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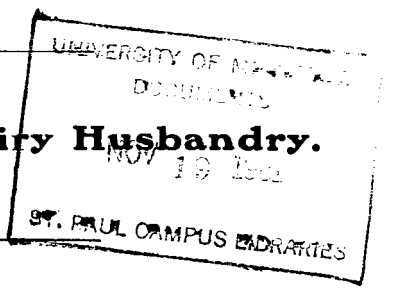

Division of Dairy Husbandry.

JANUARY, 1903.

INVESTIGATION IN MILK PRODUCTION.

1. THE FOOD OF MAINTENANCE.
2. NUTRIENT REQUIREMENTS.
3. PROTEIN REQUIREMENTS.
4. INFLUENCE OF STAGE OF LACTATION ON NUTRIENT REQUIREMENTS.

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INVESTIGATION IN MILK PRODUCTION.

T. L. HÆCKER.

1. THE FOOD OF MAINTENANCE.

In all living bodies there is a constant breaking down of tissues or wear, caused by every muscular action, just as is the case with any piece of machinery. There is also energy expended in the action of the muscles and body heat must be maintained. The nutrients used by an animal in keeping intact the body, that is, in rebuilding the portions worn out and in providing the energy and maintaining body heat when at rest in stall, is termed the Food of Maintenance or Food of Support. The generally accepted feeding standard, Wolff's, gives 18 pounds of dry matter and of nutrients, .7 of a pound of crude protein, 8 pounds of carbohydrates and .1 of a pound of ether extract or fat, as the amount needed daily for maintenance per thousand pounds live weight.

During our earlier feeding experiments it was observed that in some instances cows did fairly good work in the dairy during a whole winter on only a trifle more feed than that prescribed for food of maintenance, indicating that the amount fixed by the standard in general use was in excess of the actual requirements. Sanborn of the New Hampshire station reported in 1879 that the steer could be maintained on a smaller allowance of hay than is prescribed in the standard. Caldwell, of the Cornell Experiment Station, New York, reports a trial where four steers gained 180 pounds during a period of 60 days, on practically a maintenance ration. Kuehn, a German investigator, in experiments extending over several years showed that the mature bovine could be maintained on .7 of a pound of protein and 6.6 pounds of nitrogen free extract, and that whatever was fed in excess of this amount, caused gain in weight at the rate of from 20 to 25 per cent of the amount so in excess. It was evident therefore that at the time when the dairy division of the University of Minnesota was established, there had been

enough data obtained to show that there was still a question as to the nutrients actually required for food of maintenance. It was evident then that in a series of experiments in milk production, which would be likely to extend over two decades, more information ought to be secured as to food required for maintenance under conditions obtaining in the Northwest. It was not possible with the limited and inadequate facilities accorded the dairy division in securing the composition of food stuffs and feces to carry on the work from a purely scientific standpoint, nor was it considered advisable to do so. The work has therefore been carried on from the more practical phase in the belief that in this form it would receive more attention from milk producers than would be the case if given in more elaborate and technical form.

A mere preliminary trial on a maintenance ration was begun on the 31st of October, 1894, when two barren dry cows were fed on a daily ration of 10 pounds of timothy hay and 3 pounds of ground barley for a period of 81 days. Their weight at the beginning of the trial was 1676 pounds, and at the close, 1735 pounds, being a gain of 59 pounds, or .36 of a pound each per day. The average weight of the cows during the experiment was 853 pounds. The dry matter and nutrients of the ration per 1,000 pounds were as follows:

TABLE VI.—Giving Food and Nutrients Consumed Daily.

	Lbs.	D. M.	Digestible Nutrients		
			Protein	Carbohydrates	Ether Extract
Timothy Hay	10	8.768	.318	4.509	.18
Barley Meal	3	2.646	.283	1.792	.06
Total		11.414	.601	6.301	.24
Per 1000 lbs. live weight		13.38	.704	7.386	.28

It is shown by the above table that the ration fed was practically the amount prescribed in the Wolff standard, but contained .614 of a pound less of carbohydrates and .18 of

a pound more ether extract. Reducing the .18 of a pound of ether extract to a carbohydrate equivalent (.18 x 2.25) .405 of a pound and adding this to 7.386, the carbohydrates for convenience in comparing the ration fed with the Wolff standard, we have the following:

TABLE VII.—Giving Nutrients Consumed Daily and the Wolff Standard.

	D. M.	Digestible Nutrients		
		Protein	Carbohydrates	Ether Extract
Ration fed per 1000 lbs. live weight...	13 38	.704	7.791	.10
Wolff Standard maintenance ration ...	18.00	.70	8 00	.10

The ration fed provided, practically, the amount of protein called for by the Wolff standard and .209 of a pound less of non-nitrogenous matter, and produced a daily average gain of .36 of a pound, showing that the ration fed was in excess of the amount actually needed for food of maintenance.

The second experiment was conducted with two barren dry cows during the winter of 1896–97 covering a period of 100 days. One received 18 pounds and the other 14 pounds of fodder corn daily. The following gives their weight at the beginning of the trial and at the close, being the average of daily weighings which were in all cases made in the morning after feeding and before watering, and the average of all their weights during the trial:

	Alice.	Belle.
Weight at beginning.....	797	1005
Weight at close.....	803	985
Average weight.....	808	1010

At no time after the first 11 days did Alice fall below 800 pounds and Belle maintained a weight above 1000 pounds until the month of February when her average weight was 987. The dry matter consumed daily and nutrients digested, as determined by a digestion experiment during the trial, is given in the following:

TABLE VIII.—Dry Matter Consumed and Nutrients Digested Daily and per 1000 lbs. Live Weight.

	Average Weight	D. M.	Nutrients		
			Protein	C. H.	Fat
Alice	808	8.98	.297	5.45	.38
Belle	1010	9.23	.277	5.08	.37
Average		9.10	.287	5.27	.375

While the cows maintained their weight during the experiment, with the exception noted, there were indications that they had not been fully nourished; probably due chiefly to the small amount of protein in the ration. They looked dull, their skin was not loose and their coats were dry and harsh and were not shed until late in the spring.

During the winter of 1897-98 three barren dry cows were fed trial rations of food of maintenance on fodder corn, beets and oil meal. The preliminary feeding began in November but the fodder corn did not cure out to a uniform water content until the latter part of December which caused considerable variation in weight, so the data covers only a period from December 30th to April 11th. The following table gives the weight of the cow Alice during the experiment.

ALICE. 1897-8.

TABLE IX.—Giving Dates and Weights.

Date	Weight	Date	Weight	Date	Weight
Dec. 30	750	Feb. 3	750	Mar. 10	755
Jan. 3	760	Feb. 7	740	Mar. 14	758
Jan. 6	762	Feb. 10	735	Mar. 17	755
Jan. 10	765	Feb. 14	742	Mar. 21	750
Jan. 13	765	Feb. 17	748	Mar. 24	748
Jan. 17	762	Feb. 21	750	Mar. 28	755
Jan. 20	765	Feb. 24	750	Mar. 31	752
Jan. 24	750	Feb. 28	762	April 4	752
Jan. 27	765	Mar. 3	752	April 7	760
Jan. 31	760	Mar. 7	755	April 11	762

During the month of February it was noticed that she seemed to have difficulty in masticating food and occasion-

ally a swelling appeared on the right side of the jaw. She was killed at the close of the experiment and it was found that a tooth had been broken which probably was painful and caused shrinkage in weight. The data therefore can be used only to show how important it is in experimental work with live stock to keep close watch over the animals employed, and how a small matter may destroy the value of data obtained.

TABLE X.—Dry Matter and Nutrients Consumed Daily.

	D. M.	Digested			Daily Gain
		Protein	C. H.	Fat	Lbs.
Actually Consumed	8.89	.59	4.85	.08	.27
Per 1000 lbs. Live Weight..	11.79	.78	6.43	.10	

RECORD OF BELLE.—1897–8.

TABLE XI.—Giving Dates and Weights.

Date	Weight	Date	Weight	Date	Weight
Dec. 30...	1065	Feb. 3.....	1055	Mar. 10.....	1070
Jan. 3.....	1052	Feb. 7.....	1062	Mar. 14.....	1075
Jan. 6.....	1046	Feb. 10.....	1060	Mar. 17.... ..	1072
Jan. 10.....	1032	Feb. 14.....	1070	Mar. 21.....	1075
Jan. 13.....	1055	Feb. 17.....	1070	Mar. 24.	1075
Jan. 17.....	1025	Feb. 21.....	1072	Mar. 28.....	1075
Jan. 20.....	1065	Feb. 24.....	1062	Mar. 31.....	1078
Jan. 24.....	1045	Feb. 28.....	1070	April 4.....	1080
Jan. 27.....	1050	Mar. 3.....	1070	April 7.....	1075
Jan. 31.....	1045	Mar. 7.....	1075	April 11.....	1082

The different weighings clearly show there was a steady gain. In the first column the weight ranged from 1025 to 1065, while in the second the range is from 1055 to 1075, and in the third from 1070 to 1082. Taking the first column as preliminary and the difference between her average weight reported in the second column, with that in the third as the gain made, there is a difference of 9 pounds or at the rate of .27 of a pound per day.

The dry matter consumed and nutrients actually digested, as determined by a digestion experiment, were as follows:

TABLE XII.—Giving Nutrients Consumed Daily.

	D. M.	Digested			Daily Gain
		Protein	C. H.	Fat	Lbs.
Actually Consumed.....	11.70	.73	5.51	.11	.27
Per 1000 lbs, live weight....	10.93	.68	5.15	.10	

RECORD OF LOTTIE.—1897-8.

TABLE XIII.—Giving Dates and Weights.

Date	Weight	Date	Weight	Date	Weight
Dec. 30.....	680	Feb. 3.....	700	Mar. 10.....	710
Jan. 3.....	655	Feb. 7.....	697	Mar. 14.....	710
Jan. 6.....	670	Feb. 10.....	695	Mar. 17.....	710
Jan. 10.....	660	Feb. 14.....	695	Mar. 21.....	712
Jan. 13.....	678	Feb. 17.....	700	Mar. 24.....	712
Jan. 17.....	662	Feb. 20.....	700	Mar. 28.....	715
Jan. 20.....	665	Feb. 24.....	703	Mar. 31.....	715
Jan. 24.....	692	Feb. 28.....	710	April 4.....	710
Jan. 27.....	700	Mar. 3.....	710	April 7.....	710
Jan. 31.....	702	Mar. 7.....	705	April 11.....	705

From a careful examination of the different weights it is evident that she was gradually gaining. Her weight in the first column ranged from 655 to 702, while in the second it ranged from 695 to 710, and in the third from 705 to 715. It is exceedingly difficult to determine exactly the gain made. But by assuming that the weights during the five weeks covered by the first column are preliminary and deducting the average weight in the second column from that of the third, there is a difference of 9 pounds or a gain of .27 of a pound daily. The cow was naturally very restless and discontented and since she was a stranger in the herd and not accustomed to confinement she probably did not do normal work.

The dry matter consumed daily and nutrients actually digested were as follows:

TABLE XIV.—Giving Nutrients Consumed Daily.

	D. M.	Digested			Daily Gain
		Protein	C. H.	Fat	Lbs.
Actually Consumed.....	8.53	.51	3.80	.07	.27
Per 1000 live weight.....	12.08	.72	5.38	.10	

RECORD OF LOTTIE.—1898-99.

TABLE XV.—Giving Dates and Weights.

Date	Weight	Date	Weight	Date	Weight
Nov. 7.....	705	Jan. 2.....	750	Feb. 27.....	757
Nov. 14.....	710	Jan. 9.....	750	Mar. 6.....	762
Nov. 21.....	730	Jan. 16.....	750	Mar. 13.....	760
Nov. 28.....	725	Jan. 22.....	757	Mar. 20.....	760
Dec. 5.....	732	Jan. 30.....	752	Mar. 27.....	765
Dec. 12.....	742	Feb. 6.....	755	April 3.....	762
Dec. 19.....	750	Feb. 13.....	752	April 10.....	765
Dec. 26.....	745	Feb. 20.....	758	April 17.....	765

During this trial we again find that there was a gradual gain though it was less after the second of January. In the first column the weights ranged from 705 to 750 lbs. while in the second they ranged from 750 to 758, and in the third from 757 to 765. The average weights in the third column exceed those of the second column by 9 pounds, making an average daily gain of .16 of a pound.

The dry matter consumed daily and nutrients actually digested were as follows:

TABLE XVI.—Giving Dry Matter Consumed and Nutrients Digested Daily and per 1000 Pounds Live Weight.

	Dry Matter	Digested			Daily Gain
		Protein	Carbohydrates	Ether Extract	Lbs.
Actually Consumed.....	8.42	.39	5.09	.12	.16
Per 1000 lbs. live weight.....	11.12	.50	6.72	.15	

At the close of the experiment the cow presented clear evidence of having been amply nourished. Her eyes were bright, her movements quick, skin loose and coat new, soft

and glossy. The cows employed in the experiment during the winter previous showed similar indications of having been well nourished. Aside from gaining in weight, and on this account presenting a more smooth appearance, they shed their coat early and it had that bright, glossy appearance which is recognized among stockmen as a sure index of a healthy physical tone.

Combining the results obtained in the last three trials, we have the average daily dry matter consumed and nutrients digested, and gain made and the average for the three years:

TABLE XVII.—Giving Dry Matter and Nutrients Daily per 1000 Pounds Live Weight, and Gain in Weight.

