The plane of nutrition in relation to milk production
by Joseph C Shaw

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the Degree of Master of Science in Animal Husbandry
Montana State University

Abstract:
A pertinent problem in dairy cattle nutrition in the Western states is the selection or formulating of a practical method of feeding dairy cows whereby they may be fed more closely to theoretical requirements. The nutrients required can be estimated with a fair degree of accuracy by referring to the feeding standards which have been prepared by various investigators. These standards agree rather closely, and for all practical purposes they may be relied upon.

The usual method of apportioning grain is to feed each cow 1 pound of grain to each 3 or 4 pounds of milk produced, depending upon the richness, regardless of the quantity or quality of roughage consumed. This method of feeding is at fault, especially under Western conditions, because cows will get enough nutrients from good roughage alone to provide for the maintenance of their bodies as well as for the production of a certain amount of milk, and because 1 pound of grain does not provide enough nutrients for as much as 3 pounds of milk.

Western dairy husbandmen have attempted to work out a method of feeding that would be more satisfactory under their conditions. Since alfalfa hay Is usually the cheapest dairy cattle feed that can be produced in large quantities in many Western states, the methods suggested have been based upon the assumption that the majority of dairymen feed alfalfa hay In large quantities as the sole roughage. In making up these feeding rules an attempt Is made to determine the amount of nutrients In the faom of alfalfa hay that dairy cows will consume, In excess of their maintenance requirements. Acting upon the accepted principle that the nutrients consumed by dairy cows in excess of their maintenance requirements are converted Into milk, providing the cow does not make more than a slight gain In body weight, the number of pounds of milk that can be produced on this excess of nutrients Is determined. Concentrates are then fed in sufficient amounts to provide the nutrients required, according to a certain feeding standard, for each pound of milk produced above this amount.

The object of this thesis, "The Plane of nutrition in Relation to Milk Production", is to give a summary of the present available information which may be of value, In working out a more satisfactory method of apportioning concentrates to dairy cows in Montana, or in the revisal of the present method. A brief review is given of certain phases of dairy nutrition which deals more or less indirectly with the subject.

A more detailed review Ie given of the literature more directly applied to the subject, together with a discussion of an experiment conducted bytthe author under the direction of tha Animal Husbandry Department of the Montana Experiment Station.

For the convenience of the reader, this thesis Is divided Into five parts; Part I gives In condensed form a review of the Important daily cattle feeding stuff* in Montana.

Part II presents a review of the literature in regard to feeding methods, and experimental work dealing with the important problems involved in the feeding of alfalfa hay to dairy cows as the sole roughage.

Part III reviews very briefly the more important findings regarding the protein, energy, and vitamin requirements of dairy cows.

Part IT presents in detail the methods of procedure and the results of an experiment which the author conducted under the direction of the Staff of the Animal Husbandry Department of the Montana Experiment Station.

Part T presents the general conclusions of the review of the literature and the results of the experiment.

THE PLANE OF NUTRITION IN RELATION TO MILK PRODUCTION

by

JOSEPH C. SHAW

A THESIS

Submitted to the Graduate Committee in partial fulfillment
of the requirements for the Degree of Master
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Introduction

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PART I

FEEDS AVAILABLE FOR DAIRY CATTLE FEEDING IN MONTANA

Roughages

Roughages are the coarser feeding stuffs, which are high in fiber and supply a low percentage of digestible matter. They may be divided into two classes depending upon the amount of protein they contain. Nitrogenous roughages are high in protein and include hay and forage from the legumes. The carbonaceous roughages are low in nitrogen and include the non-legume hays, grain hays, and straws from cereal grains. Roughages may be further divided into dry roughages and green roughages.

In dairy cattle feeding the roughages usually furnish from half to all of the nutrients. Throughout the West, dairy cattle are fed much larger quantities of roughages than is the case farther East. While under Western conditions it is a common practice to feed alfalfa hay as the exclusive ration, this practice is practically unheard of in the middle Western and Eastern states where grain feeding is universally practiced.

