THE MINERAL METABOLISM OF THE MILCH COW

FIRST PAPER

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THE MINERAL METABOLISM OF THE MILCH COW

FIRST PAPER

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C. M. FRITZ, L. E. MORGAN AND S. N. RHUE

The dairy cow greatly excels any of the other farm quadrupeds in the rapidity and efficiency with which she produces proteid and mineral nutriment; and since the cow is only a transformer, but in no sense a creator of these nutrients her maximum productive capacities depend on food requirements for the kinds of nutriment especially involved which are commensurate with her remarkable functional activity.

The unusual requirement of the cow for protein in the ration is universally recognized, and receives that attention which its importance demands. The mineral requirements of the milch cow, however, have received but scant recognition. There is in the literature almost no evidence on the subject, and we ordinarily assume that cows get enough mineral matter in the ration at all times. The results of this experiment show that in this assumption we have been in error, and that we have important facts yet to learn regarding the mineral metabolism and requirements of milch cows.

Objects.—In this experiment we sought to study the mineral income and outgo of the milch cow on common practical rations, especially as influenced by the protein concentrates and by the type of roughage fed, and also to study the effects of these same factors on the digestibility of the rations.

The rations fed were the following:

Corn, cottonseed meal, timothy hay, corn silage
Corn, cottonseed meal, clover hay
Corn, cottonseed meal, clover hay, corn silage
Corn, distiller's grains, clover hay, corn silage
Corn, linseed oilmeal, clover hay, corn silage
Corn, gluten feed, clover hay, corn silage

These rations, therefore, afford a basis for the comparison of clover and timothy hay, and of the common commercial nitrogenous concentrates.

METHOD OF EXPERIMENTATION

This investigation was conducted during January, February and March, 1915, by the usual method of the metabolism experiment, involving the collection, sampling and analysis of food, urine, feces and milk.

Six cows were purchased for this investigation. Five of them were grade Holstein-Friesians, and one was purebred. The cows were from 3 to 5 years of age, and all were fresh from 4 to 6 weeks before the experiment began. The conditions under which the experiment was conducted made it impossible to breed the cows during its course, and none had been bred at the time the experiment began.

The cows were used in two groups of three each, three cows to a ration. After a preliminary feeding of 3 weeks, to accustom the cows to the place, the rations and the routine, the experiment began on January 8. The experiment covered three collection periods, mostly of 19 or 20 days' duration, separated by 10-day intervals on the feed of the next period to follow, the changes in the rations being made abruptly at the beginning of the intermediate periods. While abrupt changes in the feeding of animals are, of course, to be avoided, they were on certain accounts necessary in this experiment. In no case did they alter the general character of the ration or throw the cows off feed.

The cows were confined in stalls built for the purpose of this study, so constructed as to prevent waste of food, and to allow the cows some freedom to move about, and to lie down in comfort. The stalls were situated in the Nutrition Building. The cold-storage rooms, so important to the investigation, were directly across a hallway from the experiment room. For bedding the cows were provided with mattresses made of burlap and excelsior, and covered with heavy canvas.

The foods were assembled before the experiment began. All of those used in a 20-day period were weighed out at one time before the beginning of the period, and were sampled for analysis at the time of weighing. For convenience in weighing, sampling and storage, and for the prevention of waste in feeding, the roughage was all fed cut. All dry feeds, both grain and roughage, were weighed into paper bags. The silage was weighed into burlap bags and stored in a refrigerated room at a temperature of 0° F. Salt was fed in chemically pure form, mixed with the grain. The drinking water was distilled, and was allowed ad libitum.

The experimental day began and ended at 6:30 a. m., and the cows were weighed at 8:00 a. m. on the first and last 5 days of each experimental period.

The cows were milked into weighed pails from two to four times during the 24 hours, as required in each case to prevent loss of milk from the udder while the cows were lying down. It was also necessary with certain cows to close the teats after each milking by the use of elastic collodion. The portions of milk were weighed as soon as drawn, and were then poured into cans, one for each cow, and kept in a refrigerated room until the end of the day, when aliquot samples for analysis were taken, by weight. These daily aliquots were combined, the composite samples being stored in gallon varnish cans in a refrigerated room at a temperature of 0° F.

The urine was caught in pails by attendants sitting behind the cows. The urine portions as caught were poured into bottles, one for each cow, the transfer being completed with distilled water. The bottles were coated inside with thymol. These bottles were emptied three times daily into larger storage bottles, also coated with thymol, and kept in a refrigerated room at a temperature of 32° F. At the end of each day these larger storage bottles were taken to a laboratory room; the urine was measured, and aliquots were taken, by volume, for analysis. Certain aliquots were used for daily determinations; others were preserved at 0°F.; still others, at 32° F.

The feces were caught in weighed pails or scoop shovels, and after weighing, were transferred to friction-top cans and placed in the cooler. The feces portions from each cow were mixed each day, and aliquots were taken by weight and preserved at 0° F. All cans, pails, bottles, etc. were cleaned with distilled water at a laundry sink in the experiment room. These receptacles were then dried on a large steam table in the same room.

Three attendants, with a pail on each knee, sat behind the six cows during all the time the cows were standing. Relaxation of attention was allowed only while the cows were lying down. During this time weighed scoop shovels were especially useful, as also were emergency pans in the gutter behind each cow, since the cows frequently passed both urine and feces while reclining. The help required for the conduct of this experiment was as indicated below:

Six men (two shifts of 12 hours each) to sit behind the cows.

One man to do most of the milking, to water the cows, to relieve those sitting behind the cows, to handle the milk and cream, and to do miscellaneous labor.

Three chemists (three shifts of 8 hours each) to weigh the urine, feces and milk, to care for these products, to clean the receptacles, and to guarantee the fidelity of the men behind the cows.

One chemist to do the feeding and the daily sampling and chemical work.

One helper for this last-mentioned chemist.

One man to operate the refrigerating plant.

The experiment, therefore, required full time from 13 men, in addition to the general direction of the head of the department. In subsequent work it has been found much better to use another shift of three men behind the cows, thus reducing the working day of those engaged in the collection of the excreta to eight hours; it was also found desirable to milk and to feed all of the cows four times daily, and to provide another man to do half of the milking at morning and night and all of the milking at midnight. In the later work, then, we used a total of 17 men.

The temperature of the experiment room was kept as nearly as possible at 50° F. in order to keep the cows' appetites keen.

Before the experiment began the cows were producing about 40 pounds of milk each, per day. It was impossible to keep them up to this production, however, because of various conditions essential to the experiment, especially the disturbance of night and day attendance by a considerable number of men, and the necessity of restricting the rations so that they would be consumed without waste. On account of the amount of analytical work involved in our complete mineral balances, with other lines of observation added, and because there would be no assurance that the refused feed would be sufficient in quantity for the many chemical determinations made, it was considered highly desirable that the foods weighed to the cows be consumed without waste. In this we were entirely successful, without other compromise than a certain reduction of food consumption and of milk yield, which in no way vitiated the results of the investigation. The average daily yield of milk during the experiment was 36.1 pounds, which was satisfactory from our point of view, inasmuch as it is neither so large nor so small as to detract from the bearing of the results on the operations of the practical feeder.

RESULTS OF THE EXPERIMENT

Table I, page 334, states the average daily amounts of foods consumed, the milk produced and the live weights of the cows. It was our wish to keep the cows as nearly as possible at a constant weight. In 10 cases out of 18 there was slight gain in weight; in 1 case, no change in weight; and in 7 cases, slight loss in weight. Five out of the six cows gained in weight during the experiment as a whole. The average change in weight was a gain of 3 ounces per head per day.

The composition of the foods and milk, and the amounts of the several constituents of the rations, milk, urine and feces are stated in Tables II-VII, pages 335 to 341. These records are included for convenient reference, and do not require discussion.

The most important results of the investigation are set forth in Tables VIII, IX and X, covering Experimental Periods I, II and III, on pages 342 to 344. These tables exhibit the average daily amount of each of the constituents determined in the food, milk, urine and feces, and the final balance of income and outgo for each. The + and — signs indicate whether the cow was gaining or losing in her body-supply of the constituent represented by the accompanying numeral. Table XI, page 345, includes the balances from Tables VIII, IX and X, together with the amounts of food eaten and of milk produced, in pounds.

