2 the tenth, 32.6 the eleventh, and 28.7 percent the twelfth month.

The hypothesis advanced for this more rapid decline in production on the alfalfa hay ration is: (1) These cows were more advanced in age when they made their records on the alfalfa hay ration than when they made their records on the full-feed ration (for the most part in their first lactation period) and it is to be expected that they would be somewhat less persistent for that reason; (2) these were high-producing cows, and while they were able to consume enough nutrients when on the full-feed ration to produce up to somewhere near their inherent capacity they were unable to consume enough of the more bulky alfalfa hay ration to meet the requirements for maximum production. Consequently the level of production declined to meet the amount of nutrients consumed. During the first 3 months the alfalfa-fed cows were drawing on body reserves to some extent to meet the demands for production. The cows never reached as high a level of production on the alfalfa hay ration as on the full-feed ration, but why the decline should have been more rapid after reaching the point where the consumption of nutrients was more than meeting the demand of production is difficult to determine.

In an attempt to throw further light on the greater rapidity of decline in milk yield on the alfalfa hay ration, compilations were made in which the variable length of pregnancy period, rate and rapidity of decline in milk yield, and rate and decline in amount of hay consumed were brought together in table 5. The data in the first part of the table are for the cows that had comparable pregnancy periods on both rations; the data in the second part of the table are for the cows that were open throughout most of the lactation period on the alfalfa hay ration. In this table the average daily milk yield and the percentage that it represents of the highest average yield during that lactation period, is shown for the third, sixth, ninth, and twelfth months of lactation. For comparison the average daily consumption of hay and the percentage of maximum daily consumption is shown for those same months; and also the average daily yield and the percentage of maximum yield for the same cows when on the full-feed ration. Data for 4 months only are given in order to reduce the number of figures to be compared.

If the cows that conceived within 4 to 6 months after starting a lactation on such a bulky ration as alfalfa hay had had their consumption of hay greatly reduced, owing to the development of the fetus, it might account for the rapid decline in yield. The cows listed in table 5, that were pregnant approximately 7 months of the lactation period, did have a greater decline in hay consumption than the cows that were open throughout most of the lactation period on alfalfa hay, but the difference in hay consumption was not nearly so great as the difference in milk yield. The pregnant cows consumed an average of 35.7 pounds of hay per day during the twelfth month and produced an average of 9.5 pounds of milk per day, while the open cows consumed an average of 40.5 pounds of hay and produced an

average of 20.5 pounds of milk.

There were exceptions to the general trend, however. Four of the five open cows were producing in the twelfth month from 27 to 40 percent as much as their maximum production in any month, and were consuming from 74.4 to 87.7 percent as much as their maximum consumption of hay. The fifth cow was producing in the twelfth month 68.6 percent as much as her maximum yield and consuming 93.2 percent as much as her maximum consumption. Three of the pregnant cows were more persistent in yield than four of the open cows, and a fourth cow was in the same range.

Table 5.—Comparison of the average daily milk yield on the alfalfa hay ration and on the full-feed ration, and the percentage of maximum yield, for the third, sixth, ninth, and twelfth months of lactation, and the average daily hay consumption and percentage of maximum consumption for the same periods, for the seven cows having comparable pregnancy periods under the two systems of feeding, and for the five cows that were open throughout most of the lactation period on the alfalfa hay ration

SEVEN COW	s	٠	ws	w	0	C		ď	Εī	8
-----------	---	---	----	---	---	---	--	---	----	---

H_30										<u></u>		,
Cow   Ration   Serior   Per   Aver   Per					mo							
H-31		Ration	reived ba after ; fresh-	y consumption per day	Aver- age daily quan-	age of maxi-	age daily quan-	- navi maxi	daily daily quan- tity	cent- age of maxi- mum	age daily ounn-	cent- nge of maxi-
H-31											'	
H-53   Algorithm   H-54   Hay   Hay	H-39	Fuil feed Alfalfa Full feed	117   [A] 154   [A] 111   A 116   [A] 196   [A] 170   A	lay filk lay lilk Hilk lay filk	41. 9 40. 5 39. 1 46. 3 55. 8 42. 0 38. 3 36. 4	100. 0 80. 5 80. 0 91. 8 93. 0 100. 0 82. 7 100. 0	32, 3 50, 5 35, 3 40, 0 40, 8 31, 6 46 3 32, 4	85, 3 100, 0 72, 2 97, 2 64, 5 76, 2 100, 0 89, 0	25. 9 39, 4 25. 8 45. 8 28. 5 21, 3 31, 0 30, 0	57, 6 78, 0 52, 7 90 9 45, 1 50, 7 66, 9 82, 1	20, 0 45, 5 20, 7 38, 7 17, 4 16, 3 28, 0 20, 2	41.5 90.1 42.3 76.7 27.5 40.0 60.4 72.0
W-44   Attanta   159   Hay	H-53	Full feed.	168 (17 17 168 (17)	ay luk ay lilk	43. 7 43. 6 45. 1 45. 4	78, 6 86, 0 91, 9 82, 6	49. 5 25. 8 41. 8 36. 5	50.0 50.0 00.7 74.8	48, 1 21, 7 47, 3 34, 3	86 5 42.8 95.1 70.3	41. 6 8. fi 40. 9 27. 7	74, 8 16, 9 82, 8 56, 7
Full feed   150   HEry   31.5   600   6   31.5   600   6   29.8   94.6   29.5   93.6   65.4   14.8   66.0   Milk   31.0   86.1   35.3   39.1   33.2   29.2   24.1   66.9   Milk   30.7   71.2   22.6   52.4   21.6   50.1   13.4   31.1   31.2   31.2   32.9   32.1   33.2   32.9   32.1   34.4   31.1   31.1   31.2   32.5   32.9   32.1   33.2   32.9   32.1   33.2   32.9   32.1   33.2	W-14	Full feed	130 (11) 130 (11)	ay filk Lilk	43.4 40.3 44.1 45.2	80. 8 86. 9 88. 4 92. 6	50.7 31.8 21.7 42.9	91.4 75.0 43.5 87.9	48, 8 34, 0 5, 5 27, 0	90. S 73. 3 11. 0 55. 3	37, 7 28, 0 4, 4 28, 5	70, 2 60, 3 8, 9 58, 1
Maifa   146   Milk   23,4   78,3   19,1   37,9   6,7   13,3   0   6,5     Full feed   160   Milk   43,7   98,9   94,1   98,4   31,2   75,8   30,0   65,5     Five cows   Five cows   Five cows   Five cows   Five cows   Five cows     Has   Alfalfa   Gamma		Full feed	150   X 150   X 160   III	lay Idk Idk	31 5 31 0 30.7 33.3	100 0 86.1 71.2 79 6	31.5 33.3 22.6 36.5	100.0 98.1 52.4 87.3	29. 8 33. 2 21. 6 41. 8	94. 6 92. 9 50. 1 100. 0	29. 5 21, 1 13, 4 36, 9	7, 8 93, 6 66, 9 31, 1 87, 4 56, 6
Hay   State	W 35	1	1H	ay	43.7	99.9	41, 1	98.4	31.2	75. 8	30.0	0 66, 5 53, 6
H		,		FIVE	cows			·				
H												
11-52	H -38	Fullfeed	228   3	ay lilk	35, 6 $42, 2$	68-9 81, 4	46. 0 40. 2	91, 1 80, 4	49, 0 39, 6	04.0 79.2	48. 1 39. 5	68, 6 93, 2 79, 0 30, 9
H=62	11-52	[Full feed	120 7	lay lilk	39, 6 . 50, 2	78, 4 92, 3	46, 2	91. 5 77. 2	49, 1 36, 6	07. 2 65. 4	42. 0 33. 0	\$3, 2 60, 7
W-21 Full feed 152 Milk 56,5 166,0 91,1 45,9 83,3 41,0 74,4 Full feed 152 Milk 56,5 166,0 91,4 187,9 40,0 70,9 40,6 80,6 Alfalfa 326 Milk 38,8 173,2 29,3 55,3 24,1 45,5 18,7 35,3 We63 Full feed 326 Milk 326 Milk 38,8 173,2 29,3 55,3 24,1 45,5 18,7 35,3 We63 Full feed 326 Milk 326 M	11-62 i	Full feed	251 N	ay lilk	32, 1 55, 9	79. 9 100. 0	40, 2 12, 5	100, D : 76, O	35, 3 43, 6	87. 8 78. 0	33. 7 36, 3	83. 8 64. 9
W-63 (15-D c) 1 (10.0) (10.1) (10.1) (10.1) (10.1) (10.1) (10.1) (10.1) (10.1)	W-21 i	(Full feed	152 (UI	ay lilk	51.1 50.5	98, 2 100, 0	50. 2 : 41. 4	91. 1 87. 9	45. 9 40. 0	83, 3 70, 9	41, 0 40, 6	74. 4 80. 0
	W~63	3	320 (H	ay	. 31. 3	SH, 2	11.0	90.0	36, 7	85.4	37. 7	35. 3 87. 7 60. 5

<sup>4</sup> Did not conceive during the factation period on the alfalfa hay ration,

Cow H-31, with two consecutive lactations on the alfalfa hay ration, conceived 117 days after starting on the first lactation. In the twelfth month of the lactation, or the eighth month of pregnancy, she was still producing at the rate of 44.5 percent of her maximum yield of milk and consuming 90.1 percent as much hay as in the month of maximum consumption. Her second factation period was similar to the first, though on a somewhat lower plane of production. She was more persistent on the alfalfa hay ration than she had been on full feed. The other two cows were H-39, producing 40 percent as much

milk in the twelfth month as in her maximum month's yield and consuming 60.4 percent as much hay; and cow W-54, producing 31.1 percent of her maximum yield and consuming 87.4 percent of her maximum consumption in the twelfth month. The latter cow did not reach as high a level of production as the other cows, at any time in her lactation.

Some of the other cows, including H-53, W-44, W-47, and W-55, that showed a great lack of persistency on the alfalfa hay ration, had been very persistent producers on the full-feed ration. The cows tested at the Woodward station were the most noticeable in this respect. Possibly this was due to the fact that they were not accustomed to rations consisting entirely of roughage. The cows raised at the Huntley station were fed from the age of 8 or 9 months to the time of first freshening, on rations consisting entirely of roughage, and, therefore, were probably more accustomed to such a diet.

#### FEED AND NUTRIENT CONSUMPTION

The consumption of alfalfa hay, digestible crude protein, and total digestible nutrients by the cows when fed the alfalfa hay ration, and their nutrient requirements according to the Savage feeding standard, are shown in table 6. The amounts of various feeds consumed exclusive of pasture, together with nutrients consumed and required, by the same cows under full-feed conditions are also shown. An average of the first monthly body weight after calving and the body weight nearest the date of record completion, was used in calculating the yearly nutrient requirements for maintenance.