Dried Legume Roughages. Properly cured alfalfa hay easily ranks first among hays for dairy cattle. It is very palatable, laxative in character, and is high in protein, containing three times as much as timothy, and is the highest of all common feeds in calcium. Dairy cattle in the Western states are able to consume large quantities of alfalfa due to their ruggedness and also due to the fact that most of them are fed

large quantities of it from the time they are a few weeks old until they are mature.

A legume hay having advantages similar to alfalfa is red clover, but it is not quite as palatable, nor so abundant in protein and minerals. Sweet clover properly cured has a feeding value about the same as that of red clover, although it is not quite as palatable. A considerable proportion of the stems is usually refused by the cow. It has been found that sweet clover hay may cause death in cattle due to the failure of the blood to clot normally. A slight cut may allow the animal to bleed to death. For this reason sweet clover cannot be considered as being entirely safe.

While not grown so abundantly for hay as is alfalfa and the clovers, oat and pea hay when cut at an early stage is palatable and nutritious. The protein content is about three-fourths that of alfalfa, while the total digestible nutrients are about equal.

Dried Non-Legume Roughages. Although timothy hay in the Rocky Mountain States is a little higher in protein than the timothy hay in other states, it is not a very satisfactory feed for dairy cows. It is not only low in protein, but is the lowest in minerals of all common feeds. When it is used as the roughage, it is necessary to add considerable amounts of high protein feeds to the ration. Blue joint ranks above timothy as a hay for dairy cattle, being more palatable and higher in minerals, protein and total digestible nutrients.

One of the best non-legume hays is oat hay, cut for hay when in the milk stage. It is quite palatable and has about the same feeding value for

dairy cows as blue joint. Another cereal hay sometimes used for dairy cattle feeding is rye hay. However, this hay is low in protein and less palatable than timothy. Oat straw is also sometimes fed to dairy cattle, but is very unsatisfactory feed, being low in protein and total digestible nutrients and lacking palatability. Wheat, rye, and barley straw can not be counted on as feeds, but make good bedding material.

Corn fodder is used to some extent for dairy cattle feeding in Montana. As is commonly known, corn fodder is the stock with the ear attached. Its chief value is in the ear corn. Aside from the grain included, it is about equal to timothy hay in total digestible nutrients, but is less palatable. Silage made from the corn plant cut while still in the green stage is one of the best dairy cattle roughages, being very palatable and succulent. However, there is very little corn put up in the form of silage in Montana.

Concentrates. Concentrates are feeding stuffs in condensed nature, which are low in fiber and hence furnish a large amount of digestible matter. While concentrates do not supply a very large portion of the total digestible nutrients fed to dairy cows in Montana, they are nevertheless very valuable in supplementing the roughages. It is generally considered that half of the concentrate ration should be made up of relatively bulky feeds such as ground oats, bran and wheat screenings.

Corn forms a part of the grain ration on some Montana dairy farms, in those sections where this grain is grown. It is nutritious and palatable and a splendid feed for the cow in milk. However, it should not make up over half of the ration. Corn and cob meal was reported by McCandlish (37) of the Iowa Station to be valuable for dairy cows in just the proportion

of corn grain it contained. One hundred pounds of cracked corn was equal to 125 pounds of corn and cob meal. Barley and wheat compare very favorably with corn as a dairy cattle feed and are much more common in Montana than is corn. The barley should be ground or crushed because of the tough outer covering. Wheat has more protein than corn and is slightly superior as a source of minerals. It may safely make up half of the ration (43). Rye has a composition not greatly different from corn but ranks below it, being rather unpalatable. If mixed with other feeds it may be fed in amounts up to three pounds per day. When fed in large quantities it tends to produce butter with a hard body.

Of the more bulky concentrates bran is one of the most valuable for dairy cattle feeding because it is palatable and bulky, has a desirable laxative effect, and is one of the best sources of phosphorus. Oats, however, are fully as valuable as bran and may be substituted for bran in the ration pound for pound. Screenings from wheat are available in large quantities in this state. This product consists mainly of broken and shrunken wheat kernels and a variety of weed seeds. High grade screenings have a feeding value of about ten per cent below that of oats according to Eckles (8). Screenings have a rather bitter taste and are for this reason somewhat unpalatable. Cattle take them readily, however, when mixed with other ground feed.

