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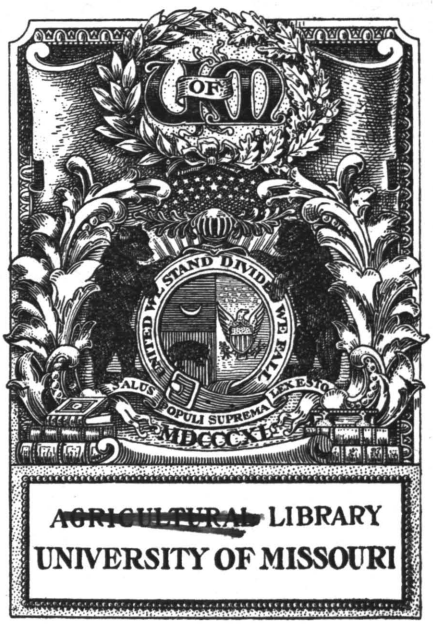

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A T H E S I S

THE EFFECT OF THE PLANE OF NUTRITION ON THE ASH CONSTITUENTS OF COW'S MILK.

by

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THE EFFECT OF THE PLANE OF NUTRITION ON THE ASH CONSTITUENTS OF COW'S MILK.

INTRODUCTION.

Only within the last few years has the importance of the mineral elements of food been recognized. The mineral elements are especially necessary during the period of growth, for, while they form but a very small part of the food, serious results occur when they are not present in sufficient quantity. Calcium and phosphorous are needed for the building up of bony structure. Rickets is sometimes caused by an insufficient supply of these in the food. A condition resembling rickets in children was produced in puppies by feeding them only lean and fat meat, while other puppies, from the same litter developed normally with the same food and, in addition, bones to gnaw. Phosphorous is needed for the central nervous system and iron in the haemoglobin of the blood.

Since the mineral elements are so necessary in the food during growth, the ash constituents of cow's milk, which forms such an important part of the diet of infants, is of considerable importance in connection with the use of milk as food. One thing that might effect the mineral

content of the milk, is the plane of nutrition of the cows. It is quite certain that all commercially kept dairy cows are at some periods underfed and at others overfed. It is possible that in the same herd and at the same time some cows may be underfed and others overfed. In times of drought when pasturage is poor or there is a shortage in the food supply, it is possible that the cows furnishing the milk for an entire city may be underfed. Just what effect the diet has on the mineral constituents of milk we do not know. It was with the hope of contributing something to the knowledge of milk as a food that the present investigation was undertaken.

Literature.---The literature is very meager and consists chiefly of general statements unsupported by experimental data. Jolles and Friedjung[1] in a paper on iron in milk say that the food has some influence on the iron content of milk. The New York Agricultural Experiment Station[2] publish tables which show that the total out put in the milk of potassium and calcium is slightly decreased by a large decrease in those elements in the food. The Wisconsin Experiment Station state[3] that the composition of the milk in respect to the ash elements is

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1. A. Jolle & J. K. Friedung Archinfür Path. und Pharm. 1901, 46, P2 47.
3. Hart. McCollum & Humphrey Wis. Exp. Sta. Research Bul. 5. 1909 P. 179, 180 - P. 188.
2. W. H. Jordan, E. B. Hart & A. J. Patten, N. Y. Expt. Sta. Tech. Bul. No. 1 1906 p. 51

constant even when a wide variation in intake of these elements prevailed, also that the form of intake of phosphorous, magnesium and potassium, whether as phytates, sulphates or chlorides appeared to have no influence on the amounts secreted by the mammary cells.

One of the most significant facts shown in this experiment[1] is that the animals will draw upon the skeleton to supply deficiencies of the lime in the food. During their feeding experiment of 110 days there was a loss of about 25 per cent of the entire lime content of the animal. A certain and definite percentage had been maintained in the milk and an apparent waste possibly indicating general cell metabolism, had been excreted. This large loss above that used for milk production could have had no other source than the skeleton.

Plan of Investigation.

The Missouri Experiment Station in cooperation with the Dairy Division of the U. S. Department of Agriculture has for some time been carrying on investigations to determine the effect of overfeeding and underfeeding upon the composition of milk. The plan of feeding and rations used in conducting this investigation were not arranged especially for the purpose of determining the influence of the plane of nutrition upon the composition of the ash

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1. Ibid. p. 186.

