XXV. THE INFLUENCE OF THE COW'S DIET ON THE FAT-SOLUBLE VITAMINS OF WINTER MILK. II.

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Report to the Medical Research Council.

(Received January 2nd, 1928.)

IN a previous communication [Golding, Soames and Zilva, 1926] it was shown that by administering cod-liver oil to cows kept on a diet rigorously restricted in the fat-soluble vitamins during the winter, the vitamin A and D content of the butter was greatly enhanced. On the other hand, when this basal diet was supplemented by kale there was an increase in the vitamin A content of the butter but its antirachitic value remained unaltered. These experiments were instituted with the definite purpose of demonstrating the differential influence of the feeding of cod-liver oil and of kale to cows during the winter on the antirachitic potency of the butter, and consequently extreme diets were aimed at independently of their practical applicability. Thus the basal diet alone was much more drastically deficient in vitamins than is usual with the winter ration of cows employed in this country. Moreover, the dose of cod-liver oil administered was of such a magnitude as to depress the fat content of the milk [Drummond *et al.*, 1924; Channon *et al.*, 1924].

Table I.

		No. of calves	Date last calved
Rigorous basal diet	Gertie II	1	Oct. 31, 1926
	Rufa III	1	Sept. 6, "
Control basal diet	Flora II	2	Dec. 28, "
	Clara I	1	Nov. 23, "
Basal diet + cod-liver oil to excess	Winsome II	1	" 30, "
	Flora I	3	" 16, "
Basal diet + 2 oz. cod-liver oil	Lily II	2	Dec. 1, "
	Doll I	8	Nov. 8, "

This communication deals with the influence of doses of cod-liver oil, which are not high enough to depress the fat content of the milk, on the vitamin D potency of butter, and also with the antirachitic value of a good ration such as is frequently given to stall-fed cows during the winter in England.

The data recorded will be mainly those which have a bearing on the antirachitic value of the butter and on the depression of the milk-fat due to the administration of cod-liver oil. Other data are reserved for future record.

Table II. *Weights of food given during experimental period.*

[illegible]

EXPERIMENTAL.

The conditions under which these experiments were carried out were essentially the same as those described in the first communication of this series. Eight dairy Shorthorns were divided into four groups, as described in Table I, which also gives the history of the animals, whilst Table II gives the diet of six of these animals during the experimental period. It will be seen that the control cows, Flora II and Clara I, received a good winter stall ration. Gertie II and Rufa III, on the other hand, were given a very restricted diet, such as would seldom be employed in practice in England. It was made up as follows:

Bean meal	...	...	...	...	...	2 parts
Extracted palm kernel meal				...	...	2 „
Decorticated ground nut meal				...	...	1 part
Barley meal	...	...	...	...	...	1 „
Crushed wheat		...	...	...	...	1 „
Oat straw	...	...	...	...	...	<i>ad lib.</i>
Roots	...	...	...	...	...	50 lb.

This diet was started on January 18, 1927.

From October 21 the cows were kept in during the night but were turned out to grass during the mornings, except Gertie II and Rufa III which were stalled during the entire 24 hours from Jan. 18th. The administration of the cod-liver oil began in the first week in January. In the case of Flora I the dose was gradually increased to 8 oz. and in that of Winsome II to 6 oz. Doll I and Lily II received 2 oz. *per diem* through the entire experimental period.

In order to observe the influence of the various doses of cod-liver oil on the fat content, the milk of each cow was weighed, mixed and sampled at each milking and the fat content determined by the Gerber method.

The butters were churned for testing purposes during the second fortnight in March and Table III gives the details of the churnings.

The antirachitic vitamin content of the butters was determined by the method previously described. Owing to exigencies of circumstances, it was not found convenient to test the butters all together, and consequently the positive and negative control groups of animals are those of the particular groups amongst which the respective samples were tested. The milks of Flora I and Winsome II were mixed together and the butter prepared from this mixed sample was tested.

DISCUSSION OF RESULTS.

The object of this investigation was to ascertain whether it was possible to feed to cows doses of cod-liver oil of such a magnitude that they would not depress the milk-fat but would raise the antirachitic value of the milk.