Most of the beet pulp fed in the state is fed as wet pulp, especially in the vicinity of the factories. It is highly valued by dairymen both in the wet and dry state. The dried pulp compares favorably with corn as a concentrate. It is especially favored for test cow

feeding. The disadvantage of wet pulp is that it spoils rapidly on exposure to the air. It is necessary to store it in large tank-like silos, straw silos or well drained trench silos. The pulp is low in minerals and protein and must be fed with feeds high in these two constituents.

Beet molasses is a valuable carbonaceous feed that is fed to some extent in Montana. It has about the same feeding value as corn when not fed in too large amounts. Compared to black strap molasses it is somewhat bitter. Dairy cows should not receive more than three pounds per day because of its laxative effect. Molasses is useful as an appetizer for cows receiving a heavy ration and is used extensively in test cow feeding.

Nitrogenous Concentrates. The most common mistake in feeding dairy cows is the failure to give enough feed to make use of the milk-producing ability of the animal. Next to the failure to feed liberally enough is the failure to give enough protein. If a cow, having enough other material to produce 30 pounds of milk, gives only 20 on account of a shortage of protein, it is useless to increase the ration further. The addition of a small amount of concentrate, high in protein, would allow the cow to make full use of all the ration.

Where liberal quantities of good quality alfalfa hay is fed, as is often the case in Montana, the addition of high protein concentrates should not be necessary. When the roughage consists of a non-legume hay or a legume hay of poor quality, it is usually necessary to add a high protein concentrate to the ration. The two most important purchased protein supplements used in Montana are cottonseed meal and linseed meal.

Bran is somewhat higher in protein content than are the cereal grains, but it must not be looked upon as a source of protein to balance home grown rations. Linseed meal is one of the best protein feeds for dairy cattle, being palatable and laxative and has a wonderful effect upon all kinds of animals to which it is fed. While cottonseed meal contains the highest amount of protein of any feed ordinarily fed to cattle, it is not quite as popular among dairymen as is linseed meal. When fed in too large amounts it has a constipating effect and when making a large portion of a ration lacking variety it may have a toxic effect. Results of Experiments by Woodward, Shepherd and Graves (61) show that large quantities of cottonseed meal may be fed to dairy cows without any apparent ill effects, if good roughage, such as pasture grass, green forage, or nicely cured hay is fed with it.

PART II

METHODS OF FEEDING - DAIRY CATTLE EXPERIMENTS WITH ALFALFA HAY

Methods of Feeding by Prominent Dairymen

Roughages usually form the major portion of dairy cattle rations. The dairy cow is very well adapted to the conversion of large quantities of roughage into edible food for man. With a few possible exceptions the cheapest and most economical feed for dairy cows is good quality roughage and it may well make up from half to all of the nutrients required. Concentrates then constitute the balance of the ration.

Although it is usually considered that the most economical production of milk can be secured by feeding large amounts of roughages and comparatively small amounts of concentrates, there are times when the digestible nutrients supplied by means of roughages are higher in price than the same amount of nutrients supplied by means of concentrates. In this case it would be more economical to feed large quantities of grain and a minimum amount of roughages. Feeding rules or methods are usually based on the fact that it is usually more economical to feed large quantities of roughage and make up the additional requirements by means of concentrates.

The object of feeding rules is to furnish a practical method of feeding dairy cows so as to enable the feeder to supply the proper amounts of the several nutrients necessary for maintenance, growth, development of the fetus and production of milk, as shown by an accepted feeding

standard. It is generally considered that for the most economical production of milk, dairy cows should be fed individually and as close as possible to their requirements as shown by one of these accepted standards.

A method of feeding recently published in bulletin form by Headley (31) of the Nevada Station is to feed dairy cows all the alfalfa hay they will eat; and to Holsteins, grain in the proportion of 1 pound to every 2½ pounds of milk they produce in excess of 30 pounds; and to Jerseys, 1 pound of grain to every 2 pounds of milk they produce in excess of 25 pounds.