	Year	Dry Matter	Digested			Daily Gain in Weight
			Protein	Carbohydrates	Ether Extract	
Belle	1897-8	10.93	.68	5.15	.10	.27
Lottie	1897-8	12.08	.72	5.38	.10	.27
"	1898-9	11.08	.50	6.72	.15	.16
Average		11.38	.63	5.75	.12	.23
Wolff Standard		18.00	.70	8.00	.10	

The trials on food of maintenance during the three winters with barren dry cows show that, with an average of 11.38 pounds of dry matter daily containing of digestible matter, as determined by actual digestion experiments, .63 of a pound of protein, 5.75 pounds of carbohydrates and .12 of a pound of ether extract, the cows were amply nourished and made a daily average gain of .23 of a pound in live weight. While the cows received on an average .63 of a pound of protein daily it does not follow that it is the minimum amount required since in the last experiment the cow received only .5 of a pound with very satisfactory results.

The experiments justify the conclusion that with cows at rest in stall in comfortable quarters, a ration of 11.5 of dry matter containing of digestible matter, .06 of a pound of protein, .6 of a pound of carbohydrates and .01 of a pound of

ether extract per hundred weight of cow, will be ample for a maintenance ration. Whether this allowance would be sufficient for cows receiving the treatment accorded them in a well regulated dairy in comfortable quarters, and allowed an outing in the yard for an hour or two during pleasant days in winter, still remains to be determined. Pending such determination it is tentatively suggested that for a cow working in the dairy and having ordinarily good care and comfortable quarters the allowance for maintenance be calculated at 1.25 pounds of dry matter, containing .07 of a pound of protein, .7 of a pound of carbohydrates and .01 of a pound of ether extract per hundred pounds live weight. These factors are suggested because they seem warranted by the data obtained, and because it is deemed desirable for convenience in feeding practice, to express the requirements for food of maintenance in the simplest form possible, so it can be understood and used by the average feeder.

The deductions from the data indicate:

That the factors for food of maintenance in the Wolff feeding standard are in excess of the requirements.

That a daily allowance of 11.38 of dry matter containing of nutrients .63 of a pound of protein, 5.75 of carbohydrates and .12 of a pound of ether extract per 1000 pounds live weight resulted in a daily average gain of about a quarter of a pound.

It is tentatively suggested that the food of maintenance for a barren dry cow when at rest in stall be expressed in nutrients .6 of a pound of protein, 6. pounds of carbohydrates and .1 of a pound of ether extract per 1000 pounds live weight and when at work in a dairy with ordinary good care and comfortable quarters, .7 of a pound of protein, 7. pounds of carbohydrates and .1 of a pound of ether extract be allowed per 1000 pounds live weight or one-tenth as much per cwt.

2. NUTRIENT REQUIREMENTS.

This report is a continuation of the one made in bulletin 71 of June, 1901, on a further study of the nutrients actually required by dairy cows in milk production. In the bulletin referred to, the subject of protein requirements only, was considered, while in this, nutrient requirements are taken up.

In bulletin 71 the subject of feeding standards was briefly reviewed and a table submitted from Henry's Feeds and Feeding, giving the several standards, which is reproduced for convenience.

TABLE XVIII.—American and German Feeding Standards for Dairy Cows, Digestible Nutrients per Day per 1000 Pounds Live Weight.

RATION	Dry Matter	DIGESTIBLE NUTRIENTS			Nutritive Ratio
		Protein	Carbohydrates	Ether Extract	
	Lbs.	Lbs.	Lbs.	Lbs.	
Wolff original (German) feeding ration....	24.0′	2.5	12.5	.4	1:5.4
Woll proposed American ration.....	24.5	2.15	13.27	.74	1:6.9
Atwater and Phelps proposed standard..	25.0′	2.5	12 to 13	.5 to .8	1:5.6
Wolff-Lehmann modified standard—					
I. When giving 11 lbs. of milk daily.	25.0	1.6	10.0	.3	1:6.7
II. When giving 16½ lbs. of milk daily.	27.0	2.0	11.0	.4	1:6.0
III. When giving 22 lbs. of milk daily.	29.0	2.5	13.0	.5	1:5.7
IV. When giving 27½ lbs. of milk daily.	32.0	3.3	13.0	.8	1:4.5
Standard maintenance ration.....	18.0	.7	8.0	.1	1:11.8

′Organic matter.

In general feeding practice it has become apparent that feeding standards based on the weight of animals without reference to product yielded, were not satisfactory guides and that some modification was desirable.

To meet this Dr. Lehmann suggested the modification given in the table, based upon certain stated yields of milk. It appears quite evident that he used the original Wolff factors for daily maintenance, that is, .7 of a pound of digestible protein, 8 pounds of carbohydrates, and .1 of a pound

of ether extract, per one thousand pounds live weight. Calculating the food of maintenance upon this basis, and making allowance for the yield of milk stated in each sub-division in the Lehmann modification, it is found that he prescribes the nutrients required for the production of one pound of milk, as appears in the following table.

TABLE XIX.—Giving Lehmann Feeding Standard Factors, for the Production of One Pound of Milk.

	Protein	Carbo-hydrates	Ether Extract
	Lbs.	Lbs.	Lbs.
When giving 11 lbs. of milk daily	.081	.18	.018
" 16½ lbs. of milk daily	.078	.18	.018
" 22 lbs. of milk daily	.081	.22	.018
" 27½ lbs. of milk daily	.094	.18	.025

It is not clear why the variations given in the table should occur when the different quantities of milk are yielded. While Dr. Lehmann's modification of the Wolff standard may be an improvement on the original, the following questions naturally suggest themselves:

1. Are the factors approximately correct?
2. Are they applicable to any and all grades or qualities of milk yielded?
3. Will they answer for heifers in milk?

These are questions that can be determined only by actual demonstration, for we have reached a stage in American agricultural research, when theoretical formulæ based merely upon calculations made in the laboratory or office carry but little weight.

1. ARE THE LEHMANN FACTORS APPROXIMATELY CORRECT?

The feeding experiment conducted at this station during the winter of 1894-5, in which the cows were given a fixed ration for a period of 154 days, during which time a full flow of milk and yield of butter fat was secured without gain or loss in body weight, throws some light on all of the points raised. Since it will be necessary to refer to the performance of the whole herd and that of some individual animals, the average daily nutrients consumed and milk and butter fat yielded by each animal and by the herd for both periods are given.

TABLE XX.—Giving the Daily Average of Dry Matter and Nutrients Consumed and Milk and Butter Fat Yielded from Nov. 19, 1894, to Feb. 10, 1895. 84 Days.

NAME	Dry Matter	DIGESTIBLE			AV. DAILY YIELD		
		Protein	C. H.	Fat	Milk	Per Cent Fat	Butter Fat
Betty	20.53	1.70	10.98	.45	10.03	6.7	.672
Dora	22.63	1.87	12.08	.49	15.02	6.3	.949
Beckley	20.08	1.63	10.72	.43	13.44	5.6	.761
Tricksey	20.53	1.70	10.98	.45	16.78	4.9	.825
Houston	23.23	1.98	12.44	.51	25.00	5.6	1.406
Sweet B	26.91	2.25	14.50	.58	30.81	4.8	1.490
Olive	20.08	1.63	10.72	.43	27.26	3.8	1.050
Topsy	31.49	2.64	16.92	.69	44.39	3.7	1.656
Lou	26.22	2.14	14.10	.55	38.01	3.7	1.410
Quidee	23.29	1.90	12.42	.50	25.55	3.5	.908
Lydia	28.34	2.39	15.22	.62	32.02	3.4	1.087
Countess	28.37	2.38	15.28	.61	45.27	2.4	1.094
Average	24.30	2.01	12.03	.53	26.96	4.1	1.109

TABLE XXI.—Giving the Daily Average of Dry Matter and Nutrients Consumed and Milk and Butter Fat Yielded from Feb. 11 to April 21, 1895. 70 Days.

NAME OF COWS	Dry Matter	DIGESTIBLE			AVERAGE DAILY YIELD		
		Protein	Carbo-hydrates	Fat	Milk	Per Cent Fat	Butter Fat
Beckley	21.19	1.68	11.10	.51	13.17	5.59	.736
Countess	29.22	2.40	15.50	.72	41.80	2.53	1.061
Houston	25.24	2.14	13.35	.64	24.88	5.38	1.340
Lou	27.00	2.21	14.10	.67	31.46	3.67	1.154
Olive	21.15	1.67	11.12	.51	21.20	4.12	.884
Reddy	20.94	1.69	11.01	.51	14.49	5.21	.755
Belle	20.56	1.76	10.89	.50	19.38	4.14	.803
Lydia	27.57	2.26	14.49	.68	27.93	3.57	.999
Quidee	22.73	1.85	11.94	.55	25.81	3.49	.902
Sweet B	27.00	2.21	14.21	.67	26.09	5.28	1.379
Topsy	31.93	2.59	16.79	.78	40.82	3.69	1.492
Tricksey	19.61	1.56	10.33	.47	15.73	5.34	.840
Average	24.51	2.00	12.90	.60	25.23	4.07	1.029

It will be seen that the two periods do not cover exactly the same number of days, one being for 84 while the other is for 70 days, but since the daily average of nutrients consumed and yield of milk and butter fat were so much alike, the average of the two will be so nearly the actual average that such use is considered allowable.

TABLE XXII.—Giving Daily Average for 154 Days.

	Weight	Digestible nutrients.			Milk Yielded
		Protein	Carbo-hydrates	Fat	
Period I, 84 days	954	2.01	12.03	.53	26.96
Period II, 70 days	958	2.00	12.90	.60	25.23
Total	1912	4.01	24.93	1.13	52.19
Daily Average	956	2.00	12.46	.56	26.09
Daily for Maintenance*		.67	6.69	.095	
Daily available for milk		1.33	5.77	.46	26.09
Nutrients to 1 lb. milk		.051	.221	.018	

* At the rate of protein .07; carbohydrates .7 and ether extract .01 per cwt.

From this it is seen that the daily average of nutrients available to a pound of milk did not differ materially from the Lehmann standard except that the herd returned a pound of milk for each .05 of available protein, being about 60 per cent of the amount prescribed by the standard. The average per cent fat in the milk during the winter was 4.07, which is a trifle above the average quality in this country. The discrepancy in the amount of available carbohydrates consumed, per pound of milk yielded is greater than is indicated by the above comparison; because the standard prescribes 8 pounds per thousand pounds live weight for food of maintenance while only 7 pounds are allowed in this table. If this factor is applied to the Lehmann standard it makes an allowance of .27 of a pound of carbohydrates to a pound of milk.

The herd came out of the winter in excellent condition and gave every evidence of having been amply nourished, and returned a maximum yield of both milk and butter fat. The following winter, 1895–6 the herd was composed of, practically the same animals, received on an average a daily allowance of 2.59 pounds of digestible protein, and its performance compared with the winter's work in review, was as follows:

TABLE XXIII.—Giving Daily Average of Nutrients Consumed and Milk and Butter Fat Produced during the Winters 1894-95 and 1895-6.

Year	Weight	Digestible Nutrients.			Milk	Per Cent Fat	Butter Fat
		Protein	Carbo-hydrates	Fat			
1894-5	956	2 00	12.46	.56	26.09	4.10	1.069
1895-6	980	2.59	12.24	.68	25.71	3.93	1.011

The data thus far submitted give strong evidence that the amount of protein prescribed in the feeding standards is greatly in excess of the amount actually needed. The cows yielded more milk and butter fat during the winter they received 2 pounds of protein daily than they did the winter following with a daily allowance of 2.59 pounds.

Since the herd returned its maximum yield and neither gained nor lost in live weight during the winter of 1894-5, it may be assumed, for the time being, *that the Lehmann modification prescribes more nutrients than are needed.*

2. Are the Lehmann Factors Applicable to any and all Grades or Qualities of Milk Yielded?

Inquiring into the question as to the standard being applicable to any grade or quality of milk, a table is compiled from the records of mature cows in the herd, *whose productive powers had been developed to their feeding capacity by careful feeding and handling for several years*, giving the per cent of butter fat in their milk and nutrients required per pound of milk yielded.

TABLE XXIV.—Giving Available Nutrients Consumed per Pound of Milk Yielded by Mature Cows.

	Per Cent Fat	Protein	Carbo-hydrates	Ether Extract	Total
Countess	2.5	.036	.16	.012	.208
Lou	3.7	.040	.20	.014	.254
Topsy	3.7	.042	.20	.014	.256
Olive	4.0	.044	.22	.016	.280
Sweet Briar	5.0	.052	.24	.018	.310
Houston	5.5	.057	.26	.019	.336

By this table it is clearly shown that the amount of nutrients to a pound of milk increases with the increase in the quality of the milk, but not in the same proportion; for

Countess gave milk containing 2.5 per cent of butter fat and used .208 of available nutrients while Sweet Briar gave milk containing twice as much butter fat but did not require twice as much protein or other nutrients. The same is the case with the other cows. The table also shows that in formulating a ration the quality of milk yielded should be considered, as well as the quantity.

Incidentally the table, which is the daily average of 154 consecutive days' work, clearly indicates that other things being equal, the richer the milk the more economical is the production of butter fat. It has been shown that the richer the milk in butter fat the more nutriment is required. Indeed it could not be otherwise, for the per cent of solids in the milk increases with the increase in butter fat, and the rate of increase in energy in rich milk is even greater than the increase in solids, because the richer the milk in butter fat, the greater the per cent of fat to solids not fat.

To show the *rate* of increase in nutrients required for the production of a pound of milk of different quality, the records of Houston and Countess are employed:

TABLE XXV.—Showing Difference in Nutrient Requirements for Milk Testing High and Low in Butter Fat.

	Per Cent Fat in Milk	Protein	Carbohydrates	Ether Extract
Houston	5.5	.057	.26	.019
Countess	2.5	.036	.16	.012
Difference for 30 tenths	3.0	.021	.10	.007
Difference for 1 tenth		.0007	.0033	.00023

By this it is seen that in the production of the rich milk the additional nutrient requirements were at the rate of .0007 of protein, .0033 of carbohydrates and .00023 of ether extract for each .1 per cent increase in per cent of butter fat.