Table III. *Weight of milk, percentage of fat, weight of fat, percentage of solids not fat, and actual weight of butter made from which samples were taken to the Lister Institute on April 27, 1927.*

Cow	Milk taken for butter	Wt of milk lb.	% fat	Wt of fat lb.	Solids not fat %	Time of churning and wt of butter	
						min.	lb. oz.
Flora I	Mar. 17, p.m.	13	3.75	0.487			
	" 18 "	14 $\frac{1}{2}$	4.15	0.612			
Winsome II	" 17 "	9 $\frac{1}{4}$	4.50	0.416			
	" 18 "	9	4.15	0.373			
Flora I	} milks	" 17 "	22 $\frac{1}{4}$	4.05	0.801		
Winsome II		" 18 "	23 $\frac{1}{2}$	4.20	0.997	—	45 1 6
Doll I	" 23, p.m.	13 $\frac{1}{2}$	4.2	0.567			
	" 24, a.m.	16	4.2	0.672			
	" 24, p.m.	13 $\frac{1}{2}$	4.85	0.655	8.95		
	" 25, a.m.	15 $\frac{3}{4}$	4.0	0.630	8.56	35	2 8
Lily II	" 23, p.m.	11 $\frac{1}{4}$	3.8	0.427			
	" 24, a.m.	17 $\frac{3}{4}$	3.0	0.532			
	" 24, p.m.	10 $\frac{1}{2}$	4.0	0.210	9.03		
	" 25, a.m.	16 $\frac{3}{4}$	2.75	0.460	8.83	25	1 15
Flora II	" 21, a.m.	27	2.85	0.769			
	" 21, p.m.	20	3.95	0.790	8.85		
	" 22, a.m.	27	3.10	0.837	8.88		
	" 22, p.m.	19 $\frac{1}{4}$	4.05	0.778			
	" 23, a.m.	26 $\frac{1}{2}$	2.70	0.722	—	37	3 8
Clara I	" 21, a.m.	18	2.95	0.531			
	" 21, p.m.	10 $\frac{1}{2}$	5.4	0.567	9.02		
	" 22, a.m.	17 $\frac{1}{2}$	3.0	0.525	9.13		
	" 22, p.m.	10 $\frac{1}{2}$	4.95	0.519			
	" 23, a.m.	18	3.20	0.576	—	35	2 8
Gertie II	" 19, a.m.	11 $\frac{1}{4}$					
	" 19, p.m.	6 $\frac{1}{2}$					
	" 20, a.m.	11 $\frac{1}{2}$					
	" 20, p.m.	6 $\frac{1}{2}$					
	" 21, a.m.	11 $\frac{1}{2}$	—	—	—	17	1 12
Rufa III	" 19, a.m.	11 $\frac{1}{2}$					
	" 19, p.m.	6 $\frac{1}{4}$	4.3				
	" 20, a.m.	12					
	" 20, p.m.	6					
	" 21, a.m.	11 $\frac{3}{4}$	—	—	—	95	1 10

The results, however, are not as clear-cut as might be desired, and further work of a confirmatory character is called for, which it is hoped will be forthcoming in connection with a wider inquiry in which the authors are now engaged.

It is seen from Fig. 1 that the curves of the average weekly percentage of fat in the milk of Flora II and Clara, which received a good winter ration, but no cod-liver oil, are nearly horizontal lines, at the level of about 4 %. In the case of Winsome II, receiving a high dose of cod-liver oil, there is a decided progressive drop in the percentage of fat until about the first week in February, when the increase of the dose to 6 oz. produced no further decrease in the percentage of the fat. The effect of the administration of similar doses of cod-liver oil to the companion cow of this group, Flora I, was less marked. When we turn our attention to the cows which received a daily dose of 2 oz. of cod-liver oil, we find that, if there be a depression in the percentage of the milk-fat, it is of a very much lower order than in the

cases of Winsome II and Flora I. The curve for Doll I is very similar to that of the control cows, Clara and Flora II. Lily II, on the other hand, shows a depression, but it will be noticed that it begins about four weeks before

Fig. 1. Chart indicating the effect of varying doses of cod-liver oil in depressing the average weekly percentage of fat in the milk of cows—Dec. 1926–May 1927.

the administration of the cod-liver oil began and persists until about the middle of the cod-liver oil period, when a gradual and sustained return to the normal begins. We are not inclined to attribute this depression to the influence of the oil.