Another method, somewhat similar to this, is to feed dairy cows all the alfalfa hay they will eat, and grain to low testing cows in the proportion of 1 pound to every 2 1/2 pounds of milk produced in excess of 16 to 20 pounds, and to high testing cows, 1 pound of grain to every 2 pounds of milk they give in excess of 10 to 14 pounds. Tretsven (52) of the Montana Station is the author of this method. When connected with the California Station, Woll (58) proposed a feeding rule for Western dairymen in which dairy cows, receiving all the alfalfa hay they would eat, were to receive 1 pound of grain to every 4 or 5 pounds of milk produced, when the cows production of butterfat exceeded 1 pound per day.

The following is a method suggested by Eckles (8): "Feed all the roughage a cow will eat. This should include a succulent feed and a legume hay. In addition, feed a Jersey or Guernsey 1 pound of grain to each 2 1/2 to 3 pounds of milk, and a Holstein, Brown Swiss, or Shorthorn, 1 pound of grain for each 3 to 3 1/2 pounds of milk. When silage is not available, feed the same grain mixture but in somewhat larger amounts".

A method differing very little from that suggested by Eckles was

advocated by Weaver (57) of the Iowa Station. Weaver's method was to: "Feed all the legume hay a cow will eat. If legume hay is the only roughage fed, the cow will eat nearly 2 pounds of it daily for each 100 pounds of live weight. If used along with silage, she will eat about 1 pound per 100 pounds of live weight and 3 pounds of silage per 100 pounds of live weight. With legume hay and silage, feed Jerseys and Guernseys 1 pound of grain for every 3 pounds of milk and a Holstein, Ayrshire or Brown Swiss 1 pound for every 3 1/2 pounds of milk produced".

A method which has given very satisfactory results under experimental conditions at the Government Station at Beltsville, Maryland, is the following as stated by Woodward (61): "When cows are given 3 pounds of silage a day for each 100 pounds of live weight and all the No. 2 or No. 3 alfalfa they will eat, give grain to Jersey cows at the rate of 0.6 pound for each pound of milk produced above 10 pounds, and to Holsteins give 0.4 pound of grain for each pound of milk above 16 pounds."

From the review of methods of feeding offered by prominent dairymen it is evident that two methods of feeding are commonly advocated: (1) The method suggested by Eckles and Weaver, based on a practice of feeding a certain amount of grain for every pound of milk produced; (2) The method which is advocated by Woodward, Tretsven and Headley based on a practice of feeding a certain amount of grain for every pound of milk produced in excess of that provided for by the roughage. The amount of grain fed for each pound of milk is just enough to produce that pound of milk. It is assumed that the roughage in addition to providing for maintenance will also provide nutrients for a certain amount of milk. Woll proposed a method that attempts to include both methods outlined, with the result that it is probably not as accurate as either one. The method worked out

by Woodward is the only one that takes into consideration the quality of the hay.

The second method can be varied so as to include both Eastern and Western conditions. The plan suggested by Woodward applies only to Eastern and Mid-Western conditions, and the plan suggested by Tretsven and Headley applies only to Western conditions. Both are based on the same principle, however. It is interesting to note that although their feeding rules are based upon the same principle, Headley and Tretsven disagree as to the point where grain feeding should begin.

Woodward (61) states that the ordinary method of apportioning grain is to give each cow 1 pound of grain to each 3 or 4 pounds of milk produced, depending upon the richness of the milk. This method is inaccurate for two reasons: (1) Because cows will get enough nutrients from good roughage alone to provide for the maintenance of their bodies, as well as for the production of a certain amount of milk, and (2) because 1 pound of grain does not contain sufficient nutrients for as much as 3 pounds of milk.

In the review of experimental work in which one or the other of the two systems of feeding were used, the first method will be referred to as "the usual method", and the second will be referred to as "Woodward's Method".

Woodward's Method Versus the Usual Method. In all the literature reviewed there was no work reported in which an experiment was conducted to compare the efficiency of the different methods of feeding. However,

in most of the dairy feeding trials reported, a definite rule for feeding was followed. It should be possible, then, by making a review of this work to glean some information that may be of value in comparing the method worked out by Woodward and the one suggested by Weaver and others. The work which should be more applicable to Montana conditions is that in which alfalfa hay is fed as a part or all of the roughage.