#### HAY CONSUMPTION

The average amount of bay consumed during a lactation period when the cows were fed the alfalfa bay ration was 14,352 pounds or a little more than 7 tons per cow. The highest individual bay consumption was 17,199 pounds (more than 8½ tons), by cow H-53 during her second lactation. The lowest consumption was 11,085 pounds for

cow W/47 during her second lactation.

The cows produced an average of 1 pound of milk for each 1.3 pounds of hay consumed and 1 pound of butterfat for each 38 pounds of hay consumed. This ratio of milk production to alfalfa hay consumption is higher than was reported in the experiments by the Kansas (19), California (1, 20), Nevada (12), and Oregon (18) stations. The ratio of butterfat production to alfalfa consumption is also higher than that reported by these stations, with the exception of California where the cows consumed only 36 pounds of alfalfa hay (or equivalent) for each pound of butterfat produced. The ratios of milk and butterfat produced to alfalfa hay consumed for the stations named and for this experiment are shown in table 7. The 15 cows used in this experiment may have had an inheritance for higher levels of production than the cows used in the other experiments, and they were also milked three times a day as compared with twice a day for the others.

Table 6.—Comparative feed and nutrient consumption and nutrient requirements of cows by lactation periods when fed the alfalfa hay ration and when on full feed

	i		When fed	the alfalfa	hay ration		
Cow No.	Alfalfa bay con- sumed	Digest- jhle erude protein con- sumed	Digest- ible crude protein required	Excess of digest- ible crude protein	Total digest- ible nutrients con- simed	Total digest- ible nutrients required	Excess (+) or deficien- ey (+) of total digest- ible nutrients
	Pounds ·	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
	4 16, 134	1,801	1, 102		8, 240		+310
11-3!	16, 304	1.820	1, 071		5, 327		+562
H-3×	15, 795	1,763 :	1, 211	552	8, 1967		-357
H-39 :	12,857	1, 136	993			7, 245	-651
H 39	11, 190	1, 283	766				÷121
H 52	15,861	1,770	1, 142	625	8, 100		-24
H -52 .	11,981	1,672	1, 1160	612	7,652	7, 835	183
H-53	16, 367	1,827	1, 191	636	8, 350	8, 642	-283
1115	17, 199	1,919	1.052	867	8,781	7,503	+981
H+62	11,954	1,331	899	423	6, 105	6, 499	39t
H 64	11, 791	1,363	917	116	6,011	6,509	-495
H-94 4	11, 530	1,333	696	637	5, 879	5, 162	+-71-
H 64	11,826	1,366	\$1117	199	6, 030	7, 079	-1.019
W 2!	15, 092	1,937	1, 221	713	8,919	8, 285	+634
W 41	16, 278	1,811	1, 190 (	810	8, 191	7, 139	+1,355
W 11.	12, 155	1, 37,7	655	689	6, 343	1, 936	+1,407
WH	11, 237	1,663	SH		7, 129	6, 297	+1, 132
W 17	13, 533	1, 533 +			7, 662	5, 927	
	11, 085	1, 256	559 ·		5, 781	6, 755	-971
W - 51	13, 164	1, 492		617	6,860	6,441	$\pm 428$
W-55	13,091	1, 481	711.	740	6,833	5, 405	+1,425
	1 16, 106 (	1,866		812	8, 592	7, 289	+1,303
W 63	13, 638	1,545;		516			
W 69 .	13, 386	1, 517	5001	633	6,985	6, 522	1-1673
27.4	1 11,089	1, 629	1,1065	561	7, 181	7, 788	-604
	1 15, 158	1,752	fiin!	750,	7, 729	7,572	+ 157
Average	11, 352	1,622	tp.a	637	7. HHI	7, 113	+257

• • •	•	11,1	1	. ,,,	•	111	,	K,	ı

			Fee	d coasna	red				Excess
	Caw No.	 Hay :	Grain	Silage	Beets of ear- rots	Pass ture	Total di- gestible nutrients in feets other than pasture	Total digest- ible nutrients required	(+) or deficien- ey (+) of total digest- thle nutrients (exclu- sive of pasture)
H .61 H .38 H .52 H .53 H .62 H .63 W .41 W .74 W .75 W .68 W .68		 Panends 7, 723 5, 536 4, 573 5, 366 1, 573 5, 368 6, 527 2, 980 3, 979 5, 580 6, 197 6, 345 7, 142	3, 790 5, 100 3, 127 3, 790 3, 450 4, 846 5, 290 3, 683 4, 877 6, 346	Ponuds 51, 881 9, 783 8, 828 12, 936 9, 127 7, 438 7, 128 8, 201 1, 127 7, 128	Pounds 395 480 1, 145 1, 660 950 1, 725 30 2, 861	Duys 114 66 67 101 109 61 183 80 124 55 25 25	7, 363 7, 529 6, 425 9, 480 6, 297 6, 832 7, 685 6, 773 7, 390 12, 123	8, 113 8, 610 7, 510 7, 500 11, 710	
150	PTORP	5, 180	1, 177	5,887	1.080	75	7, 631	8,314	713

Milked twice in day when on the allafa hay ration, and 3 times a day on full feed.
 Bred too soon, record for 285 days; not used in averages.
 Bred too soon, record far 308 days; not the aliafa hay ration.
 Bred too soon, record for 285 days; not used in averages.
 Includes some estimated sorghum roughage.

<sup>Body weights not available.
Includes some Sudan-grass hay.
Record for 255 days; cow went dry.
Dried beet pulp.</sup> 

Table 7.—Ratio of alfalfa hay consumed to milk and butterfut production by cows fed alfalfa hay only at several experiment stations

Station	Ren- ords	Hay con- sumed for each punnd of milk produced	Hay con- sumed for each pound of	Station	Rec- ords	Hay con- sumed for each pound of milk produced	stimed for each pound of butterfat
Kansas Culifornia Nevada	Number 12 fi 16	1.7	Pounds 62 36 41	Ovegon This experiment A verage	Number 6 24	2.5	Pounds 67 38 49

The amount of hay consumed daily by the 15 cows in this experiment increased on an average until the sixth month in lactation, when a slight but fairly stendy decline was noted (table 8). The daily consumption averaged slightly more, however, at the end of the lactation than at the beginning. Some of the cows consumed over 50 pounds of alfalfa hay per day for several months. The greatest amount consumed in 1 day was 69 pounds by cow H-64 at the Mandan station.

Table 8.— Average daily consumption of alfalfa hay by 15 cows during 24 lactation periods, for each month in lactation

			Aver	age dai	dy con	sumpti	ion by	month	in bæt	noite		
Caw No.	lst	24	34	1th	āth	6th	71h	Sth	9th	loth	lith	12(1)
	Lb.	Lb.	Lb.	Lb.	Lb.	1.6.	I.b.	1.6.	Lb.	Lb.	Lh.	14.
1-31	131.5	32.9 41.9	40, 5 46, 3	46 6 46 7	47.7	50, 5	50. I 50. 4	47.8	39, 4	45.2	46.7	45.
11-35	25.8	32. 2	35, 6	39, 8	41.2	49, 0 46, 0	47.2	47 2 48.9	45. S     49. O	40. 0 51. 6	39. N : 46, 5	35.
1-39	27. 9	31.1	38, 3	40.8	41.2	46.3	39. Î	38, 5	31.0	27. 4	26.9	28.
H-52.	723. 1	38.9	39, 6	42.0	45.8	46, 2	45.1	59. 5	49.1	15.0	40.3	42.
	135, 6	38.4	40. 1	42.3	43. L	41.8	40.5	43. 0	40.4	13. 1	42.0	42.
J-53	(39. 4)	44, 9 49, 4	43. 7 45. 4	146.9 146.8	47. S 46. S	49.5 44.8	50.2 46.5	55. 6 46. 4	48. L 47. 3	49. 8 1	11.6	11,
1-62	22, 5	28. 1	32.1	36, 6	1 36 2	40.2	39.0	26 0	35.3	45. 0 31. 3		40,
1-61	(30. 2	36. 7	44.5	45 0	11. 2	1 39 4	38.4	30, 3	39. 4	31.8	36.0	
	(31.9)	35, 3	37 4	38.9	41.5	28.3	30.3	21.4	25.7	30, 3	29.0	33.
W-21	, 46.7	46.5	54.1	55.1	53, 2	āti, 2	48.9	49. 6	45.9	39.7	39. 1	31.
W-14	35. 7	42.2 41.7	43. 1 · 41. 8 ·	38. 7 m 45. 6	53 7 44 0	50, 7 43, 8	48 6 1 15 2	47.3 42.9	45.5	45.0	34.6	
., -,	37.5	37.3	40.8	35.3	41.0	11.2	10 5	40.5	39 1	31.1	28, 2 39, 0	26, 37.
3+ -	144, 7	48.8	45, 2	42.1	40.7	42.9	36. 7	25 6	27.0	27.7	28.9	2.
V~17.	131.7	28, 3	31.5	31. i	31.6	31.5	21	29.7	20.8	29.7	30, 0	20.
N=51	34.3	35, 1	33 3	33 9	31, 5	36. 5	37.3	38.7	31. S	35.4	36, 7	36,
V-55,	[12.0]	45 1	43.7	42. [	43.7	41.1	42 [	39.1	31.2	28.7	27. 2	30.
V-03	145. 7 (43. 0	46 0 33, 9	50, 1 ± 34, 5	(44.5)	i 45, 7 I 37, 3 -	45 1 35.7	64.2 44.8	33. 1 35. 4	43. 4 36. 7	44. 2 i 37. 1	41.3     37.0	41, 37,
V-69.	31.4	33, 9	31.5		37.3	38.7	41.8	35. 1	36, 7	37. 1	37.0	
270	f35. 7	40.9		44.6	55, 4	52.6	51.3	43 2	37, 3	25, 0	43. 5	35.
	136, 3	36, 6	ļ-liti i	51.9	53.6	48.7	48.5	44.6	41.7	31, 2	25. 1	33,
Average	fase.	in the second	47.0	. 19 6	11.0	43. 6	43, 2	10-6	39. 8	37.6		37.