The balance data show that the intake of common salt, about 1 ounce per head per day, was usually sufficient, along with the sodium and chlorine of the rest of the ration, to maintain sodium and chlorine equilibrium, though there were 4 negative sodium balances and 5 negative chlorine balances out of 18 of each. A more liberal allowance of salt would not be excessive, and might be of benefit. The greatly increased sodium retention, without corresponding storage of chlorine, exhibited by Cows 4, 5 and 6 in Period III, was due to the influence of the gluten feed, which contained more sodium than the foods used in other periods. We have also noted, in studies with swine, a large measure of independence in the metabolism of sodium and chlorine.

Of the potassium balances 5 out of the 18 were negative, 4 of these being with Cows 5 and 6 in the consecutive Periods II and III. In Period II the potassium intake of these cows was 85.7 grams per day, and the loss was slight (0.020 and 1.265 grams). In Period III the intake was increased to 111.672 and 115.569 grams, and the negative balance increased to 0.514 and 6.832 grams, respectively. It is probable that these losses are unimportant, and that they represent simply fluctuations in the body-supply, which, in general, tends to remain somewhat nearly constant, since there is no means, in the body, of storing this element in considerable quantity.

Without exception there was loss of calcium and magnesium, and in 15 cases out of 18 a loss also of phosphorus.

The low calcium content of the ration containing timothy hay, and fed to Cows 1, 2 and 3 in Period I, is naturally reflected in maximum losses of calcium. The feeding of clover hay, as in all other periods, reduced the calcium loss, but the reduction did not correspond to the increased intake. The calcium, on some account, was poorly utilized.

In general the feces calcium was surprisingly nearly the same in amount as the food calcium, though the amounts of both varied widely; the urine calcium was in very small quantity, while the negative calcium balance (the loss of calcium) was of about the same amount as the calcium in the milk.

In Period I, Cows 1, 2 and 3, with a calcium intake of 18 to 21 grams excreted 23 to 24 grams in the feces; Cows 4, 5 and 6, with a calcium intake of about 40.5 grams excreted in the feces 44 to 46 grams.

In Period II, Cows 1, 2 and 3, with a calcium intake of 52.4 grams excreted in the feces 47 to 50 grams; Cows 4, 5 and 6, with a calcium intake of 42.5 grams excreted in the feces 44 to 46 grams.

In Period III, Cows 1, 2 and 3, with a calcium intake of 51.5 to 54 grams excreted in the feces 50 to 51 grams; Cows 4, 5 and 6, with a calcium intake of 47 to 48.5 grams excreted in the feces 47 to 52 grams.

Comparing the calcium balances of Cow 1 in Periods I and II, we note that the increase of the intake from 17.944 grams in Period I to 52.403 grams in Period II reduced the calcium loss from 25.055 grams only to 14.599 grams. That the calcium of these rations should have been so poorly utilized is remarkable. Its retention was controlled to a large extent by some factor other than the intake of this element.

It is also true that the magnesium of the urine and feces exceeded by a considerable quantity the magnesium of the food; while in regard to phosphorus, the amount of this element in the excreta was much less than in the food. The phosphorus, therefore, was much more efficiently retained than the calcium and the magnesium.

The amount of calcium required by the cows was, without doubt, much greater than that of phosphorus and magnesium. In comparison with these requirements the supply of calcium in the rations in this experiment must have been much more deficient than that of phosphorus and magnesium. In all probability the loss of each of these elements, related as they are in metabolism and in the skeleton, had its cause in the one factor which determined the loss of calcium. The intake of magnesium and of phosphorus may have been adequate, but, since neither of these elements can be stored in quantity except as combined with calcium in the skeleton, a condition which caused a loss of calcium may have rendered impossible the retention of the associated elements. It is possible, therefore, that a change of conditions which would render more efficient the utilization of calcium would incidentally bring about improved retention of magnesium and phosphorus.

These results show that there was with each cow, on every ration, a retention of nitrogen, and in all but 2 cases out of 18 a retention of sulphur, these facts indicating that the rations provided nutriment sufficient in amount, and of the right kinds, to protect and to increase the protein tissues of the cows. This condition, taken in connection with the fact that all of the cows but one gained in weight (here the loss was slight), shows that the losses of calcium, magnesium and phosphorus were not due to general undernourishment. Whatever the condition which determined these negative balances it was of a nature to affect this group of nutrients alone. This means that the animals were well nourished, except that for some unknown reason they were all obliged to draw upon their skeletons in the production of milk.

The balance data also demonstrate the existence of an extensive metabolism of silicon, the retention of this element from the first ration, which contained timothy hay, being surprisingly large. This storage of silicon may have taken place through the growth of hair, the ash of which contains silicon in considerable quantity. We found no silicon in the milk, but quantities of it in the urine.

The computation of the mineral acids and bases of the foodstuffs to cubic centimeters of normal solution of the respective elements (Table XII, page 346) shows a marked predominance of acids in the ration fed to Cows 1, 2 and 3 in Period I. The acidity of the ash of this ration is due largely to the high silicon content of the timothy hay. Approximately half of the total mineral acidity of this ration is due to silicon. The authors have not seen account taken of silicon, in other similar computations of the predominance of inorganic acids or bases in foods. Its relation to the mineral alkalis, in foodstuffs and excreta, seem to us to necessitate an accounting for silicon on the same basis as for sulphur, phosphorus and chlorine.

Table XIII, page 347, exhibits the relation of urinary ammonia, phosphates and sulphates to the balance of mineral acids and bases in the rations. The excess acidity of the ration fed to Cows 1, 2 and 3 in Period I caused these cows to produce acid urine, and the total ammonia of the urine was higher than in any other case. Associated with this high ammonia content of the urine was a high phosphorus content. A close relationship between urinary ammonia and phosphorus was not found, however, throughout the experiment. The high phosphorus and moderate ammonia contents of the urine of Cow 4, Period III, exemplifies the truth of this last observation.

No relation was observed to exist between the reaction, the ammonia or the phosphorus of the urine with the amount or the form of the urinary sulphur. No other factor was found to affect urinary sulphur to nearly so great an extent as did the high sulphur content of the gluten feed eaten by Cows 4, 5 and 6 in Period III. The high sodium and sulphur contents of this food result from the process by which it is manufactured.

A study of the nitrogen compounds of the urine was attempted, but the conditions necessary to prevent chemical change in certain of these, during protracted storage, were not attained. It is thought, however, that the results of our studies clearly point the way to successful methods of preservation of cow urine for the investigation of its nitrogen compounds.

Table XIV, page 348, sets forth the coefficients of digestibility of the rations, the object of this consideration being especially to study the effects of the nitrogenous supplements on the utilization of the nutrients. Certain differences in the digestibility of the nutrients are apparent, but these variations are not prominent, and further work will be required to establish the facts in an unmistakable way. We see here no evidence that the common commercial concentrates affect, to an important extent, the digestibility of the rations in which they are fed.

Certain low coefficients of digestibility in the records of Cows 1, 2 and 3, in Period I, and of Cow 6, in Period III, were due to slight overfeeding. The evidence of indigestion was not especially marked, and the appetites were not affected, but the facts as to these data are undoubtedly as stated.

DISCUSSION OF RESULTS

From the results of this experiment it appears that a failure to maintain mineral equilibrium must be so common among cows of the more profitable sort that it must be considered a normal condition during the time of larger production, at least if this occurs during the winter, that is, while the cows are not on pasture. We are led, therefore, to look for results of such losses, in the behavior of cows under usual methods of management.

The effects of these losses are observed most noticeably under those conditions which tend to accentuate them; thus, malnutrition of the bones is common in regions of unfertile, sandy soils, or soils of granitic origin, especially if these be worn through long cropping with insufficient fertilization, and also after seasons of drouth, overstocking of pastures, and deficient food supply. There are in the literature many hundreds of reports of malnutrition of the bones of livestock, as resulting from these causes, and also great numbers of reports establishing the ready response of animals suffering from simple malnutrition of the bones to improved treatment, especially in the way of increased supplies of the mineral nutrients, often in the form of bone meal or of chalk.

It is not necessary, however, to go into the field of pathology for instances of the practical bearings of the main point determined by this investigation. Under the best conditions of feeding and management, as understood by practical feeders, a cow often fails to breed during the season following one in which she has been fed for a record of high production. It seems quite probable that the excessive lactation has depleted the mineral reserves of the body to such an extent as to disturb the reproductive functions.

Such a depletion is also reflected in the fact of the failure of many cows fed for high production to maintain high records during two consecutive periods of lactation.

