Carotene Requirements of Dairy Cattle

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The carotene requirements of dairy cattle for growth and maintenance have been fairly well established. Guilbert and Hart (6) showed that 12 to 15 mcg. of carotene per pound of live weight was adequate to prevent clinical symptoms of avitaminosis A. Later, Guilbert *et al.* (7) concluded that this level was adequate for rats, dogs, swine, sheep, cattle, and horses, thus indicating that the minimum maintenance requirement of carotene was in direct proportion to live weight. Moore *et al.* (12) found that 30 to 34 mcg. of carotene per pound live weight was adequate for growth of cattle. Other workers have confirmed these findings. The National Research Council in its most recent report (14) recommends 40 mcg. of carotene per pound of live weight for maintenance and growth, which is 20 mcg. lower than the older recommended allowance (16).

The minimum carotene requirements of dairy cattle for normal reproduction are not so clearly defined. Guilbert and Hart (6) obtained successful reproduction with beef cattle when the maintenance requirement was tripled during the last month of pregnancy; but, later they (7) suggested a five-fold increase during the last month of gestation. Davis and Madsen (3) obtained satisfactory reproductive performance at a lower level of 27 mcg. per pound of live weight. Converse and Meigs (2), on the other hand, found that 50 mcg. was too low, and recommended 80 to 100 mcg. per pound live weight of dairy cattle during the last months of gestation.

A preliminary report by Kuhlman and Gallup (10) indicated that 45 mcg. carotene per pound of live weight was adequate for successful reproduction in Jersey cattle. This needs to be modified, however, on the basis of additional data, presented in this bulletin. In another report from the Oklahoma Experiment Station (17) it was concluded that Guernseys required 90 mcg. carotene per pound live weight to insure normal reproduction.

This bulletin summarizes research conducted over a 20-year period, 1937 to 1957, at the Oklahoma Agricultural Experiment Station relative to carotene requirements of Jersey, Guernsey, and Holstein cattle.

EXPERIMENT

The basic plan in this investigation was maintained throughout a 20-year period, although there were some adjustments in the experimental procedure from time to time. Prairie hay was fed as the primary source of carotene, with a minimum use of carotene supplements as needed. Cottonseed meal was used as the protein source, white hominy feed for energy, and beet pulp and cottonseed hulls were used primarily to balance fiber intake. A complete mineral mixture was available at all times. The animals were fed in individual stalls equipped with box mangers. They were exercised in a dry lot.

In the early work with the Jersey cattle, prairie hay was offered at levels of 25, 50, and 100 percent of what were considered normal hay intakes. Carotene intakes, however, were not very uniform throughout the periods, because of the decrease in the carotene content of the hay during storage. A few animals were fed no hay, carotene being supplied by a commercial supplement. In this manner animals were subjected to median carotene intakes varying from 25 to 288 mcg. per pound live weight during growth, gestation, and lactation periods.

In later work with Guernseys and Holsteins the hay intakes were adjusted on the basis of monthly carotene analyses, such that prescribed carotene intakes were maintained at relatively uniform levels for long periods. In this manner median carotene intakes ranged from 23 to 187 mcg. per pound live weight for Guernsey animals and from 20 to 90 mcg. for Holsteins during various periods of observation.

The first Jersey animals used were older cows transferred from another project, and their female offspring were added to the group. Thirty-nine Jerseys were involved in the study. Data were collected from 24 growing heifers, from 84 gestation periods and from 68 lactation periods. All the Jerseys were high grades.

Purebred Guernsey and Holstein heifers were placed under controlled observation at the age of 6 months. Female offspring from the foundation animals were added to each group. Data were obtained from 28 Guernseys, including 73 gestation periods and 58 lactations, and from 26 Holsteins, including 40 gestation periods and 27 lactations.

A record was kept of rate of growth and total digestible nutrients required per pound of gain between the ages of 6 and 15 months. During this period there were no complications due to differences in breeding, and all animals were treated alike except for level of carotene intake. Also recorded were the ages at conception for all the heifers and the ages at first estrus in the case of the Holsteins.

Reproductive performance was judged primarily by the condition of the calf at birth, with specific reference to any conditions which might be associated with avitaminosis A. In addition, records were kept of the number of services per conception, length of the gestation period, available TDN per pound of gain and the occurrence of retained placentae. Available TDN for gain was that amount remaining after allowances had been made for maintenance and for milk production.

During lactation, records were kept of the length of the lactation period, total 4% FCM produced, available TDN per pound of 4% FCM and live weight gain. Available TDN for production was that amount remaining after allowances had been made for maintenance and adjustments made for live weight changes using factors developed by Knott *et al.* (9).

Blood plasma carotene was determined monthly with the Guernsey and Holstein cows, and in addition, plasma vitamin A was determined in the case of the Holsteins. These blood plasma values were obtained also immediately following parturition of the Holsteins; occasionally this was done with the Guernseys. In the Guernsey study, butterfat carotene was determined monthly during each lactation period.

Carotene in the hay was determined by saponification and phasic separation between petroleum ether and 90 percent methanol as described elsewhere (4, 15). Plasma carotene and vitamin A were determined by Kimble's procedure (8) and butterfat carotene by total yellow color of a dilute solution in petroleum ether. An Evelyn photoelectric colorimeter equipped with 440 and 620 mμ. filters was used in this work after calibration with the proper blanks and known concentrations of carotene and vitamin A (5).

RESULTS AND DISCUSSION

Growth Performance

Data relative to the performance of heifers fed at various levels of carotene intake between the ages of 6 and 15 months are presented in Tables I, II and III. There was no indication that growth or the TDN required for gain was affected by changes in carotene intake. This bears out the findings of Moore, *et al.* (12, 13) with respect to carotene requirements of dairy calves as determined by the spinal fluid pressure technique. Some of the Holstein heifers in this study had carotene intakes below 30 mcg. per pound live weight which Moore and co-workers (12) indicate as the minimum. However, the levels of intake reported here represent the medians for 9-month periods, and monthly variations were probably greater than in Moore's investigation.

The conception rates of heifers apparently were not affected by carotene intakes above the growth requirement. Also, as shown by the observations of the development of estrus with Holsteins, there were no apparent effects upon the age of sexual maturity.