which is the object of the investigation here reported. However, by selecting for ash analysis samples of milk which represent the different planes of nutrition, it is possible to study the effect of underfeeding as compared with normal and overfeeding upon the constituents of the ash. The plan provided for using two animals, both near the beginning of the milking period. These animals were fed a normal ration, that is, a sufficient amount of nutrients, as far as could be estimated by calculation, to supply maintenance requirements of the body and also material for the amount of milk which the animals were producing. After the animals were kept from two to three weeks under this condition in order to secure fair samples, the ration was reduced in quantity, at the same time maintaining as nearly as possible the same ratio between the grain and the roughage fed. The plan called for the ration to be reduced to the point at which sufficient amount would be supplied for maintenance plus one-half the amount estimated to provide the nutrients necessary for milk production. The animals were kept on this ration for periods varying from two to four weeks. At the end of these periods the feeding was again increased until the normal ration was reached, and further increased when possible until a ration sufficient for maintenance and milk production was fed, plus from 25 to 50 per cent

of the nutrients used for the milk production. Many difficulties were encountered in carrying out such a plan. In the first place we have no exact data upon which to calculate the maintenance requirement, nor the amount needed in excess of maintenance by the particular animals to support milk production. Certain average figures are in use for this purpose, as for example, those given by Armsby[1], and other data is at hand which has been secured as a result of an investigation carried on at the Missouri Experiment Station.

Animals Used.---The animals supplying the samples used in this investigation were two registered Ayrshire cows:

Lady Douglass of Riverside, age 6 years, hereafter referred to as No. 300. Her production for the previous year was 11,592 pounds of milk and 447 pounds of butterfat. Date of last calving was June 10, 1910, or 29 days before the first sample was taken.

Anna H. Douglass, age 7 years, hereafter referred to as No. 301. Her production for the previous year was 10,933 pounds of milk and 423 pounds of butterfat. Date of last calving was June 17, 1910, or 16 days before the first sample was taken.

Both animals were healthy, mature cows, capable of producing liberal quantities of milk as indicated by the records of production given. The animals were kept in

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1. U. S. Dept. Agr. Farmers Bul. 346.

the stable during the night and turned into a lot during the day where they had access to water but no opportunity to get food except as it was supplied them.
They were fed and milked twice daily at regular intervals and by the same attendant except in a few cases where a change was unavoidable.

The ration fed consisted of alfalfa hay of the best quality, of that grade which is known on the market as "Choice". The grain ration consisted of a mixture of ground corn, four parts; wheat bran, two parts; and oilmeal, one part. The animals had access to salt daily. Approximately two parts of grain were fed to each three parts of hay. All the feedstuffs used were analyzed. The cows were weighed each morning after being fed and milked and before receiving water.

The amount of feed required for each animal was calculated upon the basis of energy value, without regard to the protein content, since the composition of the ration remained the same. The energy value was calculated for maintenance by using the figure .6 Therms (1000 calories) for each 100 pounds of live weight. This figure was derived from the maintenance requirements as determined for four Jersey cows at the Missouri Experiment Station.

It has been shown[1] that an average of .391 Therms

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1. Missouri Experiment Sta. Research Bul. No. 2.

were required per pound of milk by two Jersey cows under investigation for the entire year. The average energy value of the milk of these cows, found by applying the combustion value of the milk constituents as given by Hammersten[1], was .417 Therms per pound. The energy value of a number of lots of milk containing 3, 4, and 5 % fat respectively, of which complete analysis was at hand, was calculated. From these calculations a proportion was made, using the energy value required by the Jersey cows for milk production, the energy value of the milk they produced, and the energy value of the average figures for milk containing 3, 4, and 5 per cent fat. In this way a figure was derived which should show approximately the energy value required for the production of milk with the different compositions stated. While data based upon experimental results for milk of different compositions would be preferable, no such figures have ever been determined, and it is believed the plan followed gives as fair a statement of the probable needs of the animals for the production of milk varying in composition, as can be given with our present limited knowledge of this subject.

Tables I and VI give the data on energy value calculated for each period included in the samples taken for the ash analysis. The energy value of the milk is determined

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1. Physiological Chem. 1906 P. 625

by the plan described, while the energy value of the ration is calculated by using Armsby's tables based upon average composition of feed-stuffs.[1] The last columns of these tables show the energy value of the ration expressed in per cent of the normal.

The estimated normal ration, that is, the one that should maintain the animals under the conditions existing, is represented by 100. It will be observed by an examination of these figures that in some cases the ration designated as normal falls short of the amount calculated, while in other periods where the ration is supposed to be above normal, it is scarcely more than normal or even in a few cases below. These apparent discrepancies come about for the lack of a more accurate basis upon which to make calculations at the time of feeding the animal and the additional difficulty that at times the animals would not consume as much feed as was planned.

Collection of Samples.---The milk samples were taken in composites for one day or several days. When the total amount of milk given during the sampling period did not exceed that needed for the analyses the entire amount was taken. In other cases the same percent of each milking was taken, that percent being chosen in each case

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1. U. S. Dept. Agr. Farmers' Bul. 346.

to give the amount required for analysis. 10 drops of formalin per pound were added as a preservative, and the milk kept in stoppered bottles at 10^{0} Centigrade until used.