In all probability the most important results of a failure of heavy-milking cows to maintain mineral equilibrium are not in such prominent effects as we have mentioned, but in an inconspicuous shrinkage of lactation in cows which are apparently in normal condition. Since milk production, in cows such as we used in this experiment, seems to be sustained in part by drafts upon the body-reserves, and since this process cannot continue indefinitely, and since there is in cows a gradual shrinkage and final cessation of milk production coincident with this depletion of nutrient reserves, it is believable that this exhaustion of reserves should be among those factors which *cause* the gradual shrinkage of milk flow, and that by preventing, as largely as possible, these losses from the body we may be able to lessen the shrinkage and to extend the duration of the production of milk.

The time of replenishment of reserves comes, of course, during the latter part of the period of gestation. This process of repair is most efficiently accomplished while the cows are on pasture, particularly if the pasture contains a considerable proportion of leguminous vegetation, as indeed most pastures do.

Our balance data indicate that after a certain level is reached, in food consumption and milk production, the digestion of the additional mineral nutriment demanded by further increase in milk secretion is accomplished at such a decreasing rate of efficiency that the only practicable method of meeting mineral requirements is through the tearing down of bone tissue, thus causing a loss of minerals from the body—a loss which it may be impossible entirely to prevent, but which we should seek to minimize through supplying the nutrients in abundance. The overdraft should then be made good as soon as practicable. Whether such a process of depletion and subsequent repair is a part of the most profitable system of milch-cow management remains yet to be determined. The object sought in milk production is *milk* rather than maximum physiological economy; and it is possible that, as a practical measure, we may find it most profitable to exhaust the cow's mineral reserves, at a time when she is able to draw upon them to support liberal milk production, and then to repay the overdraft when the cow's tendency to produce milk has so far spent itself that the total outgo falls below the total income of the mineral nutrients.

A possible method by which the organism of the cow may draw upon her mineral reserves is suggested by conclusions of Bergeim.[1] Bergeim ascribes to the leucocytes (probably splanchnic basophiles) invading the intestinal epithelium an important function in the absorption of calcium from the intestine, it being his idea that, by virtue of the phosphonuclease which they contain, they liberate from nucleic acid (probably other phosphoric acid esters also) phosphoric acid, which dissolves calcium phosphate. This calcium is carried partly in combination with the leucocytes, and is necessary for nucleolytic action. The negative calcium, magnesium and phosphorus balances observed in this experiment involved extensive transfer of salts from the skeleton to the milk through the agency of osteoclasts. Bergeim considers that the method of their action is similar to that of the leucocytes in the process of calcium absorption, as outlined above, and that the control of these processes is maintained especially by the parathyroid, though other glands, as the thymus, are also involved, mainly as supplies and stores of nuclein. In harmony with this conception we may consider it possible that there is a temporal character of the mineral metabolism

[1] O. Bergeim, Proc. Soc. Exper. Biol. and Med. (1914), xii, pp. 22-24.

of lactation, in the same sense as of the period of gestation—this condition being only partially controllable by feeding and management.

CONCLUSIONS

Liberal milk production, on common practical winter rations fed in quantities sufficient to maintain the live weight and to cause regular nitrogen and sulphur storage, caused consistent losses of calcium, magnesium and phosphorus from the cows' skeletons. These losses occurred in spite of liberal supplies of these nutrients in the food. The limited response of the cows to increase in the intake of these elements showed that their utilization of these nutrients, on a profitable plane of food consumption and milk production, was surprisingly inefficient. The cause of this inadequate utilization of minerals, especially calcium, and the possibility of preventing losses of these nutrients stand in need of further investigation.

An extensive metabolism of silicon was demonstrated.

An excess of inorganic acids over inorganic bases in a ration, due largely to the silicon of timothy hay, caused an acid reaction and an increase in the ammonia of the urine.

No important specific effects were observed of the nitrogenous concentrates, cottonseed meal, linseed oilmeal, gluten feed and distiller's grains, on the digestibility of the rations in which they were fed.

The results of this study indicate that especial attention should be given to the calcium, magnesium and phosphorus contents of the rations of heavily-producing cows in order that the loss of these elements from the skeleton may be kept as low as possible; and a liberal supply of foods which are rich in these elements should be allowed after the cow has ceased to produce abundantly, during the latter part of the period of lactation, in order to refund previous overdrafts before the birth of the next calf.

The further study of this problem is now under way.

TABLE I.—AVERAGE DAILY FOODS CONSUMED AND MILK PRODUCED, AND LIVE WEIGHTS OF COWS (Kilograms)

Cow No., period No., and days in period			Foods consumed									Milk produced	Weights of cows	
			Corn	Cotton-seed meal	Distiller's grains	Linseed oilmeal	Gluten feed	Clover hay	Timothy hay	Corn silage	Salt		Av. first five daily weights	Av. last five daily weights
1	I	19	4.248	1.160	...	...	...	...	3.620	11.340	0.023884	18.405	476.2	475.1
2	I	19	4.300	1.240	...	...	...	...	3.620	13.600	0.028000	17.485	437.4	448.2
3	I	19	3.774	1.241	...	...	...	...	5.440	11.340	0.023274	19.854	486.8	475.6
4	I	10	4.325	0.818	...	...	...	4.080	...	...	0.025444	14.818	358.8	358.8
5	I	10	4.515	0.818	...	...	...	4.080	...	...	0.025386	14.358	410.5	412.3
6	I	10	4.310	0.815	...	...	...	4.080	...	...	0.025350	15.409	352.4	351.2
1	II	20	3.000	1.000	...	...	...	4.536	...	11.340	0.028000	18.462	479.76	478.3
2	II	20	3.000	1.000	...	...	...	4.536	...	11.340	0.028000	16.485	448.2	455.4
3	II	20	3.000	1.000	...	...	...	4.536	...	11.340	0.028000	18.605	467.76	471.6
4	II	20	2.270	...	1.730	...	...	4.082	...	5.444	0.028000	14.325	374.56	371.76
5	II	20	2.270	...	1.730	...	...	4.082	...	5.444	0.028000	14.793	422.68	429.3
6	II	20	2.270	...	1.730	...	...	4.082	...	5.444	0.028000	15.904	371.32	371.2
1	III	20	3.000	...	...	1.25	...	4.536	...	11.340	0.028000	17.804	472.1	477.0
2	III	20	3.000	...	...	1.25	...	4.536	...	14.516	0.028000	15.229	459.5	468.8
3	III	20	3.000	...	...	1.25	...	4.536	...	14.516	0.028000	18.183	468.4	468.3
4	III	20	2.270	...	...	...	1.720	4.536	...	9.072	0.028000	14.476	375.5	384.2
5	III	20	2.270	...	...	...	1.720	4.536	...	10.886	0.028000	14.999	430.2	438.5
6	III	20	2.270	...	...	...	1.720	4.536	...	10.886	0.028000	15.240	377.7	384.5

TABLE II.—COMPOSITION OF FOODS

Period	Food	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen-free extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
I	Corn.............	0.8927	0.04250	0.042787	0.01555	0.09719	0.6974	0.01280	0.000537	0.003257	0.000135	0.001310	0.001385	0.000281	0.002700	0.000195
I	Cottonseed meal..	0.9250	0.08007	0.1169	0.06767	0.42294	0.2479	0.05724	0.000593	0.01520	0.002074	0.006212	0.004607	0.000288	0.009951	0.000397
I	Clover hay........	0.9129	0.02323	0.305801	0.01574	0.09838	0.4194	0.06606	0.000317	0.01483	0.009332	0.002332	0.001131	0.000446	0.001216	0.000919
I	Timothy hay.....	0.9249	0.02414	0.312623	0.00702	0.04388	0.4977	0.04651	0.000223	0.01117	0.001678	0.000777	0.001177	0.002529	0.001388	0.00740
I	Corn silage.......	0.2928	0.00811	0.06979	0.00331	0.02069	0.1765	0.01772	0.000109	0.002182	0.000784	0.000848	0.000418	0.000477	0.000504	0.00308
II	Corn.....	0.8927	0.04250	0.042787	0.01555	0.09719	0.6974	0.01280	0.000537	0.003257	0.000135	0.001310	0.001385	0.000281	0.002700	0.000195
II	Cottonseed meal...	0.9327	0.08074	0.11785	0.06823	0.42644	0.2499	0.05771	0.000598	0.01533	0.002091	0.006264	0.004646	0.000290	0.010034	0.000400
II	Distiller's grains..	0.9353	0.13448	0.1616	0.04932	0.30825	0.3129	0.01809	0.000600	0.002427	0.000643	0.001214	0.004581	0.000451	0.003285	0.00205
II	Clover hay........	0.9099	0.02374	0.28816	0.01643	0.10269	0.4281	0.06723	0.000314	0.01539	0.009000	0.002195	0.001155	0.000430	0.001232	0.00132
II	Corn silage.... ..	0.2924	0.00859	0.07002	0.00316	0.01975	0.1783	0.01574	0.000113	0.00207	0.000801	0.000882	0.000428	0.000435	0.000461	0.00263
III	Corn..............	0.8927	0.04250	0.042787	0.01555	0.09719	0.6974	0.01280	0.000537	0.003257	0.000135	0.001310	0.001385	0.000281	0.002700	0.000195
III	Linseed oilmeal...	0.9191	0.07096	0.10779	0.05643	0.35269	0.3376	0.05011	0.000754	0.01122	0.003517	0.005573	0.004275	0.000256	0.007966	0.000744
III	Gluten feed.......	0.9429	0.03597	0.09075	0.04481	0.28006	0.4906	0.04547	0.009695	0.01061	0.001085	0.004042	0.007055	0.002114	0.008041	0.000960
III	Clover hay........	0.7780	0.02294	0.30168	0.01480	0.09250	0.4416	0.06349	0.000475	0.01467	0.008389	0.002093	0.001093	0.000373	0.001311	0.00133
III	Corn silage........	0.2702	0.00776	0.06414	0.00286	0.01788	0.1652	0.01520	0.000109	0.002148	0.000764	0.000801	0.000376	0.000429	0.000464	0.00241