Taking the nutrients required for a pound of milk testing 2.5 per cent butter fat as a basis, and the nutrients required in addition for each one tenth per cent increase, we have the following table giving approximately the nutrients required for the production of a pound of milk of a given per cent butter fat.

TABLE XXVI.—Giving Net Nutrients Used by Mature Cows for the Production of One Pound of Milk Testing a Given Per Cent Butter Fat.

	Protein	Carbohydrates	Ether Extract
Milk testing 2.5	.0362	.164	.0124
" 2.6	.0369	.167	.0126
" 2.7	.0376	.171	.0128
" 2.8	.0383	.174	.0131
" 2.9	.0390	.177	.0133
" 3.0	.0397	.181	.0136
" 3.1	.0404	.184	.0138
" 3.2	.0411	.187	.0140
" 3.3	.0418	.190	.0142
" 3.4	.0425	.194	.0145
" 3.5	.0432	.197	.0147
" 3.6	.0439	.200	.0149
" 3.7	.0446	.204	.0152
" 3.8	.0453	.207	.0154
" 3.9	.0460	.210	.0156
" 4.0	.0467	.214	.0159
" 4.1	.0474	.217	.0161
" 4.2	.0481	.220	.0163
" 4.3	.0488	.223	.0165
" 4.4	.0495	.227	.0168
" 4.5	.0502	.230	.0170
" 4.6	.0509	.233	.0172
" 4.7	.0516	.237	.0175
" 4.8	.0523	.240	.0177
" 4.9	.0530	.243	.0179
" 5.0	.0537	.247	.0182
" 5.1	.0544	.250	.0185
" 5.2	.0551	.253	.0187
" 5.3	.0558	.256	.0189
" 5.4	.0565	.260	.0192
" 5.5	.0572	.263	.0194
" 5.6	.0579	.266	.0196
" 5.7	.0586	.270	.0199
" 5.8	.0593	.273	.0201
" 5.9	.0600	.276	.0203
" 6.0	.0607	.280	.0206
" 6.1	.0614	.283	.0208
" 6.2	.0621	.286	.0210
" 6.3	.0628	.289	.0212
" 6.4	.0635	.293	.0215
" 6.5	.0642	.296	.0217
" 6.6	.0649	.300	.0219
" 6.7	.0656	.303	.0222
" 6.8	.0663	.306	.0224
" 6.9	.0670	.309	.0226
" 7.0	.0677	.313	.0229
Co-efficients for Food of Maintenance per cwt....	.07	.7	.01

The table is very closely in accord with the nutrients used to a pound of milk yielded by the mature members of the herd not making material gain in body weight, except that it provides more than was actually used by the cows giving milk of medium quality, say for that testing from 3.5 to 4.5 per cent of butter fat. In the table given, .0007 of a pound of protein available for product was allowed for each .1 of one per cent increase in the per cent fat in the milk, while in fact, the difference was not so great between the lower grades of milk.

To illustrate the *rate* of increase of protein used, per pound of milk yielded by the cows, as their milk was richer

in butter fat, after making allowance for protein needed for maintenance, the following deductions from the record are submitted, though it does not follow that the *rate* of increase of protein per pound of milk, as it increased in fat content, was actually needed.

TABLE XXVII.—Showing Rate of Increase in Protein Requirements.

	Per Cent Fat in Milk	Protein to 1 lb. Milk
Lou and Topsy, average	3.7	.041
Countess	2.5	.036
Difference for	12 points	.005
Difference for each point		.0004
Olive	4.0	.044
Countess	2.5	.036
Difference for	15 points	.008
Difference for each point		.0005
Sweet Briar	5.0	.052
Countess	2.5	.036
Difference for	15 points	.016
Difference for each point		.0006
Houston	5.5	.057
Countess	2.5	.036
Difference for	30 points	.021
Difference for each point		.0007

As has been stated, the rate of increase of protein for the various grades of milk was based upon the difference per point between that used by the cow yielding milk containing 2.5 per cent fat and that used by the cow yielding milk testing 5.5 per cent, and more protein is prescribed for cows giving milk of medium quality than they actually used. The slight excess, however, is not a serious objection.

The tables submitted show *that the quality of milk is quite as important a factor in formulating a feeding standard or guide to feeding practice, as quantity of milk yielded.*

3. Are the Lehmann Factors Applicable to Heifers in Milk?

Heifers with first and second calf, covering the periods of their three and four-year old form, make considerable growth which requires nutriment as well as does the elaboration of milk. If the feeding standard is based solely upon the flow of milk and weight of cow, there will be a shortage of nutriment needed. It is obvious that heifers yielding milk similar in quantity and quality may differ in amount of nutrmient actually needed, because they may differ in rate of growth, and on this account there will be a greater variation in nutriment required by different individuals than was found to be the case with mature cows. Since the ratio of nutrients required for growth of body is practically the same as that required for milk production, the extra amount of nutriment needed for growth should be provided for, with the nutrients needed for milk production and not with those calculated for simply food of maintenance. The factors used for food of maintenance for mature cows will, therefore, be applied to heifers. The following table gives a list of heifers in milk during the time covered by the record under review, which was 154 days, except in the case of Reddy, that came in four weeks later, and the nutrients required to a pound of milk after deducting the food of maintenance.

TABLE XXVIII.—Giving Available Nutrients Consumed per Pound of Milk Yielded by Heifers.

	Per Cent Fat	Protein	Carbo-hydrates	Ether Extract
Lydia	3.5	.052	.25	.018
Quidee	3.5	.049	.24	.016
Tricksey	5.1	.068	.33	.023
Beckley	5.6	.079	.37	.027
Reddy	5.2	.079	.38	.029
Average for Heifers		.065	.314	.022
Average for Mature Cows		.045	.213	.015

The heifers used nutrients in proportion to the quantity and quality of milk yielded, the same as was the case with the mature cows, but they returned a pound of milk to .065 of protein available for product, while the mature cows returned a pound of milk to .045 of protein; the heifers requiring nearly one-half more available nutrients to a pound of milk than did the cows.

Again seeking the rate of increase in nutrients required for each .1 per cent increase in butter fat, between the average amount of nutrients required by the heifers yielding milk containing 3.5 per cent of butter fat, and those yielding milk testing above 5 per cent, it is found to be .00125 of a pound of protein, .00567 of carbohydrates and .000432 of ether extract. Multiplying this by ten and subtracting the product from the nutrients used by the heifers yielding milk

TABLE XXIX.—Giving Net Nutrients Required by Heifers for the Production of One Pound of Milk Testing a Given Per Cent of Butter Fat.

	Protein	Carbohydrates	Ether Extract
Milk Testing 2.5	.0380	.188	.0127
" 2.6	.0393	.194	.0131
" 2.7	.0405	.200	.0135
" 2.8	.0418	.205	.0140
" 2.9	.0430	.211	.0144
" 3.0	.0443	.217	.0148
" 3.1	.0455	.222	.0153
" 3.2	.0468	.228	.0157
" 3.3	.0480	.234	.0161
" 3.4	.0493	.239	.0166
" 3.5	.0505	.245	.0170
" 3.6	.0518	.251	.0174
" 3.7	.0530	.256	.0179
" 3.8	.0543	.262	.0183
" 3.9	.0555	.268	.0187
" 4.0	.0568	.273	.0192
" 4.1	.0580	.279	.0196
" 4.2	.0593	.285	.0200
" 4.3	.0605	.290	.0205
" 4.4	.0618	.296	.0209
" 4.5	.0630	.302	.0213
" 4.6	.0643	.307	.0218
" 4.7	.0655	.313	.0222
" 4.8	.0668	.319	.0226
" 4.9	.0680	.324	.0230
" 5.0	.0693	.330	.0235
" 5.1	.0705	.336	.0239
" 5.2	.0718	.341	.0243
" 5.3	.0730	.347	.0248
" 5.4	.0743	.353	.0252
" 5.5	.0755	.358	.0256
" 5.6	.0768	.364	.0261
" 5.7	.0780	.370	.0265
" 5.8	.0793	.375	.0269
" 5.9	.0805	.381	.0274
" 6.0	.0818	.387	.0278
Coefficients for Food of Maintenance per cwt.	.07	.7	.01

testing 3.5 per cent butter fat, gives approximately, that required in the production of milk testing 2.5 per cent butter fat, which is .038 of a pound of protein, .1883 of carbohydrates and .01268 ether extract per pound of milk yielded, from which is deduced the following graduated scale of approximate nutrient requirements for the production of a pound of milk testing a given per cent of butter fat, based upon the performance of the heifers in the station herd covering a period of 154 days.

The factors of nutrients required for the production of one pound of milk by the heifer Reddy are not used in calculating the rate of increase of nutrients because she made gain more than for normal growth, as will be seen from the following table, giving the weight at the beginning and close of the experiment.

TABLE XXX.—Giving Gain in Weight by Each Heifer.

	Lydia	Quidee	Tricksey	Beckley	Reddy
At Close	1083	869	763	862	791
At Beginning	1014	785	723	839	747
Total Gain	69	84	40	23	44
Daily Gain	.47	.57	.27	.16	.78

The rate of gain made by Reddy shows why the nutrients consumed daily were not proportionate with the yield and quality of milk. Tricksey gave milk testing 5.1 per cent fat and returned a pound of milk to .068 of a pound of protein, while Reddy gave milk testing only .1 of a per cent higher returned a pound of milk to .079 of protein, showing that she converted part of the nutrients into body fat. Neither was she in milk during the earlier weeks of the experiment. The weights are the average of three weekly weighings at both the beginning and close, and for Lydia, Quidee, Tricksey and Beckley they cover a period of 147 days, and for Reddy only 56 days.

The data submitted show *that heifers require more nutrients per pound of milk yielded than do mature cows.*

OBSERVATIONS.

It has long since been recognized that because of the difference in composition of the various kinds of feed stuffs no single standard of composition for all feeds would be practical, and yet, while there is as great a difference in the composition of milks as there is in feed stuffs, there has been no adjustment of the nutrients in the ration to the quantity and character of the solids contained in the milk yielded, though, as has been shown, such an adjustment appears to be quite simple and practicable. If in formulating a ration it is deemed necessary in economic milk production, to take note of the fact that one feed stuff contains 12 per cent of protein and another 20 per cent, is it not equally important in our attempt to adjust the ration to the needs of the cow in milk production to also take into account the fact that one cow may give milk containing 3 per cent fat while that of another may contain twice as much? It would seem quite as consistent to feed an animal food regardless of its composition as to feed an assumed balanced ration regardless of the composition of the product which is to be elaborated from the nutrients in the food.

Great stress has been placed upon the fact that the nutrients in milk have a nutritive ratio of approximately one to five, and that therefore the ration for a milch cow should have a similar nutritive ratio; apparently overlooking the fact that only about fifty per cent of the ration is used in milk production and the balance for maintenance of body. If note is taken of the fact that about half the ration is used for maintenance and that the maintenance ration has a nutritive ratio of one to ten, it becomes apparent that for the production of milk of average quality by an animal of average milk producing powers the nutritive ratio of the ration should be approximately 1:7.5. But since animals vary in productive powers, and since this variation is not in proportion to weight of body, it follows that if rations are adjusted to the actual requirements of animals the nutritive ratio of the rations will also vary, as will be shown.

The author has used tables XXVI and XXIX for two years in class work with highly satisfactory results. The tables of nutrients required to a pound of milk ranging in

per cent fat from 2.5 to 6.5, are printed on pasteboard cards 7x3½ inches, and on the reverse side a table giving the nutrients in a pound of ordinary feeding stuffs. Given the daily yield of milk in pounds, its per cent of butter fat, and the weight of the cow expressed decimally, it is an easy matter to determine the required ration. As an illustration, suppose a mature cow weighs 825 pounds, gives 20 pounds of milk daily, testing 4 per cent butter fat. One pound of 4 per cent milk requires of protein .0467, carbohydrates .214, and of ether extract, .0159, multiplying these factors by 20 it is found that for the production of milk she needs .934 of protein, 4.28 of carbohydrates and .318 of ether extract. For food of maintenance multiply .07 protein, .7 carbohydrates and .01 of ether extract (maintenance formula) by 8.25 which gives protein .578, carbohydrates 5.78 and ether extract .082; adding to this the nutrients required for milk production, we have 1.51 of protein, 10.06 carbohydrates and .40 ether extract, the nutrients required in the ration. They should be supplied in such manner with reference to bulk that it will satisfy the appetite. A ration like this should be largely made up of roughage.

But suppose a cow weighing 850 pounds yields 40 pounds of 4 per cent milk daily, the required ration would be:

Pro.	C.H.	Fat		Pro.	C.H.	Fat
(.0467	–.214	–.0159)x	40=	1.868	– 8.56	–.636
(.07	–.7	–.01)x	8.50=	.595	– 5.95	–.085
		Ration required,		2.463	-14.51	–.721

A ration like this should be largely composed of grain so that it will not contain so much bulk that she will go off her feed, and yet furnish the nutrients required. If a cow's ration is adjusted in bulk with reference to her feeding capacity and in nutriment content to the work she is doing, she will not be overfed nor go off her feed. A cow will not do her best unless she is so fed that she is satisfied, but the ration should not contain more nutriment than she actually needs. From this it follows that cows do not require a uniform nutritive ratio in their rations, but that it varies according to the quantity of milk yielded and weight of cow.

To illustrate, let us take a cow weighing 1200 pounds and yielding 20 pounds of milk daily, and one weighing 850 pounds yielding 40 pounds of milk, both testing 4 per cent fat.

	Pro.	C. H.	Fat
Nutrients for 1 lb. of 4 per cent milk,	.0467	.214	.0159
Nutrients for 1 cwt., maintenance,	.07	.7	.01

For cow weighing 1200 lbs. and yielding 20 lbs. of 4 per cent milk:

	Pro.	C. H.	Fat	
Nutrients for 20 lbs. milk,	.93	4.28	.32	
Nutrients for 12 cwt. maintenance,	.84	8.40	.12	
Ration required,	1.77	12.68	.44	
Nutritive ratio,				1:7.7

For cow weighing 850 lbs. and yielding 40 lbs. of 4 per cent milk.