Analyses---The milk was analyzed for nitrogen, fat, moisture, total solids, sugar and ash. The analyses with the exception of nitrogen were made by the official methods.[1] The nitrogen was determined by the Kjeldahl method, the oxidation being effected by means of sulphuric acid aided by a little copper sulphate. For the ash, two portions of 500 c.c. each were acidified with Acetic acid, evaporated to dryness and ashed, giving duplicate results of the percent of ash in the milk. In the samples through sample No. 1141, the ash was leached when partly burned and the insoluble part ignited at a higher temperature till free from carbon. It was then ground with the soluble portion which had been evaporated to dryness and the two ignited at a low heat. In the remaining samples the ash was not leached but was burned over a low flame till the ash contained little or no visible carbon.

The ash was analyzed for calcium, magnesium, sodium, potassium, phosphorous, iron, sulphur and chlorine. A higher sulphur and chlorine content would probably have been found had the analyses been made on the original milk. However, as the analysis of the ash was not under-

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1. U. S. Dept. Agr. Bureau of Chem. Bul. 107 Revised.

taken till some months after the original experiment this was impossible.

A weighed sample of the ash was taken up with water and acid, made up to a definite volume and aliquot portions taken for each analysis. Nitric acid was used in dissolving the ash for the chlorine and phosphorous determinations, and hydrochloric acid, for the rest. The chlorine was determined by the Volhard method[1], the phosphorous by the Uranium acetate method for total phosphates[2]. This method was compared with the gravimetric method for total phosphoric acid,[3] and found slightly lower.

The iron was determined by the Mixer and Dubois modification of the Zimmermann Reinhardt method.[4] The sulphur was determined by the Folin method[5]. The Sodium and potassium were determined by the Hans Aron method.[6] The calcium was determined by the following method which is a modification of several methods. The sample diluted to about 100 c.c. was made just alkaline with NH_4OH, acidified with acetic acid, and about 3 c.c. of 50 % acetic acid added in excess. The mixture was heated to boiling and while boiling an excess of a sat-

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1. Food Inspection & Analysis. Leach 1909 P. 304
2. Practical Physiol. Chem. Hawk. 1909 p. 383.
3. U. S. Dept. Agric. Bureau Chem. 1908 Bul. 107 Revised. p.1
4. Mixer & Dubois J. Am. Chem. Soc., 1895, 17, 405.
5. Folin. Jour. of Biol. Chem. I Amer. Jour. Physiol. 13.
6. Handbuch der Biochem. Arbeit. E. Abderhalden 1910 Vol. I, 410

urated solution of ammonium oxalate was added in small portions, waiting for the solution to boil each time and the calcium oxalate to become granular. After standing several hours the calcium was filtered and washed. The precipitate was dissolved in 20 c.c. hot HCl. Sp.Gr. 1.04 and titrated at 70°C. in a bulk of about 100 c.c. with N/20 $KMnO_4$. The magnesium was determined in the filtrate from the calcium[1] by the official method.

Experiment A. Cow No. 300.

Cow 300, previously described, was fed during the following periods as indicated:

1.	July 3-15	Normal
2.	July 16-Aug. 7	Above normal
3.	Aug. 8-22	Normal
4.	Aug. 23 -Sep.7	Sub-normal
5.	Sept. 8-15	Sub-normal to normal
6.	Sept. 15-Oct.4	Above normal
7.	Oct. 5-7	Above normal to sub normal
8.	Oct. 8-21	Sub-normal
9.	Oct. 22-Nov. 3	Normal

Table I gives the average weight of the cow during each period, the pounds of hay and of grain mixture fed, the pounds of milk given and the energy value, calculated

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1. U. S. Dept. Agr. Bureau Chem. 1908 Bul. 107 Revised p. 16.

as previously described. The weight of the cow varies as we should expect with the ration given, except, that the increase when the normal ration was fed after the sub-normal, was not as great as the decrease when the change was made from a normal to a sub normal ration. The amount of nutrients in the ration fed did not always correspond to the amount planned, for the reason given more fully in the general plan of the experiment. Thus, "normal ration No. 1" was 98.1 per cent, instead of 100, "normal ration No. 3", 110.4 per cent, and "normal ration No. 9", 98.2 per cent.

Table II gives the composition of the milk in percent of protein, fat sugar, and total ash. The percent of total ash varies slightly but not with any uniformity, the percent of sugar remains quite constant, but the percents of protein and of fat increase as the amount of milk given (See Table I) decreases.