Reproductive Performance

Observations on reproductive performance of the Jersey, Guernsey, and Holstein animals are summarized in Tables IV, V, and VI, respectively. Major emphasis was placed upon the condition of the calves at birth.

Jersey

In the Jersey cows a carotene intake of about 75 mcg. per pound live weight appeared to be necessary to insure successful reproduction. Although some cows had successful reproduction at daily intakes as low as 25 mcg. per pound live weight, there was a high proportion of reproductive failures at intake levels of 70 mcg. or less. One-half of the full-term calves produced by cows receiving 70 mcg. or less carotene per pound live weight were abnormal in some way. Thirty-three percent exhibited anomalies characteristic of avitaminosis A, and there were five abortions. Only one-fifth of the calves dropped by cows on high intake exhibited abnormalities, and only 7 percent showed clinical vitamin A deficiency symptoms. One cow receiving a median carotene intake of 70 mcg. per pound live weight during her second gestation gave birth to a blind calf.

While notes were made relative to the condition of each calf for some time after birth, this information has not been considered in this summary. It was felt that the case histories were not adequately detailed to afford a true judgment of the nature of certain post-natal complications. A multiplicity of factors may have affected the calves during this period. For example, the feeding of limited colostrum or low vitamin A potency milk to the new-born calves may have contributed to some early deaths. Numerous factors such as chilling and defective post-natal management may have pre-disposed calves to infections and other complications causing deaths. This possibly could have occurred with calves which had been healthy and normal at birth. Calf survival has been used in other work (6) as a measure of reproductive efficiency, but because of the foregoing uncertainties this was not taken into account.

In a preliminary report (10) based on 17 animals with 31 gestation periods, it had been tentatively concluded that about 45 mcg. carotene per pound live weight would be adequate for normal reproduction in Jersey cows. This report took into consideration the average carotene intake during the gestation periods which may have been misleading due to the variability of the monthly intakes. In this respect it seemed more realistic to use median values, thus avoiding the influence of one or two extreme values. Had this been done, however, the tentative recommendation would have been increasd only by about 5 mcg. per pound live weight. The difference between the tentative conclusion and the conclusion now presented indicates the need for long time observations in work of this nature.

A recent report by Byers *et al.* (1) indicated that continued exposure for two and three generations to suboptimal carotene intakes may have intensified degenerative effects upon certain tissues. Some such evidence may be suggested by the Jersey data in this study, but it is not very conclusive. To obtain reliable evidence on this point in a production study such as this one, a larger number of animals in the second and third generations would be required.

There seemed to be a higher incidence of retained placentae among the cows on the lower carotene intakes. Adequate information was available for 72 parturitions in this regard, and it showed that the placentae were retained 22 percent of the time at intakes below 70 mcg. carotene per pound live weight, whereas they were retained only 15 percent of the time at higher intakes. This comparison was imbalanced, however, since 45 animals at low intakes were compared to 27 at higher intakes.

Other criteria associated with reproductive efficiency did not appear to be affected by the level of carotene intake. The average services per conception in the entire Jersey study was 1.55. Only four conceptions involved particularly low efficiencies (4 to 7 services each) and they were associated with carotene intakes between 44 and 75 mcg. per pound live weight. The ten conceptions in the lowest median carotene intake range (25 to 38 mcg. per pound live weight) and the ten conceptions occurring in the highest carotene intake range (147 to 275 mcg. per pound live weight) each required 13 services.

Since the monthly carotene intakes were quite variable, the possibility existed that the carotene intake during the service period may have been markedly different from the median intake during the gestation period. Information for 68 conceptions made possible a study of the effects of the carotene intake during the service period on the breeding efficiency. With 36 conceptions associated with carotene intakes between 21 and 70 mcg., the breeding efficiency was 73 percent as compared to 55 percent with 32 conceptions at carotene intakes ranging from 70 to 368 mcg. per pound live weight.

A preliminary report (11) based on 58 conceptions indicated a trend toward a decreased breeding efficiency at lower carotene intake levels; however, the final summary involving 84 conceptions does not bear out those earlier indications. Actually a higher breeding efficiency was suggested in connection with low carotene intakes.

The lengths of the gestation periods, aside from those terminating in abortion, did not seem to differ with levels of carotene intake. The 10 full-term gestation periods associated with the lowest carotene intakes and the 10 associated with the highest intakes were found to range in length from 264 to 288 days and from 266 to 279 days, respectively. Gestation periods at the lower intakes averaged 2 days longer than at the higher intakes, but the median length was the same in each group.

The efficiency of conditioning the cows during pregnancy appeared to be comparable at all levels of carotene intake as indicated by the available TDN utilized for gain in live weight. This is a calculated expression, with probably a low degree of precision, which results in highly variable values. Any indicated differences would need to be relatively large and quite consistent before being considered noteworthy.

Guernsey

Observations with Guernsey cows during gestation and parturition indicated that their carotene requirement for reproduction was somewhat higher than that of Jerseys. One Guernsey cow on a median intake of 83 mcg. per pound live weight gave birth to a blind calf. Of 37 full-term calves resulting from pregnancies associated with median carotene intakes of 83 mcg. or less, 19 or about 50 percent had some abnormality, 14 of these showing clinical symptoms of avitaminosis A. There were 28 calves born to animals on higher levels of intake and nine of these showed abnormalities, none of which was characteristic of a vitamin A deficiency. There were five abortions in the lower range of carotene intake and two abortions at the higher levels.

There was a 54 percent incidence of retained placentae at intakes below 83 mcg. and a 39 percent incidence above this intake level. Retained placentae were even more prevalent at lower levels of intake with an incidence of 65 percent when 60 mcg. or less carotene was received daily during gestation. More difficulty with retained placentae was experienced with the Guernsey cows than with either of the other two breeds.

The breeding efficiency of the Guernsey cows was lower than that of the Jerseys, but it did not seem to be materially affected by the level of carotene intake. Thirty-six cows receiving from 37 to 84 mcg. carotene per day during the service period required 2.11 services per conception as compared to 2.22 services for 36 animals with intakes ranging from 84 to 199 mcg. per day. The over-all conception rate for all the Guernseys was 46 percent, which was higher than the 41 percent efficiency prevalent in the entire college Guernsey herd during this same period.