	Pro.	C. H.	Fat	
Nutrients for 40 lbs. of milk,	1.87	8.56	.64	
Nutrients for 8.5 cwt. maintenance,	.59	5.95	.08	
Ration required,	2.46	14.51	.72	
Nutritive ratio,				1:6.5

But if the cow weighing 12 cwt. yields 40 pounds of milk per day and the cow weighing 8.5 cwt. yields 20 pounds, the nutrient requirements for their respective rations according to table—will be as follows:

	Pro.	C. H.	Fat	
Nutrients for 40 lbs. of 4 per cent milk,	1.87	8.56	.64	
Nutrients for 12 cwt. maintenance,	.84	8.40	.12	
Required ration,	2.71	16.96	.76	
Nutritive ratio,				1:6.8

	Pro.	C. H.	Fat	
Nutrients for 20 lbs. of 4 per cent milk,	.93	4.28	.32	
Nutrients for 8.5 cwt. maintenance,	.59	5.95	.08	
Required ration,	1.52	10.23	.40	
Nutritive ratio,				1:7.3

In prescribing rations upon the basis of flow and quality of milk and weight of cow and using the factors given in the table the nutritive ratio becomes a factor of very little importance the same as is the case with dry matter in a ration.

If the nutrients required or a given flow of milk are provided for in the concentrates the food of maintenance may be secured by feeding at least a portion of the roughage *ad lib.* If the grain mixture has a nutrive ratio of 1 to 5 or 5.5 it will fairly meet the requirements.

In adjusting rations for cows fresh in milk note should be taken of surplus nutriment stored in the body during the time that a cow goes dry. If she gained rapidly in weight and is well rounded out with fat she will be able to do normal work during the first few weeks of her lactation on a light grain ration, for she will use the stored fat in generating body heat and energy and may also use some in the elaboration of milk solids. So as this milking-down in body weight takes place the concentrates should be gradually increased so that she will be on full feed by the time she reaches her normal working weight. From then on the amount of concentrates should be as constant as the flow of milk will permit until after the sixth month of gestation when it should be gradually decreased so she will go dry during the seventh, when a couple of pounds a day will suffice.

The deduction from the data indicates that the Wolff feeding standard for dairy cows is fairly correct in the average amount of total nutriment required, but faulty in that it prescribes an excess of protein and in the assumption that cows need nutrients in proportion to their weight.

That the Wolff-Lehmann standard is faulty in that it prescribes an excess of protein and other nutrients; does not designate the nutrients required upon a basis of a unit in weight of milk; does not recognize the fact that quality of milk yielded should be considered as well as quantity, nor, that heifers require more nutrients for a given flow of milk than mature cows.

That the nutrient requirements in milk production depend:

1st.—Upon the weight of the cow.

2nd.—Upon the quantity of milk yielded.

3rd.—Upon the quality of the milk, and

4th.—Upon the age of the cow.

3. PROTEIN REQUIREMENTS.

The experimental feeding of the dairy herd for the winter 1901-2 was planned to secure more data for the further study of protein requirements in milk production. The subject is one of great pecuniary importance to the feeder because food stuffs containing a high per cent of protein are expensive and if cows require less protein than the standards have prescribed, the fact should be definitely determined so that farmers will not be led into incurring unnecessary expense in providing feed for their cows.

The basement in which the dairy stock is kept is partitioned into four divisions, each of which will accommodate 20 cows, and has two alleys, one running lengthwise through the middle and another crosswise, dividing the cows into four groups of five each. In the 1st division groups 1 and 2 were fed ration I; groups 3 and 4, ration II; in the 2nd division groups 5 and 6 received ration III, and groups 7 and 8, ration IV. The cows were not arranged with reference to this experiment, but were left for the winter just as they happened to stand when the experiment began. Since some were farrow, some far advanced in their period of lactation, some to come in during the experiment and others fresh in milk, the records of all are not included in the principal tables from which deductions are made. For tables cows were selected that were doing normal work. In the first division no disturbance of a serious character took place during the winter. But one cold night the door leading from the second division to the third, which is a covered runway, was left open accidentally, and the cows were subjected to a draft, which gave some of them severe colds, proving fatal in one case—Rose—and causing serious inflammation in the udder with another—Tricksey. But fortunately, with Rose, the cold did not take a serious turn until toward spring, when it was necessary to close her record a week before the end of the experiment. Tricksey's condition was more crit-

ical at the time when the accident occurred, but being young, full of vigor and in good condition, she was soon again in good working order.

It was intended to maintain a fixed ratio between grain and roughage for all the cows but in some cases a slight deviation had to be made to feed each to her full limit. The directions were, to feed by weight five times as much corn silage as grain and half as much hay as grain, but in certain cases it was found necessary to deviate a little from this rule. On this account there is a slight variation in the average nutritive ratio of the rations fed to cows in the same group. The rations were made up as follows:

For Group I,—The grain was equal parts corn, bran and gluten meal.

For Group II,—The grain was corn and bran, 4 parts each, and gluten meal 1 part.

For Group III,—The grain was equal parts corn, barley and oats, except Letta, that received bran instead of oats.

It was not known what the nutritive rotios of the several rations would be because the composition of the feed stuffs was not known at the time the experiment began, but it was estimated that a ration containing 8 pounds of grain with the roughage accompanying it would contain of dry matter and nutrients as follows:

TABLE XXXI.—Rations as Estimated.

RATION	Dry Matter	DIGESTIBLE NUTRIENTS			Nutritive Ratio
		Protein	C. H.	Ether Extract	
I	19.32	2.00	10.55	.53	1:5.8
II	19.29	1.62	10.66	.53	1:7.3
III	19.24	1.37	10.95	.50	1:8.8

The estimated nutrient content of the rations was not made from the American table of average composition of feed stuffs but upon Minnesota averages taking into account the character of the soil upon which the roughage was grown and the condition of the weather during the growing season. By chemical analysis the rations showed the following composition:

TABLE XXXII.—Actual Composition of the Rations Fed.

RATION	DIGESTIBLE NUTRIENTS			Nutritive Ratio
	Protein	C. H.	Ether Extract	
I	2.04	11.79	.53	1:6.3
II	1.68	11.75	.57	1:7.6
III	1.32	11.76	.50	1:9.7

It will be observed that the rations contained more carbohydrates than was estimated and were therefore a little wider than was intended, though their protein content fairly met expectations.

The corn silage was grown in double drills requiring about a bushel of seed to the acre, but the stand was not as good as was desired on account of some of the seed failing to germinate. In the rows the stalks were about 4 inches apart on the average and contained some small nubbins. It was planted about the middle of June and cut the last week in August.

The hay was from bottom land prairie and was of poor quality, badly bleached and had little flavor, but on account of the small quantity fed, was all consumed.

The beet pulp was not of good quality as some had been too much exposed to the air which caused some fermentation to take place. The cows did not seem to take to it kindly and would probably have done better work without it.

The composition of the food stuffs is given in the following table:

TABLE XXXIII.—Giving Percentage Composition of Food Stuffs as Determined by the Chemical Division.

	Dry Matter	Crude Protein	Ether Ex.	Crude Fiber	Carbohydrates	DIGESTIBLE		
						Protein	C. H.	Ether Ex.
Corn	88.60	11.00	4.69	2.41	69.13	6.60	65.40	4.03
Barley	87.73	14.19	3.36	7.25	60.34	9.93	59.13	2.99
Oats	88.80	13.69	4.47	12.99	54 10	10.68	43.72	3.71
Bran	88.78	17.60	5.12	11.36	47.46	14.08	35.95	3.89
Gluten M	90.47	36.06	3.74	3.16	45.88	32.09	44.44	3.47
Corn Silage	24.62	2.38	.66	7.29	12.72	1.24	13.30	.36
Prairie Hay	89.10	5.78	2.02	32.56	41.89	2.72	43.74	.97
Beet Pulp	9.97	1.02	.08	2.29	6.23	.64	7.13	.04

Feeding commenced with the morning of November 11, and continued without any change in feed until the morning of February 17th, from and after which a new supply of grain was fed and corn fodder was substituted for silage, and a new supply of prairie hay of poor quality was used. The tables of food consumed and milk and butter fat yielded are the daily averages for the eight consecutive weeks—beginning with December 30th and ending with February 16th, except that the records of two cows in groups I and III extend from 1 to 3 weeks into the fodder-corn period.

TABLE XXXIV.—List of Cows.

NAME	Age	BREEDING	Date of Calving	Remarks
Dorrit	9	Grade Jersey,	September 6, 1901,	
Euroma	4	Jersey,	October 16, 1901,	
Iris	3	Brown Swiss,	December 14, 1901,	
L'Etoile	12	Jersey,	January 19, 1902,	
Topsy	6	Jersey-Holstein,	January 4, 1902,	
Trust	6	Jersey,	November 12, 1901,	
Countess	6	Holstein,	October 17, 1901,	
Dora F	9	"	December 12, 1901,	
Fay	3	"	November, 1901,	
Fly T	13	Ayrshire,	November 18, 1901,	
Houston	6	Jersey-Guernsey,	November 17, 1901,	
Pride	6	Jersey,	November 29, 1901,	
Delle II	6	Grade Jersey,	December 3, 1901,	
Klondike	8	Jersey-Holstein,	April 5, 1901,	Aborted, farrow,
Puss	9	Jersey,	January 15, 1902,	
Rose	10	Grade Short-Hn,	January 12, 1902,	
Tricksy	5	Guernsey,	December 12, 1901,	
Letta	3	Jersey,	November 6, 1901,	
Euroma II	2	"	November 2, 1901,	
Duchess	5	"	October 11, 1900,	Farrow,
Leeoma	4	"	August 3, 1901,	Farrow,
Lou	5	Holstein,	February 23, 1901,	
Nora	7	Grade Jersey,	July 28, 1901,	
Shorty	10	Native,	July 25, 1901,	
Sweet Briar	17	Guernsey,	December 9, 1901,	
Trusty Lee	2	Jersey,	December 19, 1901,	

The records of all the cows are not used in the tables because in order to make them comparable they must be under fairly similar conditions, especially as to time of lactation; for the food or nutriment required for a given product varies considerably in the early stages of lactation. But after 8 or 9 weeks they become remarkably constant for an indefinite time unless interrupted by a new period of gestation.

The following tables give the daily average consumption of food by the several groups and its dry matter content.

TABLE XXXV.—Group I, Giving Pounds Food Consumed Daily.

The grain being equal parts of Corn, Bran and Gluten Meal.

COWS	Grain	Silage	Fodder Corn	Prairie Hay	Beet Pulp	Dry Matter
Dorrit	8	40		4	14.5	21.98
Euroma	7	35		3.5	13.5	19.32
L'Etoile	7.8	11	10	4	9.7	20.56
Iris	7.7	37		4	13.9	20.74
Topsy	8.6	25.75	6.7	4.5	15	23.76
Trust	8	33		4	14.5	20.25

TABLE XXXVI.—Group II, Giving Pounds of Food Consumed Daily.

The Grain being Corn 4, Bran 4, Gluten Meal 1.

Cows	Grain	Silage	Prairie Hay	Beet Pulp	Dry Matter
Countess	9	44.4	4.5	17.2	24.64
Dora F	9.9	48.7	5	13	26.53
Fay	7.1	35.6	3.6	6.5	18.93
Fly T	7	39 4	3.9	7.7	20.20
Houston	8	32	4	5.2	19.07
Pride	7	35	3.5	13	19.25

TABLE XXXVII.—Group III, Giving Pounds of Food Consumed Daily.

The Grain being equal parts Corn, Barley and Oats.

Cows	Grain	Silage	Fodder Corn	Prairie Hay	Beet Pulp	Dry Matter
Delle II.	7	35		3.5	8.75	18.79
Klondike	8	40		4	14	21.83
Letta	7	29.7		3.5	13	17.19
Puss	7.9	12.4	10	3.9	9.75	20.82
Rose	7.2	21.2	6	4	13	20.29
Tricksey	7.7	40		3.9	7.25	20.89

The quantity of fodder corn and beet pulp entered in the above tables is not the amount taken while these were fed, but the average for the whole period, so by multiplying them them by 56, the time covered, gives the total amount consumed.

The following tables give the daily average of nutrients consumed and the pounds of milk, butter fat and milk solids

yielded during the period. Since a nutrient is something that nourishes, the term digestible seems superfluous and is therefore not used, as nutrient refers only to that part of a food stuff which is digestible.

TABLE XXXVIII.—Giving Digestible Nutreints Consumed and Products Yielded Daily by Group I.

Cows	Crude Protein	Carbo-hydrates	Ether Extract	Milk	Per Cent Fat	Butter Fat	Total Solids
Dorrit	2.104	11.99	.57	21.98	5.40	1.186	3.207
Euroma	1.847	10.55	.50	21.30	5.47	1.165	3.118
L'Etoile	2.014	12.17	.49	27.67	4.73	1.309	3.779
Iris	1.975	11.31	.53	25.88	3.54	.916	3.176
Topsy	2.275	13.64	.57	37.77	3.98	1.503	4.897
Trust	2.018	11.08	.53	32.00	4.64	1.484	4.246
Average	2.039	11.79	.53	27.77	4.54	1.260	3.737

TABLE XXXIX.—Giving Digestible Nutrients Consumed and Products Yielded Daily by Group II.