Table IV.

Rat	Initial weight g.	Final weight g.	Weight of bone g.	% of water	% of fat	% of organic residue	% of ash	Ratio A/R	Average ratio A/R
<i>Positive controls for Winsome and Flora I (mixed) and Clara and Flora II</i>									
Daily dose—3 drops of cod-liver oil									
5919	50	74	1.1041	51.40	6.81	21.13	20.67	0.9779	
5920	50	69	1.1638	54.33	2.48	22.77	20.88	0.9170	
5921	50	77	1.1566	58.99	2.32	23.08	18.26	0.7911	
5922	50	74	1.0479	49.91	4.39	23.59	22.09	0.9361	
5923	50	63	1.0199	55.99	2.53	22.06	20.04	0.9084	
5924	50	75	1.0511	50.03	2.19	23.27	24.52	1.0540	
5925	50	57	0.9712	56.20	3.11	22.17	18.51	0.8354	
5926	50	74	1.1742	55.01	1.50	23.09	20.44	0.8853	0.9132
<i>Negative controls for Winsome and Flora I (mixed) and Clara and Flora II</i>									
5911	50	59	0.9409	58.86	5.08	22.05	14.04	0.6370	
5912	50	84	1.1012	59.09	5.32	21.41	14.20	0.6633	
5914	50	78	1.1582	62.43	2.98	21.35	13.24	0.6184	
5915	50	86	1.2851	63.87	2.54	21.88	11.72	0.5357	
5916	50	79	1.1373	60.68	2.22	22.86	13.72	0.6002	
5917	50	76	1.1940	65.16	2.51	22.82	9.51	0.4168	
5918	50	74	1.0853	60.91	3.12	24.40	11.58	0.4710	0.5632
6-8 oz. cod-liver oil (Winsome and Flora I mixed)									
Daily dose—0.2 g. butter									
5899	50	70	1.1039	60.29	1.67	22.56	16.39	0.7269	
5900	50	84	1.2262	58.93	4.83	21.20	15.03	0.7087	
5901	50	76	0.9960	63.17	2.28	24.32	10.24	0.4211	
5902	50	75	1.1054	54.24	3.87	22.64	19.33	0.8540	
5903	50	82	1.0403	52.70	2.80	24.47	19.94	0.8131	
5904	50	70	1.1295	54.25	7.74	20.53	17.44	0.8494	0.7289
Daily dose—0.6 g. butter									
5905	50	88	1.1933	60.05	1.70	22.80	15.49	0.6794	
5906	50	70	1.1357	58.09	2.38	23.08	17.29	0.7491	
5907	50	75	1.0048	52.34	1.68	23.63	22.34	0.9454	
5908	50	80	1.1966	54.45	3.87	21.68	19.98	0.9216	
5909	50	74	1.1474	49.68	0.97	20.28	20.40	1.0060	
5910	50	86	1.2115	52.17	4.48	22.62	20.70	0.9151	0.8694
<i>Good winter ration (Clara)</i>									
Daily dose—0.2 g. butter									
5927	50	79	1.1049	63.36	2.10	14.48	10.91	0.7536	
5928	50	72	0.9815	57.58	3.48	22.72	16.19	0.7126	
5930	50	79	0.9509	60.52	3.62	21.81	14.06	0.6447	
5931	50	72	1.0610	60.82	2.55	21.68	14.96	0.6900	
5932	50	80	1.1331	61.20	4.07	21.84	12.87	0.5893	0.6780
Daily dose—0.6 g. butter									
5933	47	71	0.9939	58.06	2.99	21.55	17.41	0.8076	
5934	50	90	1.1500	60.84	2.82	21.75	14.59	0.6710	
5935	50	70	0.9286	59.78	3.22	22.09	14.91	0.6749	
5936	50	68	1.1021	57.31	1.74	21.71	19.17	0.8830	
5937	50	85	1.0451	59.51	2.19	22.43	16.29	0.7258	
5938	50	86	1.1729	56.45	4.71	21.44	17.40	0.8110	0.7622
<i>Good winter ration (Flora II)</i>									
Daily dose—0.2 g. butter									
5939	50	78	1.0825	63.46	2.58	22.25	11.69	0.5254	
5940	50	72	0.9781	61.98	2.59	22.24	13.19	0.5937	
5941	50	85	1.1384	53.52	3.79	22.06	20.66	0.9369	
5942	50	73	1.0223	63.45	2.79	22.30	11.49	0.5152	
5943	50	86	1.3120	59.87	4.94	21.59	13.59	0.6295	0.6401

Table IV (cont.)