The range in lengths of gestation periods appeared to be comparable at all levels of carotene intake. There seemed to be an increase in the incidence of short-term pregnancies other than abortions as carotene intakes decreased below about 91 mcg. per pound live weight. Fitfy-one percent of the gestation periods associated with intakes less than 91 mcg. were shorter than 280 days, whereas 41 percent of those associated with intakes higher than 91 mcg. were shorter than 280 days. The trend was not consistent, however, when comparisons were made between subgroups of more nearly equal animal numbers. Thus it was shown that gestation periods were less than 280 days in 50, 31, 70 and 41 percent of the time for groups of cows on various intake levels ranging from 23 to 56 mcg., 60 to 77 mcg., 80 to 91 mcg., and 92 to 138 mcg. per pound live weight, respectively.

The ratio of available TDN to gain in live weight was highly variable between animals, but was comparable at all ranges of carotene intake.

Holstein

Fewer animals and pregnancies were available for study with the Holstein than with the other two breeds. The data collected have more meaning, perhaps, since the feeding was controlled very rigidly to assure uniform carotene intakes over longer periods of time than was possible in the study with Jersey and much of the study with Guernsey cattle. This was borne out when it was observed that there was little difference between median and average values of carotene intakes. However, in view of discrepancies which have been shown between preliminary and final reports in the case of the Jersey study, it would seem advisable to consider the Holstein observations as tentative. Information was available from only 11 gestation periods of 10 second-generation heifers. Had further observations been made on these and other second and third generation animals the trends indicated might have been different.

It seems that when daily carotene intakes have been maintained at or above 60 mcg. per pound live weight the reproductive performance of Holsteins has been reasonably satisfactory. Very few typical vitamin A deficiency symptoms were shown by calves produced by first generation dams, and those were largely by calves of cows receiving about 30 mcg. or less carotene per day per pound live weight. One cow dropped normal, healthy calves during three gestations at intakes of 31, 26, and 20 mcg. of carotene, but produced a weak calf in her fourth gestation during which she received 21 mcg. carotene per pound live weight, daily.

One second generation heifer having a median daily carotene intake of 59 mcg. during gestation gave birth to a calf which lacked coordination and displayed symptoms which suggested avitaminosis A. Abnormalities typical of vitamin A deficiences were observed in other animals of the second generation at lower levels of carotene intake. Among this group of animals there was apparently normal performance at carotene intakes as low as 30 mcg. Two second generation heifers experienced difficult parturitions, resulting in one caesarean section, and in the production of dead calves at daily carotene intake levels of 73 and 78 mcg. per pound live weight. While these responses were not typical of vitamin A deficiencies, observations made in this study would not rule out entirely some possible association with carotene intake levels. Unfortunately, histological examinations could not be made of these calves. One second generation heifer aborted while receiving 72 mcg. carotene. A first generation animal aborted after receiving 76 mcg. carotene, but later produced a normal calf while on a carotene intake of 30 mcg. per pound live weight during gestation.

The breeding efficiency of this group of Holsteins was very low, but of the same order as that of the college Holstein herd during the same periods wherein serious breeding problems were encountered. It was clear that the breeding efficiency was no better at the higher levels of carotene intake than at the lower levels. Only eight cows in the whole group conceived to one service, and five of these had daily carotene intakes of about 30 mcg. per pound live weight.

The gestation lengths of the Holsteins apparently were not affected by the level of carotene intake. Six gestations associated with carotene intakes over 80 mcg. were predominantly longer than those at lower intakes, but this apparently was due to cow differences rather than to differences in carotene intakes. Four of these gestations ranging from 276 to 285 days in length were by two cows which later, while receiving about 30 mcg. of carotene, had gestation periods of 282 and 287 days. Unfortunately, no comparisons could be made with cows which had started at low carotene intakes and which later had been raised above 80 mcg. carotene. Increases of carotene intakes of various cows from about 30 mcg. to 45 and 65 mcg. did not have any effect on the length of gestation.

The incidence of retained placentae was lower among Holsteins than among Guernseys. Low carotene intake seemed to influence placenta retention, however, in that four cases were observed at daily intakes between 26 and 31 mcg. per pound live weight. Only two cases were observed at higher intake levels, and one of these followed an abortion.

Lactation Performance

The 153 lactation records summarized in Tables VII, VIII, and IX, show that even the lower levels of carotene in this study were adequate for milk production. The variability between lactations of individual cows seemed to be about the same whether or not carotene intakes were similar between lactations This appeared to be so, regardless of whether total production or efficiency of TDN utilization was considered.

Carotene and Vitamin A Levels

The plasma and butterfat carotene values of the Guernsey cows summarized in Table X were highly variable. The level of plasma carotene for any one cow during any particular period could not be considered as a reflection of carotene intake. For example, there were nine cows that in 11 gestations periods maintained rather uniform carotene levels between 325 and 375 mcg. per 100 ml. plasma. Among these animals median daily carotene intakes ranged from 32 to 133 mcg. per pound of live weight. One cow in this group maintained median carotene plasma levels of 336, 338, and 364 mcg. per 100 ml. while her median daily intakes of carotene were 76, 83 and 51 mcg. per pound live weight. Blood plasma and butterfat carotene values during lactation displayd erratic patterns similar to those cited during gestation. An extremely low correlation between carotene intake and plasma lvels has ben indicated previously (17).

The plasma vitamin A and carotene values of the Holstein animals during gestation and lactation did not seem to reflect carotene intake levels. The drop in plasma vitamin A values at parturition appeared to be more marked and more consistent at low intake levels than at higher levels, but there were exceptions in both directions. Low parturient blood levels recovered quickly, however, so that the plasma vitamin A levels during lactation were comparable, in most cases, at all levels of carotene intake. Such trends were not as evident for plasma carotene in either the Holstein data or the more limited Guernsey data.

SUMMARY AND CONCLUSION

A 20-year study of carotene requirements of dairy cattle is reported. Ninty-three animals of the Jersey, Guernsey and Holstein breeds with 197 gestation periods and 153 lactations were involved in the study. Carotene intakes were varied over a wide range by adjusting the level of prairie hay which was the sole source of carotene. Cottonseed meal, hominy feed, beet pulp and cottonseed hulls were used to balance the rations with respect to digestible protein, total digestible nutrients, and fiber.