In three feeding trials of from five to six weeks each, Woll (59) and associates of the California Station found that the method of feeding grain to dairy cows at the ratio of 1 pound for every 5 pounds of milk yielded within 5 per cent as good results, on the average, as a ratio of 1 pound of grain to every 3 pounds of milk. The roughage fed consisted of equal parts of corn silage and alfalfa. The "full grain" group averaged 22.8 pounds of milk per day containing .894 pound of butterfat and the same group on the "limited grain" ration averaged 21.8 pounds of milk and .859 pound of butterfat per day. It is therefore quite evident that these experiments were conducted with cows of very average production. Since grain alone in the proportion of either 1 to 3 or 1 to 5 does not provide enough nutrients to produce 1 pound of milk, it is evident that the roughage furnishes part of the nutrients for milk production as well as maintenance.

In all, during a period of 214 cow days, the heavy grain group consumed an average daily ration of 22 pounds of silage, 22 pounds of alfalfa hay, 5 pounds of beets, 1.8 pounds of beet pulp, and 7.5 pounds of grain.

The limited grain group in a period of 214 cow days consumed

an average daily ration of 22 pounds of silage, 21.8 pounds of alfalfa hay, 5.5 pounds of beets, 1.9 pounds of beet pulp and 4.2 pounds of grain. Table I gives the average production of milk and a comparison of the nutrients consumed with the nutrients required.

Table I - Heavy Versus Light Grain Feeding

Group	Milk	Test	Average Wt.	Total Digestible Nutrients			Increase In Production
				Required	Consumed	Difference	
Heavy grain	22.8	3.9	1157	16.47	22.84	+6.37	5%
Light grain	21.8	3.9	1158	16.22	20.00	+3.78	

Two conclusions may be arrived at from the data in this table: (1) Both groups were fed in excess of requirements, when fed in the proportion of 1 to 3 and 1 to 5, and (2) there was an increase in production when an already liberal ration was made more liberal.

At the Huntley Field Station, Moseley, Stuart, and Graves (45) fed a group of 10 Holstein cows on a ration of alfalfa, beet silage, and beet pulp; the next year the group was fed the same roughages and grain in the proportion of 1 pound to each 6 pounds of milk; the third year the group received the same roughages and in addition, 1 pound of grain to each 3 pounds of milk. Ten cows in all completed a 365-day test on each of the three rations. Since they were on pasture in the summer the comparisons were made of the three groups during the winter feeding period of 201 days.

The group fed grain at the rate of 1 pound to 6 pounds of milk consumed very close to their theoretical requirements, according to the Meigs and Converse standard (39), their average consumption of total digestible nutrients being 2.4 per cent in excess of their requirements. They also produced 18.2 per cent more butterfat than the group fed roughages exclusively, and gained an average of 87 pounds in live weight.

The group fed roughages exclusively failed by 4.6 per cent to consume enough nutrients according to the Meigs and Converse tables, and lost an average of 23 pounds of live weight during the 201 days.

The third group, or the group receiving 1 pound of grain for each pound of milk, produced only 5.7 per cent more butterfat than the group fed at the rate of 1 pound of grain to each 6 pounds of milk. This group consumed 29.2 per cent more nutrients than were required and gained an average of 106 pounds in live weight during the winter feeding period.

All of the cows in this experiment were high producers and there was but very little variation in their production during the year. During the year they received grain at the rate of 1 pound to 6 pounds of milk, these 10 cows produced an average of 576.45 pounds of butterfat, varying in production from 471.88 to 627.08 pounds of butterfat in their 365-day period.

Since all of these cows produced at about the same level, it is very probable that in this case the proportion of 1 pound of grain to 6 pounds of milk was about the correct proportion for cows producing that quantity of milk and butterfat. Three different rates of feeding were tried on the same group and one proved to be about right for that group. However, would this experiment have proved so satisfactory if the cows had varied widely in production as is more often the case? Due to the fact that the roughages furnished such a large proportion of the nutrients and the cows were such high producers, the data may be interpreted as indicating that low producers would receive a sufficient amount of nutrients from the roughage alone. The fact that these high

producers, when fed nothing but roughage, consumed almost enough nutrients to supply their requirements also indicates that such is the case. The consumption of such large amounts of nutrients in the form of roughage was probably due to the great variety of roughages fed.