Rat	Initial weight g.	Final weight g.	Weight of bone g.	% of water	% of fat	% of organic residue	% of ash	Ratio A/R	Average ratio A/R
<i>Good winter ration (Flora II)</i>									
Daily dose—0.6 g. butter									
5944 ♀	50	84	1.0925	56.06	1.07	22.01	19.54	0.8877	
5945 ♀	50	80	1.1217	53.44	3.94	22.12	20.48	0.9259	
5946 ♂	50	98	1.3468	60.60	2.80	22.03	14.84	0.6736	
5947 ♀	50	74	1.0589	57.89	3.07	22.13	16.92	0.7650	
5948 ♀	50	72	1.0268	55.54	3.51	21.96	19.04	0.8670	
5949 ♀	50	78	1.1106	61.75	3.30	22.59	12.34	0.5462	0.7776
<i>Positive controls for Lily and Gertie</i>									
5846 ♀	33	57	0.8783	54.91	3.77	21.75	19.58	0.9005	
5849 ♀	32	52	0.7545	54.33	5.69	21.40	18.49	0.8632	
5850 ♀	30	50	0.7696	55.05	7.93	18.75	18.28	0.9802	0.9146
<i>Negative controls for Lily and Gertie</i>									
5851 ♂	32	47	0.8547	64.36	4.95	21.41	9.28	0.4333	
5852 ♀	30	42	0.7012	63.36	3.18	22.88	10.59	0.4640	
5853 ♀	35	50	0.7784	58.98	4.50	23.64	13.17	0.5572	
5854 ♀	35	54	0.7170	60.63	5.24	21.51	12.12	0.5635	
5855 ♀	33	47	0.6826	62.82	3.97	22.63	10.56	0.4667	
5856 ♀	30	48	0.8262	65.73	2.59	22.49	9.19	0.4085	
5857 ♀	35	53	0.7997	61.87	2.18	24.03	11.92	0.4960	
5858 ♀	37	57	0.9641	63.27	3.34	22.91	10.47	0.4590	0.4810
2 oz. cod-liver oil (Lily)									
Daily dose—0.2 g. butter									
5819 ♂	50	80	1.2600	63.36	3.50	22.24	10.90	0.4904	
5820 ♂	30	58	0.8623	64.83	3.17	20.81	11.21	0.5389	
5821 ♀	37	67	0.9975	59.55	0.09	23.97	15.56	0.6498	
5822 ♀	47	75	0.9728	58.34	5.93	24.69	13.55	0.4463	
5824 ♀	46	63	0.9072	62.79	3.51	23.48	10.23	0.4356	0.5122
Daily dose—0.6 g. butter									
5825 ♀	30	54	0.8838	57.57	4.37	20.90	9.14	0.8206	
5826 ♀	32	59	0.7978	57.61	6.05	21.51	14.83	0.6895	
5827 ♀	36	67	0.9370	57.82	4.23	22.54	20.42	0.9055	
5828 ♀	36	65	1.0422	62.91	1.74	20.25	15.11	0.7464	
5829 ♀	34	65	0.8597	61.83	2.26	21.83	14.07	0.6448	
5830 ♀	32	59	0.9406	57.90	4.02	21.11	17.02	0.8063	0.7689
<i>Very restricted diet (Gertie)</i>									
Daily dose—0.2 g. butter									
5831 ♀	33	59	0.8825	64.22	3.37	22.45	9.91	0.4417	
5832 ♀	37	62	0.8583	63.68	2.40	22.42	11.50	0.5130	
5833 ♀	36	62	0.8890	63.11	2.36	22.80	11.73	0.5144	
5834 ♀	42	63	0.9340	61.81	3.44	22.62	11.57	0.5117	
5835 ♀	30	50	0.8045	64.33	2.60	22.70	10.36	0.4567	
5836 ♂	35	60	0.8528	65.59	3.76	21.98	9.70	0.4414	0.4798
Daily dose—0.6 g. butter									
5837 ♀	33	51	0.7397	64.45	3.26	22.94	9.37	0.4085	
5838 ♂	34	57	0.9792	64.66	3.87	21.65	9.82	0.4533	
5839 ♀	33	53	0.9139	59.91	7.39	20.85	11.95	0.5738	
5840 ♀	34	63	0.9233	55.75	4.28	21.52	17.97	0.8351	
5841 ♀	33	69	0.9304	61.52	4.86	22.25	11.37	0.5110	
5842 ♀	40	68	1.0986	61.89	3.98	21.97	12.14	0.5524	0.5557
<i>Positive controls for Rufa and Doll</i>									
Daily dose—1 drop cod-liver oil									
5883 ♀	40	70	1.0226	50.23	8.18	21.00	20.55	0.9786	
5884 ♂	48	55	0.9439	51.87	3.91	21.94	21.09	0.9620	
5885 ♂	33	65	0.8673	51.76	7.89	21.25	19.08	0.8978	
5886 ♀	48	75	1.1396	52.36	5.94	20.96	20.71	0.9880	0.9566