The following inferences can be drawn from the data presented:

1. Successful reproduction should be expected with Guernsey, Jersey, and Holstein cows when they receive 75 to 85 mcg. carotene per pound live weight daily.

2. Normal lactation can be expected at carotene intake levels considerably below those suggested for reproduction.

3. Blood plasma levels of vitamin A and carotene are not reliable indices of the adequacy of carotene intake for reproductive purposes.

4. The growth of heifers between the ages of 6 and 15 months is not affected by increasing carotene intake levels above current recommended growth requirements.

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TABLE I—Response of Growing Jersey Heifers to Varying Levels of Carotene Intake.

Animal No.	Median Carotene Intake	Growth, 6 to 15 Months: Av. Daily Gain	Growth, 6 to 15 Months: TDN/lb. Gain	Age at Conception
	Mcg./lb. live wt.	lb.	lb.	Days
1537	32	0.96	5.88	523
3306	33	1.14	5.06	—
2513	39	1.14	5.29	524
2338	40	1.19	5.01	477
1524	44	0.96	5.75	—
1604	54	0.93	4.65	477
12504	58	1.14	6.00	517
1436	59	1.04	5.55	744
3431	65	1.04	6.70	652
5331	68	0.91	7.18	560
624	69	1.11	5.50	464
713	76	1.00	5.62	391
2436	79	1.12	5.46	477
2504	80	1.11	5.56	464
31338	80	1.08	6.27	529
537	84	1.01	4.90	593
21338	88	1.19	5.40	705
738	102	0.96	6.11	498
2538	106	1.03	6.17	540
12604	106	0.87	6.58	584
22224	114	1.25	5.33	497
3338	125	1.04	5.81	595
4331	154	1.00	6.16	525
3313	174	1.05	5.86	546

TABLE II—Response of Growing Guernsey Heifers to Varying Levels of Carotene Intake.

4	40	0.98	4.92	602
405	41	0.78	11.20	566
3	49	0.90	5.71	636
10	61	0.98	4.88	—
22	68	0.83	4.78	—
106	76	1.09	4.42	698
321	78	1.37	6.22	635
404	82	1.11	7.65	537
12	86	1.21	5.39	551
11	88	1.00	5.58	669
9	90	1.14	4.73	832
7	94	1.17	4.54	530
5	94	1.02	5.19	557
1	95	1.03	4.73	608
205	99	1.30	5.78	592
6	106	0.91	5.91	526
8	115	0.83	6.18	—
2	119	1.02	4.95	600
305	119	1.11	7.04	632
32	123	0.88	10.58	663
23	131	1.15	6.82	478
403	141	1.24	7.65	540
1106	167	1.10	8.40	525
33	214	0.99	9.39	—

TABLE III—Response of Growing Holstein Heifers to Varying Levels of Carotene Intake.

Animal No.	Median Carotene Intake	Growth, 6 to 15 Months Av. Daily Gain	Growth, 6 to 15 Months TDN/lb. Gain	Age 1st Estrus	Age Conception
	Mcg./lb. Live Wt.	lb.	lb.	Days	Days
H-83	23	1.43	5.64	354	*
H-8	27	1.37	6.57	383	550
H-4	27	1.54	5.47	388	455
H-3	28	1.34	7.35	371	454
H-9	29	1.47	6.91	310	656
H-82	29	1.44	6.26	427	783
H-32	29	1.61	5.20	366	488
H-92	31	1.47	6.24	370	730
H-43	31	1.34	6.24	433	*
H-63	31	1.53	5.54	387	*
H-41	34	1.89	4.38	380	664
H-91	36	1.59	4.95	408	693
H-7	48	1.32	6.89	456	575
H-5	50	1.67	5.72	326	671
H-52	51	1.60	5.55	380	586
H-2	55	1.55	6.28	325	787
H-72	55	1.35	6.35	426	526
H-22	56	1.52	5.89	396	478
H-1	65	1.60	6.23	349	596
H-02	66	1.52	6.00	376	419
H-10	66	1.52	6.53	401	658
H-11	72	1.78	4.98	400	446
H-6	73	1.49	6.30	281	530
H-12	80	1.54	5.36	352	454
H-01	86	1.73	4.58	427	1025
H-61	87	1.64	5.01	320	836

* Not bred before termination of experiment.

TABLE IV—Response of Jersey Cows to Varying Levels of Carotene Intake During Gestation.

Animal No.	Median Carotene Intake	Gest. No.	Length	Services	Avail TDN/lb. Gain	Placenta Retained	Condition of Calf at Birth*
	Mcg./lb. live wt.		Days		Lb.		
338	25	2	288	1	2.30	No	1
2338	32	1	264	1	2.94	No	6, 9
2436	32	1	276	1	2.85	No	6
3338	33	1	237	1	3.31	No	5
604	35	4	271	2	2.68	No	1
2604	36	2	273	2	5.79	No	6
1604	36	2	230	1	2.76	Yes	5
2604	36	3	275	1	8.37	—	1
1604	37	1	285	1	2.23	No	3
338	37	3	273	2	3.20	No	1
604	38	1	278	1	2.87	No	1
613	38	1	279	2	2.72	No	6
3313	39	3	267	1	3.80	Yes	6
338	39	5	261	1	13.87	Yes	3
2224	40	4	275	1	4.43	Yes	1
2224	42	1	280	2	3.03	No	1
331	43	6	276	1	4.37	Yes	5, 9
1537	44	1	137	1	1.97	Yes	5
1436	44	1	254	7	2.94	No	3
604	44	2	274	1	1.60	No	1
431	44	2	268	1	2.64	No	6, 8
2504	44	2	259	1	4.11	No	3
537	44	2	281	1	2.73	No	1
738	45	2	269	1	3.18	Yes	6
538	45	4	270	1	6.20	No	1
537	46	1	272	1	2.47	No	1
4331	46	1	272	1	4.40	No	6
613	47	2	272	4	2.79	No	1
604	47	3	273	1	1.21	No	1
713	49	3	264	2	2.54	No	1
2224	50	2	287	2	2.45	No	1
2504	50	3	274	1	4.26	No	1
338	50	4	277	1	1.85	No	1
2513	53	2	265	2	2.97	No	8, 9
1338	53	4	265	1	7.71	Yes	6
22224	55	1	271	1	4.24	No	1
424	55	5	267	1	4.67	Yes	1
424	56	3	281	2	3.07	No	1
2538	58	1	266	1	4.64	No	6
331	58	7	204	1	3.03	—	5
1436	59	2	254	3	2.94	—	4, 6
431	59	3	277	3	2.30	No	1
12504	60	1	271	3	3.90	No	6
21338	61	1	279	6	4.31	Yes	2
2583	62	2	231	1	4.35	—	5
624	63	1	267	1	3.22	No	3
2504	64	1	270	2	3.07	No	1
2436	64	2	285	1	5.28	—	1
424	66	6	276	3	4.37	—	—
4331	68	2	281	2	7.04	—	—
2513	69	1	282	1	3.51	No	3
3431	69	1	284	3	3.79	—	—