The total amount of hay offered and the amount consumed by each cow are shown in table 9. It was the intention to offer the cows about 10 percent in excess of what they would consume. Difficulty was experienced, however, in doing this. For example, cow H-62 at the Huntley station consumed 11,954 pounds of hay, or only 65.4 percent

of the 18,278 pounds offered. On the other hand, cow W-47 (second lactation) at the Woodward station consumed 11,085 pounds of hay, only 869 pounds less than cow H-62, and consumed 93.4 percent of the amount offered. There was also considerable variation with individual cows in their different lactation periods. Cow H-31, for example, at the Huntley station consumed about the same amount of hay for both lactations, although she was offered 21,434 pounds during her first lactation and 18,681 pounds during her second. In the first lactation she consumed 75.3 percent of the amount offered, and in the second 87.3 percent.

Table 9. Amount of alfalfa hay offered and the amount and percentage consumed by 15 cows in 24 luctation periods

Cow No.	Alfalfa hay of-		Percent-	Cow No	Alfalfa hay (f)		Percent-
		sumed	consumed		fere-l	simed	consumed
<del></del>	•						
	Pounds	Pounds			Pounds	Pounds	
11-31	[ _i, 434 ]		75.3	W (1	r 19, 993	16, 278	81.4
11-38	T. 18,681	16, 301	87.3		i 13,720	12, 155	88.4
	18, 784		81.1	W 113	15, 430	14, 237	92.3
11-391	17,003		75, 2	W 47	1 17,394	13, 533	77.9
H 30 <sup>2</sup>	13, 041	11, 490	. 88.1		) 11,875	-11.085	93, 4
31-523	18,783	15, 861	81.4	W 51	14, 362	13, 164	91.7
11-52	16, 947	11, 981			1 11,665	13, 091	89.3
	1 48,801		87.1	W 55	1 17, 835	16, 166	92.3
11-53.	1 19, 281	17, 199		W 63	14, 712	13, 638	
11-62	18, 278	11, 951	65. 1	W 69			92.5
H-61				W 00.	14, 177	13, 386	
	14, 580	10,791	80, 9	270	1 17, 105	14,089	82.4
H-n14	13, 57 t	11,530 .			U 17, 866	15, 158	· SI.8
H- 64	11, 223	11, 826	83 1				
W=21	20,695	17,092	82.6	A verage	16, 679	14, 134	84.7
L							

<sup>·</sup> Milked twice a day. - Record for 285 days.

The continued feeding of alfalfa hav alone does not significantly affect the amount consumed, as is shown by the average consumption per cow for the second successive lactation on the alfalfa ration by the five cows H 31, H 52, H 53, W 47, and 270, which was only 251 pounds less than in the first lactation (table 10). The hay consumption was maintained although the average milk production was less for the second than for the first lactation. were about the same.

Comparative consumption of alfalfa hay by cows that were fed the alfalfa hay ration throughout two or more consecutive lactation periods

<b></b>		Day consumed by cow un.											
	Lactation	H 31 H 39	H 52	11 53 1	ны.	W 44 J	W-47	W 55	270				
First Second Third		Pounds Poans 16, 131 - 12, 85, 16, 304 - 241, 496	7 15,861	16,367 - 1 17,199 - 1	1, 791 1, 530	16, 278	13, 533 11, 685	13, 091 : 16, 466 :	14, 659 15, 155				

<sup>)</sup> Bred too soon, factation period only 308 days

<sup>3</sup> Regord for 308 days, 4 Record for 255 days.

Bred too soon, factation period only 285 days.
 Bred too soon, factation period only 265 days.
 Record for 285 days, dried off.

The records of the two cows (H-64 and W-44) that were fed the alfalfa hay ration continuously for three consecutive lactations are not entirely comparable, but offer further evidence on this point. H-64 consumed approximately the same amount of hay in all three lactations, but her first lactation period was only 308 days, her second was 265 days, and her third was 365 days. The second lactation of cow W-44 is not comparable with her first and third lactations, so far as hay consumption is concerned, because of its short duration, but in her third lactation period she consumed 13 percent less hay than in her first lactation, and produced 32 percent less milk.

While there was considerable variation in consumption, due probably to the characteristics of the individual cows and to the quality of the hay, it is apparent that cows will consume large amounts of alfalfa hay if it is fed exclusively and will continue this heavy consumption over long periods without any depressing effect on their appetites. For limited periods some of the cows on the alfalfa hay ration exhibited a craving for other roughage. This was most pronounced in the case of cow 270 at the Mandan station. This cow was kept in a fenced-off portion of a new pen barn and was stanchioned only at feeding time. Her pen was bedded with wheat straw. At times she consumed sufficient amounts of the straw bedding to affect her alfalfa hay consumption markedly. Occasionally, some of the cows at the other stations would eat small quantities of bedding but the craving was not marked and they did not eat enough to affect the amount of hay consumed. Possibly, for the cows that were light consumers of alfalfa hav the addition of some other kind of hay to the exclusive alfalfa ration might have increased the consumption of roughage, with a consequent favorable effect on production, but with the heavier consumers it does not seem possible that their capacity for such bulky feed would have permitted a very great increase in consumption.

#### CHEMICAL ANALYSES AND NUTRIENTS IN THE HAY

The composition of the 34 samples of hay taken for analysis at the 4 stations, and the calculated amounts of digestible crude protein and total digestible nutrients averaged by stations, are given in table 11. The digestion coefficients used for calculating the digestible crude protein and the total digestible nutrients in this table and under Consumption of Nutrients are from Henry and Morrison (13).

The average crude protein content of the hay fed at each station was fairly close, but there was great variation in the individual samples. There was likewise considerable variation in the other nutrients, especially crude fiber. The Huntley and Mandan hays had a much higher average phosphorus content and a lower calcium content than the hays from Ardmore and Woodward. The average ratio of phosphorus to calcium is 1 to 6.6 for the Huntley and Mandan samples and 1 to 10.0 for the Ardmore and Woodward samples. The hay fed at Ardmore and Woodward for the most part was produced under dry-land conditions, while most of the hay fed at Mandan and all of that fed at Huntley was grown under irrigation.

Table 11.—Analyses of samples of the alfalfa hay fed as the sole ration, arranged by stations

Station where fed	Moisture	Crude protein	Fat	Crude fiber	Nitrogen-free extract	Oigestible erade protein	Total digesti- tile nutrients	Caleium	Phosphorus	Remarks (year, cutting, etc.)
Ardmore, S. Dak	8.2	13, 4	1.6		35.5 33.0 41.1			2, 26 1 23 2 10	. 148	1930, third cutting.
A verage	8, 67	1a. 73.	1, 93	25, 75	38, 05	- 11, 17		1,90	155	
Huntley, Mont	8.17 9.78 9.78 9.78 9.78 9.78 8.88 8.77 8.77	17.3 13.9 19.3 15.1 14.5 16.3 16.3 14.9 14.9 16.9 16.6 16.8 16.1 19.8	2.1 1.9 1.1 2.0 1.8 1.2 1.3 1.4 2.0 2.1	32, 4 35, 9 30, 6 27, 0 37, 1 31, 1 32, 1 32, 2 20, 7 30, 5 22, 7 30, 5 22, 7 31, 1	33, 7 29, 7 35, 9 35, 9 35, 9 35, 9 35, 9 37, 8 37, 8 37, 8			1, 26 1, 10 1, 32 1, 24 1, 16 1, 32 2, 06 1, 07 1, 12 1, 13 1, 13 1, 34 1, 44 1, 06		1925, first cutting, 1925, second cutting, 1923, third cutting, 1930, second cutting, 1930, second cutting, 1930, second cutting, 1930, second cutting, 1931, first cutting, 1931, first cutting, 1931, third cutting, 1932, first cutting,
Average	8,28	15.72	1.61			11, 16			. 1840	
Wasdward, Okin	5.9 9.5 8.6 7.6	15.7 15.3 17.7	1.5 2.4 2.1 1.8 2.0	26, 0 36, 1 27, 8 30, 8 30, 4 26, 6	36, 9 35, 1 31, 7 37, 0 37, 0 38, 5			1,30 1,41 1,40 1,82	. 139 . 148 . 117 . 191	1928, 1929, 1936, first cutting, 1936, second cutting, 1932, station cut. 1932, station cut.
Average	S. 16	15, 95				11.33	52. IN	1.38	 . 157	
Maudan, N. Dak	[ 8. 2 [ 8. 1	20, 7 12, 4 14, 0 16, 7 16, 2 17, 7	1, 8 1, 4 1, 3	25 0 35, 0 36, 2	31. 0 35. 1 51. 0			1, 43 1, 13 1, 00 1, 280 1, 40	. 192 . 138, . 159 . 292 . 178	1936, Station grown, 1931, Montana grown, 1932, Montana grown, 1932, Station grown, 1932, Montana grown, 1932, Montana grown,
A verage	8, 27	16, 28	1, 63	31.50	31. 02	11, 50	ā0 99	1 25		

#### CONSUMPTION OF NUTRIENTS'

All the cows on the alfalfa bay ration consumed more than enough digestible protein, and in 15 of the 26 lactation periods more than enough total digestible nutrients, to meet their requirements for maintenance and for the amount of milk and butterfat produced during the lactation period (table 6). In only two lactation periods was the deficiency of total digestible nutrients as great as 10 percent of the total requirements. This fact is probably not very significant, however, since the production probably dropped to somewhere near the level of nutrients consumed.

These same cows when on the full-feed ration and producing at a higher level probably also consumed sufficient nutrients to meet their requirements. The data in table 6 showing the nutrients consumed on

the full-feed ration are for the entire lactation period, but do not take into account the nutrients supplied by pasture. The amount of into account the nutrients supplied by pasture. nutrients consumed and required by the 15 cows during that part of their lactation period on full feed when they did not have access to pasture is shown in table 12.

Table 12. Actual production and feed consumption by the 15 cows during the time they were on the full-feed ration without pasture

	Period on full	Produ	Production		Feed co	nsumed		i ,	:   Gain	Total digestible nu- tr. als			
Cow No.	teed. with- out pas- ture	Milk	Butter- fat	Ordin	Hay	  Silage	Roots <sup>‡</sup>	Aver- uge body weight	or toss in body weight	Con- somed	Re- quired	Excess (±) or defici- ency (+)	
H-31	Days 251 229 235 207 217 236 365 176 260 238 210 281 292 365	Lb. 11, 140 9, 046 7, 132 7, 786 00, 973 15, 215 7, 343 8, 808 7, 637 10, 286 13, 730 21, 763 10, 546	Lb. 389 273 259 289 285 227 227 227 227 227 227 227 227 227 22	Lb. 3, 067 2, 228 1, 763 1, 943 1, 850 1, 659 2, 659 2, 630 2, 633 4, 009 3, 879 6, 316 3, 033	2 5, 770 7, 442	Lb. 7, 330 8, 210 6, 960 7, 273 7, 462 6, 916 5, 860 8, 419 5, 675 8, 200 7, 722 8, 128	7,h, 305 480 1, 135 1, 060 950 1, 725 30 12, 864	Lb. 1, 470 1, 372 1, 220 1, 206 1, 247 1, 116 1, 238 (3) 1, 021 1, 035 1, 106 1, 204 1, 003 1, 458		Tb. 6,656 6,710 4,331 5,016 5,511 9,480 4,913 4,117 5,155 7,329 7,159 12,123 6,398	6.5.475. 4.354. 4.697. 5.327. 4.851. 4.798. 6.564. 11,710. 5,993.	#130 +130 +330 +600 +800 +1,150 +1,150 +500 +350 +410 +400 +400	

Sugar beets or carrots,
 Hay consumption partially estimated. Includes some Sudan grass hay,
 Body weights not available.