Table IV (cont.)

Rat	Initial weight g.	Final weight g.	Weight of bone g.	% of water	% of fat	% of organic residue	% of ash	Ratio A/R	Average ratio A/R
<i>Positive controls for Rufa and Doll</i>									
Daily dose—3 drops cod-liver oil									
5887 ♀	30	60	1.0029	53.55	1.75	20.22	18.73	0.9263	
5888 ♂	35	55	0.8721	51.36	8.40	21.37	18.79	0.8792	
5889 ♀	36	60	0.9006	50.18	6.65	22.38	20.81	0.9298	
5890 ♀	33	55	0.7598	47.63	8.16	21.01	19.79	0.9419	0.9183
<i>Negative controls for Rufa and Doll</i>									
5893 ♂	43	53	0.8814	55.97	7.16	22.28	14.59	0.6548	
5894 ♂	45	65	0.9260	59.88	6.56	21.93	11.64	0.5308	
5895 ♀	33	60	0.8237	60.87	3.11	23.19	12.81	0.5524	
5896 ♀	35	70	0.9838	62.40	5.44	22.06	10.09	0.4574	
5897 ♂	42	55	0.7669	55.04	7.41	22.41	15.15	0.6760	
5898 ♂	32	55	0.8130	56.72	7.88	21.03	14.35	0.6824	0.5923
<i>Very restricted diet (Rufa)</i>									
Daily dose—0.2 g. butter									
5859 ♀	42	47	0.8123	65.51	1.01	23.96	9.49	0.3961	
5860 ♀	42	60	0.8695	63.90	3.22	22.67	10.09	0.4450	
5861 ♂	45	67	1.0434	64.54	9.49	24.99	9.56	0.3825	
5862 ♀	43	65	0.9922	58.86	3.02	23.23	15.09	0.6496	
5863 ♀	43	63	1.1461	70.84	2.09	19.81	9.15	0.4618	
5864 ♀	38	45	0.8451	55.52	3.62	24.19	16.65	0.6878	0.5039
Daily dose—0.6 g. butter									
5865 ♀	44	60	0.9065	62.70	3.73	22.07	11.51	0.5215	
5866 ♀	36	60	0.8876	61.35	3.62	21.96	13.07	0.5952	
5867 ♂	48	70	1.0601	55.14	6.09	20.92	17.86	0.8537	
5868 ♂	44	70	0.9524	62.63	0.95	24.60	11.82	0.4806	
5869 ♂	40	60	0.9424	60.03	3.00	23.35	13.58	0.5815	
5870 ♀	38	59	0.7954	59.19	4.73	21.79	14.29	0.6559	0.6147
<i>2 oz. cod-liver oil (Doll)</i>									
Daily dose—0.2 g. butter									
5871 ♂	40	65	0.9515	55.95	2.90	23.36	17.88	0.7654	
5872 ♀	43	55	0.8668	63.97	1.29	22.32	13.15	0.5849	
5873 ♂	43	65	1.1204	64.04	1.80	21.97	12.21	0.5560	
5874 ♀	35	60	0.9592	57.57	4.09	21.21	17.12	0.8071	
5876 ♀	37	55	0.8505	—	—	22.76	16.23	0.7131	0.6853
Daily dose—0.6 g. butter									
5877 ♀	36	55	0.8627	53.83	5.55	21.92	18.69	0.8527	
5878 ♂	48	60	1.0690	51.29	9.74	21.10	17.89	0.8480	
5879 ♂	37	63	0.9482	56.82	2.07	23.44	17.69	0.7547	
5880 ♀	50	75	0.9480	53.71	6.55	20.39	19.34	0.9485	
5881 ♂	35	60	1.0774	55.89	8.41	19.80	15.95	0.8055	
5882 ♂	37	60	0.9451	56.83	6.66	20.77	15.74	0.7583	0.8279