TABLE IV—(Continued)

524	69	1	278	1	1.48	No	1
3338	70	2	263	1	4.10	No	6, 9
2224	71	3	281	1	2.49	No	1
2338	73	2	233	1	4.15	No	6
12604	74	1	233	2	3.66	—	—
436	75	1	279	5	2.19	No	1
5331	76	1	273	1	4.24	—	3
331	78	4	289	1	5.13	No	2
2138	84	1	271	2	2.79	Yes	3
1338	89	3	277	2	5.17	No	1
513	91	2	274	1	2.73	No	1
331	92	3	280	1	2.07	No	1
424	95	4	273	1	3.58	No	1
436	98	2	274	2	2.44	No	1
538	103	1	274	1	2.96	No	1
538	115	2	275	1	3.06	No	1
538	121	3	298	1	2.07	No	1
738	122	1	279	1	3.08	No	1
338	134	6	258	1	3.91	Yes	6
3313	137	1	271	1	2.27	No	8
713	139	1	274	1	3.03	No	1
424	143	2	277	1	4.65	No	1
713	147	2	274	2	4.75	—	1
436	153	3	266	2	4.72	No	1
13	156	11	277	1	6.46	Yes	1
331	161	5	279	1	3.62	No	1
713	164	4	273	2	5.27	No	1
1338	169	1	275	1	3.46	No	1
1338	204	2	274	1	4.38	Yes	1
3313	205	2	276	1	3.49	No	1
2604	215	1	273	1	3.03	No	1
13	275	10	275	1	4.50	No	1

*1. Normal
2. Weak
3. Dead
4. Scours
5. Aborted
6. Incoordinated
7. Exophthalmos
8. Xerophthalmia
9. Blind

TABLE V—Response of Guernsey Cows to Varying Levels of Carotene Intake During Gestation.

Animal No.	Median Carotene Intake	Gest. No.	Length	Services	Avail. TDN/lb. Gain	Placenta Retained	Condition of Calf at Birth*
	Mcg./lb. Live Wt.		Days		Lb.		
1106	23	2	279	2	8.07	Yes	5, 8
321	27	1	270	4	3.86	Yes	5, 8
30	33	3	285	1	0.71	No	1
21	34	4	219	1	2.72	—	4
21	34	5	286	2	0.71	Yes	1
403	40	1	275	3	2.29	Yes	3
21	41	3	286	3	3.37	No	1
23	43	2	279	6	4.52	Yes	5, 8
305	44	1	281	4	3.51	No	1
11	44	2	263	1	——	Yes	1
7	48	4	282	1	2.81	—	5
205	51	3	193	2	4.29	Yes	4
3	51	5	278	2	5.86	Yes	1
6	54	2	281	4	——	Yes	5
21	55	1	295	4	0.75	Yes	5, 7
5	55	5	278	1	5.86	No	1
1106	56	1	278	3	3.34	No	5, 7
21	56	2	283	1	——	Yes	1
205	60	2	280	1	2.59	No	1
9	61	5	283	1	3.00	Yes	5
7	62	3	286	1	1.21	Yes	8
106	64	1	286	3	1.32	—	1
7	65	2	193	3	0.42	—	4
106	66	2	284	1	2.10	No	1
20	66	6	281	2	2.22	No	1
20	67	5	198	2	1.32	Yes	4
404	68	1	279	1	5.28	Yes	8
5	68	2	278	4	0.61	No	6, 7
5	69	3	281	2	0.60	—	1
4	73	5	278	2	19.79	No	5
31	74	1	282	3	3.03	Yes	5
5	74	4	281	4	2.06	No	1
3	76	1	247	2	3.23	Yes	3
11	76	1	70	3	4.74	—	4
3	76	4	282	3	2.08	Yes	1
5	77	1	269	2	2.06	No	1
305	77	2	285	1	2.34	No	1
2	80	5	232	1	0.97	Yes	3
6	82	1	277	1	2.82	—	1
9	82	1	283	7	2.62	No	1
405	82	1	275	4	3.39	No	2
3	83	2	266	1	1.48	No	8
7	84	1	270	2	2.43	—	—
30	85	2	278	1	2.75	No	1
4	87	1	277	1	2.70	No	1
9	88	4	280	1	5.17	Yes	1
20	88	4	284	1	——	No	1
1	89	1	275	1	4.59	No	2
32	90	2	281	3	2.65	Yes	1
11	90	4	262	2	4.18	No	2

(Continued on following page)

TABLE V. (Continued) — Response of Guernsey Cows to Varying Levels of Carotene Intake During Gestation.

Animal No.	Median Carotene Intake	Gest. No.	Length	Services	Avail. TDN/lb. Gain	Placenta Retained	Condition of Calf at Birth*
	Mcg./lb. Live Wt.		Days		Lb.		
2	91	1	262	2	2.81	Yes	3
12	91	1	248	1	2.13	No	1
30	91	1	279	1	5.46	Yes	1
12	91	3	290	1	1.03	No	1
9	92	3	283	1	4.04	No	1
205	93	1	274	4	2.64	No	1
32	93	1	274	5	5.31	Yes	2
3	93	3	270	1	0.83	No	1
12	95	2	286	3	0.99	Yes	1
9	98	2	285	1	6.12	No	1
1	102	2	279	2	5.38	No	2
20	102	3	287	4	1.56	Yes	1
2	103	6	125	2	1.14	Yes	4
23	105	1	279	1	4.52	No	2
4	111	2	286	2	1.67	—	1
4	113	3	288	1	1.94	No	1
2	115	2	277	2	3.04	Yes	3
2	115	3	270	1	1.31	Yes	1
20	119	2	282	1	3.66	No	1
20	127	1	283	—	1.82	No	1
4	133	4	283	3	6.13	No	1
11	138	3	286	1	1.84	—	1
2	171	4	124	4	4.43	—	4

*1. Normal
2. Weak
3. Dead
4. Aborted
5. Incoordinated
6. Lacrimation
7. Exophthalmos
8. Blind

TABLE VI—Response of Holstein Cows to Varying Levels of Carotene Intake During Gestation.