Dairy cattle feeding trials were conducted by Foster and Latta (16) of the New Mexico Station, in which strictly alfalfa hay feeding was compared with alfalfa hay and grain feeding, by use of the reversal method. The alfalfa was fed ad libitum to both groups and the grain was fed in the proportion of 1 pound of grain to each 3 pounds of milk produced. The grain fed group produced 10 per cent more butterfat than the strictly alfalfa group.

The cows used in these experiments were mostly grade Jerseys with a few pure bred Jerseys, Guernseys and Holsteins. The grain fed consisted of equal parts of corn and bran, containing 73.3 per cent total digestible nutrients according to the Henry and Morrison's tables. The cows fed alfalfa and grain over a period of four months averaged 14.7 pounds of 4.8 per cent milk on 25.6 pounds of alfalfa and 6.66 pounds of grain, and gained 25 pounds in live weight per month. Since their average weight was about 1,100 pounds, their requirements for total digestible nutrients according to the Meigs and Converse tables was 14.23 pounds per day; whereas they received 18.08 pounds of total digestible nutrients per day.

The cows fed alfalfa alone averaged 13.1 pounds of 4.8 per cent milk on 31.25 pounds of good alfalfa hay, and gained 2 pounds per month in live weight. Considering the weight again at 1,100 pounds, the requirements of total digestible nutrients would be 13.6 pounds per day;

whereas they apparently received 16.1 pounds per day.

This experiment furnished a good example of one of the common faults of feeding a certain amount of grain for every pound of milk produced. The alfalfa alone provided sufficient nutrients for these low producing cows. The fact that they gained 2 pounds per month on alfalfa alone indicates that they were receiving about the proper amount of nutrients. The groups receiving grain consumed about the proper amount of nutrients. The groups receiving grain consumed considerable more total digestible nutrients than was required and gained 29 pounds per month in live weight. The increase in production by the grain fed group may have been due to a combination of factors, namely: the supernormal plane of nutrition, and the increased variety and palatability of the ration.

The feeding of alfalfa hay as the exclusive ration for dairy cows was compared with the feeding of barley and alfalfa hay by True, Woll and Voorhies (53) during two successive winter feeding periods. Fourteen cows were fed in the first trial and 18 were fed in the second trial. In both trials the reversal method was used. The ration consisted of alfalfa hay, green alfalfa and barley, in the case of the cows on the grain ration. The group on roughage exclusively received green alfalfa and alfalfa hay. In both trials the addition of barley to the ration increased the production of milk 13 per cent.

The cows in this experiment would be considered as low producers since their average daily production of butterfat was only 0.6 pounds. Barley was fed at the rate of 1 pound to each 5 pounds of milk produced.

Since the information was available on the average live weight of the cow, production of milk, per cent of butterfat, and average daily feed consumption, it was possible to compare the amount of total digestible nutrients eaten by the barley fed groups with the theoretical requirements of these cows according to the Meigs and Converse standard.

The results show that in the first trials the cows received enough nutrients to produce 35 pounds of milk and gain slightly in weight. However, this group averaged only 25 pounds per day. In the second trials the cows received enough nutrients to provide for 35 pounds of milk but produced only 19.2 pounds.

Here, again, low producers were fed in excess of their requirements when allowed a certain amount of grain for every pound of milk produced.

Woll (60) fed one group of heifers exclusively on alfalfa and another group alfalfa, silage and concentrates. The feeding began one year before freshening and continued through two lactation periods. The exclusive alfalfa ration consisted of two-fifths green alfalfa and three-fifths alfalfa hay. The mixed rations were made up of alfalfa hay, green alfalfa, silage and concentrates. The concentrate ration consisted of bran, barley, dried beet pulp and coconut meal. The method of feeding the grain was not given.

The results show that the group on the mixed ration gained 20 per cent more in weight and showed a tendency towards a slightly greater body development, as shown by the measurements of the height of shoulders and hips, width between hips, length from hip bone to pin bone, length from shoulder to pin bones and heart girth.