4 Beet pulp. 5 Average for 8 cows.

These data indicate that all but I cow consumed an excess of nutrients over their requirements, and that for the 15 head the digestible nutrients consumed exceeded the requirements by an average of 6.7 percent. On both rations, then, the books were practically balanced at the end of the lactation year insofar as the consumption of total digestible nutrients meeting the needs for maintenance and milk and butterfat production is concerned. Actually, however, there was considerable difference in the way in which the requirements were met on the two rations. Six cows on the full-feed ration did not have access to pasture in the early months of lactation and consumed on an average of 83 percent of their nutrient requirements in the first month. of lactation, 93 percent in the second month, and 96 percent in the third month. The 15 cows in 24 lactation periods on the alfalfa hay ration had an average consumption of 74 percent of their nutrient requirements in the first month, 82 percent in the second month, and 91 percent in the third month.

The average daily requirements per cow for each month for maintenance and for milk yield during the 24 lactations on the alfalfa hay ration, and the percentage of the total requirements that was con-

sumed, are shown in table 13.

Table 13.—Average daily requirements and average daily consumption per cow of total digestible nutrients, by months in lactation, during 24 lactation periods on the alfalfa hay ration

	Digestibl	c nutrients	required	Total digest- ible nu-	Excess (十) or defi- ciency (寸)	Percent-	
Month in lactation	Mainte- Produc-		Total	trients con- sumed <sup>2</sup>	of total digestible nutrients	require- ments	
	Pounds	Pounds	Pounds	Pounds	Pounds		
First	10, 168	14, 546	24, 714	18, 291	-6.423	74	
Second	9.835	14.515	24, 350	19, 884	-4.466	82	
Third	9, 748	13, 334	23, 082	21, 066	2, 016	91	
Fourth	9, 732	11,803	21, 535	22, 093	1 +.558	102	
Fifth.,	9, 716	10,750	20, 460	22,710	+2.211	iii	
Sixth	9.732	9, 750	19, 482	22, 402	-2,920	115	
Seventh	9,812	8,741	18, 553	22, 196	3, 643	120	
Eighth	9, 835	7, 656	47, 491	20, 860	+3, 360	119	
Ninth	0.970	6,890	16, 860	20, 449	1 +3.589	121	
Tenth	10, 144	5,975	16, 119	19, 319	43, 200	120	
Eleventh.	10.318	4,976	15, 294	18, 754	+3,460 ]	122	
Twelfth.	10. 556	3,700	14, 256	19, 011	44,745	133	

¹ Calculation based on milk testing 3.5 percent of butterfal.
² Calculation based on total digestible nutrient content in alfalfa hay of 51.38 percent, the average of samples from all stations.

On the alfalfa hay ration the greatest desciency in consumption of total digestible nutrients occurred in the months of greatest production. The first month in lactation showed the greatest desciency and as consumption increased and production decreased, the desciency became less each month until by the fourth month there was a small average excess in daily consumption. The declino in milk yield (on the average) was not seriously checked when this occurred, however, and since the consumption of alfalfa continued to increase until the fifth month and to hold up well through the sixth and seventh months, then to decline but slowly to the twelfth month, there was an increasingly greater average excess of nutrients consumed over requirements.

Why was the decline in milk yield not checked in the fourth month when the consumption of nutrients was more than enough to meet the needs for the amount of milk and butterfut produced? Was it because these animals had expended too much energy in the consumption of the large amounts of bulky feeds in the first part of the lactation period when heavy production was making a great demand on reserve nutrients, or was there a deficiency of some essential nutrient in the alfalfa hay ration that limited the yield? Some light may be thrown on these questions by comparing the two rations to show the amount of milk produced per pound of digestible nutrients consumed. Since most of these cows made their records on full feed during their first lactation periods and their records on the alfalfa hay ration when most of them were mature, they were larger animals when the latter records Therefore, any comparison should be based on the were made. amount of total digestible nutrients available for production, that is, on the difference between the amount consumed and the amount required for maintenance. The fact that all but 2 of the 15 cows were on pasture varying lengths of time during the lactations in which they were on the full-feed rations makes some of the individual data incomparable. Five cows (H-64, 270, W-55, W-63, and W-69) were selected for comparison.

Table 14.—Comparison of the production, and the total digestible nutrients consumed in excess of maintenance requirements, by five cows on the alfalfa hay ration and on the full-feed ration without pasture for comparable lengths of time

	Dave in		s required atenance		ge body it on—	Milk pr	oduction	Butterfa tie	t produc- on	sumed i	ements	to proc	on on alfal- i relation luction il feed	Relation of the amout of nutrients consumed, in excess of main-
Cow No.	Days in lactation com- pared	Full feed	Alfalfa hay	Full feed	Alfalfa hay	Full feed	Alfalfa hay	Fuil feed	Alfalfa hay	Full feed	Alfalfa hay	Milk	Butter- fat	tenance require- ments, on alfalfa hay to the amount consumed on full feed
H-64 W-55 W-63 W-69 270.	Number   308   265   365   184   184   232   252   365   365	Pounds 2, 966 2, 502 3, 609 1, 557 1, 557 2, 094 1, 961 4, 219 4, 219 2, 743	Pounds 3, 163 2, 809 3, 717 1, 559 1, 704 2, 186 2, 213 4, 388 4, 171 2, 882	Pounds 1, 215 1, 191 1, 248 1, 068 1, 129 982 1, 458 1, 458	Pounds 1, 296 1, 338 1, 285 1, 097 1, 160 1, 179 1, 124 1, 517 1, 442	Pounds 13, 212 11, 584 15, 215 10, 307 10, 307 8, 945 12, 468 21, 763 21, 763	Pounds 10, 294 7, 108 9, 978 6, 788 6, 796 8, 254 8, 375 11, 210 9, 713	Pounds 445. 1 385. 1 522. 0 320. 0 320. 0 305. 0 394. 7 800. 5 800. 5	Pounds 370. 9 260. 3 375. 5 209. 7 200. 2 288. 3 270. 3 437. 5 389. 4	Pounds 5, 196 4, 536 5, 870 3, 433 3, 433 3, 684 4, 376 7, 904 5, 148	Pounds 2, 851 3, 070 2, 313 2, 536 2, 716 2, 400 2, 572 2, 796 3, 558 2, 757	Percent 77. 9 61. 4 65. 5 65. 9 65. 9 92. 3 67. 2 51. 5 44. 6 62. 5	Percent 83. 3 67. 6 71. 9 65. 5 62. 6 94. 6 68. 4 54. 5 48. 6	Percent 54. 9 67. 7 39. 4 73. 8 79. 1 65. 1 58. 8 35. 4 45. 0 53. 6

Cows H-64 and 270 had no pasture while on the full-feed rations, and cows W-55, W-63, and W-69 were on the full-feed ration 184, 234, and 252 days, respectively, before they had pasture. The amount of digestible nutrients consumed in excess of maintenance requirements, that is, the amount of nutrients available for production, was computed for these cows up to the time they had access to pasture and also for comparable periods on the alfalfa hay ration. The data for the comparison of nine lactation periods for these five cows are shown in table 14.

The comparison shows that the five cows for nine lactations (280 days) on the full-feed ration produced 2.71 pounds of milk containing 3.42 percent butterfat to each pound of total digestible nutrients available for production; and during their nine lactations on the alfalfa hay ration (280 days) they produced 3.16 pounds of milk containing 3.57 percent butterfat to each pound of nutrients available for production. This comparison would appear to indicate that the digestible nutrients in the alfalfa hay were just as efficient, pound for pound, as were the digestible nutrients in the ration that contained a variety of

grains, corn silage, and alfalfa hay.

However, the individual results as indicated in table 14 are quite Cow H-64 had yields of milk in her three lactation periods that were 77.9, 61.4, and 65.5 percent as great on alfalfa as on full feed for the same periods of time; whereas, the amount of nutrients available for production was 54.9, 67.7, and 39.4 percent, respectively, as great on alfalfa as on full feed. This is a great variation in relative consumption on the two rations, and does not seem consistent with the relative yields. The percentages for relative yields of cow W-55 in her two lactation periods on alfalfa were lower than the percentages for her relative consumption, while the reverse was true for cows W-63 and W-69. Cow 270 had two 365-day lactation periods on alfalfa hay for comparison with a 365-day lactation period on full feed without pasture. This cow made a very large record on full feed and was well advanced in age when she made the records on alfalfa. yield on alfalfa was relatively low and her consumption was also The relationship between yield and consumption is relatively low. closer for this cow in her second lactation on alfalfa than for any other

The data for these five cows show surprisingly little relationship between the ratio of yield on the two rations and the ratio of consumption of total digestible nutrients above the requirements for main-Perhaps this was due to environmental factors that affected the individual animals in different ways, such as the differences in age of the animals when they made the different records, or the fact that all the cows except those raised at the Huntley station were unaccustomed to rations consisting entirely of roughage, which undoubtedly resulted in some cases in a lowered consumption. The ideal method of carrying out such an experiment would be to use only mature cows for making records on both the alfalfa hay and the full-feed rations, and only cows that had been accustomed to rations consisting entirely of roughage. Such animals were not available in sufficient numbers in the station herds. Perhaps if immature grass, or alfalfa hay with less crude fiber and a more concentrated nutrient content than hay cut at the usual stages of maturity, had been fed to these cows in the early

months of the lactation period, they might have been able to consume more digestible nutrients, reach a higher level of production, and have a less rapid decline in milk yield.

#### CONSUMPTION OF CALCIUM AND PHOSPHORUS

It was not planned to determine the possible mineral deficiencies of a ration composed entirely of alfalfa hay in this experiment, because facilities for balance experiments are not available at the field stations. The data available from this experiment, therefore, do not afford conclusive evidence on this phase of the problem, though they are of interest when considered from the standpoint of results obtained by

other investigators.