Composition of salt: Na=0.39028; Cl=0.60172.

TABLE III.—COMPOSITION OF MILK (Percent)

Cow No. and period No.		Moisture	Nitrogen	Protein (N x 6.37)	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
1	I	88.41	0.3623	2.3079	3.1400	0.6776	0.0470	0.1544	0.0980	0.0127	0.0272	0.0772	0.0765
2	I	89.84	0.2625	1.6721	2.5260	0.6516	0.0420	0.1754	0.0754	0.0092	0.0234	0.1065	0.0769
3	I	89.77	0.2304	1.4676	2.5120	0.6253	0.0502	0.1542	0.0740	0.0086	0.0183	0.1274	0.0637
4	I	90.58	0.2805	1.7868	3.3740	0.6430	0.0487	0.1384	0.0912	0.0091	0.0288	0.0992	0.0778
5	I	90.34	0.2349	1.4963	2.7550	0.6129	0.0428	0.1450	0.0823	0.0080	0.0218	0.1099	0.0737
6	I	88.86	0.2725	1.7358	3.3220	0.6136	0.0366	0.1493	0.0832	0.0092	0.0216	0.0838	0.0767
1	II	88.41	0.3670	2.3378	3.2350	0.6588	0.0373	0.1548	0.0939	0.0113	0.0253	0.0726	0.0730
2	II	90.26	0.3006	1.9148	2.7160	0.6605	0.0408	0.1679	0.0834	0.0100	0.0257	0.0984	0.0879
3	II	90.48	0.2649	1.6874	2.6370	0.6139	0.0342	0.1462	0.0818	0.0084	0.0237	0.1041	0.0842
4	II	89.50	0.3712	2.3645	3.0330	0.7224	0.0538	0.1400	0.1068	0.0100	0.0244	0.1123	0.0768
5	II	88.15	0.3323	2.1168	3.1970	0.6809	0.0514	0.1443	0.0921	0.0101	0.0233	0.1121	0.0682
6	II	88.59	0.3791	2.4149	3.6570	0.6943	0.0399	0.1549	0.0953	0.0107	0.0250	0.0896	0.0753
1	III	88.36	0.3999	2.5474	3.1220	0.6504	0.0405	0.1568	0.0925	0.0114	0.0290	0.0797	0.0799
2	III	89.07	0.3683	2.3461	2.7430	0.7101	0.0479	0.1605	0.1093	0.0099	0.0284	0.1016	0.0801
3	III	89.63	0.2894	1.8435	2.6430	0.6396	0.0488	0.1410	0.0859	0.0082	0.0242	0.1075	0.0649
4	III	89.32	0.3809	2.4263	2.6910	0.7100	0.0599	0.1438	0.1074	0.0098	0.0278	0.1257	0.0766
5	III	89.04	0.3319	2.1142	2.9690	0.6582	0.0520	0.1499	0.0864	0.0094	0.0282	0.1212	0.0667
6	III	88.10	0.3682	2.3454	3.5250	0.6671	0.0401	0.1515	0.0983	0.0099	0.0285	0.0944	0.0794

TABLE IV.—CONSTITUENTS OF DAILY RATIONS (Grams)

Period and cow No.		Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Nitrogen-free extract	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
I	1	11533.7	452.8	2240.5	207.500	1296.9	7053.4	14.3340	96.6470	17.9443	25.1998	20.2284	30.4635	33.7528	63.0041
I	2	12315.8	479.8	2409.8	221.204	1382.5	7508.3	16.2619	102.9637	19.8891	27.6815	21.6137	34.0558	35.8282	70.0068
I	3	12868.8	483.1	2798.7	218.388	1365.0	7648.6	20.9183	116.6638	21.1022	26.4962	22.0873	34.5893	35.8051	76.4118
I	4	8342.2	344.1	1528.4	186.827	1167.7	4930.3	14.0313	87.0265	40.3550	20.2618	14.3731	18.5808	24.7787	4.9176
I	5	8511.8	352.2	1536.5	189.781	1186.2	5062.8	14.1107	87.6454	40.3806	20.5107	14.6363	18.5993	25.2917	4.9546
I	6	8326.0	343.3	1527.4	186.391	1165.0	4919.0	13.9848	86.9321	40.3468	20.2235	14.3386	18.5191	24.7084	4.9136
II	1	11053.9	413.3	2347.4	225.240	1407.8	6305.9	15.8425	118.4178	52.4033	30.1524	18.8936	24.8646	28.9501	36.7967
II	2	11053.9	413.3	2347.4	225.240	1407.8	6305.9	15.8425	118.4178	52.4033	30.1524	18.8936	24.8646	28.9501	36.7967
II	3	11053.9	413.3	2347.4	225.240	1407.8	6305.9	15.8425	118.4178	52.4033	30.1524	18.8936	24.8646	28.9501	36.7967
II	4	8950.5	472.8	1934.2	204.893	1280.6	4842.6	15.0817	85.6995	42.5175	18.8355	18.1138	22.3897	19.3508	23.6951
II	5	8950.5	472.8	1934.2	204.893	1280.6	4842.6	15.0817	85.6995	42.5175	18.8355	18.1138	22.3897	19.3508	23.6951
II	6	8950.5	472.8	1934.2	204.893	1280.6	4842.6	15.0817	85.6995	42.5175	18.8355	18.1138	22.3897	19.3508	23.6951
III	1	10420.1	408.3	2358.8	216.753	1354.9	6390.7	16.8720	114.6974	51.5176	29.4734	18.7204	24.5680	29.2660	34.8773
III	2	11278.2	432.9	2562.6	225.837	1411.6	6915.3	17.2181	121.5195	53.9440	32.0174	19.9146	25.9305	30.7396	42.5315
III	3	11278.2	432.9	2562.6	225.837	1411.6	6915.3	17.2181	121.5195	53.9440	32.0174	19.9146	25.9305	30.7396	42.5315
III	4	9628.5	332.9	2203.5	205.451	1284.1	5928.7	31.9656	111.6724	47.1562	26.6864	23.6475	26.7060	30.1156	29.9903
III	5	10118.6	347.0	2319.8	210.639	1316.5	6228.4	32.1634	115.5688	48.5421	28.1394	24.3295	27.4842	30.9573	34.3621
III	6	10118.6	347.0	2319.8	210.639	1316.5	6228.4	32.1634	115.5688	48.5421	28.1394	24.3295	27.4842	30.9573	34.3621

TABLE V.—CONSTITUENTS OF AVERAGE DAILY MILK (Grams)