Animal No.	Median Carotene Intake	Gest. No.	Length	Services	Avail. TDN/lb. Gain	Placenta Retained	Condition of Calf at Birth*
	Mcg./lb. Live Wt.		Days		Lb.		
H-8	20	3	271	2	3.56	No	1
H-8	21	4	273	6	8.46	No	2
H-9	23	3	274	9	6.05	No	1
H-9	26	1	263	9	4.57	No	1
H-8	26	1	267	5	6.46	Yes	1
H-41	30	1	258	6	5.94	Yes	3
H-3	30	1	275	1	4.08	No	3
H-91	30	2	267	1	6.36	No	6
H-10	30	3	282	2	5.58	No	7
H-6	30	3	267	2	8.12	Yes	1
H-32	30	1	269	3	6.80	No	1
H-4	31	3	273	1	2.97	No	7
H-91	31	1	68	4	6.67	—	4
H-4	31	1	277	1	4.73	No	1
H-8	31	2	273	1	4.04	No	1
H-2	31	3	262	5	8.72	Yes	3, 8
H-1	32	3	287	3	7.30	No	1
H-3	37	2	277	10	3.12	No	1
H-9	43	2	272	3	4.87	No	1
H-4	45	2	274	7	2.64	No	3
H-7	49	2	273	8	1.07	No	1
H-22	49	1	275	1	5.25	No	1
H-2	51	1	267	8	3.33	No	3
H-7	52	1	267	6	5.20	No	1
H-5	54	1	277	9	6.32	No	1
H-52	54	1	258	3	4.91	Yes	3
H-61	59	1	262	11	6.48	No	5
H-2	60	2	270	4	3.24	No	1
H-3	65	3	276	5	5.88	No	1
H-5	67	2	270	2	3.69	No	1
H-01	72	1	211	14	3.11	—	4
H-12	73	1	274	2	5.28	—	3, 9
H-6	76	2	188	2	2.16	Yes	4
H-02	78	1	276	1	4.19	No	3
H-6	83	1	288	3	5.46	No	1
H-1	83	1	285	4	4.52	No	1
H-10	85	2	280	7	2.72	No	1
H-11	85	1	275	1	2.35	No	1
H-10	86	1	276	8	2.55	No	1
H-1	90	2	281	6	2.45	No	1

*1. Normal
2. Weak
3. Dead
4. Aborted
5. Incoordinated
6. Nyctalopia
7. Blind
8. Lesions central nervous system
9. Caesarean

TABLE VII—Response of Jersey Cows to Varying Levels of Carotene Intake During Lactation.

Animal No.	Median Carotene Intake	Lact. No.	Length	4%FCM	Avail. TDN/lb. FCM	Live wt. Gain
	mcg./lb. live wt.		days	lb.	lb.	lb.
538	36	3	307	6829.1	0.374	—6
436	37	3	239	3316.4	0.437	37
2338	37	2	69	1116.2	0.417	—24
2224	38	3	308	5278.3	0.421	73
338	39	3	306	8875.4	0.317	—7
2604	40	1	309	4344.1	0.375	113
424	41	2	308	7562.7	0.350	7
331	43	5	366	8395.8	0.396	16
431	43	2	307	4252.8	0.549	—44
604	43	1	350	5435.5	0.280	131
431	45	1	307	4702.9	0.327	89
537	46	2	284	5652.2	0.383	51
2604	46	2	275	4404.8	0.407	110
338	47	2	307	7530.7	0.336	—46
604	47	2	307	6102.7	0.280	45
1604	47	1	307	5775.3	0.280	118
2504	47	2	329	5039.3	0.385	247
738	48	1	306	5508.5	0.361	38
613	49	1	310	6239.9	0.305	70
1338	49	3	307	7974.8	0.373	50
537	50	1	308	6078.9	0.321	30
538	50	4	276	5293.1	0.387	—78
2224	51	1	306	4984.7	0.333	93
424	54	4	308	6471.1	0.423	19
524	54	1	136	2008.7	0.369	—40
604	58	4	307	5428.2	0.408	—113
2504	58	3	174	5614.5	0.377	—74
331	60	6	313	7142.8	0.443	—84
1436	60	1	305	4773.3	0.471	—7
2604	60	3	129	1632.8	0.425	—85
2436	61	2	182	2029.3	0.476	89
2513	62	1	308	4831.8	0.408	31
338	65	4	306	6224.3	0.403	—47
1338	65	4	269	6211.0	0.411	—53
2436	65	1	301	4239.4	0.409	146
2538	65	1	312	5209.0	0.330	142
2513	67	2	290	7060.8	0.415	23
21338	67	1	256	3756.1	0.420	—242
22224	67	1	275	6812.9	0.372	—20
12504	68	1	243	3895.2	0.433	24
2224	69	2	306	5148.7	0.318	85
424	73	5	335	7332.1	0.386	78
613	73	2	306	3585.0	0.308	—80
436	81	1	307	3537.3	0.382	75
604	81	3	307	5571.2	0.319	17
2138	84	1	108	1484.7	0.460	—85
331	86	3	307	8177.9	0.378	91
331	91	2	308	7355.2	0.390	106
424	94	3	307	7343.7	0.378	—10
2338	96	1	296	5064.1	0.328	116
331	100	4	305	8012.4	0.363	—25

Continued on following page

TABLE VII. (Continued) — Response of Jersey Cows to Varying Levels of Carotene Intake During Lactation.