Cows	Crude Protein	Carbo-hydrates	Ether Extract	Milk	Per Cent Fat	Butter Fat	Total Solids
Countess	1.930	10.61	.65	36.39	3 18	1.157	4.060
Dora F	2.084	14.54	.70	37.30	3.27	1.220	4.229
Fay	1.489	10.33	.51	26.23	3.52	.923	3.042
Fly T	1.538	11.02	.53	30.13	3.93	1.184	3.723
Houston	1.559	10.40	.52	23.25	4.98	1.159	3.261
Pride	1.505	10.62	.51	30.31	4.42	1.339	3.999
Average	1.684	11.75	.57	30.60	3.80	1.164	3.719

TABLE XL.—Giving Digestible Nutrients Consumed and Products Yielded Daily by Group III.

Cows	Crude Protein	Carbo-hydrates	Ether Extract	Milk	Per Cent Fat	Butter Fat	Total Solids
Delle II	1.221	10.74	.48	27.85	4.00	1.115	3.542
Klondike	1.427	12.56	.56	22.75	4.92	1.120	3.073
Letta	1.261	10.15	.46	19.22	5.65	1.087	2.874
Puss	1.365	12.94	.48	31.89	4.69	1.496	4.237
Rose	1.310	12.25	.48	30.81	3.50	1.078	3.728
Tricksey	1.351	11.91	.54	28.50	4.20	1.198	3.689
Average	1.322	11.76	.50	26.84	4.40	1.182	3.524

TABLE XLI.—Giving a Summary in Pounds of Digestible Nutrients Consumed and Products Yielded by the Three Groups.

GROUP	Crude Protein	Carbo-hydrates	Ether Extract	Milk	Per Cent Fat	Butter Fat	Total Solids
I.	2.039	11.79	.53	27.77	4.54	1.260	3.737
II.	1.684	11.75	.57	30.60	3.80	1.164	3.719
III.	1.322	11.76	.50	26.84	4.40	1.182	3.524

The amount of nutrients consumed daily other than crude protein by the different groups was remarkably similar, groups I and II each receiving 12.32 pounds while group III received 12.26 pounds, being only .06 of a pound less per day. Of protein, group I received 2.039 pounds daily and yielded 27.77 pounds of milk testing 4.54 per cent fat. Group II received 1.684 of protein and gave 30.60 pounds of milk testing 3.8 per cent butter fat and group III taking ration 4, received 1.322 pounds of protein daily and returned 26.84 pounds of milk testing 4.4 per cent butter fat. The sufficiency of the rations containing different amounts of protein cannot be measured by the quantity of milk yielded because the milks from the three groups differed in quality. The yield of butter fat is a better guide as to the productive virtue of the rations. Group I, that received 2,039 of protein daily, yielded 1.260 lbs. butter fat, while group II, with 1.684 of protein, gave 1.164 of butter fat and group III with 1.322 of protein gave 1.182 of butter fat, showing that the difference in the yield was not caused by the difference in protein supply alone, because croup III returned more butter fat than group II. Comparing the yield of milk and butter fat by the different groups with the nutrients consumed by each, it appears that a ration containing 1.322 of protein is practically as potent in milk production as are the rations that contain 1.684 and 2.039 pounds of protein respectively; that the product yielded bears a closer relation in quantity to *total* nutrients consumed than to the protein supply or nutritive ratio of the rations.

In seeking for further light as to the sufficiency of the protein in the different rations, by examining into the products returned to available nutrients consumed, the following tables, taking into account the food of maintenance, are submitted:

TABLE XLII.—Giving the Weight of Cows in Group I, Total Nutrients, Nutrients for Maintenance, Nutrients Available for Products, and Nutrients to Products Yielded.

GROUP I	Weight	Nutrients Daily	For Maintenance	Net Nutrients	Net Nutrients to		
					100 lbs Milk	1 lb. Butter Fat	1 lb. Total Solids
Dorrit	902	14.66	7 03	7.63	34.72	6.44	2.38
Euroma	780	12.90	6.08	6.82	32.02	5.85	2.19
L'Etoile	920	14.67	7.18	7.49	27.07	5.72	1.98
Iris	1034	13.82	8.06	5.76	22.27	6.29	1.81
Topsy	921	16.49	7.18	9.31	24.64	6.19	1.90
Trust	785	13.63	6.12	7.51	23.45	5.06	1.77
Average	890	14.36	6.94	7.42	26.72	5.89	1.98

TABLE XLIII.—Giving the Same for Group II.

GROUP II	Weight	Nutrients Daily	For Maintenance	For Product	Net Nutrients to		
					100 lbs Milk	1 lb. Butter Fat	1 lb. Total Solids
Countess	1040	16.18	8.11	8.07	22.18	6.98	1.99
Dora F	1197	17.33	9.34	7.99	21.41	6.54	1.89
Fay	780	12.33	6.08	6 25	23.81	6.77	2.05
Fly T	860	13.08	6.71	6.37	21.65	5.38	1.71
Houston	811	12.47	6.32	6.15	26.47	5.31	1.89
Pride	769	12.63	6 00	6.63	21 87	4.95	1.66
Average	909	14.00	7.09	6.91	22.59	5.94	1.86

TABLE XLIV.—Giving the Same for Group III.

GROUP III	Weight	Nutrients Daily	For Maintenance	For Product	Net Nutrients to		
					100 lbs Milk	1 lb. Butter Fat	1 lb. Total Solids
Delle II	718	12.45	5.60	6.85	24.58	6.14	1.93
Klondike	943	14.54	7.35	7.19	31.61	6.42	2.34
Letta	716	11.87	5 58	6.29	32.72	5.78	2.19
Puss	834	14.79	6.50	8.29	25.98	5.54	1.95
Rose	993	14.03	7.74	6.29	20.43	5.84	1.69
Tricksey	874	13.80	6.82	6.98	24.49	5.83	1.89
Average	846	13.58	6.60	6.98	26 00	5.90	1.98

TABLE XLV.—Giving the Averages of the Groups in Weight, Total Nutrients Daily, Nutrients for Maintenance, Nutrients Available for Product, and Nutrients to Products Yielded.

Group	Wt.	Total Nutrients Daily	For Maintenance	For Product	Net Nutrients to		
					100 lbs. Milk	1 lb Butter Fat	1 lb Total Solids
I	890	14.36	6.94	7.42	26.72	5.89	1.98
II	909	14.00	7.09	6.91	22.59	5.94	1.86
III	846	13.57	6.60	6.97	26.00	5.90	1.98

By eliminating the nutrients calculated for food of maintenance at the rate of Pro. .07, C. H. .7, and ether extract .01 per cwt., it is found that the cows in Group I, that received 2.039 pounds of protein daily, returned a hundred pounds of milk testing 4.54 per cent butter fat to 26.72 pounds of net nutrients; that the cows in Group II, that received 1.684 pounds of protein daily, returned a hundred pounds of milk, testing 3.8 per cent butter fat to 22.59 pounds of net nutrients, and that the cows in Group III, that received 1.322 pounds of protein daily, returned a hundred pounds of milk testing 4.4 per cent butter fat to 26.00 pounds of net nutrients. That is, ration III having 1.32 of protein and with a nutritive ratio of 1 : 9.7 appeared as potent for milk production as was ration I having 2 pounds of protein and a nutritive ratio of 1 : 6.3, and that the nutrients required in milk production were proportionate with the quality of the milk yielded.

Also, comparing the nutrients available for product with the butter fat yielded, it appears that the nutrients required to a pound of fat were very nearly the same with each group, regardless of the protein supply, since the milk testing 4 54 per cent required 5.89 pounds of nutrients to a pound of fat, that testing 4.4 per cent required 5.90 pounds of nutrients to a pound of fat, and that testing 3.8 required 5.94 pounds of nutrients.

Again, comparing the available nutrients in the rations with the total milk solids returned, it appears that the group of cows yielding milk testing 3.8 per cent fat returned one pound of milk solids to 1.86 pounds of nutrients, that the group of cows yielding milk testing 4.40 and 4.54 per cent fat respectively returned a pound of milk solids to 1.98

pounds of nutrients; that is, the milk solids produced did not depend so much on the protein content of the rations, as upon the total nutrients, and the character of the milk solids with reference to the per cent fat to solids not fat.

Since the group of cows that received the rations differing in protein content, differed in live weight, it may be of interest to note the amount of protein they received and dairy products returned relatively.

TABLE XLVI.—Giving Protein Received and Products Returned Daily per 1000 Pounds Live Weight.

GROUP	Weight	Protein	Milk	Per Cent Fat	Butter Fat	Solids Not Fat
I	890	2.29	31.20	4.54	1.415	2.671
II	909	1.85	33.99	3.80	1.280	2.811
III	846	1.56	31.72	4.40	1.397	2.768

The cows in Group I returned 31.20 pounds of milk, those in Group II 33.99 pounds and Group III 31.72 pounds, but since the milk yielded by Group I contained 4.54 per cent butter fat, that of Group II 3.8, and Group III 4.4, comparison cannot be made in yield of milk. If account is taken of the fat content it is found that 31.20 pounds of milk testing 4.54 per cent fat are equivalent to 37.27 pounds testing 3.8 per cent fat, and to 32.19 pounds testing 4.4 per cent fat and that Group I made the greater return. But since the excess of yield of Group I over II is 15 times greater than its yield is over Group III the discrepancy in yield cannot be ascribed to a shortage of protein because Group III received less than Group II. In comparing the butter fat yielded by the three groups we find that Group I gave .235 more than Group II and .018 more than Group III. There was also a product of milk solids not fat which must be taken into account. It will be seen that when this product is made the basis, results are just reversed; that Group II yielded .14 of a pound more than Group I and .043 more than Group III; again showing that the difference in yield cannot be due to the difference in the protein fed.

A better comparison can be made by reducing the nutriment consumed daily by each group to a starch or carbohydrate equivalent by multiplying the ether extract by 2.4—see

Henry's Feeds and Feeding, Article 132—and adding the product to the sum of carbohydrates and protein, showing total nutriment consumed daily per 1000 pounds live weight, also multiplying the butter fat by 2.5 and adding the product to the solids not fat for total product daily, and giving the net nutriment required to a pound of total product.

TABLE XLVII.—Giving Pounds of Nutriment Consumed and Total Product Yielded Daily per 1000 Pounds Live Weight and Net Nutriment to a Pound of Total Product.

GROUP	Total Nutriment Daily	Total Product Daily	Nutriment to 1 lb of Product
I	16.88	6.208	1.46
II	16.28	6.011	1.41
III	16.88	6.260	1.45

By this it is clearly shown that the three groups yielded dairy products in proportion to the nutriment available for product, and not according to protein supply, and that the amount of nutriment required to a pound of total product depended upon the ratio of butter fat to milk solids not fat.

The following table gives the daily average ration fed during the three winters, reduced to a basis of 1000 pounds live weight; total nutrients and the Wolff standard:

TABLE XLVIII.—Giving in Pounds Average Daily Ration Fed, and the Wolff Standard.

YEAR	Nutrients Daily per 1000 lbs. Live Weight			Total Nutrients	Nutritive Ratio
	Protein	Carbohydrates	Ether Extract		
1895–6	2.63	12.44	.69	15.76	1:5.3
1894–5	2.09	13.03	.58	15.81	1:6.8
1901–2	1.90	13.33	.60	15.85	1:7.7
Wolff Standard	2.50	12.50	.40	15.40	1:5.3

Comparing the rations fed during the winters 1894–5, 1895–6 and 1901–2 with the Wolff Standard we find little difference so far as total digestible matter is concerned; the rations exceeding it by about .4 of a pound. They contain about 50 per cent more ether extract. The carbohydrates also exceed those given in the standard, except for the win-

ter 1895–6 when they fell slightly below it, but this was more than made good by the excess of protein. In the protein we find the greatest variation; that fed during the winter of 1901–2 falling .6 of a pound below the Wolff Standard while one of the groups had .65 of a pound less and another .94 of a pound short. The uniformity in total nutrients used, is especially noteworthy from the fact that the cows were not fed by the standard, but simply according to each animal's needs, so far as amount of food consumed was concerned. Each cow was fed to her full limit and shows that Wolff's finding in this respect was wonderfully in accord with the average needs of cows. The apparent defect in the Wolff Standard is in the amount of protein prescribed, and not being applicable to the needs of the individual cow.

TABLE XLIX.—Giving Net Nutrients to a Pound of Milk, and the Lehmann Factors.

NET NUTRIENTS	1895-6	1894–5	1901-2	Lehmann Factors
Protein Daily	2.63	2.09	1.90	
Protein to 1 lb. Milk	.0755	.0510	.0375	.0818
Carbohydrates to 1 lb. Milk	.2082	.2211	.1969	.2400
Ether Extract to 1 lb. Milk	.0224	.0177	.0156	.0180
Total Net Nutrients	.3061	.2898	.2500	.3398

Comparing the protein and other nutrients consumed to a pound of milk yielded with that prescribed in the Lehmann standard, it is found that each winter the cows used less of each nutrient than the standard provides; and that in applying the two standards, that formulated by Wolff comes nearer the average requirements. The Lehmann standard seems specially faulty in the assumption that it requires .081 of net protein to a pound of milk, and in not recognizing that nutrient requirements vary with the quality of the milk yielded.

To make further comparisons in regard to the nutrients required in milk production a table is submitted giving the net nutrients used to a pound of butter fat yielded, the daily average yield of milk and butter fat and the daily average

gain or loss in body weight during the three periods under review.

TABLE L.—Giving Net Nutrients to a Pound of Butter Fat, and Daily Yield of Products.