To offset a probable shortage of phosphorus in an exclusive ration of alfalfa hay and with cows of such high production, special steamed bonemeal was placed in a sheltered box where each cow had continuous or frequent access to it. A weighed amount was placed in the box and at frequent intervals the remaining portion was weighed and the difference was considered as the amount consumed. After the experiment had been in progress a few weeks, it was observed that some of the cows were not taking any bonemeal and some only a small The amount consumed from some of the boxes was so small as to be easily accounted for by a change in moisture content. Cows in the regular milking herds also consumed extremely small amounts. At the Mandan station bonemeal prepared especially for poultry feeding was substituted for the steamed bonemeal with the expectation that consumption might be increased, as was indicated by results at the Beltsville station (21). The change had little effect, however. Measuring the bonemeal consumed by the majority of the cows was later discontinued because it was realized that the methods employed were not sufficiently accurate. However, data were obtained for seven cows for an average of 361 days covering both the lactating and dry periods. These cows consumed an average of 9.26 g of bonemeal per day. Samples of the bonemeal which were chemically analyzed were very uniform and showed an average calcium content of 32.82 percent and a phosphorus content of 13.45 percent.

The amounts of calcium and phosphorus consumed by the 15 cows when fed the alfalfa hay ration during 24 lactations are shown in table 15. The phosphorus requirements of these cows were calculated according to the standard recommended by Huffman and associates (15), that is, 10 g of phosphorus per day per 1,000 pounds body weight and 0.75 g of phosphorus per pound of milk produced. During lactation the cows consumed on an average 11,601 g of phosphorus in the hay and benemeal, or 91 percent of the 12,720 g required. If only the phosphorus in the alfalfa hay is considered, the cows consumed 88 percent of their phosphorus requirements during factation. The lowest consumption of phorphorus was for cow W-47 during her second factation when she consumed only 74 percent of her requirements; the highest was for cow H-53, second factation, when she

exceeded her requirements by 10 percent.

The calcium and phosphorus consumption and the phosphorus requirements per cow per day by months in lactation are shown in table 16. Calcium and phosphorus consumption in the hay is based on the average content in all the hay samples analyzed (table 11). During the first month in lactation the cows consumed only 61 percent

of their phosphorus requirements if in addition to the hay they ate an average of 9.26 g of bouemeal per day, or 58 percent without the bonemeal. The deficiency steadily became less, but it was not until the sixth month in the lactation period that the phosphorus consumption approached the requirements. From then on the consumption exceeded the requirements and by the twelfth month the cows were consuming 35 percent more phosphorus than they required. The average hay consumption continued at approximately 35 pounds daily while the cows were dry, and they were consuming enough phosphorus in hay alone to exceed their maximum body weight requirements by 81 percent. While the shortage of phosphorus was rather pronounced during the first 4 months in lactation, the excess during the last 4 months in lactation and during the dry period would probably offset the shortage incurred during the first few months and the cows should have been able to build up a reserve supply.

Table 15.—Calcium and phosphorus consumption and phosphorus requirements of 15 cows fed the alfalfa hay ration (with free access to honement) for 24 lactations

						-	_				
	Alfalfo	Esti- ported	Calçin	ni con tion	dimb-		spharus umptio		, Total .	Excess (+) or	Per- centage of re-
Cow No.	hay con- sump- tion	hone- meal con- sump- tion 1	in hay	In bone- ment	† Total	lu bay	In bone- meal	Total	phose phorus re- quired		quired phos- phorus can- sumed
									·,		
	(barren da	Canana	A	Crossa	Crane	(*======	C=		Geams	C	ŀ
	1 16, 134		88, 543		80, 652				14, 254		40
31-31	16, 304		80, 495		100, 610					+188	101
31-38	15, 795		86,683		87, 792					-2,105	
11-39	12, 857		110, 814		111, 923	9, 027				-3.009	
	f 15, 861		87,046		88, 155					-726	
11-52	1/14, 981	3,350	82, 238	1, 109	83, 347	12,519					
H-53	J 16, 367	3,350	89, 813	1, 100				14, 108		-513	
	1 17, 199		94, 394	1, 109						$\pm 1.375$	
11-62	11,951		65, 591	1,109		9, 979				-1,326	
JI-64 4	11,794		66, 561	936						-1,304	
11-61	11, 826		67, 042		168, 151	10, 025				-1,694	
W-21	17, 092		107,004		108, 113	12, 156					
W~0.	16, 275		101, 879		102,988					-963	
W 44 2	12, 155		76,000	566		5,664				4:2	
W-44.	14, 237	3,380		1, 109		10, 161	455			Ui	99
W-47	[ 13, 533 1 11, 085		51, 732 20, 301						10, 748	677	94
W-54.	13, 161			1, 109 1, 109			455 455			-3,255	
	13, 094		81,066		81, 075	9,344			9, 973	-1,642 -174	
W-55	16, 466		103, 058		104, 167		455		13, 901	-1.698	
W-64	13, 638		85, 365		86, 477		155			-2.776	
W-69.	13,356			1,109			455		11,858	-1.877	
	11,089	3, 380			80, 988					- 1990	
270	1 15, 158	3, 350	85, 937		57,000					T744	
Average	14, 352	3,327	85, 799	1,092	56, 590	11, 153	448	11,601	12, 720	-1, 110	91
							· · · · · · · · · · · · · · · · · · ·				

 $<sup>^{1}</sup>$  Based on an average daily consumption by 7 cows (p. 30).  $^{5}$  Record for 308 days.

Results of investigations on calcium metabolism have been somewhat contradictory. Consequently, the data in tables 15 and 16 are confined to the amounts of calcium consumed. Meigs and coworkers (16) recently suggested that for Jersev cows which are capable of giving 3,000 kg of milk or more annually, an intake of 25 g of calcium daily is somewhat inadequate. As the average daily intake of calcium for the Holstein cows in this experiment in each month of lactation was well over 200 g per day, it is evident that they received sufficient calcium.

<sup>4</sup> Record for 285 days, cow went dry.

Table 16.—Average daily calcium and phosphorus consumption and phosphorus requirements by months in lactation of 15 cases fed the alfalfa hay ration for 24 lactations

Month	Aver-	Aver- ngo liny :	ngo ngo		m cans per day			horus co I per da		l'bos- phorus	Excess (+) or defi-	Per- centage of re-
in luc- tation	age hody weight	con- sump- tion per day	pro- duc- tion per day	In hay	In hone- meal 1	Total	in bay	In bone- meal	Total	re- quired per day	AT	quired phos- phorus con- sumed
									-	; <u>-</u>	_ <del>-</del>	
			Pounds.				Grams			Grams	Grams	
First	1, 283			-209,61)		212, 65					- 18, 31	61
Second	1, 241	35.7		227.86	3.01		20.86	1, 25	31.11		- 15, 43	67
Third	1, 230	41. 1		211,99	3, 04				32.96		10, 69	76
Fourth	1, 228	43. O		253, 15					34, 43			56
Fifth.	1, 226	44.2		260, 23		263, 27	34, 103		35, 35			94
Sixth, _	1,228	43.6				259. 73			34.89			99
Seventh_	1.23%				3, () 1				34, 58			
Eighth	1, 241	40.6	24.0			241, 69			32, 58			
Ninth	1, 255	39.8						1. 25				
Tenth		37, 6		221,40	3.04			1.25	30, 26			
Eleventh.		36. 5				217.06			29, 44			
Twelfth	1, 332	37. 0	11 6	217/80	3, 64	220, 90	28, 55	1, 25	29, 80	22, 02	十7.78	135

<sup>1</sup> Bonement consumption estimated (see text).

The calcium-phosphorus ratio of the hay samples analyzed averaged 7.6:1, which is a much higher ratio than is usually considered desirable. The ideal proportion of these minerals is assumed to be between the ratios of 1:1 and 2:1. When an ample supply of vitamin D is present, the proportion of calcium can probably be much greater than 2:1 and still give satisfactory results. Hang, Jones, and Brandt (10) obtained distinctly positive calcium and phosphorus balances with a cow fed on alfalfa hay and bonemeal. There were no outward indications that any of these cows on the alfalfa hay ration suffered from mineral deficiencies. One of the cows at the Woodward station was killed at the end of her lactation period on the alfalfa hay ration and bones from her skeleton were examined and analyzed. They appeared to be normal in every respect.

# EFFECTS OF FEEDING ALFALFA HAY ALONE ON CONDITION OF THE COWS AND ON THE MILK

Much information concerning the condition of the cows, such as age, breeding and calving records, body weights, etc., has been given in considering the comparative quantities of milk and butterfat produced on the two rations, and in discussing whether the nutrients and minerals consumed on the bay ration were meeting the animals' requirements for maintenance and production.

Additional information obtained in this experiment from observations of the effects of feeding alfalfa hay alone over long periods, on the condition of the cows in respect to gain or loss in body weight, fertility, breeding and calving, percentage of fat in the milk, and abnormal milk is presented in this part of the bulletin. The observations and conclusions of other investigators were previously mentioned in reviewing the literature.

#### GAIN OR LOSS IN BODY WEIGHT

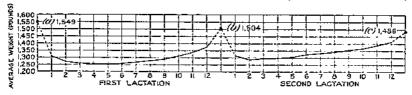
One of the chief points of interest with respect to the feeding of a ration restricted to alfalfa hay for extended periods is the effect on body weight. It was recognized that a comparison of the monthly

body weights during the lactation periods on the alfalfa ration with corresponding body weights under other systems of feeding would not necessarily give a correct interpretation, since it would not show the ability of the alfalfa-fed animals to recover any loss in weight sustained during the dry period. Comparisons based on precalving weights before going on alfalfa and precalving weights following lactation on alfalfa, together with the more alfalfa probably offer the faircest weapened a remarking

alfalfa, probably offer the fairest means of comparison.

Table 17 was prepared to show these data for the c

Table 17 was prepared to show these data for the cows during their first and second lactations. All the cows had been fed grain (either full-feed or limited-grain rations) during the lactation period preceding their first lactation on the alfalfa hay ration. The average precalving weight following the grain feeding, and just prior to the lactation on alfalfa, of the 11 cows that are comparable was 1,505 pounds. The average precalving body weight of the same cows following one lactation on alfalfa was 1,483 pounds, an average loss of 22 pounds per cow on this method of comparison. However, 5



MONTH IN LACTATION

FIGURE 2.- Average monthly body weights of eight cows that were on the alfalfa hay ration for two consecutive lactation periods; and precalving weights (a) following the previous ration, (b) following the first and (c) the second lactation on alfalfa.

cows, of which 4 were at the Woodward station, gained weight and 6 cows lost weight, the maximum loss being 154 pounds for cow 270.