Animal No.	Median Carotene Intake	Lact. No.	Length	4%FCM	Avail. TDN/lb. FCM	Live wt. Gain
	mcg./lb. live wt.		days	lb.	lb.	lb.
436	105	2	306	4960.4	0.443	6
713	108	3	306	7627.5	0.400	97
538	109	2	307	7332.1	0.319	58
538	111	1	307	7402.0	0.304	139
13	121	11	204	2693.4	0.590	—41
338	125	5	308	2573.1	0.547	121
713	131	2	308	7260.4	0.357	36
337	134	2	142	1485.6	0.457	72
3313	141	1	306	5751.3	0.343	49
1338	144	2	307	6060.9	0.431	14
2504	144	1	306	5867.4	0.366	67
13	170	9	297	5056.8	0.403	38
338	178	6	131	2752.3	0.561	—40
713	193	4	122	4428.2	0.382	—171
1338	204	1	308	6228.0	0.398	57
713	214	1	306	6031.3	0.392	60
13	288	10	305	5558.1	0.450	11

TABLE VIII—Response of Guernsey Cows to Varying Levels of Carotene Intake During Lactation.

Animal No.	Median Carotene Intake	Lact. No.	Length	4%FCM	Avail. TDN/lb. FCM	Live wt. Gain
	mcg./lb. live wt.		days	lb.	lb.	lb.
4	25	5	227	4266.1	0.441	—15
30	35	2	300	4747.5	0.251	149
21	38	4	300	5561.1	0.283	52
305	39	1	300	4234.1	0.399	124
106	41	2	257	3953.4	0.420	120
11	46	1	66	684.2	——	—126
32	46	1	300	6249.4	0.258	129
1106	50	1	300	7528.0	0.344	35
31	51	1	300	6221.6	0.370	132
21	55	3	300	5166.4	0.366	238
9	55	4	300	5485.3	0.352	207
3	58	5	300	6183.9	0.267	—75
106	60	1	300	4562.8	0.317	80
21	62	1	290	4891.8	0.255	90
21	62	2	300	4616.2	0.312	122
20	62	5	300	6706.6	0.312	—24
7	63	2	300	4834.7	0.286	139
7	64	1	300	5556.3	0.350	18
205	65	1	300	6344.8	0.368	26
7	65	3	300	7276.9	0.306	54
6	67	1	67	272.2	——	—153
5	71	4	240	3709.9	0.515	—102

(Continued on following page)

TABLE VIII. (Continued) — Response of Guernsey Cows to Varying Levels of Carotene Intake During Lactation.

Animal No.	Median Carotene Intake	Lact. No.	Length	4%FCM	Avail. TDN/lb. FCM	Live wt. Gain
	mcg./lb. live wt.		days	lb.	lb.	lb.
5	77	3	261	4795.9	0.352	—11
4	78	4	300	7447.3	0.431	22
2	79	4	300	8317.6	0.328	64
9	82	5	237	4361.0	0.387	63
23	83	2	268	4473.6	0.359	59
5	84	1	300	4422.9	0.344	129
205	84	2	269	4545.6	0.331	64
3	85	1	300	4282.8	0.298	158
30	86	3	292	4300.3	0.418	29
23	87	1	300	5885.9	0.451	78
5	88	2	300	4390.9	0.278	146
9	93	1	300	6163.9	0.319	—26
30	98	1	300	6306.3	0.333	105
3	99	4	300	7475.7	0.431	115
9	100	2	300	4908.6	0.349	182
3	101	2	300	6744.5	0.324	92
12	102	1	300	4354.0	0.289	153
9	103	3	300	4454.0	0.456	128
1	104	1	300	6032.1	0.309	21
1	104	2	300	6228.4	0.384	82
12	108	2	240	4534.2	0.301	42
12	108	3	254	5358.7	0.326	205
20	114	3	300	8417.3	0.280	15
20	120	2	300	5868.3	0.356	—25
20	125	4	300	8018.8	0.371	61
3	128	3	300	7839.2	0.291	75
2	129	2	300	7758.8	0.330	90
2	130	1	300	5706.6	0.365	21
4	132	3	300	8222.7	0.357	—5
20	134	1	300	5577.9	0.334	—39
4	135	1	300	5774.2	0.383	71
4	138	2	300	6137.2	0.308	110
7	139	4	300	7728.1	0.401	46
2	140	3	300	8212.2	0.337	180
11	164	2	300	6648.5	0.343	26
11	187	3	81	978.6	——	—73

TABLE IX.—Response of Holstein Cows to Varying Levels of Carotene Intake During Lactation.

Animal No.	Median Carotene Intake	Lact. No.	Length	4%FCM	Avail. TDN/lb. FCM	Live wt. Gain
	mcg./lb. live wt.		days	lb.	lb.	lb.
H-8	21	3	267	5723.5	0.543	41
H-9	22	2	300	8981.0	0.438	152
H-8	24	2	251	5150.9	0.450	168
H-3	24	1	97	1294.7	0.719	90
H-6	26	3	302	9877.1	0.402	66
H-8	28	1	295	5969.4	0.390	284
H-91	28	2*	298	8697.4	0.432	82
H-3	30	2	61	569.2	1.302	46
H-4	30	1	300	8687.2	0.248	161
H-41	31	1	300	8901.5	0.398	125
H-9	32	1	300	9052.4	0.449	22
H-11	32	1	305	9487.8	0.384	131
H-4	32	2	300	10181.5	0.448	113
H-2	32	2	300	10303.9	0.435	118
H-5	32	2	300	7327.6	0.454	110
H-10	32	2	300	11354.0	0.419	29
H-1	32	2	281	9816.4	0.386	26
H-6	36	2	300	10630.1	0.430	136
H-7	39	2	243	8080.1	0.390	82
H-7	50	1	300	6312.0	0.447	22
H-5	59	1	300	7780.5	0.343	133
H-2	65	1	302	9945.0	0.400	23
H-3	68	3	157	1909.6	0.492	109
H-1	69	1	300	6723.4	0.313	277
H-6	74	1	300	9818.0	0.386	83
H-10	76	1	288	8912.3	0.400	0
H-61**	79	1	272	7689.8	0.351	208

*No lactation after early abortion in 1st gestation.

**In vet. clinic for observation of non-specific digestive upset for a portion of lactation.

TABLE X—Median Carotene Intake and Blood Plasma Carotene and Butterfat Carotene of Guernsey Cows.