Table III gives the percentages of the various mineral elements in the milk. It will be observed that the percent of P_2O_5 drops during "Above Normal. Period No. 2", remains fairly constant thru "normal period No. 3" and "sub-normal period No. 4", rises in "above normal period No. 6" and does not drop again till the latter part of the succeeding "subnormal period No. 8". The K_2O varies rather inconsistently in above normal period 2, but after that rises and falls quite regularly with the ration. It will be observed

too, that the percent of K_2O increases as the amount of milk the animal was producing decreased. The Na_2O shows no direct relation with the rations, but shows a gradual decrease in the milk as the amount of milk given decreased. Apparently no relation exists between the percents of MgO and CaO and the rations. However, the CaO drops suddenly in the beginning of "Above normal period No. 2" and after that shows a gradual increase as the amount of milk produced decreased.

Table Iv gives the amount of the daily intake of the various elements. The calcium, magnesium, phosphorous, and sulphur were determined on the actual feeds. The amounts of the other mineral elements were taken from Henry's table.[1] As the same feeds were given and in nearly the same proportions during the entire experiment the amounts of the various minerals received in the feed varied with the ration. The amounts of sodium and chlorine in the food are of little value in the present case as the animal had access to salt daily and no records were kept of the amounts consumed.

Table V gives the number of grams of the various mineral constituents in the daily output of milk. The amounts of CaO, K_2O, P_2O_5, Fe and SO_3 vary quite consistently with the rations, but of course a much smaller quantity appeared in the milk as the amount of milk producer decreased.

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1. W. A. Henry, Feeds & Feeding, 1910 p. 593

Table I Rations. Cow 300

Period.	Ration.	Average Weight	Lbs. Hay per day	Lbs. Grain per day.	Lbs. Milk per day.	Energy Value of Ration Therms	Energy Value for Maintenance Therms	Energy Value for Milk Therms	Total Energy Value Required Therms.	Ration in per cent of normal
1. I	Normal	955	20	14.6	44.68	17.946	5.730	12.555	18.285	98.1
2 II	Above Normal	958	22	19.	46.60	21.976	5.748	13.653	19.401	113.2
2 III	Above Normal	958	22	19	45.90	21.976	5.748	12.301	18.049	121.8
2 IV	Above Normal	958	19	19.	43.18	18.332	5.592	11.572	17.164	106.8
3 V	Normal	932	19	15.	39.68	17.911	5.592	10.634	16.226	110.4
4. VI	Sub. Normal	932	14	9.34	30.41	11.901	5.370	8.727	14.097	84.4
6 VII	Above Normal	945	19	14.	30.80	17.153	5.670	9.763	15.433	111.1
8 VIII	Sub Normal	916	12	7.	27.80	9.437	5.496	7.811	13.307	70.9
8 IX	Sub Normal	916	12	7.	19.17	9.436	5.496	5.961	11.457	82.4
9 X	Normal.	921	16.3	8.9	21.11	12.418	5.526	7.114	12.640	98.2

TABLE II COMPOSITION OF MILK COW NO. 300.

Period	Date	Ration	Protein %	Fat %	Sugar %	Total Ash %
1.	Jul. 9-15	Normal	2.93	3.23	4.61	0.70
2.	Jul. 18	Above Normal	2.68	3.43	4.55	0.68
2	Jul. 20	Above Normal	2.49	2.61	4.63	0.70
2	Aug. 1-7	Above Normal	3.06	3.078	4.46	0.66
3.	Aug. 16-22	Normal	3.00	2.993	4.52	0.65
4.	Sept. 1-7	Sub Normal	3.00	3.3	4.81	0.69
6.	Sept. 28-Oct. 4	Above Normal	3.19	3.81	4.57	0.75
8	Oct 12	Sub Normal	3.25	3.79	4.51	0.74
8	Oct. 19-21	Sub Normal	3.25	3.74	4.35	0.71
9.	Oct. 28-Nov.3	Normal	3.45	4.20	4.62	0.72

Table III Percentages of Minerals in the Milk. Cow No. 300.