Period and cow No.		Nitrogen	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphoru	Chlorine
I	1	66.680	577.902	124.709	8.650	28.417	18.036	2.337	5.006	14.079	14.208
I	2	45.899	441.678	113.934	7.344	30.669	13.184	1.609	4.092	13.446	18 621
I	3	45.744	498.738	124.148	9.967	30.615	14.692	1.707	3.633	12.647	25 294
I	4	41.565	499.966	95.281	7.217	20.508	13.514	1.349	4.268	11.529	14.700
I	5	33.727	395.568	88 001	6.145	20.819	11 817	1.149	3.130	10.582	15.780
I	6	41.990	511.897	94.552	5.640	23.006	12.821	1.418	3.328	11.819	12.913
II	1	67.754	597.231	121.625	6.886	23.579	17.335	2.086	4.671	13.477	13.403
II	2	49.554	447.731	108.883	6.726	27.678	13.748	1.649	4 237	14.490	16.221
II	3	49.284	490.605	114.214	6.363	27 200	15.219	1.563	4.409	15.665	19.367
II	4	53.175	434.483	103.485	7.707	20.055	15.299	1.433	3.495	11.002	16.082
II	5	49.157	472.935	100.726	7 604	21.346	13.624	1.494	3.447	10.089	16.583
II	6	60.293	581.617	110.423	6.346	24.636	15.157	1.702	3.976	11.976	14.250
III	1	71.198	555.836	115 796	7.211	27.916	16.469	2.030	5.163	14.225	14.190
III	2	56.086	417.712	108.136	7.294	24.441	16.645	1.508	4.325	12.198	15.472
III	3	52.621	480.574	116.298	8.873	25.638	15.619	1.491	4.400	11.801	19.547
III	4	55.141	389.560	102.782	8.671	20.817	15.548	1.419	4.024	11.089	18.197
III	5	49.783	445.331	98.726	7.800	22.484	12.959	1.410	4.230	10.005	18.179
III	6	56.111	537.183	101.661	6.111	23.087	14.980	1.509	4.343	12.100	14.386

TABLE VI.—CONSTITUENTS OF AVERAGE DAILY URINE (Grams)

Period and cow No.		Nitrogen	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
I	1	33.981	1.374	12.488	0.934	8.372	3.323	8.445	0.869	0.554
I	2	44.698	3.102	17.413	0.969	6.218	4.042	4.884	1.908	0.780
I	3	41.008	1.400	18.818	2.353	4.552	3.837	2.107	0.089	0.548
I	4	33.399	6.078	48.313	0.000	4.655	2.079	0.000	1.115	0.163
I	5	58.668	4.924	49.368	0.000	5.270	2.713	0.000	0.333	0.062
I	6	50.018	4.985	43.415	0.000	5.644	2.527	0.000	0.139	0.000
II	1	35.457	3.061	69.459	0.091	7.800	2.909	0.348	0.116	0.512
II	2	57.511	4.881	70.470	0.124	7.799	3.382	0.218	0.220	0.435
II	3	35.204	3.307	72.509	0.067	6.739	3.411	0.175	0.100	0.252
II	4	48.111	1.444	49.576	0.071	4.597	3.146	0.114	0.398	0.203
II	5	54.821	2.124	51.395	0.076	5.077	3.337	0.143	0.130	0.224
II	6	44.486	4.244	46.698	0.160	5.232	3.259	1.356	0.062	0.132
III	1	44.800	1.248	68.803	0.013	7.308	3.053	0.550	0.097	0.511
III	2	61.870	1.889	77.663	0.021	7.357	3.696	0.192	0.183	0.411
III	3	55.836	2.853	79.995	0.014	7.143	3.655	0.179	0.108	0.551
III	4	53.187	3.013	66.307	0.017	6.317	6.538	0.186	3.316	0.517
III	5	54.512	0.365	67.104	0.135	6.550	6.580	0.093	0.156	0.524
III	6	50.945	3.065	62.938	0.056	7.180	6.660	0.941	0.092	0.369

TABLE VII.—CONSTITUENTS OF AVERAGE DAILY FECES (Grams)

Period and cow No.		Total weight	Dry matter	Ether extract	Crude fiber	Nitrogen	Protein	Metabolic nitrogen	Indigestible nitrogen	Nitrogen-free extract
I	1	628,852	4934.8	131.827	1350.377	95.354	595.962	35.679	59.675	2426.053
I	2	530,681	4806.8	131.832	1265.814	96.333	602.079	34.383	61.950	2403.789
I	3	717 453	5584.8	197.111	1525.909	102.445	640.280	31.379	71.066	2755.526
I	4	133,413	2501.5	74.044	733.505	80.928	505.802	27.190	53.739	990.000
I	5	134,531	2566.9	74.503	769.786	86.140	538.376	26.234	59.907	977.500
I	6	161,797	2698.8	88.018	800.733	85.704	535.649	29.253	56.451	1059.400
II	1	637,225	4071.9	105.461	1280.504	101.956	637.225	32.753	69.203	1724.650
II	2	531,162	3718.2	96.937	1134.828	97.415	608.844	26.558	70.857	1563.100
II	3	534,908	3800.5	105.644	1131.598	97.353	608.458	27.040	70.314	1646.700
II	4	355,250	3227.5	92.383	909.618	93.715	585.718	26.004	67.711	1385.200
II	5	328,569	3073.8	100.986	871.694	98.127	613.295	25.809	72.318	1240.700
II	6	438,748	3060.3	89.373	893.291	95.494	596.834	26.742	68.752	1238.350
III	1	570,774	3758.6	97.346	1166.947	95.091	594.318	28.168	66.923	1593.450
III	2	564,593	4059.4	129.010	1128.057	98.493	615.583	28.766	69.727	1842.650
III	3	526,023	3966.2	115.804	1165.141	108.256	676.597	29.273	78.982	1663.850
III	4	462,960	3474.5	113.055	971.059	94.236	588.972	30.278	63.958	1491.950
III	5	522,582	3783.5	129.862	1093.764	96.495	603.092	28.664	67.831	1609.550
III	6	408,119	3653.9	114.216	1018.096	93.919	586.996	30.065	63.856	1589.627

TABLE VII.—CONSTITUENTS OF AVERAGE DAILY FECES (Grams)—Concluded

Period and cow No.		Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon
I	1	6.653	54.214	24.029	21.580	15.523	8.307	23.466	46.833
I	2	1.955	50.610	22.819	22.819	10.949	8.854	20.361	49.968
I	3	1.548	64.231	22.845	25.073	12.537	8.798	25.300	50.939
I	4	0.854	12.447	43.880	15.516	7.885	2.882	13.728	4.710
I	5	3.417	13.278	44.678	16.359	8.502	1.978	16.803	3.740
I	6	2.055	20.031	45.708	16.131	9.061	3.009	16.034	5.016
II	1	0.127	17.460	49.576	26.795	10.928	10.578	16.281	31.001
II	2	3.745	17.396	47.964	25.629	10.756	9.375	16.041	31.631
II	3	0.267	15.245	46.644	26.879	10.832	7.195	15.539	31.586
II	4	1.066	15.933	44.744	16.874	10.338	4.601	10.817	19.752
II	5	2.974	12.979	46.016	17.036	10.580	4.107	12.420	18.383
II	6	2.347	15.641	44.555	16.541	9.938	6.230	9.784	21.959
III	1	2.026	20.120	49.714	24.087	10.160	8.162	16.781	31.022
III	2	4.940	18.942	51.463	28.314	10.981	9.259	18.688	31.307
III	3	7.628	14.860	50.866	26.327	11.125	5.970	16.964	29.536
III	4	2.407	23.472	44.629	22.731	11.759	7.338	15.555	24.375
III	5	3.057	26.495	52.232	24.065	12.046	7.786	23.020	29.238
III	6	2.285	36.376	48.429	24.459	11.753	12.488	19.970	29.846

TABLE VIII, PERIOD I.—AVERAGE DAILY RATIONS; AND BALANCES OF MINERALS AND NITROGEN (Grams)