It is probably more significant to compare the weights of eight of the nine cows that were on the alfalfa hay ration for two consecutive lactations. The ninth cow, W-47, is not included because she aborted during the eleventh month of her first lactation and was dry for approximately 17 months before she started her second lactation. The precalving weights of the eight cows previous to their first lactation on the alfalfa hay ration averaged 1,549 pounds, and their precalving weights following their first lactation averaged 1,504 pounds, or a loss of 45 pounds per cow. Their average precalving weight following their second lactation on alfalfa was 18 pounds less than their precalving weight following their first lactation. For their two lactations on alfalfa they showed an average combined loss of 63 pounds, based on precalving weights.

In the first lactation period there was a decided drop in weight from the first to the second month and a continued small loss until the lifth month, after which the eight cows gained gradually and steadily. Their continuous weight curve for the two lactations is shown in figure 2.

It is interesting to note the marked difference in the weight curve for their second lactation period. Although they averaged 45 pounds less previous to calving than for their preceding lactation, period, their first calving weight (first month in lactation) was slightly more than that of the first month of the first lactation period. They started to gain in weight beginning with the fifth month in lactation and continued to gain steadily. For their twelfth month in lactation they averaged 1,411 pounds, which was 34 pounds more than they weighed at the corresponding month during their first lactation.

Table 17.—Precalving and monthly weights and gain or loss in weight of cows fed the alfalfa hay ration for one and two consecutive lactation periods

	7)	Average weight during months of first lactation period												Pre- calving	Differ-
Cow No.	Pre- calving weight <sup>1</sup> (A)	First month	Second month	Third month	Fourth month	Fifth month	Sixth month	Seventh month	Eighth month	Ninth month	Tenth month	Eleventh month	Twelfth month		ence in pre- calving weights
H-31 H-38 H-39 H-52 H-53 H-63 H-64 W-21 W-44 W-47 W-55 W-63 W-63 W-63	F 1, 642 L 1, 696 L 1, 564 L 1, 683 F 1, 450 L 1, 493 L 1, 542 F 1, 285 L 1, 310 L 1, 340 F 1, 310 F 1, 570 F 1, 290 L 1, 737	Pounds 1, 322 1, 270 1, 340 1, 421 1, 125 1, 246 1, 341 1, 189 1, 107 1, 117 1, 117 1, 118 1, 245 1, 190 1, 523	Pounds 1, 295 1, 326 1, 305 1, 260 1, 365 1, 043 1, 244 1, 305 1, 086 1, 105 1, 078 1, 203 1, 484	Pounds 1, 23 1, 340 1, 282 1, 392 1, 091 1, 218 1, 238 1, 080 1, 110 1, 048 1, 147	Pounds 1, 205 1, 351 1, 303 1, 402 1, 032 1, 203 1, 203 1, 116 1, 126 1, 031 1, 053 1, 148 1, 148 1, 148 1, 148 1, 158 1, 158 1, 143	Pounds 1, 256 1, 206 1, 361 1, 301 1, 385 1, 053 1, 248 1, 233 1, 043 1, 194 1, 134 1, 033 1, 185 1, 066 1, 389	Pounds 1, 282 1, 235 1, 338 1, 294 1, 380 1, 066 1, 248 1, 250 1, 033 1, 060 1, 149 1, 053 1, 163 1, 048 1, 408	Pounds 1, 308 1, 263 1, 313 1, 295 1, 394 1, 070 1, 275 1, 232 1, 051 1, 081 1, 134 1, 074 1, 140 1, 049 1, 443	Pounds 1, 331 1, 262 1, 275 1, 326 1, 434 1, 946 1, 184 1, 098 1, 121 1, 078 1, 113 1, 1057 1, 440	Pounds 1, 360 1, 271 1, 247 1, 340 1, 457 1, 054 1, 310 1, 181 1, 027 1, 155 1, 146 1, 120 1, 121 1, 072 1, 462	Pounds 1, 384 1, 290 1, 259 1, 340 1, 461 1, 097 1, 317 1, 198 1, 065 1, 195 1, 167 1, 181 1, 140 1, 109 1, 480	Pounds 1, 403 1, 205 1, 203 1, 349 1, 485 1, 114 1, 345 1, 100 1, 091 1, 187 1, 188 1, 234 1, 168 1, 163 1, 163 1, 511	Pounds 1, 427 1, 292 1, 334 1, 368 1, 540 1, 135 1, 380 1, 210 1, 128 1, 212 1, 230 1, 281 1, 225 1, 223 1, 560	Pounds 1, 503 (2) 1, 518 1, 607 1, 725 (2) 3 1, 380 (2) 1, 302 1, 682 1, 350 1, 415 (4) 1, 250 1, 583	Pounds -139 -46 -76 +44 -113 +117 +105 +50 +105 -40 -1
A verage of 11.	1, 505 1, 549	1, 272 1, 305	1, 229 1, 266	1, 222 1, 259	1, 226 1, 257	1, 218 1, 252	1, 219 1, 257	1, 225 1, 269	1, 229 1, 278	1, 242 1, 290	1, 264 1, 311	1, 294 1, 339	1, 336 1, 377	1, 483 1, 504	-2 -4

Table 17.—Precalving and monthly weights and gain or loss in weight of cows fed the alfalfa hay ration for one and two consecutive lactation periods—Continued

		Average weight during months of second lactation period										Pre-	Difference in pre- calving weights			
Cow No.	Precalving weight	First month	Second month	Third month	Fourth month	Fifth month	Sixth month	Seventh month	Eighth month	Ninth month	Tenth month	Eleventh month	Twelfth month	weight following two consecutive lactation periods (C)	A minus	
H-31 H-38	Pounds See (B)	Pounds 1, 325	Pounds 1,305	Pounds 1, 364	Pounds 1, 374	Pounds 1, 373	Pounds 1,389	Pounds 1, 387	Pounds 1, 407	Pounds 1,414	Pounds 1, 401	Pounds 1, 416	Pounds 1, 439	Pounds 1, 468	Pounds -35	Pounds 174
H-39 H-52 H-53 H-62	- do	1, 338 1, 459 1, 383	1, 299 1, 401 1, 359	1,309 1,381 1,396	1, 331 1, 371 1, 399	1, 342 1, 373 1, 429	1, 355 1, 360 1, 479	1, 360 1, 338 1, 483	1, 362 1, 335 1, 473	1, 383 1, 380 1, 473	1, 402 1, 423 1, 469	1, 451 1, 487	1, 466 1, 508	1, 407 1, 513 1, 617	-111 -94 -108	-157 -170 -64
H-64 W-21	do do	1, 273	1, 267	1, 249	1,215	1, 262	1, 297	1, 345	1, 379	1, 397	1, 403	1, 453	1, 474	9 1, 495	+115	+2
W-44 W-47, W-54	da da da	1, 139 1, 414	1, 111 1, 346	1, 094 1, 275	1,089 1,216	1,075 1,251	1,078 1,260	1, 100 1, 265	1, 105 1, 285	1, 116 1, 329	1, 166 1, 384	1, 228 1, 425	1, 280 1, 448	1, 400 1, 512	+98 -170	+115 +202
W-55 W-63 W-69	do do do	1, 159	1, 143	1,111	1, 151	1, 155	1, 169	1, 179	1, 211	1,211	1, 234	1, 244	1, 268	1, 497	+82	+187
270	do	1, 411	1, 415	1, 420	1, 389	1, 413	1, 452	1, 463	1, 456	1, 443	1, 447	1, 443	1, 444	1, 494	-89	
Average of 8 *	do	1,311	1, 288	1, 295	1, 294	1, 303	1, 322	1, 332	1, 341	1, 356	1, 368	1, 389	1,411	1,486	-18	-63

<sup>1</sup> On (F) full-grain or (L) limited-grain system of feeding.

2 Not with ealt.

3 Milked for 308 days, calved in 11 months.

4 Aborted.

5 Not available.

6 Includes cows H-31, H-39, H-52, H-53, H-64, W-44, W-47, W-54, W-55, W-69, and 270.

7 Includes cows H-31, H-39, H-52, H-53, H-64, W-44, W-55, and 270.

8 Milked for 285 days, calved in 10 months.

9 Milked for 265 days, calved in 11 months.

The previous system of feeding may have had some effect on the body weights during the first lactation on the alfalfa hay ration. Four cows, II-31, W-44, W-55, and W-69, had been on full feed before they were started on the alfalfa hay ration. They lost an

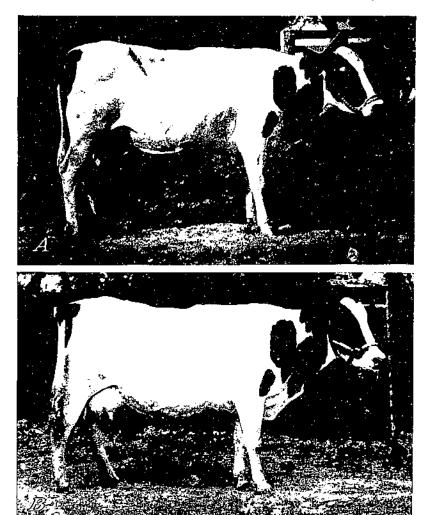


FIGURE 3.—Condition of cow 11-31 at different times during factorion on the alfalfa hay ration: A, after 214 days in milk (first factorion) B, after 136 days in milk (second factation).

average of 14.2 pounds during the first lactations on the alfalfa hay ration. Three of these four cows started the lactation as 3-year-olds. They carried calves for an average of 233.5 days during the lactation period and produced 353.3 pounds of butterfat (actual production). Six cows, H 39, H 52, H 53, H 64, W 54, and 270, had been fed under limited-grain conditions before they were started on the alfalfa hay ration. Their average loss in body weight was 48.5 pounds

during the first lactation on the alfalfa hay ration. They carried calves for an average of 179 days and produced 41...3 pounds of butterfat (actual production). Four of these cows were mature when they started the lactation period and two were 4-year-olds. Differences in age, production, and length of time a call was carried, may

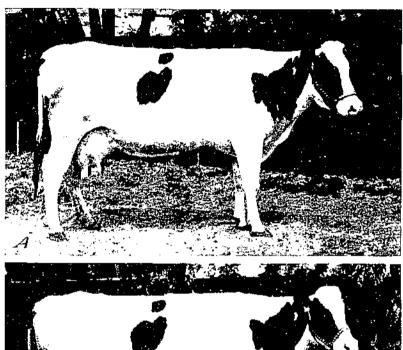




Figure 4. Condition of row 41-55 at different times during factation on the alfalfa hay ration: A. After 181 days in tailk (first Letation). B. after 43 days in tailk (second lactation).

have been factors in causing the difference in loss of weight in the two groups, as well as method of feeding in the prior lactation period.