The results of the antirachitic tests (Table IV and Fig. 2) do not reveal any striking superiority of the butters from Doll I and Lily II over those from Flora II and Clara. In the higher doses there is an advantage for the former, but in lower doses the reverse is the case. In both cases, however, the differences are more or less within the limits of experimental error. The butters from the cows which received the higher doses of cod-liver oil are decidedly antirachitically superior to those from Flora II and Clara and much more so to those from the cows Gertie and Rufa, which were on a very restricted diet. This confirms our last year's results.

Two striking features emerge from these experiments. First, the fact that the administration of a daily dose of 2 oz. of cod-liver oil to a good winter stall ration made no very significant difference to the vitamin D content of the butter. Whether this is accidental or whether a dose of cod-liver oil below a certain magnitude does not influence antirachitically the milk will be decided by our future work. Second, the comparatively high antirachitic value of the basal diet received by Flora II and Clara. In comparing this diet with the very restricted diet of Gertie and Rufa, it is found that, apart from the slight variations in the composition of the concentrates, the main difference lies in the inclusion of silage and hay in the former diet. It is also to be observed that Gertie and Rufa were stalled all the time. From preliminary results at our disposal we feel disposed to favour the view that the silage was responsible for the vitamin D potency of the ration. In this case too we hope to obtain further experimental evidence.

Fig. 2.

Fig. 3.

Fig. 2 represents results with 0.2 g. of butter, Fig. 3 with 0.6 g. of butter. In both figs. the ordinates represent the percentages of the increase of A/R ratio above the figures of the negative control. Increase of positive control over negative control=100.

The probable antirachitic value of silage raises an interesting problem from a theoretical as well as from a practical point of view, and is illustrative of the general importance of investigating dairy products from the vitamin

standpoint. It is particularly necessary to stress this at the present juncture of vitamin research. The dramatic discovery of the activation of foodstuffs by irradiation opened up a field of fascinating problems for research, mainly of a fundamental nature. The possible bearing of these problems on practical dietetics is, of course, patent. Does, however, our present scientific, and above all clinical, knowledge of the subject justify the cautious scientific investigator in urging the immediate application of this very incomplete knowledge to practical nutrition? The position with respect to active natural products is different. The antirachitic value of cod-liver oil and, to a smaller extent, of milk and butter, has been established clinically almost from time immemorial. The development of vitamin research has only offered a glimpse into their mode of action, thus affording a means of studying the best conditions for their production and utilisation. There is a great possibility that substances activated by irradiation may find an important place in therapeutics, but, as the ideal aim in dietetics must obviously be in the main prophylactic, the vitamin value of natural products in nutritional hygiene should not be even temporarily eclipsed by the consequences of the uncontrolled enthusiasm of the laboratory worker.

SUMMARY.

A winter ration for cows containing silage and hay is described, which produced an antirachitic butter of moderate potency. The daily addition of 2 oz. of cod-liver oil to this ration did not significantly depress the percentage of milk-fat nor did it raise the vitamin D of the butter to any appreciable extent. Higher doses of cod-liver oil depressed the percentage of milk-fat and raised the antirachitic potency of the butter.

Our thanks are due to Mr James Mackintosh who arranged for the feeding and management of the cows and to Miss Janet Robison who sampled the milk and weighed the foods for the cows.

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