Cow No.	Av. daily milk yield	Average daily ration	Sodium Food Milk Urine Feces Balance	Potassium Food Milk Urine Feces Balance	Calcium Food Milk Urine Feces Balance	Magnesium Food Milk Urine Feces Balance	Sulphur Food Milk Urine Feces Balance	Chlorine Food Milk Urine Feces Balance	Phosphorus Food Milk Urine Feces Balance	Silicon Food Milk Urine Feces Balance	Nitrogen Food Milk Urine Feces Balance
1	18,405	Corn 4248; cottonseed meal 1160; timothy hay 3620; corn silage 11340; salt 23.884	14.334 8.650 1.374 6.653 — 2.343	96.647 28.417 12.488 54.214 + 1.528	17.944 18.036 0.934 24.029 —25.055	25.200 2.337 8.372 21.580 — 7.089	20.228 5.006 3.323 15.523 — 3.624	30.461 14.208 8.445 8.307 — 0.496	33.753 14.079 0.869 23.466 — 4.661	63.004 0.000 0.554 46.833 +15.617	207.500 66.680 33.981 95.354 + 11.485
2	17,485	Corn 4300; cottonseed meal 1240; timothy hay 3620; corn silage 13600; salt 28.000	16.262 7.344 3.102 1.[illegible]55 + 3.861	102.964 30.669 17.413 50.610 + 4.272	19.889 13.184 0.969 22.819 —17.083	27.682 1.609 6.218 22.819 — 2.964	21.614 4.092 4.042 10.949 + 2.531	34.056 18.621 4.884 8.854 + 1.697	35.828 13.416 1.908 20.361 + 0.113	70.007 0.000 0.780 49.968 +19.259	221.204 45.899 44.698 96.333 + 34.274
3	19,854	Corn 3774; cottonseed meal 1241; timothy hay 5440; corn silage 11340; salt 23.274	20.918 9.967 1.400 1.548 + 8.003	116.664 30.615 18.818 64.231 + 3.000	21.102 14.692 2.353 22.845 —18.788	26.496 1.707 4.552 25.073 — 4.836	22.087 3.633 3.837 12.537 + 2.080	34 589 25.294 2.107 8.798 — 1.610	35.805 12.647 0.089 25.300 — 2.231	76.412 0.000 0.548 50.939 +24.925	218.388 45.744 41.008 102.445 + 29.191
4	14,818	Corn 4325; cottonseed meal 818; clover hay 4080, salt 25.444	14.031 7.217 6.078 0.854 — 0.118	87.027 20.508 48.313 12.447 + 5.759	40.355 13.514 0.000 43.880 —17.039	20.262 1.349 4.655 15.516 — 1.258	14.373 4.268 2.079 7 885 + 0.141	18.581 14.70[illegible] 0.00[illegible] 2.882 + 0.999	24.779 11.529 1.115 13.728 — 1.593	4.918 0.000 0.163 4.710 + 0.045	186.827 41.565 33.399 80.928 + 30.935
5	14,358	Corn 4515; cottonseed meal 818; clover hay 4080; salt 25.386	14.111 6.145 4.924 3.417 — 0.375	87.645 20.819 49.368 13.278 + 4.180	40.381 11.817 0.000 44.678 —16.114	20.511 1.149 5.270 16.359 — 2.267	14.636 3.130 2.713 8.502 + 0.291	18.599 15.780 0.000 1.978 + 0.841	25.292 10.582 0.333 16.803 — 2.426	4.955 0.000 0.062 3.740 + 1.153	189.781 33.727 58.668 86.140 + 11.246
6	15,409	Corn 4310; cottonseed meal 815; clover hay 4080; salt 25.350	13.985 5.640 4.985 2.055 + 1.305	86.932 23.006 43.415 20.031 + 0.480	40.347 12.821 0.000 45.708 —18.182	20.224 1.418 5.644 16.131 — 2.969	14.339 3.328 2.527 9.061 — 0.577	18.519 12.913 0.000 3.009 + 2.597	24.708 11.819 0.139 16.034 — 3.284	4.914 0.000 0.000 5.016 — 0.102	186.391 41.990 50.018 85.704 + 8.679

TABLE IX, PERIOD II.—AVERAGE DAILY RATIONS; AND BALANCES OF MINERALS AND NITROGEN (Grams)

Cow No.	Av. daily milk yield	Average daily ration	Sodium Food Milk Urine Feces Balance	Potassium Food Milk Urine Feces Balance	Calcium Food Milk Urine Feces Balance	Magnesium Food Milk Urine Feces Balance	Sulphur Food Milk Urine Feces Balance	Chlorine Food Milk Urine Feces Balance	Phosphorus Food Milk Urine Feces Balance	Silicon Food Milk Urine Feces Balance	Nitrogen Food Milk Urine Feces Balance
1	18,462	Corn 3000; cottonseed meal 1000; clover hay 4536; corn silage 11340; salt 28.	15.843 6.886 3.061 0.127 + 5.769	118.418 28.579 69.459 17.460 + 2.920	52.403 17.335 0.091 49.576 −14.599	30.152 2.086 7.800 26.795 − 6.529	18.894 4.671 2.909 10.928 + 0.386	24.865 13.403 0.348 10.578 + 0.536	28.950 13.477 0.116 16.281 − 0.924	36.797 0.000 0.512 31.001 + 5.284	225.240 67.754 35.457 101.956 + 20.073
2	16.485	Corn 3000; cottonseed meal 1000; clover hay 4536: corn silage 11340; salt 28.	15.843 6.726 4.881 3.745 + 0.491	118.418 27.678 70.470 17.396 + 2.874	52.403 13.748 0.124 47.964 − 9.433	30.152 1.649 7.799 25.629 − 4.925	18.894 4.237 3.382 10.756 + 0.519	24.865 16.221 0.218 9.375 − 0.949	28.950 14.490 0.220 16.041 − 1.801	36.797 0.000 0.435 31.631 + 4.731	225.240 49.554 57.511 97.415 + 20.760
3	18,605	Corn 3000; cottonseed meal 1000: clover hay 4536; corn silage 11340; salt 28.	15.843 6.363 3.307 0.267 + 5.906	118.418 27.200 72.509 15.245 + 3.464	52.403 15.219 0.067 46.644 − 9.527	30.152 1.563 6.739 26.879 − 5.029	18.894 4.409 3.411 10.832 + 0.242	24.865 19.367 0.175 7.195 − 1.872	28.950 15.665 0.100 15.539 − 2.354	36.797 0.000 0.252 31.586 + 4.959	225.240 49.284 35.204 97.353 + 43.399
4	14,325	Corn 2270; distiller's grains 1730; clover hay 4082; corn silage 5444; salt 28.	15.082 7.707 1.444 1.066 + 4.865	85.700 20.055 49.576 15.933 + 0.136	42.518 15.299 0.071 44.744 −17.596	18.836 1.433 4.597 16.874 − 4.068	18.114 3.495 3.146 10.338 + 1.135	22.390 16.082 0.114 4.601 + 1.593	19.351 11.002 0.398 10.817 − 2.866	23.695 0.000 0.203 19.752 + 3.740	204.893 53.175 48.111 93.715 + 9.892
5	14,793	Corn 2270; distiller's grains 1730; clover hay 4082; corn silage 5444; salt 28.	15.082 7.604 2.124 2.974 + 2.380	85.700 21.346 51.395 12.979 − 0.020	42.518 13.624 0.076 46.016 −17.198	18.836 1.494 5.077 17.036 − 4.771	18.114 3.447 3.337 10.580 + 0.750	22.390 16.583 0.143 4.107 + 1.557	19.351 10.089 0.130 12.420 − 3.288	23.695 0.000 0.224 18.383 + 5.088	204.893 49.157 54.821 98.127 + 2.788
6	15,904	Corn 2270; distiller's grains 1730; clover hay 4082; corn silage 5444; salt 28.	15.082 6.346 4.244 2.347 + 2.145	85.700 24.636 46.688 15.641 − 1.265	42.518 15.157 0.160 44.555 −17.354	18.836 1.702 5.232 16.541 − 4.639	18.114 3.976 3.259 9.938 + 0.941	22.390 14.250 1.356 6.230 + 0.454	19.351 11.976 0.062 9.784 − 2.471	23.695 0.000 0.132 21.959 + 1.604	204.893 60.293 44.486 95.494 + 4.620

TABLE X; PERIOD III.—AVERAGE DAILY RATIONS; AND BALANCES OF MINERALS AND NITROGEN (Grams)