Period	Ration	Total Ash %	CaO %	MgO %	Na_2O %	K_2O %	P_2O_5 %	Fe %	SO_3 %	Cl. %
1.	Normal	0.70	0.1401	0.0172	0.0541	0.1745	0.2207	lost	0.0072	0.0035
2.	Above Normal	0.68	0.1235	0.0145	0.0541	0.1667	0.2013	0.0028	0.0084	0.0019
	Above Normal	0.70	0.1297	0.0156	0.0594	0.1792	0.2051	0.0052	0.0082	0.0219
	Above Normal	0.66	0.1260	0.0139	0.0540	0.1634	0.1831	0.0054	0.0119	0.0035
3.	Normal	0.65	0.1251	0.0122	0.0411	0.1784	0.1803	0.0054	0.0119	0.0086
4.	Sub Normal	0.69	0.1363	0.0156	0.0484	0.1783	0.1795	0.0058	0.0070	0.0995
6.	Above Normal	0.75	0.1453	0.0177	0.0441	0.2119	0.2152	0.0083	0.0102	trace
8.	Sub Normal	0.74	0.1465	0.0175	0.0478	0.1818	0.2137	0.0053	0.0101	0.0312
	Sub Normal	0.71	0.1487	0.0170	0.0640	0.1956	0.1853	0.0084	0.0106	0.0669
9.	Normal.	0.72	0.1535	0.0158	0.0403	0.2105	0.1810	0.0090	0.0153	0.0888

Table IV — Mineral Elements in Feed. — Cow No. 300.

Period	Ration	Total Ash grams	CaO grams	MgO grams	Na_2O grams	K_2O grams	P_2O_5 grams	Fe grams	SO_3 grams	Cl grams
1.	Normal	118.1	194.5	76.2	9.53	187.3	134.5	0.147	155.0	32.7
2.	Above Normal	1345	216.9	91.9	10.94	218.3	162.5	0.179	165.5	36.1
	Above Normal	1345	216.9	91.9	10.94	218.3	162.5	0.179	165.5	36.1
	Above Normal	1199	189.3	86.9	9.85	200.0	155.0	0.169	155.0	28.4
3.	Normal	1140	186.1	75.7	9.23	182.5	136.0	0.146	138.5	28.2
4.	Sub-Normal	763	135.8	50.8	6.53	127.1	88.3	0.051	96.7	22.8
6.	Above Normal	1124	185.4	72.6	9.07	178.5	126.9	0.140	135.9	31.0
8	Sub-Normal	682	115.6	40.8	5.44	108.3	70.0	0.096	81.2	19.5
	Sub Normal	682	115.6	40.8	5.44	108.3	70.0	0.096	81.2	19.5
9.	Normal	918	154.8	53.6	7.30	139.9	96.7	0.054	106.5	26.5

Table V Mineral Elements in Milk Cow 300

Period	Ration	Total Ash grams	CaO grams	MgO grams	Na_2O grams	K_2O grams	P_2O_5 grams	Fe grams	SO_3 grams	Cl grams
1.	I Normal	142.0	28.39	3.49	11.00	35.43	44.70	lost.	1.457	0.703
2.	II Above Normal	143.9	29.60	3.07	11.45	35.21	42.60	0.573	1.748	0.406
	III Above Normal	145.9	29.20	3.25	12.38	37.30	42.70	1.162	1.708	0.456
	IV Above Normal	127.4	25.05	2.72	10.60	32.04	35.90	1.049	2.330	0.684
3.	V Normal	124.3	22.28	2.20	7.40	32.18	32.50	0.964	2.140	1.546
4.	VI Sub-Normal	96.4	20.07	2.18	6.77	24.90	25.05	0.810	0.990	1.390
6.	VII Above Normal	118.1	20.15	2.69	6.72	32.20	32.74	1.262	1.550	0.000
8.	VIII Sub Normal	93.2	18.50	2.20	6.02	22.90	27.34	0.667	1.272	0.393
	IX Sub Normal	63.5	12.92	1.52	6.41	17.50	16.59	0.750	0.947	0.597
9.	X Normal.	68.9	14.81	1.53	3.86	20.15	17.31	0.861	1.465	0.859

Table VI Rations. Cow 301.

Period		Ration	Average Weight	Lbs. Hay per day	Lbs Grain per day	Lbs Milk per day	Energy Value of Ration. Therms	Energy Value for Maintenance Therms	Energy Value for Milk Therms	Total Energy Value Required Therms	Ration in percent of Normal.
1.	I	Normal	998	17.1	11.2	37.15	14.374	5.988	11.330	17.318	83.0
2.	II	Sub-Normal	931	14.0	9.0	35.30	11.641	5.580	10.131	15.711	74.4
	III	Sub-Normal	931	14.0	9.0	34.90	11.641	5.580	10.016	15.596	74.6
	IV	Sub-Normal	931	13.9	9.0	34.11	11.616	5.580	10.403	15.983	72.6
	V	Sub-Normal	931	13.8	9.0	33.03	11.570	5.580	% fat lost		
3.	VI	Normal	939	16.4	12.4	34.03	15.055	5.634	9.562	15.196	99.1
4.	VII	Above Normal	941	17.4	14.1	31.51	16.720	5.646	10.373	16.019	100.4
5.	VIII	Above to Sub-Normal	982	14.0	10.0	29.80	11.399	5.886	9.089	14.975	76.1
6.	IX	Sub-Normal	946	14.0	8.0	22.23	10.883	5.676	7.580	13.256	81.1
7.	X	Above Normal	955	16.0	12.4	25.60	14.907	5.730	8.627	14.357	100.3
	XI	Above Normal	955	14.5	12.8	24.32	14.729	5.730	7.904	13.634	107.96
	XII	Above Normal	955	15.8	11.1	22.90	13.663	5.730	7.717	13.447	101.6
8.	XIII	Normal	952	12.5	9.0	21.14	11.149	5.706	7.124	12.830	86.7
10.	XIV	Sub-Normal	930	13.0	6.4	16.39	9.326	5.580	5.720	11.300	72.5