The data indicate there is a slight decline in body weight during the first lactation on an exclusive ration of alfalfa hay, which is somewhat more pronounced when the lactation follows one on limited grain than when it follows heavy feeding of grain. There does not appear to be any significant decline in body weight for the second consecutive lactation on alfalfa. Data for the third consecutive lactation are very limited, but they show no evidence of a further decline in weight. The experiments by Headley (12), previously reviewed, corroborate this interpretation.

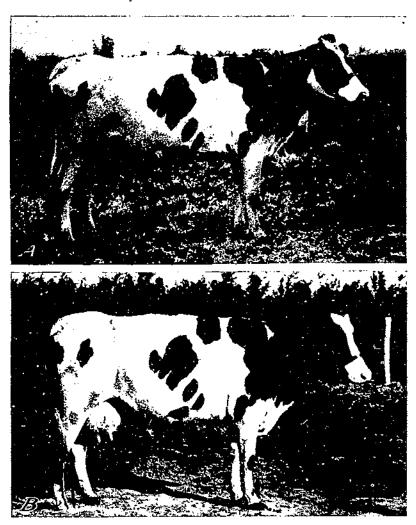


FIGURE 5.—Condition of cow H-31 at different times during hectation on the alfalfa bay ration: A. After 97 days in milk (first hectation); B. after 193 days in milk (third hectation).

While the cows fed alfalfa hay alone were lighter in weight than when they were fed grain in addition, at no time could they be called extremely thin or emaciated. Early in their lactations they became thin, but at the end of their lactations and during their dry periods they took on weight and had the appearance of well-fed cows. The photographs of cows H 31, H 53, and H-64 are included as being typical of their condition (figs. 3 5).

# EFFECT ON FERTILITY AND ON BREEDING AND CALVING

During the progress of this experiment numerous questions have been asked as to the effect of an exclusive ration of alfalfa hay, especially when fed over long periods, on the fertility and other breeding conditions of the cows. These questions have arisen probably because the feed was restricted to one plant and because a shortage of phosphorus was possible. A review of the literature does not reveal any data that would suggest lack of fertility or breeding troubles in cows when fed exclusively on alfalfa hay. In the Kansas experiments (19) less difficulty was experienced in bringing about conception in cows fed alfalfa hay than in those fed mixed rations. The data from the Nevada experiment (12) are limited and inconclusive from this standpoint, and only a suggestion of breeding trouble with cows fed alfalfa hay was mentioned.

One of the best measures of fertility in cows, if the bull is known to be fertile, is the number of services necessary for conception. Table 18 was prepared to show the number and ratio of services per conception (1) when the cows were fed alfalfa hay as the sole ration, (2) when the same cows were on full-feed rations, and (3) when the cows were fed on all planes of feeding except a sole ration of alfalfa hay. The latter grouping includes those cows fed full-grain rations, limited-grain rations, and roughage-alone rations. In most cases, pasture

was a part of the ration.

Table 18. -- Effect of feeding an exclusive ration of alfalfa hay as compared with other systems of feeding on ratio of services to conceptions

Cow No.				ay as the	· ·	. 6	r on full sed	When on all sys- tems not in- cluding bay alone		
	Serv- ices	.Concep-	Serv-	Conceptions	Serv- ices	Concept Concept Units	Serv-	Concep- tions	Serv-	Concep- tions
	 Number	Number	Number	Number	Number	Number	Number	Vumber	Vander	Vicenter-
Л-31.	. 1		! 1	1	1 * 10 //4///	2-11/10/11/1	. 2	1.00	, , , , , , , , , , , , , , , , , , , ,	. ` n mar i
11-38 1	. 0	. (1					4	2	Š	. 4
11-39 11-52	; 2	. 1	Ĭ	1 1			4	2	. 11	į c
H-53	3	1 (	. 7	1 1		:	į !	!!!	: 9	
11-62 3		: 6		,			: 1		į	i 1
11-61.	i i	Ϋ́	1	i 1.	3.1		7		. 4	
W-21 (	. 0	i ó		•	,	' '	· .	: :	70	i
W 44	1	1	. 1	1.0	1.	. 13	1	i	4	3
W-17	1	, 1	. 2	1 -	1	: j :	ī	i i:	3	! ä
W-54	' !	, 1					2	: 1	5	3
W-55 W-63		. !	2					. 1	2	
W-60	2						. !	1	ā.	2
270	į	i i	. 2	1 1:			5	<b>!</b> ;	3 : 15 :	3
415					·				, ,	l <u></u>
Total	10	12	13	9 :	6	3	22	15	79	40
Ratio	1.58;1		1.44;1		2.00:1		1.4	7:L	1.61:1	

 <sup>1</sup> H-38 did not come in cestrus during her lactation on alfalfa hay. Data not included in totals or ratios.
 2 H-62 developed vaginitis; did not conceive. Data not included in totals or ratios.
 3 Bull used was of questionable fertility.

\* W-21 was in cestrus at all times; did not conceive. Data not included,

If H-52, the only cow that gave any great trouble in conceiving during the first lactation, is excluded, the ratio is 1.27 services per conception instead of 1.58. It will be noted also that cow H-64 was bred four times before she conceived during her third lactation. The bull to which she was bred was of uncertain fertility and undoubtedly was responsible for her failure to conceive. Her breeding record for other lactations is almost perfect. Apparently the continuous feeding of alfalfa for as many as three lactations had no effect on the fertility of the cows as indicated by the ratio of services to conceptions. Considering all the lactations on the alfalfa hay ration together, the ratio is 1.58 services per conception. Omitting the data for H-52 during her first lactation on the alfalfa hay ration and for H-64 in her third lactation on alfalfa, there were 22 conceptions resulting from 29 services during all lactations on the alfalfa hay ration, a ratio of 1.32

services per conception.

The breeding records of cows H-38, H-62, and W-21 are given but are not included in the calculations. Cow H-38 did not come in oestrus during her lactation on the alfalfa hay ration and was not bred. An epidemic of vaginitis started in the Huntley herd during the time this experiment was running and approximately half of the cows showed irregular oestrual periods and other symptoms of the disease. The uterus of cow H-38 was enlarged and flabby, although her ovaries were pronounced normal. After completing her record on alfalfa hay, she was given a limited-grain ration and pasture with the regular herd. She came in oestrus 7 months after completing her record on alfalfa hay and was bred but did not conceive. She came in oestrus again in 78 days, was bred and conceived. As so many other cows in the herd fed limited- and full-grain rations were similarly affected, it is believed that the exclusive feeding of alfalfa hay was not responsible for the abnormal breeding condition of cow H-38. Cow H-62 was also in the Huntley herd and developed vaginitis at the same time. Cow W-21 developed the typical symptoms of a nymphomaniac early in her lactation on alfalfa. Near the end of the lactation she become stiff in the rear quarters and walked with difficulty. She was later sold as a nonbreeder. The ration of alfalfa hay was not considered responsible for her condition.

Under full-feed conditions the same cows required 1.47 services per conception. Under all systems of feeding, except the alfalfa hay ration, the same cows required 1.61 services per conception, which is essentially the same ratio as when they were fed the alfalfa hay ration. Some of the sires used were quite old and at times showed evidence of low fertility which would influence these data. This was the case under all systems of feeding, however. The data clearly show that the exclusive feeding of alfalfa hay over long periods had no detrimental effect on the fertility of cows as measured by the ratio of services to conception. That the exclusive feeding of alfalfa hay was not harmful from the standpoint of normal calves dropped is evidenced by the fact that of the 23 conceptions resulting in births, 20 of the calves, or 87 percent, were normal and living at birth. One calf was dead at birth and there were two abortions. Of 48 conceptions resulting in births on all other systems of feeding, the same cows dropped 43 living normal calves or 90 percent. Two of the calves were dead

at birth and there were three abortions.

#### SEX RATIO OF THE CALVES

The total number of calves of each sex that were born following the lactation periods on the alfalfa hay ration and following the lactation period on the full-feed ration was determined in order to learn whether either type of ration had any effect on the sex ratio. There were 24 calves born following lactations on the alfalfa hay ration, of which 14 or 58 percent were females. There were 16 calves dropped following lactations on the full-feed ration of which 11 or 69 percent were males. The number of calves is probably too small for the results to be significant, but they are so interesting that further data on the subject will be secured. This study of the sex ratio is prompted by the observation of Gerstell (8) that the fawn crop produced on an overbrowsed portion of the Pennsylvania deer range showed a sex ratio wherein the females outnumbered the males by more than 2 to 1, while on the less heavily browsed portions of the range, the ratio never equaled or exceeded a 2 to 1 ratio in favor of the females.

It has been shown previously that the cows on the alfalfa hay ration in this experiment were actually underfed only during the first 3 months of the lactation period. Presumably any factor that would affect the sex ratio would have to be active at the time of conception. At the time of conception most of the alfalfa-fed cows were receiving sufficient nutrients to meet their requirements, though a short time

previously they had been somewhat underfed.

# INFLUENCE OF EXCLUSIVE RATION OF ALFALFA HAY ON PERCENTAGE OF FAT IN THE MILK

There was an increase in the average percentage of fat in the milk when the cows were on the alfalfa hay ration. The average percentage of fat in the milk of each cow for each of the 26 records made on alfalfa hay and also for the 15 records made on full feed is given in table 19. In 18 of the 26 lactations (70 percent) on alfalfa the percentage of fat in the milk was higher than when the same cows were on full feed. It is probable that the increase in percentage of fat is the result of the reduced level of milk production when on the alfalfa hay ration. The average percentage of fat in the milk was higher when on the alfalfa hay ration in spite of the fact that the cows were practically mature, whereas their average age was 2 years 11 months when they were on the full-feed ration. It is a well-established fact that as age advances the percentage of fat in the milk tends to decline slightly.

The cows that had two or more consecutive lactations on the alfalfa hay ration showed a slight tendency toward an increased percentage of fat in the milk produced during the second and third lactations. Of the nine cows that had two consecutive lactations on the alfalfa hay ration, five showed a higher percentage of fat during their second lactation. This increase, however, was always accompanied by, and was probably the result of, a lowered level of milk

production for the later lactation.