	1895-6	1894-5	1901-2
Protein used daily (in lbs.)	2.63	2.09	1.90
Protein to 1 lb. Butter Fat	1.920	1.244	.885
Carbohydrates to 1 lb. Butter Fat	5.295	5.395	4.652
Ether Extract to 1 lb. Butter Fat	.570	.434	.370
Total	7.785	7.073	5.907
Yield of Milk	25.71	26.09	28.40
Yield of Butter Fat	1.011	1.069	1.202
Daily Gain or Loss in Body Weight	+.20	+.12	—.13

Since no standards have taken butter fat and the quality of milk yielded into account, comparisons can only be made with results obtained during the three winter's work under review. When the cows had a daily allowance of 2.63 pounds of protein they returned a pound of butter fat to 1.92 of net protein; when they received daily 2.09 lbs. they returned a pound of butter fat to 1.244 of protein and when they received 1.90 they returned a pound of butter fat to .885 of protein and that it required 7.785 of net nutrients to a pound of butter fat when receiving 2.63 pounds of protein, 7.073 when receiving 2.09 and 5.907 when receiving 1.9 of protein; that is, the greater the protein supply, the more nutrients were used to a pound of butter fat yielded.

From the last sub-division of the table, it is seen that the winter the cows received 2.63 of protein they yielded daily 25.71 pounds of milk; when receiving 2.09 pounds of protein they gave 26.09 pounds and when receiving 1.9 of protein they gave 28.40 pounds. But since the milks differed in quality the yield is not comparable, but the daily yield in butter fat was 1.011, 1.069 and 1.202 respectively; that is, the yield of butter fat, as well as milk, was inversely to the protein supply. In examining the record as to the gain or loss in weight of cows it is shown that the winter they re-

ceived 2.63 pounds of protein they made a daily average gain of .2 of a pound, when receiving 2.09 of protein they gained .12 of a pound and when receiving 1.90 they lost .13 of a pound daily. Whether the decrease in gain the second year and the loss in weight the third year was due to the decrease in the protein supply or for some other cause does not appear. But it is possible, it might be said quite probable, that it was due to the difference in the ratio of grain to roughage. During the winter 1901-2 two-thirds of the nutrients in the rations were provided by the roughage, while during the winter 1894-5, just half the nutrients were in the roughage, and during the winter 1895-6 less than half. The fact that the loss in weight during the winter of 1901-2 occurred with all groups indicates that the cows were required to take so much of the daily ration in roughage that the nutrient content did not quite meet the requirements of the cows for the work they were doing and maintain their weight, though they ate to their full limit.

Reviewing the results obtained, it appears—

That the rations having a nutritive ratio of 1:7.7 and 1:9.7, respectively, were as effective in the production of milk, butter fat and milk solids as was the one having a nutritive ratio of 1:6.3.

That the protein required in milk production depends upon the quantity and quality of milk yielded.

That in the production of butter fat, actually more but relatively less protein and other nutrients were required to a pound of butter fat with cows giving milk containing a high per cent of fat than with those giving milk containing a low per cent of fat.

That in the production of milk solids less nutrients were required to a pound with cows giving milk having a low per cent of butter fat than with cows giving milk having a high per cent of fat.

It is not held that the decrease in the average daily yield and increased nutriment required to a given product was caused by the increase in protein supply, or that the increase in daily yield and decrease in nutriment required to a given product was caused by the decrease in protein supply,

but that a maximum yield is secured at a minimum cost of food by a proper adjustment of the amount of nutriment in the ration to the animal's needs for maintenance and for product yielded, and the bulk of the ration to its feeding capacity. An excess of nutriment in a ration does not seem to increase materially the flow of milk or yield of butter fat, but results in an increase in body weight and a relative decrease in dairy products; while a diminished nutriment supply resulted in a decreased gain in live weight and a relative increase in dairy products. The record for 1901-2 also shows that when a ration is short of nutriment because of excess bulk the cows maintained their flow at the expense of live weight, and that it was not because of the shortage of any particular component in the ration—for if such had been the case there would have been a decrease in the yield of milk because of lack of material for its production.

lished an equilibrium between the in-go of nutrients and out-go of dairy product. She was in good flesh when she calved, and having stored in her body a large excess of body fat and other substances, she was enabled for ten consecutive weeks to yield more dairy products than the food supply would, under normal conditions, produce. The sudden shrinkage the fourth week in milk flow cannot be accounted for, but an examination of the record of the herd would probably show. Her average daily loss in weight during the first 42 days was 3.33 pounds. The extra ten pounds in weight the 9th week was probably caused by drinking more than the ordinary amount of water the day previous.

The following gives a similar record of Pride, covering the first 11 weeks of her lactation.

PRIDE, CALVED NOV. 29th.

TABLE LII.—Giving Weight, Nutrients Consumed and Products Yielded from 1st-11th Week of Lactation.

Week	Weight	Nutrients Daily			Product Yielded			Nutrients to 1 lb.	
		Protein	C. H.	Fat	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
1st	847	1.309	9.42	.47	29.74	1.483	4.288	3.09	1.07
2nd	825	1.322	9.55	.47	31.47	1.497	4.308	3.28	1.14
3rd	822	1.468	10.27	.51	30.14	1.458	4.198	4.00	1.39
4th	805	1.486	10.40	.50	32.06	1.461	4.213	4.18	1.45
5th	782	1.486	10.40	.50	31.30	1.423	4.116	4.42	1.49
6th	770	1.512	10.69	.51	32.01	1.357	4.094	4.94	1.64
7th	762	1.512	10.69	.51	30.78	1.407	4.124	4.81	1.64
8th	765	1.512	10.69	.51	30.24	1.323	4.019	5.10	1.68
9th	767	1.512	10.69	.51	29.10	1.228	3.925	5.48	1.71
10th	757	1.512	10.69	.51	28.76	1.270	3.819	5.36	1.78
11th	747	1.512	10.69	.51	28 28	1.241	3.684	5.54	1.86
Average...	786	1.467	10.38	.50	30.35	1.368	4.071	4.104	1.387

Pride weighed 847 pounds at the beginning of her lactation, received daily the first week 1.309 of protein, 9.42 pounds of carbohydrates and .47 of a pound of ether extract and gave 29.74 pounds of milk, 1.483 of butter fat and 4.288 milk solids, and returned a pound of butter fat to 3.09

pounds of net nutrients and a pound of milk solids to 1.07 pounds of nutrients. Her decrease in weight was more gradual and continued during the 11 weeks when she had lost 100 pounds. She did not sacrifice so much in weight in any one week as did Trust, nor did she yield products so much in excess of nutrients consumed. This was due to her temperament—not being so pronounced a dairy type. She is not as great a feeder as Trust and after the 5th week had reached her normal ration. As her weight decreased the nutrients required to a pound of product increased, but she had not by the close of the 11th week reached an equilibrium between the in-go of nutrients and out-go of product, for under normal conditions it requires over 6 pounds of nutrients to a pound of butter fat and about 2.45 to a pound of milk solids. During the 77 days covered by the record she lost on an average 1.4 pounds per day and had not reached her normal working weight.

EUROMA, CALVED OCT. 16.

TABLE LIII.—Giving Nutrients Consumed and Products Yielded from 5th-18th Week of Lactation.

Week	Weight	Nutrients Daily			Product Yielded			Nutrients to 1 lb	
		Protein	C.H.	Fat	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
5th	795	1.760	9.57	.49	23.87	1.348	3.650	4.18	1.54
6th	807	1.847	10.53	.52	24.36	1.390	3.734	4.75	1.76
7th	812	1.847	10.53	.52	23.73	1.336	3.635	4.91	1.80
8th	787	1.847	10.53	.52	22.94	1.304	3.521	5.12	1.89
9th	792	1.702	9.95	.49	22.06	1.311	3.457	4.62	1.75
10th	800	1.824	10.30	.49	21.31	1.283	3.409	4.97	1.87
11th	787	1.824	10.30	.49	21.38	1.188	3.151	5.45	2.05
12th	772	1.850	10.59	.50	21.38	1.101	2.999	6.28	2.31
13th	772	1.850	10.59	.50	21.76	1.126	3.179	6.14	2.11
14th	777	1.850	10.59	.50	21.94	1.150	3.221	5.98	2.10
15th	787	1.850	10.59	.50	21.21	1.193	3.211	5.70	2.11
19th	785	1.850	10.59	.50	20.93	1.198	3.185	5.69	2.10
17th	777	1.850	10.59	.50	20.56	1.167	3.109	5.87	2.21
18th	782	1.850	10.59	.50	21.24	1.196	3.224	5.72	2.12
Ave.	789	1.835	10.42	.50	22 05	1.235	3.334	5.34	1.98

Euroma came in four weeks before the feeding experiment began, so we have here a record covering a period from the 5th to the 19th week of lactation, leaving off the greater portion of the natural "milking down" period, so there are no such marked changes in weight as was shown in the tables preceding it. As the period of lactation advanced the nutrients required to a pound of product increased and during the 14 weeks she used on an average 5.34 pounds of nutrients to a pound of butter fat, while Pride required 4.104 and Trust 3.79. She returned a pound of milk solids to 1.98 pounds of nutrients, while Pride required 1.39 and Trust 1.34. This difference seems to be due to the difference in the rate of decrease of body weight and with Euroma, also, to the farther advance in lactation.

DORRIT, CALVED SEPT. 16, 1901.

TABLE LIV.—Giving Nutrients Consumed and Products Yielded from 9th-23rd Week of Lactation.

Week	Wt.	Nutrients Daily			Products Yielded			Nutrients to 1 lb.	
		Protein	C. H.	Fat	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
9th	897	2.111	12.03	.61	25.60	1.489	3.953	5.23	1.96
10th	902	2.111	12.03	.61	24.81	1.477	3.821	5.23	2.02
11th	902	2.111	12.03	.61	24.81	1.477	3.821	5.23	2.02
12th	897	2.012	10.97	.56	21.84	1.311	3.407	4.99	1.92
13th	892	2.012	10.97	.56	23.00	1.337	3.501	4.92	1.87
14th	900	2.044	11.33	.56	22.66	1.344	3.474	5.14	1.99
15th	912	2.076	11.64	.56	22.50	1.258	3.391	5.70	2.11
16th	905	2.076	11.64	.56	22.31	1.280	3.307	5.64	2.18
17th	895	2.076	11.64	.56	21.96	1.180	3.189	6.18	2.28
18th	895	2.114	12.11	.57	22.61	1.233	3.233	6.34	2.41
19th	892	2.114	12.11	.57	22.40	1.167	3.163	6.71	2.47
20th	897	2.114	12.11	.57	22.37	1.176	3.302	6.63	2.36
21st	910	2.114	12.11	.57	21.33	1.137	3.138	6.77	2.45
22nd	910	2.114	12.11	.57	21.17	1.148	3.135	6.70	2.45
23rd	910	2.114	12.11	.57	21.70	1.168	3.181	6.59	2.41
Ave.	901	2.085	11.78	.57	22.59	1.265	3.371	5.85	2.19

Dorrit calved September 16th so she was in her 9th week of lactation on the 11th of November when the feeding experiment began, and the record covers her work from the be-

ginning of the 9th week to the close of the 23rd week. By taking the average weight of the first four weeks of the record and the last four, we find that she weighed 10 pounds more two weeks before the record closed than she did two weeks after it began, being a daily average gain in weight of .10 of a pound; that she required only 5.23 pounds of nutrients to a pound of butter fat the 9th week, and the 18th, when an equilibrium had been obtained between the food consumed and products yielded, she required 6.34 pounds and for milk solids 2.41 pounds. From the 18th to the end of the 23rd she required on the average more than the normal amount, because some was diverted to gain in weight, though the excess was very slight. It will be observed that there was a decrease in the nutrients in the rations fed during 6 weeks of the experiment, this is the case with all the cows in the herd and was an unfortunate occurrence for the character of the work in hand. It was caused by introducing beet pulp in the ration and resulted in a depression in both yield of milk, per cent fat content, and per cent of total milk solids.

TABLE LV.—Giving Record of Klondike from the 29th-42nd Week of Lactation.

Week	Weight	Nutrients Daily			Product Yielded			Nutrients to 1 lb	
		Protein	C. H.	Fat	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
29th	952	1.330	11.56	.55	22.37	1.138	3.080	5.25	1.95
30th	975	1.429	12.62	.60	22.88	1.144	3.123	6.16	2.26
31st	972	1.429	12.62	.60	22.08	1.100	3.009	6.43	2.35
32nd	967	1.330	11.56	.55	23.58	1.173	3.183	5.03	1.85
33rd	952	1.362	11.92	.55	22.41	1.177	3.142	5.45	2.04
34th	942	1.426	12.27	.55	22.48	1.117	3.186	6.17	2.16
35th	940	1.426	12.27	.55	23.00	1.084	2.972	6.38	2.33
36th	945	1.426	12.27	.55	21.33	1.060	2.860	6.49	2.40
37th	940	1.432	12.70	.56	22.71	1.086	3.070	6.78	2.40
38th	937	1.432	12.70	.56	23.24	1.161	3.188	6.34	2.32
39th	947	1.432	12.70	.56	22.88	1.176	3.128	6.21	2.33
40th	947	1.420	12.56	.56	22.23	1.094	3.039	6.53	2.35
41st	950	1.420	12.56	.56	23.14	1.144	3.112	6.23	2.29
42nd	942	1.432	12.70	.56	23.48	1.153	3.221	6.37	2.28
Ave.	951	1.409	12.36	.56	22.49	1.129	3.094	6.12	2.23

The record of Klondike affords most excellent data for the study of nutrient requirements near the close of a year's lactation. The food given was quite constant as to quantity, showing that the bulk of the ration fairly met her feeding capacity, and that there was no shrinkage in the flow of milk or yield of butter fat, shows that there was no serious lack in nutriment, though there was a slight shortage to the 37th week, as is shown by the weekly weighings. Her average weight the first four weeks was 966, and the last four, 946, being a loss of 20 pounds in 70 days. The nutrient requirements to a pound of butter fat and milk solids were as uniform as could be expected, in view of the constant variations that occur in the per cent fat in milk. During the 29th, 32nd and 33rd week there was a decrease in the nutrients to a pound of butter fat and milk solids, but this was due to a reduction in the feed. The food was increased during the 30th and 31st week and decreased the 32nd. With the increase of feed she decreased in product and the 32nd week she gained in milk and butter fat on the diminished ration, but this was the residual effect of the over-supply of nutriment the week previous.