During the first lactation period the group on the mixed rations produced 40 per cent more butterfat than the alfalfa fed group, and in the second lactation period produced 23 per cent more. Except for some trouble in the second year with one cow in the mixed ration group, which cut her production in half, this group would have shown about the same increase in production over the alfalfa fed group as it did the previous year.

Here again all the figures are available to compare the two groups on the basis of nutrients required and nutrients received by the use of the Meigs and Converse standard. The alfalfa fed group received enough total digestible nutrients above maintenance for the production of 21.5 pounds of milk; whereas their average production was 17 pounds of milk. The mixed ration group received enough nutrients above maintenance to provide for 34 pounds of milk, whereas their production was only 24.5 pounds of milk.

Apparently the mixed ration had a tendency to increase the production. However, since the group on mixed rations were fed considerably in excess of their requirements, some of this increase may have been due to the super-normal plane of nutrition.

Vernon (55) of the New Mexico Station fed one group of cows all the alfalfa they would eat and eight pounds of bran and another group alfalfa exclusively, using the reversal method, during two periods of six weeks each.

The groups on alfalfa and bran produced 16.5 per cent more milk, but at a lower efficiency of 8 per cent due to an excess of nutrients

above requirements. The cows in this group consumed 33.3 pounds of alfalfa per day, or 22 pounds of total digestible nutrients and produced 16.5 pounds of milk per day.

The groups on alfalfa exclusively consumed an average of 33.8 pounds of alfalfa per day or 17.44 pounds of total digestible nutrients and produced 13.7 pounds of milk per day.

Since the cows used were mostly grade Jerseys, it is evident that the production and maintenance was well provided for by the 33 pounds of alfalfa consumed. The eight pounds of bran fed was apparently in excess of requirements. In summarizing this work then it is apparent that the increase in production following the addition of bran may have been due not only to the increased variety and palatibility, but also to an excess of nutrients.

After conducting continuous feeding trials covering four years, Headley (28) of the Nevada Station concluded that when a pound of total digestible nutrients in the form of alfalfa hay is cheaper than a pound of total digestible nutrients in the form of grain, the amount of grain fed should correspond to the milk and fat produced, and its use should be discontinued when production declines to the point where roughage alone will supply the nutrients. The increase in butterfat from feeding grain amounted to .2 pound daily for 250 days for four cows consuming an average of 8 pounds of grain per day.

The results of an experiment with 71 Holsteins and Jerseys over a period of three winters were reported by Woodward, Shepherd and Graves (61), during which time the cows were fed according to Woodward's method which

was previously explained in the text of this thesis.

From experiments in which cows had been given all the roughage they would eat, they determined the amount of alfalfa hay large cows and small cows would eat when it was fed in addition to a definite quantity of silage. They found as expected, that the large cows consumed more roughage than the small cows and that Jerseys and Holsteins of the same size ate about the same quantity of roughage. When cows were fed 3 pounds of silage a day per 100 pounds of live weight and all the good alfalfa hay they would eat, the small cows ate about 8 pounds of alfalfa per day above the amount required for maintenance, and the large cows ate about 10 pounds of alfalfa per day above maintenance requirements, or enough to produce 10 and 16 pounds of Jersey and Holstein milk respectively. Jerseys producing over 10 pounds of milk per day were fed .6 pound of grain for each pound of milk over that amount and Holsteins were fed .4 pound of grain for each pound of milk over sixteen pounds.

They state that: "For comparison of this new method of feeding grain to dairy cows with the usual method of feeding 1 pound of grain for each 3 or 4 pounds of milk produced, it would have been desirable to have had similar data on the production, decline in milk yield, and gain or loss in body weight of cows fed by the Usual Method. However, if the nutrients provided by each of these two methods of feeding are compared with those provided by the Haecker and Savage standards, it will be found that, as a rule, this new method more nearly supplies the nutrients in the amounts prescribed by the standards than the one in common use. Furthermore, the results of experimental feeding here reported show that the nutrients were

actually supplied in very nearly the correct amounts".