One Holstein cow fed exclusively on alfalfa hay by Woll (1) at the California station for two consecutive lactations showed an increase in percentage of fat in her second as compared with her first lactation. Her total milk production was slightly less for the second lactation. In the Kansas experiment (19) there was a decrease in the percentage

of fat for the second consecutive lactation on hay alone as compared with the first, which in this case was accompanied by a slight increase in the amount of milk produced. In the Nevada experiment (12) there was a gradual decline in percentage of fat from the first to the third consecutive lactation and a gradual increase in total milk produced by lactations. For the group of cows that received grain in alternate years the average milk production and percentage of fat was slightly lower than during the 2 years when only alfalfa hay was fed.

Table 19.—Comparative effect of the alfalfa hay ration and the full-feed ration on the average percentage of butterfat in the milk

		butter- tofmilk on—			butter- t of milk on-		Average butter- fat test of milk when in—		
Cow No.	Alfalfa liny alone	Full feed	Cow no.	Alfalfa hay alone	Full feed	Cow no.	Alfalfa hay alone	Full feed	
П-31 II-38 II-39 II-52 II-62	Percent (3. 49) (3. 51) (3. 38) (3. 75) (3. 98) (3. 73) (4. 13) (4. 13) (3. 70) (3. 36)	3. 33 3. 81 3. 45	W-44 W-44 W-454	Percent [3, 60] [3, 77] [3, 23] [3, 47] [3, 32] [3, 54] [3, 08] [3, 11] [3, 36]	Percent 3, 43 3, 42 3, 44 3, 41 3, 21	W-55 W-63 W-69 270	Percent  {3. 11} {3. 06} {3. 45} {3. 49} {3. 90} {4. 01}  3. 53	Percent 3, 14 3, 49 3, 13 3, 89 3, 42	

While the data in this experiment are not extensive enough to show that the exclusive feeding of alfalfa hay over long periods will in itself definitely increase the percentage of fat in milk, they do indicate there is no decrease.

# ABNORMAL FLAVORS AND ODORS IN THE MILK

The milk of cow H-39 at the Ardmore station developed a very strong odor and taste shortly after she calved for her second lactation on the alfalfa hay ration, and the condition persisted for practically the entire lactation. If the same abnormality was present during her first lactation on alfalfa, it was so slight that it was not observed.

The milk of cow H-52 at the Huntley station developed a very distinct odor of sulphur and tar immediately after she calved for her first lactation on the alfalfa hay ration. Her calving was abnormal and she was given daily vaginal douches over a period of 30 days. The odor in the milk cleared up in 3 weeks, however, and was probably due to her condition following abnormal calving rather than to the alfalfa hay ration. It will be recalled that this cow required five services for conception during this lactation which is further evidence of an abnormal physical condition. These were the only cases of abnormal milk noted. No attempt was made, however, to detect alfalfa flavors or odors in the milk during the experiment.

# ECONOMIC PHASE OF EXCLUSIVE FEEDING OF ALFALFA HAY

The economic phase of feeding dairy cattle on rations restricted to alfalfa hay is of great importance.

Data from this experiment and from other feeding experiments carried on at the Bureau's field stations have been used by Graves

and Shepherd <sup>6</sup> as a basis for a study of certain phases of the economics of dairy cattle feeding. They analyzed the published information showing the cost of producing various crops in eight counties in three Midwestern States and found that alfalfa hay produced a greater quantity of total digestible nutrients per acre than any other crop, or 18 percent more than corn, which ranked second. The cost of producing 100 pounds of total digestible nutrients was the same in alfalfa hay and timothy hay and these hays produced the nutrients at less cost than any other crop, with clover hay a close second. Compared with the cost in alfalfa or timothy hay, the cost was 34 percent greater in husked corn, 154 percent greater in corn silage, 155 percent greater in oats, 189 percent greater in wheat, and 111 percent greater in barley.

Using these cost figures and the acre yields on which they were based, Graves and Shepherd calculated the cost of growing the feeds consumed by cows in feeding experiments at the Bureau's various stations, when the cows were fed the following rations: (1) Roughage alone; (2) roughage at will and 1 pound of grain to each 3 pounds of milk produced (full-grain ration); and (3) roughage at will and 1 pound of grain to each 6 pounds of milk produced (limited-grain

ration).

When the relative production of milk and butterfat on the three rations was compared, and the cost of producing the feed and the value of the product were also taken into consideration, the results were such that the investigators concluded that many farmers would find it advantageous to change their system of farming to one in which they would keep most of their land in permanent pastures and in legumes and grow very little grain. The pastures and other roughage would be the basal ration and grain would be fed only when the resulting increase in milk or butterfat production could be obtained at a profit, based on the cost of producing home-grown grain or on the price of purchased grain. When the prices for milk or butterfat were low in relation to grain prices the dairy farmer would feed roughage more exclusively. Production would be lower when less grain was included in the ration, but the cost of the ration would also be enough lower to make production more profitable.

#### SUMMARY AND CONCLUSIONS

This study was undertaken primarily to determine the advantages or disadvantages of feeding dairy cows on a ration consisting entirely of alfalfa hay, as compared to other systems of feeding, with particular reference to the relative production of milk and butterfat and to the effects of the alfalfa hay ration on the fertility, breeding, and calving activity, and general condition of the cows.

Feeding experiments were conducted over a period of several years at four of the Bureau's field experiment stations, in which 15 Holstein-Friesian cows were fed for a total of 26 lactation periods on the alfalfa hay ration, for comparative study with 15 lactation records made previously by the same cows under full-feed conditions. The latter records were made in connection with the regular test required of all cows in the Bureau's breeding experiments.

The cows fed the alfalfa hay ration had access to bonemeal and the full-feed ration consisted of roughage and grain fed at the rate of 1 pound to each 3 pounds of milk produced, and pasture in most cases.

<sup>6</sup> Oraves, R. R., and Shepherd, J. B. See footnote 4.

On the alfalfa hay ration, the 15 cows averaged 11,125 pounds of milk and 389.6 pounds of butterfat (mature basis) for 24 lactation periods. This was 57 percent as much milk and 60 percent as much butterfat as they averaged under full-feed conditions. There is evidence, however, to indicate that cows accustomed to a ration consisting entirely of high-quality roughage for long periods may exceed

these percentages somewhat.

Seven cows that were fed the alfalfa hay ration for two consecutive lactation periods averaged 10 percent less in butterfat production in the second lactation than in the first. The difference for individual cows ranged from a 40-percent decrease to a 40-percent increase in the second lactation, although only one cow made an increase. The higher average production in the first lactation may have been due in in part to the higher condition of the cows resulting from grain feeding in preceding lactations.

The decline in daily nulk yield throughout the lactation period was more rapid when the cows were on the alfalia hay ration than when they were under full-feed conditions. During the sixth month in lactation, the average daily milk production was 61.8 percent of the maximum daily production on the alfalia hay ration, compared

with 85.6 percent of the maximum on full feed.

The cows in this experiment consumed an average of 14,352 pounds, or slightly more than 7 tons, of alfalfa hay per cow for each lactation period. One cow consumed more than  $S_2$  tons. The cows reached their highest average daily consumption of 44.2 pounds during their lifth month in lactation. The highest individual daily consumption was 69 pounds.

They consumed an average of 1.3 pounds of alfalfa hay for each pound of milk produced and 38 pounds of alfalfa hay for each pound

of butterfat produced.

Feeding alfalfa hay continuously over two lactation periods had little effect on consumption. This is shown by the fact that five cows fed hay alone under comparable conditions consumed an average of only 251 pounds less hay in the second lactation than in the first.

Under the conditions of this experiment the cows refused to eat approximately 15 percent of the amount of lary offered to them, but there was great variation in this respect, due probably to differences in the palatability of the hay fed and individuality of the cows.

There was marked variation in the nutrients and minerals in the various lots of hay fed, even in that produced on the same land and

during the same year.

On the alfalfa hay ration, the 15 cows consumed an average of 3.6 percent more total digestible nutrients per lactation than they required for maintenance and production. They consumed only 74, 82, and 91 percent of their requirements in the first, second, and third month of the lactation, respectively. From the fourth to the twelfth month there was an increase each successive month in the nutrients consumed in excess of requirements.

Six of these cows that did not have pasture early in the lactation period when they were on the full-feed ration, consumed on the average 83, 93, and 96 percent of their nutrient requirements in the first.

second, and third month of the lactation, respectively.

A comparison of nine records under both systems of feeding for the first 280 days of lactation (the average number of days the nine cows

were on the full-feed ration without pasture) shows that on the alfalfa hay ration the cows produced 62.5 percent as much milk and consumed 53.6 percent as much total digestible nutrients above maintenance requirements as when they were on the full-feed ration. There was great variation in the ratio of production and the ratio of consumption of nutrients for the nine records, however. On alfalfa hay alone they gave an average of 3.16 pounds of (3.57-percent fat) milk for each pound of total digestible nutrients available for production, as compared with an average of 2.71 pounds of (3.49-percent fat) milk for each pound of total digestible nutrients consumed above maintenance requirements when on full feed. Apparently there was little difference in efficiency for milk production of the total digestible nutrients derived from the alfalfa and that derived from the grain, hay, and silage ration.

The cows on the alfalfa hay ration consumed but little of the special steamed bonemeal that was made available to them. The amount they did consume was insignificant from the standpoint of the calcium

and phosphorus furnished.

From the standpoint of phosphorus consumed, it is believed that the cows did not suffer a shortage as measured by the standard used. While there was a deficiency up to and including their sixth month in lactation, the excess for the remainder of their lactations and dry periods would probably more than offset any deficiency incurred during the first 6 months in lactation. The data, however, do not show how much of the phosphorus was utilized.

Only two cows in this experiment showed any marked craving for other roughage or feed. However, other cows in the station herds that were fed on a variety of feeds showed similar symptoms. None of the symptoms that are commonly associated with deprayed appetite,

or lack of appetite were observed.

The decline in body weight for the first year on the alfalfa hay ration, as shown by the precalving weight prior to the first lactation period and the precalving weight subsequent to the first lactation, average for 11 cows, was 22 pounds, or 1.4 percent. After the first lactation there was no further measurable decline in body weight when all influencing factors are considered.

While the cows were lighter in body weight when fed on hay only,

they had a well-fed appearance.

The long-continued feeding of the alfalfa hay ration had no detrimental effect on the fertility or breeding and calving condition of the

cows

The exclusive feeding of alfalfa hay over long periods did not lower the percentage of butterfat in the milk. There is evidence that the percentage of butterfat was increased somewhat though this increase was probably associated with level of milk production.

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