A similar result is observed with Duchess the 70th and 71st week of lactation. There was a decrease in butter fat the 33rd, when the feeding of beet pulp began, to the close of the 36th week. This decrease was checked by adding 6 pounds of pulp to the ration; but when it became necessary to reduce the ration the 40th week, a diminuation in butter fat again occurred, but with a gain in weight. A careful study of the food supply, product yielded, and nutrients required to a given product, shows that the food provided was very close to her actual requirements. Special attention is invited to the daily protein supply, being on an average 1.409 pounds and leaving only .743 of a pound of protein available for product and she returned a pound of milk to .03 of protein, while the Wolf-Lehmann standard prescribes .08. The average test of the milk during the time covered by the record was 5 per cent. Table XXVI in the 2nd Article gives the nutrients used to a pound of 5 per cent milk .053 protein, .247 corbohydrates and .018 of ether extract.

Klondike returned a pound of milk to .03 protein, .253 carbohydrates and .020 of ether extract. She received .303 lbs. net nutrients to a pound of milk and lost .29 of a pound daily in body weight, while the table referred to prescribes .318 of a pound of net nutrients to a pound of milk. For the present it is not recommended that cows should be fed on a ration having so little protein, that is, with a nutritive ratio of 1:10, for it might ultimately cause a depression in milk giving functions and deterioration in dairy temperament in the off-spring. However, as yet no ill effects have been manifested from feeding the wide rations. The most surprising feature is a shrinkage in weight with wide rations as shown in Table L.

DUCHESS.

TABLE LVI.—Giving Nutrients Consumed and Products Yielded by Duchess from her 58th-71st Week of Lactation.

Week	Weight	Nutrients Daily			Product Yielded			Nutrients to 1 lb	
		Protein	C. H.	Fat	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
58th	822	1.254	9.62	.45	13.83	.856	2.167	5.74	2.27
59th	832	1.509	10.63	.53	13.36	.871	2.160	7.09	2.86
60th	830	1.254	9.62	.45	13.53	.844	2.147	5.75	2.26
61st	835	1.254	9.62	.45	13.53	.827	2.117	5.82	2.27
62nd	845	1.267	9.76	.45	13.33	.871	2.146	5.61	2.28
63rd	850	1.286	9.98	.45	12.41	.798	1.979	6.37	2.57
64th	835	1.231	9.39	.42	12.77	.784	1.966	5.78	2.30
65th	820	1.231	9.39	.42	13.48	.741	1.944	6.26	2.39
66th	807	1.257	9.68	.43	13.52	.741	1.974	6.74	2.53
67th	812	1.257	9.68	.43	13.63	.684	1.919	7.36	2.62
68th	822	1.257	9.68	.43	14.18	.788	2.147	6.29	2.31
69th	825	1.257	9.68	.43	13.87	.770	2.018	6.41	2.45
70th	822	1.512	10.69	.51	14.23	.773	2.060	8.15	3.06
71st	825	1.257	9.68	.43	15.17	.854	2.278	5.78	2.17
Ave.	827	1.292	9.79	.45	13.63	.800	2.073	6.35	2.45

The heifer Duchess aborted and was in her 58th week of lactation when the feeding experiment began. Her average weight during the first three weeks was 828 pounds, and the last three, 824 pounds, being a decrease of only 4 pounds, taking the three first and three last weighings as a basis. There was, however, quite a change in her weight, gradually increasing to the 63rd week and then decreasing to the 66th week and this was probably due to the reduction in her feed,

for when it was increased she regained her weight. The decrease in total nutrients at this stage of the experiment was due to the reduction in silage and at attempt to replace it it with beet pulp. The change in the amount of nutriment was due to the addition of 4 pounds of pulp and resulted in an increase in the flow of milk, but there was an abnormal depression in the fat content which raised the nutriment used to 7.36 pounds to a pound of butter fat. The increase in nutriment the 59th and the 70th week was due to an error in feeding 7 pounds of grain instead of 5, the amount assigned to her. Duchess and Leeoma were the only cows in the herd that were fed according to yield of milk and butter fat, and the result was that both returned butter fat and milk solids for the normal amount of nutriment regardless of advanced stage of lactation. Duchess returned a pound of butter fat to 6.35 pounds of nutriment, while Leeoma required .14 less; though this would naturally follow because Duchess' milk contained more solids not fat, and on this account she was enabled to return a pound of total solids to 2.45 of nutriment, while Leeoma used 2.47.

LEEOMA, ABORTED AUG. 3, 1900.

TABLE LVII.—Giving Nutrients Consumed and Products Yielded from 119th-132nd Week of Lactation.

Week	Weight	Nutrients Daily			Product Yielded			Nutrients to 1 lb	
		Protein	C. H.	Fat	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
119th	895	1.126	9.12	.41	8.90	.610	1.523	6.03	2.41
120th	902	1.126	9.12	.41	9.06	.623	1.565	5.82	2.32
121st	902	1.126	9.12	.41	8.88	.604	1.519	6.00	2.39
122nd	900	1.039	8.18	.38	8.77	.607	1.499	4.25	1.72
123rd	900	1.139	9.26	.41	8.51	.598	1.484	6.34	2.55
124th	902	1.158	9.48	.41	8.27	.583	1.420	6.89	2.82
125th	890	1.071	8.54	.38	8.47	.541	1.355	5.64	2.25
126th	882	1.103	8.89	.38	8 31	.554	1.372	6.30	2.55
127th	895	1.129	9.18	.39	8.61	.546	1.398	6.81	2.66
128th	900	1.129	9.18	.39	8.76	.553	1.387	6.65	2.65
129th	905	1.129	9.18	.39	8.93	.580	1.456	6.27	2.50
130th	902	1.129	9.18	.39	8.94	.591	1.476	6.21	2.48
131st	887	1.257	9.68	.43	9.11	.587	1.518	7.57	2.93
132nd	890	1.129	9.18	.39	9.44	.604	1.558	6.22	2.41
Ave.	896	1.128	9.09	.40	8.78	.584	1.467	6.21	2.47

The foregoing table covers the record of the daily average for each week beginning with the 119th week of lactation to the close of the 132nd week. While there was some variation in the weight from week to week there was no marked gain or loss. Twice her feed was reduced, the 122nd and 125th, the latter time it covered two weeks. The 127th it was again raised and for 28 consecutive days there was no change. It was then raised and the week following it was again found necessary to reduce it. She maintained her flow in milk but there was a slight decrease in butter fat. When her feed was lowered she used less than the normal amount of nutrients, about 6 pounds, to a pound of butter fat yielded. During the 131st week of lactation when her feed was raised, she returned a pound of fat to 7.57 pounds nutriment and did not increase in yield of fat, but the week following there was a slight increase. Notwithstanding that the record covered a period from the 119th to the 132nd week of lactation she required only 6.21 pounds of nutriment to a pound of butter fat and 2.47 to a pound of milk solids being the normal amount required by cows when no change in body weight takes place.

BESS, CALVED JULY 9, 1897.

TABLE LVIII.—Giving Nutrients Consumed and Products Yielded from 237th-248th Week of Lactation.

Week	Weight	Nutrients Daily			Product Yielded			Nutrients to 1 lb	
		Protein	C.H.	Ether Ex.	Milk	Butter Fat	Total Solids	Butter Fat	Total Solids
237th	1050	1.770	10.86	.57	14.00	.690	1.96	7.26	2.60
238th	1065	1.716	11.00	.55	12.77	.661	1.83	7.51	2.70
239th	1072	1.897	12.09	.58	14.30	.690	1.98	8 99	3.53
240th	1075	1.897	12.08	.58	14.93	.723	2.03	8.54	3.04
241st	1075	1.897	12.09	.58	14.51	.696	1.99	8.87	3.10
242nd	1077	1.897	12.08	.58	14.97	.698	2.05	8.54	3.00
243rd	1085	1.873	11.70	.57	15.48	.718	2.13	7.91	2.66
244th	1085	1.873	11.70	.57	14 14	.698	1.96	8.11	2.90
245th	1105	2.182	12.75	.63	13.41	.687	1.90	10.11	3.65
246th	1122	1.940	11 34	.56	14.17	.703	1.93	7.22	2.63
247th	1125	2.142	12.55	.63	15.56	.711	2.12	9.20	3.08
248th	1130	1.904	11.15	.56	16.40	.736	2.18	6.52	2.20
Ave.	1088	1.915	11.78	.58	15.39	.701	2.00	8.01	2.89

In the record of Bess data are presented covering a period from the beginning of the 237th to the close of the 248th week of lactation. It is not expected that in a cow, farrow so long, the lacteal functions would be very active, or that on full feed she would make normal return in dairy products. At the beginning of the record presented, she weighed 1050 pounds and at the close 1130, being a daily gain of 1.04. Her daily yield of butter fat was .701 of a pound and 2 pounds of milk solids. She returned a pound of fat to 8.01 pounds of nutriment and a pound of milk solids to 2.89 pounds. She evidently received more nutriment than she needed for the work she was doing in the dairy and placed the surplus to her credit in gain in weight, though she made a slight gain in flow of milk, and yield of butter fat and milk solids. There was no attempt to feed her according to her yield, but she received full feed for the group she happened to be with during the winter of 1900-1, and the same data are used in different form in Bulletin 71. The ration was small in bulk and strong in nutriment when she was so fed that she was satisfied with the bulk; by the end of the week she would show signs of going off her feed because there was too much nutriment; when it was decreased in quantity by the end of the week she wanted more because it lacked in bulk, though the nutriment was ample. This made her receive a light ration one week and a heavier one the next, as is shown by the latter part of the table. Bess dropped her calf when she was two years old and this was in the fifth year of lactation.

TABLE LIX.—Giving Stage of Lactation, Loss or Gain in Weight, Yield of Butter Fat and Total Solids and Net Nutriment to 1 lb. of Butter Fat and 1 lb. of Milk Solids.

	Time of Lactation		Daily Gain or Loss in Weig't	Daily Yield		Net Nutriment to 1 Lb.	
	From Week	To Week		Butter Fat	Total Solids	Butter Fat	Total Solids
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Trust	1st	11th	—2.00	1.591	4.494	3.79	1.34
Pride	1st	11th	—1.40	1.368	4.071	4.10	1.39
Euroma	5th	18th	— .30	1.235	3.334	5.34	1.98
Dorrit	9th	23rd	+ .10	1.265	3.371	5.85	2.19
Klondike	29th	42nd	— .30	1.129	3.094	6.12	2.23
Duchess	58th	71st	— .05	.800	2.073	6.35	2.45
Lecoma	119th	132nd	.00	.584	1.467	6.21	2.47
Bess	237th	248th	+1.04	.701	2.000	8.01	2.89

During the first eleven weeks one cow returned a pound of butter fat to 3.79 pounds of net nutriment, and lost daily in weight 2 pounds, while another cow required 4.10 pounds and lost 1.4 pounds daily in weight. That from the 5th to 18th week one required 5.34 pounds of nutriment to a pound of butter fat and shrunk in weight .30 of a pound daily; another from the 9th to the 23rd weeks required 5.85 pounds of net nutriment to a pound of butter fat and gained .10 of a pound daily; another from the 29th to the 42nd week returned a pound of butter fat to 6.12 pounds of available nutriment; that from the 29th to the 132nd week there was little change in nutriment requirements to a pound of butter fat, the range being from 6.12 to 6.35 pounds, and that if a cow is fed more nutriment than she needs normally for dairy products she will convert the surplus to gain in weight. During the early stages of lactation she may return more than twice the product that the net nutriment would provide for, under normal working condition of body weight. If a cow is in good condition when she drops her calf, the yield is largely in excess of the nutriment supply in the ration, and will be in excess until she has milked down to normal weight, after which the nutriment required to a pound of butter fat will remain quite constant for an indefinite time under proper management.

It has been shown that the rate of decrease in live weight when cows are fresh in milk varies with different individuals, and that it gradually decreases as the period of lactation advances. Also that the excess of yield in dairy products decreases from week to week until the yield, especially of butter fat, is fully provided for by the available or net nutriment consumed; but that the excesss of yield in total solids is prolonged for a time after a stationary body weight is reached. To further illustrate this peculiar phenomena, and to show the average rate of increase in nutriment requirements for a pound of butter fat and a pound of total milk solids, as the lactation period advances, a table is submitted showing the average weight after calving of 15 cows, their average weekly weight for the first nine weeks, their average daily yield of butter fat for each week and net nutriment to

a pound of butter fat and total solids; also the nutriment requirement for the three cows that were far advanced in lactation.

TABLE LX.--Giving Average Weekly Weight of 15 Cows. Average Daily Yield of Butter Fat and Average Net Nutriment Required to 1 Pound of Butter Fat and 1 Pound of Total Solids.

Lactation Weeks]	Average Weight	Butter Fat Daily	Net Nutriment to 1 lb.	
			Butter Fat	Total Solids
1st	966	1.083	3.24	.92
2nd	917	1.369	3.60	1:13
3rd	900	1.325	4.24	1.35
4th	877	1.295	4.71	1.51
5th	873	1.259	5.38	1.63
6th	863	1.232	6.07	1.72
7th	865	1.202	6.18	1.75
8th	858	1.159	6 24	1.81
9th	853	1.120	6.25	1.89
1 Cow 29th to 42nd.....	951	1.129	6.12	2.23
1 Cow 58th to 71st.....	827	.800	6.35	2.45
1 Cow 119th to 132nd.....	896	.584	6.21	2.47

The cows weighed on an average 966 pounds at the beginning of lactation and 853 the 9th week being an average daily loss per cow of 2 pounds. The first week they returned a pound of butter fat to 3.24 pounds net nutriment, and a pound of milk solids to .92 of a pound, and as the cows decreased in weight the nutriment required to a given product yielded increased up to the 9th week when a pound of butter fat was returned to 6.25 pounds of nutriment, but then the nutriment required to a pound of total solids had reached only 1.89 pounds, showing that while an equilibrium had been reached between the daily nutriment supply and butter fat yielded, such was not the case with reference to the nutriment required to a pound of milk solids, for as will be seen by comparing it with the amount required by the three cows, ranging in lactation from the 29th to the 133rd week the normal requirement is 2.4 pounds.