Cow No.	Av. daily milk yield	Average daily ration	Sodium Food Milk Urine Feces Balance	Potassium Food Milk Urine Feces Balance	Calcium Food Milk Urine Feces Balance	Magnesium Food Milk Urine Feces Balance	Sulphur Food Milk Urine Feces Balance	Chlorine Food Milk Urine Feces Balance	Phosphorus Food Milk Urine Feces Balance	Silicon Food Milk Urine Feces Balance	Nitrogen Food Milk Urine Feces Balance
1	17,804	Corn 3000; linseed oilmeal 1250; clover hay 4536; corn silage 11340; salt 28.	16.872 7.211 1.248 2.026 + 6.387	114.697 27.916 68.803 20.120 − 2.142	51.518 16.469 0.013 49.714 −14.678	29.473 2.030 7.308 24.087 − 3.952	18.720 5.163 3.053 10.160 + 0.344	24.568 14.190 0.550 8.162 + 1.666	29.266 14.225 0.097 16.781 1.837	34.877 0.000 0.511 31.022 + 3.344	216.753 71.198 44.800 95 091 + 5.664
2	15,229	Corn 3000; linseed oilmeal 1250; clover hay 4536; corn silage 14516; salt 28.	17.218 7.294 1.889 4.940 + 3.095	121.520 24.441 77.663 18.942 + 0.474	53.944 16.645 0.021 51.463 −14.185	32.017 1.508 7.357 28.314 − 5.162	19.915 4.325 3.696 10.981 + 0.913	25.931 15.472 0.192 9.259 + 1.008	30.740 12.198 0.183 18.688 − 0.329	42.532 0.000 0.411 31.307 +10.814	225.837 56.086 61.870 98.493 + 9.388
3	18,183	Corn 3000; linseed oilmeal 1250; clover hay 4536; corn silage 14516; salt 28.	17.218 8.873 2.853 7.628 − 2.136	121.520 25.638 79.995 14.860 + 1.027	53.944 15.619 0.014 50.866 −12.555	32.017 1.491 7.143 26.327 − 2.944	19.915 4.400 3.655 11.125 + 0.735	25.931 19.547 0.179 5.970 + 0.235	30.740 11.801 0.108 16.964 + 1.867	42.532 0.000 0.551 29.536 +12.445	225.837 52.621 55.836 108.256 + 9.124
4	14,476	Corn 2270; gluten feed 1720; clover hay 4536; corn silage 9072; salt 28.	31.966 8.671 3.013 2.407 +17.875	111.672 20.817 66.307 23.472 + 1.076	47.156 15.548 0.017 44.629 −13.038	26.686 1.419 6.317 22.731 − 3.781	23.648 4.024 6.538 11.759 + 1.327	26.706 18.197 0.186 7.338 + 0.985	30.116 11.089 3.316 15.555 + 0.156	29.990 0.000 0.517 24.375 + 5.098	205.451 55.141 53.187 94.236 + 2.887
5	14,999	Corn 2270; gluten feed 1720; clover hay 4536; corn silage 10886 salt 28.	32.163 7.800 0.365 3.057 +20.941	115.569 22.484 67.104 26.495 − 0.514	48.542 12.959 0.135 52.232 −16.784	28.139 1.410 6.550 24.065 − 3.886	24.330 4.230 6.580 12.046 + 1.474	27.484 18.179 0.093 7.786 + 1.426	30.957 10.005 0.156 23.020 − 2.224	34.362 0.000 0.524 29.238 + 4.600	210.639 49.783 54.512 96.495 + 9.849
6	11,430	Corn 2270; gluten feed 1720; clover hay 4536; corn silage 10886; salt 28.	32.163 6.111 3.065 2.285 +20.702	115.569 23.087 62.938 36.376 − 6.832	48.542 14.980 0.056 48.429 −14.923	28.139 1.509 7.180 24.459 − 5.009	24.330 4.343 6.660 11.753 + 1.574	27.484 14.386 0.941 12.488 − 0.331	30.957 12 100 0.092 19.970 − 1.205	34.362 0.000 0.369 29.846 + 4.147	210.639 56.111 50.945 93.919 + 9.664

TABLE XI.—AVERAGE DAILY FEED, MILK, LIVE WEIGHT AND BALANCE DATA FROM SIX COWS

Cow No.	Period and days	Rations (Pounds)	Milk yield Pounds	Gain or loss to the body (Grams) Live weight	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Nitrogen
1	I 19	Corn 9.37; cottonseed meal 2.56; timothy hay 7.98; corn silage 25.00; salt 0.053	40.58	− 78.5	− 2.343	+1.528	−25.055	−7.089	− 3.624	−0.496	−4.661	+15.617	+11.485
2	I 19	Corn 9.48; cottonseed meal 2.73; timothy hay 7.98; corn silage 30.0; salt 0 062	38.55	+771.4	+ 3.861	+4.272	−17.083	− 2.964	+2.531	+1.697	+0.113	+19.259	+34.274
3	I 19	Corn 8.32; cottonseed meal 2.74; timothy hay 11.992; corn silage 25.00; salt 0.051	43.77	−800.0	+ 8.003	+3.000	−18.788	−4.836	+2.080	−1.610	−2.231	+24.925	+29.191
4	I 10	Corn 9.53; cottonseed meal 1.80; clover hay 8.99; salt 0.056	32.67	0.0	− 0.118	+5.759	−17.039	−1.258	+0.141	+0.999	−1.593	+ 0.045	+30.935
5	I 10	Corn 9.95; cottonseed meal 1.80; clover hay 8.99; salt 0.056	31.65	+360.0	− 0.375	+4.180	−16.114	−2.267	+0.291	+0.841	−2.426	+ 1.153	+11.246
6	I 10	Corn 9.50; cottonseed meal 1.80; clover hay 8.99; salt 0.056	33.97	−240.0	+ 1.305	+0.480	−18.182	−2.969	−0.577	+2.597	−3.284	− 0.102	+ 8.679
1	II 20	Corn 6.61; cottonseed meal 2.20; clover hay 10.00; corn silage 25.00; salt 0.062	40.70	−100.0	+ 5.769	+2.920	−14.599	−6.529	+0.386	+0.536	−0.924	+ 5.284	+20.073
2	II 20	Corn 6.61; cottonseed meal 2.20; clover hay 10.00; corn silage 25.00; salt 0.062	36.34	+480.0	+ 0.491	+2.874	− 9.433	−4.925	+0.519	−0.949	−1.801	+ 4.731	+20.760
3	II 20	Corn 6.61; cottonseed meal 2.20; clover hay 10.00; corn silage 25.00; salt 0.062	41.02	+253.0	+ 5.906	+3.464	− 9.527	−5.029	+0.242	−1.872	−2.354	+ 4.959	+43.399
4	II 20	Corn 5.00; distiller's grains 3.81; clover hay 9.00; corn silage 12.00; salt 0.062	31.58	−187.0	+ 4.865	+0.136	−17.596	−4.068	+1.135	+1.593	−2.866	+ 3.740	+ 9.892
5	II 20	Corn 5.00; distiller's grains 3.81; clover hay 9.00; corn silage 12.00; salt 0.062	32.61	+440.0	+ 2.380	−0.020	−17.198	−4.771	+0.750	+1.557	−3.288	+ 5.088	+ 2.788
6	II 20	Corn 5.00; distiller's grains 3.81; clover hay 9.00; corn silage 12.00; salt 0.062	35.06	− 7.0	+ 2.145	−1.265	−17.354	−4.639	+0.941	+0.454	−2.471	+ 1.604	+ 4.620
1	III 20	Corn 6.61; linseed oilmeal 2.76; clover hay 10.00; corn silage 25.00; salt 0.062	39.25	+327.0	+ 6.387	−2.142	−14.678	−3.952	+0.344	+1.666	−1.837	+ 3.344	+ 5.664
2	III 20	Corn 6.61; linseed oilmeal 2.76; clover hay 10.00; corn silage 32.00; salt 0.062	33.57	+620.0	+ 3.095	+0.474	−14.185	−5.162	+0.913	+1.008	−0.329	+10.814	+ 9.388
3	III 20	Corn 6.61; linseed oilmeal 2.76; clover hay 10.00; corn silage 32.00; salt 0.062	40.09	− 7.0	− 2.136	+1.027	−12.555	−2.944	+0.735	+0.235	+1.867	+12.445	+ 9.124
4	III 20	Corn 5.00; gluten feed 3.79; clover hay 10.00; corn silage 20.00; salt 0.062	31.91	+580.0	+17.875	+1.076	−13.038	−3.781	+1.327	+0.985	+0.156	+ 5.098	+ 2.887
5	III 20	Corn 5.00; gluten feed 3.79; clover hay 10.00; corn silage 24.00; salt 0.062	33.07	+553.0	+20.941	−0.514	−16.784	−3.886	+1.474	+1.426	−2.224	+ 4.600	+ 9.849
6	III 20	Corn 5.00; gluten feed 3.79; clover hay 10.00; corn silage 24.00; salt 0.062	33.60	+453.0	+20.702	−6.832	−14.923	−5.009	+1.574	−0.331	−1.205	+ 4.147	+ 9.664