TABLE VII COMPOSITION OF MILK, COW NO. 301.

Period	Date	Ration	Protein %	Fat %	Sugar %	Total Ash %
1.	July 3-8	Normal	3.00	3.61	4.99	0.69
2	July 12	Sub-Normal	2.55	3.27	4.86	0.66
	July 14	Sub-Normal	2.74	3.27	4.81	0.65
	July 16-22	Sub-Normal	2.80	3.61	4.63	0.66
	July 23-29	Sub-Normal	2.80	lost	4.63	0.65
3.	Aug. 15-21	Normal	3.00	3.17	4.54	0.61
4.	Sept. 5-11	Above Normal	3.00	3.99	4.80	0.62
5.	Sept. 16	Sub-Normal	3.06	3.56	4.68	0.58
6.	Sept. 22-27	Sub-Normal	3.00	4.27	4.60	0.65
7	Oct.2	Above Normal	3.13	4.20	4.62	0.69
	Oct. 10-16	Above Normal	3.13	3.91	4.80	0.67
	Oct. 25-31	Above Normal	3.19	4.17	5.00	0.68
8	Nov. 5-11	Normal	3.19	4.21	4.92	0.68
10.	Nov. 24-30	Sub-Normal	3.13	4.5	4.78	0.64

Table VIII Percentages of Minerals in the Milk. Cow 301.

Period		Ration	Total Ash %	CaO %	MgO %	Na_2O %	K_2O %	P_2O_5 %	Fe %	SO_3 %	Cl %
1.	I	Normal	0.69	0.1122	0.0182	0.0458	0.1969	0.2074	0.0092	0.0161	0.0091
2.	II	Sub-Normal	0.66	0.0924	0.0111	0.0662	0.1930	0.1983	0.0025	0.0146	0.0791
	III	Sub-Normal	0.65	0.1091	0.0173	0.0653	0.1576	0.1938	0.0027	0.0112	0.0126
	IV	Sub-Normal	0.66	0.1278	0.0191	0.0375	0.1958	0.1943	0.0025	0.0105	0.0035
	V	Sub-Normal	0.65	0.1217	0.0174	0.0542	0.1585	0.1742	0.0044	0.0139	0.0012
3.	VI	Normal	0.61	0.1207	0.0152	0.0605	0.1409	0.1640	0.0046	0.0140	0.0070
4.	VII	Above Normal	0.62	0.1185	0.0207	0.0271	0.2059	0.1826	0.0086	0.0078	0.0083
5.	VIII	Above to Sub-Normal	0.58	0.1085	0.0162	0.0338	0.1560	0.1619	0.0051	0.0152	0.0626
6.	IX	Sub-Normal	0.65	0.1290	0.0187	0.0441	0.2048	0.1914	0.0096	0.0166	0.0694
7.	X	Above Normal	0.69	0.1374	0.0185	0.0509	0.1950	0.1715	0.0092	0.0238	0.0006
	XI	Above Normal	0.67	0.1365	0.0192	0.0466	0.1796	0.1849	0.0090	0.0141	0.0331
	XII	Above Normal	0.68	0.1299	0.0196	0.0461	0.1796	0.1827	0.0074	0.0143	0.0719
8.	XIII	Normal	0.67	0.1322	0.0183	0.0412	0.1952	0.1897	0.0071	0.0153	0.0685
10.	XIV	Sub-Normal	0.64	0.1345	0.0200	0.0438	0.1780	0.1734	0.0066	0.0145	0.0779

Table IX Mineral Elements in Feed Cow No. 301.