Again referring to Table LI, to show the product re-

turned to net nutriment available for product by the cow Trust, the following table is given showing the daily average consumption of total nutriment during each week for 11 consecutive weeks, the nutriment needed daily for maintenance, that available for product, total product yielded daily and nutriment to one pound of product. The *total nutriment* consumed daily is obtained by multiplying the ether extract taken daily by 2.4 and adding the product to the digestible protein and carbohydrates taken daily; and the *total product* yielded by multiplying the butter fat yielded by 2.5 and adding the product to the milk solids not fat yielded daily.

While butter fat may have a uniform energy value, cows differ with reference to the per cent fat yielded to solids not fat, and so even total solids cannot be employed as a correct measure of product yielded. It is for this reason that an attempt is made to reduce the two products, solids fat and solids not fat, to a common energy value by the method stated.

TABLE LXI.—Showing Disposition Made of Nutriment Consumed by Trust During a Period of 77 Days.

Week	Total Nutriment Daily	Nutriment for Maintenance	Nutriment for Product	Total Product Daily	Lbs. of Net Nutriment to 1 lb. of Total Product
1st	11.026	7.215	3.811	6.633	.57
2nd	12.813	6.525	6.388	8.209	.77
3rd	11.782	6.455	5.327	7.491	.71
4th	11.782	6.256	5.526	5.973	.92
5th	12.174	6.217	5.957	6.679	.89
6th	12.556	6.201	6.355	6.803	.93
7th	13.845	6.123	7.722	6.524	1.08
8th	13.845	6.123	7.772	6.711	1.15
9th	14.337	6.201	8.136	6.502	1.25
10th	14 337	6.123	8.214	6.854	1.19
11th	15.592	6.123	9.469	6.140	1.54
Average...			6.788	6.774	1.00

Special attention is invited to the gradual increase from week to week of the amount of nutriment consumed daily as the period of lactation advanced, except the second week,

when she received more than she could take any of the four weeks following, showing that she was over-fed the second week; that she varied considerably from week to week in the daily average of total product yielded; that during the first week she yielded 1 pound of product to .57 of a pound of nutriment, being nearly twice as much product as she had nutriment available for product; that for six consecutive weeks the product yielded was in excess of the available nutriment; that during the 77 days, covered by the table, she had available for product 522.7 pounds of nutriment and yielded 521.6 pounds of product; that the daily average of net nutriment was 6.788 pounds; the daily average of product yielded was 6.774, and returned a pound of product to practically a pound of net nutriment.

While it is clearly shown that the cow was enabled to make greater return in butter fat to nutriment consumed, because of having stored surplus body fat during the time that she was dry, the question suggested is, was it economical, considering the extra nutriment required, to provide for the gain in body fat sacrificed. By referring to table LX it will be seen that it required about 6.25 pounds of net nutriment to a pound of butter fat, where cows had been in milk for some considerable time, and were neither gaining nor losing in body weight. During 77 days Trust yielded 121.8 pounds of butter fat and had during that time 522.7 pounds of net nutriment, which, under normal conditions, would have provided for 83.6 pounds of butter fat. But she lost in body weight 140 pounds and produced 38.2 pounds of butter fat above the normal yield, losing 3.66 pounds in body weight to each pound of butter fat yielded in excess of the amount provided for in the net nutriment.

By making similar calculations from table LII to show the influence on yield of dairy products by decrease in weight of body, the following table is submitted.

TABLE LXII.—Showing Disposition Made of Nutriment Consumed During a Period of 77 days by Pride.

Week	Total Nutriment Daily	Nutriment for Maintenance	Nutriment for Product	Total Product Daily	Lbs. of Net Nutriment to 1 lb. of Total Product
1st	11.857	6.607	5.250	6.511	.81
2nd	12.000	6.435	5.565	6.553	.88
3rd	12.962	6.412	6.550	6.380	1.02
4th	13.086	6.279	6.807	6.404	1.06
5th	13.086	6.100	6.986	6.250	1.10
6th	13.426	6 006	7.420	6.129	1.21
7th	13.426	5.944	7.582	6.334	1.19
8th	13.426	5.957	7.469	6.003	1.24
9th	13.426	5.983	7.443	5.767	1.29
10th	13.426	5.903	7.521	5.724	1.31
11th	13.426	5.826	7.600	5.545	1 37
Average...			6.926	6.145	1.127

In the performance of Pride it can be again seen that cows do not take full rations in the early part of the lactation period, and that when a cow's temperament is such that she does not decrease so rapidly in weight of body, she will more quickly reach a stage when she will take a full ration as did Pride the 6th week, but while she received a full ration the last six weeks, she had not milked down to her normal working weight by the 11th, and was then returning a pound of total product to 1.37 pounds of nutriment, while at the same stage of lactation Trust used 1.54 pounds. By referring to table LII it will be seen that she decreased in weight of body more slowly and that she used more nutriment to a given product yielded, and that the *rate* of decrease in weight of body has a bearing on the amount of nutriment required in milk production. During the 77 days she had 533.3 pounds of nutriment available for product which under normal conditions would have provided for a yield of 85.3 pounds of butter fat. But she lost 100 pounds in body weight and produced 105.3 pounds of butter fat, being 20 pounds more than the nutriment provided for. She therefore sacrificed 5 pounds in live weight to each pound of butter fat yielded in excess of that provided for by the nutriment consumed.

It is not expected that by making any one product the basis of calculation the exact results from decrease in weight of body can be shown, because dairy products have not a common energy value, and because all the solids yielded in milk are derived either from the nutriment consumed or from the substances stored in the body, but it would seem to be more in accord with the natural order of things that nearly all the milk solids are the direct product of the nutriment then taken, and the maintenance and energy expended are chargeable at least in part to oxidation of body tissue.

Making similar calculations from the records of the cows Klondike, Duchess and Leeoma, that were made from the records of Trust and Pride, it can be approximately determined what the nutriment requirements are where no material change in weight of body takes places.

TABLE LXIII.—Showing Total Nutriment Daily, Nutriment Available for Product and Nutriment Required to a Pound of Total Product Yielded.

	Total Nutriment Daily	Nutriment Daily for		Total Product Daily	Lbs. of Net Nutriment to 1 lb. of Total Product
		Maintenance	Product		
Klondike	15.113	7.418	7.695	4.788	1.60
Duchess	12 162	6.451	5.711	3.273	1.74
Leeoma	11.178	6.989	4.189	2.343	1.78
Total	38.453	20.858	17.595	10 404	
Average	12.818	6.953	5.865	3.468	1.69

From this it is seen that it required from 1.60 to 1.78 pounds of nutriment to 1 pound of product. By referring to table LIX it will be seen that the cow Klondike was really loosing weight at the rate of about a quarter of a pound a day, and this had a noticeable influence on the nutriment she used to a pound of product. Her system had the alternative of using the full complement of nutriment required for maintenance and shrink in yield of dairy product, or maintain the yield and shrink in body weight, but it chose to give full return in dairy product and draw on body tissue to make good the shortage in the nutriment supply, showing how wonderfully responsive the dairy bred cow is to the demands of her lacteal functions.

The record of the cow Duchess gives a further illustration of the influence of change in body weight upon the return of

dairy products to food consumed. In her case, as may be seen by referring to table LIX, the slight daily loss of less than .1 of a pound in weight is reflected in the amount of nutriment required to a pound of product. There was doubtless a waste of nutriment during the 59th and 70th weeks of lactation because of the sudden increase in the rations fed during the two weeks. This is indicated by the fact that she stands charged in the table referred to, with 6.35 pounds of nutriment to 1 pound of butter fat yielded, while Leeoma required only 6.21.

Taking into account the changes in the weight of the cows referred to, it is quite evident that it requires about 1.75 pounds of available nutriment to produce 1 pound of product; that is, of the available nutriment, 43 per cent is expended in energy and 57 per cent is returned in the milk solids.

Of the total nutriment consumed daily approximately 54 per cent was required for maintenance, 19 per cent for energy and 27 per cent was returned in the milk solids.

Again taking the record of Trust during the first ten weeks of her period of lactation, showing the decrease in weight from week to week, the average daily nutriment available for product each week, the butter fat yielded, the normal daily yield, and average daily yield in excess, the compensatory yield by virtue of a daily loss in weight of 2 pounds is shown.

TABLE LXIV.—Showing Decrease in Weight of Trust, Daily Average of Net Nutriment, Yield of Butter Fat, Normal Yield and Excess.

Week	Weight	Net Nutriment Daily	Butter Fat Daily	Daily Normal Yield Butter Fat	Daily Excess Yield Butter Fat
1st	925	3 811	1.452	.609	.843
2nd	875	6.388	1.817	1.022	.795
3rd	825	5.327	1.750	.852	.898
4th	802	5.526	1.708	.884	.824
5th	797	5.957	1.558	.953	.605
6th	795	6.355	1.573	1.017	.556
7th	785	7.722	1.544	1.235	.309
8th	785	7.722	1.531	1.235	.296
9th	795	8.136	1.487	1.302	.185
10th	785	8.214	1.610	1.314	.296
Average...		6.516	1.603	1.042	.561

The first week the cow received daily 3.811 pounds of nutriment available for product and yielded 1.452 pounds of butter fat. It has been shown that the normal requirements for a pound of butter fat is 6.25 pounds of nutriment and on this basis the nutriment available for product provided for only .609 of a pound of butter fat and her daily yield was .843 of a pound in excess. During the 70 days covered by the table she received daily on an average 6.516 pounds of net nutriment and yielded 1.603 of butter fat—being a daily yield in excess of that provided for in the ration of .561 of a pound. Since she decreased in weight on an average 2 pounds per day, the excess yield of butter fat was .28 of a pound for each pound of body weight sacrificed, or a decrease of 3.57 pounds body weight to a pound of excess yield of butter fat.

The record of the 15 cows that came into milk from and after the 11th of November also gives some evidence in regard to the amount the daily yield of butter fat is increased by virtue of the milking down of body weight, and the relation between the daily decrease in weight and excess yield of butter fat.

TABLE LXV.—Showing Decrease in Weight, Daily Average Yield of Butter Fat, Normal and Excess Above Normal Yield.

Week	Weight	Net Nutriment Daily	Butter Fat Daily	Daily Normal Yield Butter Fat	Daily Excess Yield Butter Fat
1st	966	.....	.....	.....	.....
2nd	917	4.648	1.369	.744	.620
3rd	900	5.363	1.325	.858	.467
4th	877	5.989	1.295	.958	.337
5th	873	6.156	1.259	.985	.274
6th	863	6.500	1.232	1.040	.192
7th	865	6.390	1.202	1.022	.180
8th	858	6.511	1.159	1.042	.118
9th	853	6.535	1.120	1.045	.075
Daily Average.....		6.011	1.245	.962	.283

The cows received daily on an average 6.011 pounds of digestible matter available for product, and yielded daily 1.245 pounds of butter fat. The data already submitted shows that it requires 6.25 pounds of net digestible matter to a pound of butter fat, and upon this basis the nutriment provided daily was only enough for a daily yield of .962 of a pound butter fat, while the average daily excess yield per cow was .283 of a pound. Since the daily average loss in body weight per cow was 2 pounds, the daily compensatory yield by virtue of decrease in live weight was at the rate of .14 of a pound of butter fat per pound of decrease in weight of body, being a sacrifice of 7 pounds of live weight to 1 pound of butter fat yielded in excess of the yield provided for in the ration.

The following deductions are made from the data submitted:

1. During the early stages of the period of lactation cows lose rapidly in body weight; of 15 cows the average decrease per cow the first week was 49 pounds, and during 56 days there was a daily average loss per cow of 2 pounds.

2. During the time when the decrease in body weight takes place cows yield dairy product in excess of the amount provided for by the food consumed; the excess of yield depending upon the rate of loss in weight of body, in some instances it is more than twice the amount provided for by the available nutriment.

3. The excess yield of dairy products gradually decreases until about the 11th week when an equilibrium generally obtains between the nutriment consumed and dairy products yielded, though in this respect cows differ; those of a pronounced dairy temperament taking less time, while those not strong in dairy temperament decrease more slowly in weight and require more time to reach normal work in milk production. Before such equilibrium is reached the body fat and possibly other substances contribute directly or indirectly to product.

4. The normal net nutriment requirements to a pound of butter fat is approximately 6.25 pounds, with a slight increase by cows yielding milk containing a low per cent butter

fat, and less with cows giving milk containing a high per cent of butter fat.

5. The normal net nutriment requirements to a pound of milk solids yielded is approximately 2.4 pounds with a slight increase with cows yielding milk rich in butter fat and less with cows giving milk containing a low per cent of butter fat.

6. When the daily nutriment available for product and the products yielded daily are reduced to an approximate common value of energy, it is found that it requires about 1.75 pounds of available nutriment to 1 pound of product; that is, of the available nutriment, 43 per cent is expended in energy and 57 per cent is returned in the milk solids.

7. The daily yield of butter fat in excess of the nutriment supply, by virtue of an average daily loss per cow of 2 pounds in body weight, was .283 of a pound, being a sacrifice of 7 pounds in body weight to 1 pound of butter fat yielded in excess of that provided for in the ration.

8. When the normal working condition of body weight is reached, the nutriment required to a pound of butter fat and a pound of milk solids remains quite constant for an indefinite time under proper management.