TABLE XII.—CUBIC CENTIMETERS NORMAL SOLUTION OF MINERALS IN DAILY RATIONS

Period and cow No.		Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Silicon	Total base	Total acid	Excess base	Excess acid
I	1	623.22	2471.79	895.65	2072.35	1261.52	859.09	2174.79	4452.59	6063.01	8747.99	....	2684.98
I	2	707.04	2633.34	992.72	2276.44	1347.91	960.40	2308.52	4947.48	6609.54	9564.31	....	2954.77
I	3	909.49	2983.73	1053.27	2178.96	1377.44	975.45	2307.03	5400.13	7125.45	10060.05	....	2934.60
I	4	610.06	2225.74	2014.23	1666.27	896.36	523.99	1596.57	347.53	6516.30	3364.45	3151.85	....
I	5	613.51	2241.57	2015.50	1686.74	912.77	524.51	1629.62	350.15	6557.32	3417.05	3140.27	....
I	6	608.03	2223.33	2013.82	1663.12	894.21	522.25	1592.04	347.25	6508.30	3355.75	3152.55	....
II	1	688.80	3028.59	2615.59	2479.64	1178.27	701.20	1865.34	2600.47	8812.62	6345.28	2467.34	....
II	2	688.80	3028.59	2615.59	2479.64	1178.27	701.20	1865.34	2600.47	8812.62	6345.28	2467.34	....
II	3	688.80	3028.59	2615.59	2479.64	1178.27	701.20	1865.34	2500.47	8812.62	6345.28	2467.34	....
II	4	655.73	2191.80	2122.16	1548.97	1129.64	631.41	1246.83	1674.56	6518.66	4682.44	1836.22	....
II	5	655.73	2191.80	2122.16	1548.97	1129.64	631.41	1246.83	1674.56	6518.66	4682.44	1836.22	....
II	6	655.73	2191.80	2122.16	1548.97	1129.64	631.41	1246.83	1674.56	6518.66	4682.44	1836.22	....
III	1	733.57	2933.44	2571.38	2423.80	1167.47	692.84	1885.69	2464.83	8662.19	6210.83	2451.36	....
III	2	748.61	3107.92	2692.49	2633.01	1241.95	731.26	1980.64	3005.76	9182.03	6959.61	2222.42	....
III	3	748.61	3107.92	2692.49	2633.01	1241.95	731.26	1980.64	3005.76	9182.03	6959.61	2222.42	....
III	4	1389.81	2856.07	2353.69	2194.61	1474.74	753.13	1940.44	2119.46	8794.18	6287.77	2506.41	....
III	5	1398.41	2955.72	2422.86	2314.10	1517.27	775.08	1994.67	2428.42	9091.09	6715.44	2375.65	....
III	6	1398.41	2955.72	2422.86	2314.10	1517.27	775.08	1994.67	2428.42	9091.09	6715.44	2375.65	....

TABLE XIII.—RELATION OF URINARY AMMONIA, PHOSPHATES AND SULPHATES TO BALANCE OF MINERAL ACIDS AND BASES IN THE RATION—Amounts per day

Period and cow No.		Average daily rations Grams	Excess base in ration	Excess acid in ration	Ammonia	Phosphorus	Total sulphur	Total sulphates	Inorganic sulphates	Ethereal sulphates
			C. C.	C. C.	Grams	Grams	Grams	Grams	Grams	Grams
I	1	Cottonseed meal 1160; corn 4248; timothy hay 3620; corn silage 11340; salt 23.884	....	2684.98	2.412	0.869	3.323	2.476	0.658	1.704
I	2	Cottonseed meal 1240; corn 4300; timothy hay 3620; corn silage 13600; salt 28.000	....	2954.77	2.013	1.908	4.042	3.208	0.750	2.344
I	3	Cottonseed meal 1241; corn 3774; timothy hay 5440; corn silage 11340; salt 23.274	....	2934.60	1.823	0.089	3.837	3.180	0.123	2.762
I	4	Cottonseed meal 818; corn 4325; clover hay 4080; salt 25.444	3151.85	....	0.229	1.116	2.078	1.571	0.041	1.567
I	5	Cottonseed meal 818; corn 4515; clover hay 4080; salt 25.386	3140.27	....	0.216	0.333	2.713	1.919	0.011	1.909
I	6	Cottonseed meal 815; corn 4310; clover hay 4080; salt 25.350	3152.55	....	0.247	0.139	2.527	1.740	0.126	1.648
II	1	Cottonseed meal 1000; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	2467.34	....	0.319	0.116	2.909	2.086	0.308	1.798
II	2	Cottonseed meal 1000; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	2467.34	....	0.352	0.219	3.382	2.721	0.483	2.279
II	3	Cottonseed meal 1000; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	2467.34	....	0.322	0.998	3.411	2.652	0.275	2.227
II	4	Distiller's grains 1730; corn 2270; clover hay 4082; corn silage 5444; salt 28.000	1836.22	....	0.536	0.398	3.146	2.248	0.316	1.909
II	5	Distiller's grains 1730; corn 2270; clover hay 4082; corn silage 5444; salt 28.000	1836.22	....	0.269	0.130	3.337	2.484	0.195	2.171
II	6	Distiller's grains 1730; corn 2270; clover hay 4082; corn silage 5444; salt 28.000	1836.22	....	0.380	0.062	3.259	2.560	0.183	2.138
III	1	Linseed meal 1250; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	2451.36	....	0.266	0.097	3.053	2.333	0.174	2.197
III	2	Linseed meal 1250; corn 3000; clover hay 4536; corn silage 14516; salt 28.000	2222.42	....	0.326	0.183	3.696	3.051	0.285	2.839
III	3	Linseed meal 1250; corn 3000; clover hay 4536; corn silage 14516; salt 28.000	2222.42	....	0.302	0.108	3.655	2.844	0.016	2.644
III	4	Gluten feed 1720; corn 2270; clover hay 4536; corn silage 9072; salt 28.000	2506.41	....	0.570	3.316	6.538	5.406	1.410	4.116
III	5	Gluten feed 1720; corn 2270; clover hay 4536; corn silage 10886; salt 28.000	2375.65	....	0.316	0.156	6.580	5.583	1.775	3.671
III	6	Gluten feed 1720; corn 2270; clover hay 4536; corn silage 10886; salt 28.000	2375.65	....	0.466	0.093	6.659	5.956	1.329	4.144

TABLE XIV.—COEFFICIENTS OF DIGESTIBILITY OF RATIONS

Period and cow No.		Average daily rations Grams	Protein	Nitrogen-free extract	Ether extract	Crude fiber
I	1	Cottonseed meal 1160; corn 4248; timothy hay 3620; corn silage 11340; salt 23.884	71.24	65.60	70.89	39.73
I	2	Cottonseed meal 1240; corn 4300; timothy hay 3620; corn silage 13600; salt 28.000	71.99	67.98	72.52	47.47
I	3	Cottonseed meal 1241; corn 3774; timothy hay 5440; corn silage 11340; salt 23.274	67.46	63.97	59.20	45.48
I	4	Cottonseed meal 818; corn 4325; clover hay 4080; salt 25.444	71.24	79.92	78.48	52.01
I	5	Cottonseed meal 818; corn 4515; clover hay 4080; salt 25.386	68.43	80.69	78.85	49.90
I	6	Cottonseed meal 815; corn 4310; clover hay 4080; salt 25.350	69.71	78.46	74.36	47.58
II	1	Cottonseed meal 1000; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	69.28	72.65	74.48	45.45
II	2	Cottonseed meal 1000; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	68.54	75.21	76.55	51.66
II	3	Cottonseed meal 1000; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	68.78	73.89	74.44	51.79
II	4	Distiller's grains 1730; corn 2270; clover hay 4082; corn silage 5444; salt 28.000	66.95	71.40	80.47	52.97
II	5	Distiller's grains 1730; corn 2270; clover hay 4082; corn silage 5444; salt 28.000	64.70	74.38	78.64	54.93
II	6	Distiller's grains 1730; corn 2270; clover hay 4082; corn silage 5444; salt 28.000	66.44	74.43	81.10	53.82
III	1	Linseed meal 1250; corn 3000; clover hay 4536; corn silage 11340; salt 28.000	69.12	75.07	76.16	50.53
III	2	Linseed meal 1250; corn 3000; clover hay 4536; corn silage 14516; salt 28.000	69.13	73.35	70.20	55.98
III	3	Linseed meal 1250; corn 3000; clover hay 4536; corn silage 14516; salt 28.000	65.03	75.94	73.25	54.53
III	4	Gluten feed 1720; corn 2270; clover hay 4536; corn silage 9072; salt 28.000	68.86	74.84	66.04	55.93
III	5	Gluten feed 1720; corn 2270; clover hay 4536; corn silage 10886; salt 28.000	67.80	74.16	62.58	52.85
III	6	Gluten feed 1720; corn 2270; clover hay 4536; corn silage 10886; salt 28.000	51.50	74.48	67.08	56.11