Period	Ration	Total Ash grams	CaO grams	MgO grams	Na_2O grams	K_2O grams	P_2O_5 grams	Fe grams	SO_3 grams	Cl grams.
1.	Normal	990	165.8	61.4	7.84	154.5	106.8	0.118	117.5	37.85
2	Sub-Normal	808	135.5	42.9	6.48	125.8	86.1	0.096	95.6	22.82
	Sub-Normal	808	135.5	42.9	6.48	125.8	86.1	0.096	95.6	22.82
	Sub-Normal	755	134.5	49.7	6.45	125.2	86.0	0.095	95.2	22.08
	Sub-Normal	751	133.6	49.5	6.41	124.2	85.8	0.095	95.0	22.53
3.	Normal	965	160.1	63.6	7.88	155.5	97.7	0.122	118.0	27.00
4.	Above Normal	1047	170.5	70.2	8.50	169.0	122.5	0.136	132.5	28.50
5.	Above to Sub-Normal	773	136.1	45.4	6.64	130.2	91.8	0.117	98.6	22.90
6.	Sub-Normal	743	134.5	40.1	6.33	121.8	80.9	0.090	92.3	22.80
7	Above Normal	956	156.5	62.8	7.73	152.8	109.1	0.123	116.0	26.20
	Above Normal	890	142.9	61.5	7.25	145.1	108.8	0.119	110.3	23.80
	Above Normal	926	153.5	59.0	7.46	146.2	102.5	0.150	111.2	25.80
8	Normal	736	121.8	46.3	5.93	116.8	82.3	0.091	88.4	20.40
10.	Sub Normal	721	124.1	40.7	5.72	108.5	69.4	0.078	82.6	21.10

Table X Mineral Elements in Milk. Cow No. 301

Period.	Ration	Total Ash grams	CaO grams	MgO grams	Na_2O grams	K_2O grams	P_2O_5 grams	Fe grams	SO_3 grams	Cl grams
1.	Normal	117.2	18.95	1.821	7.73	33.1	35.00	1.55	2.71	1.53
2.	Sub-Normal	105.6	14.80	1.780	16.10	30.9	31.75	0.40	2.34	12.68
	Sub-Normal	102.9	17.40	2.750	10.35	24.9	30.50	0.44	1.77	1.99
	Sub-Normal	102.1	19.75	2.950	5.80	30.3	30.10	0.39	1.65	0.54
	Sub-Normal	97.5	18.50	2.610	8.12	23.8	26.00	0.66	2.08	0.18
3.	Normal.	94.1	18.62	2.450	9.34	21.7	25.30	0.71	2.16	1.08
4.	Above Normal	88.7	16.95	2.960	3.88	29.4	26.10	1.23	1.12	1.18
5.	Above to Sub-Normal	78.3	14.65	2.190	4.57	21.1	21.82	0.69	2.05	8.46
6.	Sub Normal	65.7	13.04	1.890	4.46	20.8	19.32	0.97	1.67	7.00
7.	Above Normal	80.2	15.95	2.150	5.91	22.6	19.92	1.14	2.76	0.07
	Above Normal	73.9	15.08	2.120	5.14	19.8	20.40	0.99	1.55	3.65
	Above Normal	70.7	13.50	2.040	4.79	18.7	18.95	0.77	1.49	7.48
8.	Normal	64.2	12.68	1.760	3.95	18.7	18.18	0.68	1.47	6.57
10.	Sub Normal	47.6	10.00	1.490	3.25	13.5	12.88	0.49	1.76	5.78

Experiment B. Cow No. 301.

Cow 301, previously described, was fed during the following periods as indicated:

1.	June 27 - July 7	Normal
2.	July 8 - 29	Sub-normal
3.	July 30 - Aug. 22	Normal.
4.	Aug. 22 - Sept. 12	Above normal
5.	Sept. 13 - 16	Above normal to below normal
6.	Sept. 17 - 29	Below normal
7.	Sept. 30 - Oct.31	Above Normal
8.	Nov. 1-17	Normal
9.	Nov. 18 -20	Normal to below normal
10.	Nov. 21 - 30	Sub-normal.

Table VI gives the average weight of the cow during each period, the pounds of hay and of grain mixtures fed, the pounds of milk given and the energy value as previously described. As in Table I, the normal is not always 100 per cent, also the same variation in weight of the animal is found as in Table I.

Table VII gives the composition of the milk in percent of protein, fat, sugar and total ash. As in Table II, the percentages of total ash and sugar remain fairly constant, the protein and fat increasing slightly as the amount of milk given (See Table VI) decreases.

Table VIII gives the percentages of the various

mineral elements in the milk. The same general relationships are found here as in Table III, a gradual, though not perfectly regular, diminution in percent of P_2O_5, a gradual increase in the percent of CaO, but no variation great enough to have any grave effect on the food value of the milk.

Table IX gives the number of grams of the mineral elements in the feed.

Table X gives the number of grams of the mineral elements in the milk.

Discussion of Results.