"This method does not apply with accuracy to the irrigated sections of the West where hay of excellent quality is grown, nor will it apply to those sections where a poor roughage is used, as straw, corn stover, cottonseed hulls, or coarse or weather damaged hay. In the former case the excellent roughage alone will support a production much in excess of 10 pounds for Jerseys and 16 for Holsteins: in the latter case the poor roughage will not provide for the nutrients for 10 to 16 pounds respectively."

Experimental work conducted at the Havre Station, under the direction of Vinke (56) shows that 40 pregnant but dry milking shorthorn cows made an average daily gain of .37 pound, on 18.3 pounds of alfalfa hay, during a period of 111 days. Since they averaged 1,082 pounds in body weight they apparently consumed only 1.1 pounds of total digestible nutrients in excess of maintenance requirements, according to the Meigs and Converse standard. Most of these cows calved shortly after the completion of the experiment so it is evident that, although they made an actual gain of .37 pound per day in body weight, this would represent a loss in fleshing of approximately .5 pound per day, due to the fact that the .37 pound per day would not account for the total increasing weight of the fetus. From this work, it is apparent that alfalfa hay fed not to exceed requirements, according to the Meigs and Converse standard, would very nearly provide for the maintenance of a cow.

Conclusions. 1. In all the experiments reviewed, except the Huntley

work, the cows were comparatively low producers. The majority of them were fed by the usual method and the ratio of pounds of grain to pounds of milk was 1 to 3, 1 to 4, or 1 to 5. According to the Meigs and Converse tables, the low producing cows in all cases received an excess of nutrients ranging from a few pounds to almost double their requirement.

2. The high producing cows at Huntley received sufficient nutrients from a great variety of roughages, and grain fed at the rate of 1 pound to 6 pounds of milk. We must conclude, therefore, that the roughage provided the nutrients for the major portion of the milk and that low producers fed that same variety of roughages would not need grain.

3. In all experimental work reported in which alfalfa was fed ad libitum to dairy cows as the only roughage, both low and high testing cows consumed enough alfalfa to take care of maintenance and at least 20 pounds of milk per day.

4. When sufficient nutrients were being provided according to the Meigs and Converse tables, the addition of concentrates to the ration increased the production from 10 to 43 per cent.

5. Production was increased by a supernormal plane of nutrition, but not in proportion to the nutrients supplied.

6. Feeding trials at Beltsville, Maryland, showed that the method of feeding suggested by Woodward more nearly supplies the nutrients in the amounts prescribed by the accepted feeding standards than the one in common use.

Amount of Alfalfa Hay that Dairy Cows will Consume. The method of feeding suggested by Woodward, Shepherd and Graves (61) requires that the

average consumption of roughage by the various breeds of dairy cattle must be known. They determined what the average consumption of alfalfa hay of good quality would be when the cows were fed silage in the proportion of 3 pounds per day for each 100 pounds of live weight. In order to formulate a method for Western conditions by using this same plan, it is desirable to determine how much alfalfa the cows of the various breeds will consume when concentrates are included in the ration.

From the results of several experiments with alfalfa hay feeding, Headley (28) concludes that the capacity of the average cow for hay is limited to about 30 pounds per day for a 1,000 pound cow or 36 pounds for a 1,300 pound cow.

Table II gives the average consumption of alfalfa hay by dairy cows at the Nevada Station during 1931 in an experiment conducted by Headley (29). These cows did not receive any other feed than alfalfa hay from the time they dropped their first calf. Numbers 1 and 2 dropped their first calves in 1925 and did not receive any other feed than alfalfa until 1932.

Table II Daily Consumption of Alfalfa

Cow Number	Hay Eaten Per Day: Highest for any one month	Hay Eaten Per Day: Average for Year 1931	Average milk production per day for year 1931	Average Weight of Cow
	Lbs.	Lbs.	Lbs.	
1	44.2	38.9	20.6	1430
2	41.8	35.0	18.6	1335
3	43.2	38.9	24.0	1160
4	33.1	30.6	17.6	955
5	35.9	31.0	16.7	1035

Headley (30) stated that he had observed that cows eat the most alfalfa hay during periods of high production and least when they were dry. He also stated that the amount of hay varies with the amount of milk