As compared with other analyses the sulphur content is somewhat low. This is probably due to the fact that the analysis were made on the ash and not on the original milk. However, as the present investigation was not undertaken until some time after the close of the feeding experiment it was impossible to make any analyses on the original milk. The chlorine is also low, and fluctuates very widely. This was probably caused by the manner of ashing which was not done by the writer, who therefore has no means of knowing how far results may have been vitiated in the ashing in regards to the volatile constituents, sulphur and chlorine. The iron is very high, but as excellent checks were obtained in the titrations, the results are of value merely as showing relatively the amounts of

iron in the milk during these feeding periods. An attempt is being made to trace the cause of the high iron values obtained but as yet no explanation has been found.

Kellner[1] computes that dairy cows yielding 20 Kilograms of milk daily require per 1000 Kilograms of live weight about 143 grams of calcium and 61 grams of phosphorous in the ration. This is equivalent to 63.59 grams of P_2O_5 and 105 grams of CaO per 1000 pound cow giving 20 pounds of milk daily. From Henneberg's determinations it is calculated that the maintenance per 1000 pounds of steer's weight is 22.7 grams of P_2O_5 and 45.37 grams of CaO.

From these figures we calculated the approximate amounts of these elements required for the different amounts of milk given, assuming the weight of the cow to be 1000 pounds during the entire experiment.

1. Kellner Die Ernährung der landw. Nutztiere, Berlin 1907 pp. 569, 570. Also Ohio Agr. Exp. Sta. Bul. 201, p. 170

Cow No. 300.

Period.	Ration	CaO Grams		P_2O_5 Grams	
		Fed	Required	Fed	Required
1	Normal	194.5	184.3	134.5	115
2	Above normal	216.9	184.3	162.5	118.2
	Above normal	216.9	181.9	162.5	116.7
	Above normal	189.3	173.9	155.	111
3	Normal	186.1	163.4	136	104.2
4	Sub-normal	135.8	137.4	88.3	85.8
6	Above normal	185.4	137.4	126.9	85.8
8	Sub-normal	115.6	128.4	70.0	79.7
	Sub-normal	115.6	102.4	70.0	61.9
9	Normal	154.8	108.4	96.7	66

Cow No. 301.

Period	Ration	CaO Grams		P_2O_5 Grams	
		Fed	Required	Fed	Required
1.	Normal	165.8	156.37	106.8	98.7
2.	Subnormal	135.5	150.67	86.1	95.1
	Sub normal	135.5	149.37	86.1	94.2
	Sub normal	134.5	146.87	86.0	92.7
	Sub normal	133.5	143.87	85.8	90.6
3.	Normal	160.1	146.87	97.7	92.7
4	Above normal	170.5	139.37	122.5	87.2
5	Sub normal	136.1	133.07	91.8	83.8
6.	Sub normal	134.5	111.77	80.9	68.2
7.	Above normal	156.5	121.77	109.1	75.2
	Above normal	142.9	117.87	108.8	72.4
	Above normal	153.5	113.67	102.5	69.7
8.	Normal	121.8	108.37	82.3	66
10	Sub normal	124.1	94.37	69.4	56.3

It will be observed that the animals were overfed in CaO and P_2O_5 during the greater part of the experiment and, that Cow No. 301 was slightly underfed in CaO and P_2O_5 during "Sub normal period No. 2", and Cow No. 300 in CaO during "Sub normal period No. 4", and in both CaO and P_2O_5 during the first part of "Sub normal period No. 8".

No data is at hand to calculate the amounts of other mineral elements required but a comparison of Tables IV and V, and IX and X shows a greater amount of mineral elements were fed than the quantity of output of those elements in the milk. Sodium and iron are exceptions but as the animals had daily access to salt, more sodium was ingested than that taken in the food itself. As before stated the amounts of iron given for the milk are far too high.

It is possible to underfeed cows from a nutritive standpoint and still overfeed them in all or some of the mineral constituents. This was done in the present investigation in which the cows were overfed in lime, in some periods when they received insufficient nutrients. This was due to the use in the ration of alfalfa which is especially high in lime.

It is also possible to give them sufficient nutrients and an insufficient amount of mineral. It is possible that this would have a greater effect on the mineral content of the milk. However, from what little work has

already been done we should conclude that even this would not effect the minerals enough to impair the value of milk as food.

Summary.

From the results of the present investigation we would conclude that underfeeding or overfeeding cows from a nutritive standpoint when they are receiving a sufficient supply of mineral elements does not cause a sufficient variation in the mineral content of the milk to seriously impair its value as food.

The investigation upon which this Thesis is based was made under the direction of Dr. Matthew Steel in the Laboratory for Dairy Research, maintained by the Dairy Division, U. S. Dept. of Agric., in cooperation with the Department of Dairy Husbandry of the University of Missouri.

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