Animal No.	Carotene Intake		Plasma Carotene			Butterfat Carotene
	Gestation	Lactation	Gestation	Parturition	Lactation	
	Mcg./Lb. Live Wt.	Mcg./Lb. Live Wt.		mcg/100 ml		mcg/g
321-1	27	—	152	—	—	—
403-1	40	—	266	—	—	—
305-1	44	39	164	54	191	2.66
-2	77	—	409	—	—	—
21-1	55	62	396	—	464	2.59
-2	56	62	389	—	525	2.30
-3	41	55	401	—	395	2.44
-4	34	38	358	—	189	2.26
-5	34	—	222	—	—	—
1106-1	56	50	317	—	216	2.92
-2	23	—	186	—	—	—
106-1	64	60	968	—	532	4.68
-2	66	41	747	648	513	3.39
404-1	68	—	300	—	—	—
31-1	74	51	245	—	219	2.01
3-1	76	85	336	—	348	3.59
-2	83	101	338	322	444	4.25
-3	93	128	497	425	678	4.86
-4	76	99	525	746	412	3.27
-5	51	58	364	373	322	4.33
11-1	76	46	441	—	138	2.33
-2	44	164	460	460	567	5.00
-3	138	187	689	—	350	6.54
-4	90	—	560	—	—	—
5-1	77	84	247	120	225	2.81
-2	68	88	271	—	400	4.25
-3	69	77	398	471	471	5.86
-4	74	71	247	—	232	3.31
-5	55	—	200	156	—	—
6-1	82	67	425	292	452	9.33
-2	54	—	740	—	—	—
9-1	82	93	300	214	249	2.81
-2	98	100	356	—	364	3.59
-3	92	103	290	144	239	2.89
-4	88	55	247	—	201	3.00
-5	61	82	192	99	307	2.44
405-1	82	—	239	154	—	—
7-1	84	64	284	—	237	1.60
-2	65	63	282	206	318	2.30
-3	62	65	337	319	481	2.59
-4	48	139	418	—	572	2.31
4-1	87	135	199	—	307	1.96
-2	111	138	291	—	441	2.15
-3	113	132	425	487	413	2.08
-4	133	78	364	—	208	1.30
-5	73	25	193	—	122	1.84
1-1	89	104	383	—	237	2.01
-2	102	104	379	—	452	3.27
2-1	91	130	245	157	331	2.40
-2	115	129	522	—	514	2.66
-3	115	140	563	348	373	2.57
-4	171	79	543	—	246	2.01
-5	80	—	210	—	—	—

Continued on following page

TABLE X. (Continued) — Median Carotene Intake and Blood Plasma Carotene and Butterfat Carotene of Guernsey Cows.

Animal No.	Carotene Intake		Plasma Carotene			Butterfat Carotene
	Gestation	Lactation	Gestation	Parturition	Lactation	
	Mcg./Lb. Live Wt.	Mcg./Lb. Live Wt.		mcg /100 ml		mcg /g
-6	103	—	375	—	—	—
12-1	91	102	338	—	427	4.25
-2	95	108	495	—	519	4.90
-3	91	108	984	420	444	3.63
30-1	91	98	406	—	222	1.43
-2	85	35	251	188	140	1.60
-3	33	86	140	215	154	1.43
205-1	93	65	457	—	215	1.94
-2	60	84	178	—	132	2.51
-3	51	—	304	413	—	—
32-1	93	46	452	—	266	3.08
-2	90	—	473	—	—	—
23-1	105	87	330	245	245	2.48
-2	43	83	166	—	286	1.15
20-1	127	134	350	200	402	—
-2	119	120	383	199	355	2.66
-3	102	114	484	—	646	5.22
-4	88	125	485	—	420	3.67
-5	67	62	297	—	198	2.61
-6	66	—	198	—	—	—

TABLE XI. Median Carotene Intake and Blood Plasma Vitamin A and Carotene Levels of Holstein Cows.

Animal No.	Carotene Intake		Plasma Vitamin A			Plasma Carotene		
	Gestation	Lactation	Gestation	Parturition	Lactation	Gestation	Parturition	Lactation
	Mcg./Lb. Live Wt.	Mcg./Lb. Live Wt.	mcg./100 ml. plasma			mcg./100 ml. plasma		
H- 9-1	26	32	16.9	3.5	15.2	214	144	132
-2	43	22	14.5	13.4	22.1	134	62	132
-3	23	—	13.8	6.2	—	49	32	—
H- 8-1	26	28	12.5	7.3	12.5	200	139	126
-2	31	24	12.4	6.7	12.6	127	96	118
-3	20	21	24.0	Trace	9.3	115	112	59
H- 8-4	21	—	11.1	4.6	—	42	54	—
H-41-1	30	31	19.4	3.4	13.9	104	34	41
H-32-1	30	—	11.3	3.4	—	63	94	—
H- 3-1	30	24	14.8	7.2	14.5	162	144	153
-2	37	30	16.1	0.3	28.6	78	59	137
-3	65	68	19.7	5.7	14.2	65	23	82
H-91-1	31	—*	17.2	14.0	—	155	161	—
-2	30	28	12.7	18.1	13.8	60	51	86
H- 4-1	31	30	16.8	4.3	16.7	174	128	123
-2	45	32	12.4	4.6	17.2	100	67	130
-3	31	—	18.6	3.2	—	132	35	—
H-22-1	49	—	14.2	3.9	—	76	104	—
H- 2-1	51	65	14.4	13.0	13.8	120	77	151
-2	60	32	18.0	6.8	19.2	151	137	100
H- 2-3	31	—	16.7	—	—	44	—	—
H- 7-1	52	50	15.8	5.2	15.6	187	142	94
-2	49	39	18.8	20.1	16.4	90	155	140
H-52-1	54	—	12.2	5.2	—	68	97	—
H- 5-1	54	59	16.3	13.1	13.9	220	142	123
-2	67	32	10.7	12.0	18.7	135	90	158
H-61-1	59	79	14.0	9.2	12.2	98	54	87
H-01-1	72	—	16.1	16.4	—	58	64	—
H-12-1	73	—	10.7	7.1	—	81	77	—
H-02-1	78	—	12.1	9.0	—	61	98	—
H- 6-1	83	74	13.5	19.5	14.9	187	212	210

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TABLE XI. (Continued) — Median Carotene Intake and Blood Plasma Vitamin A and Carotene Levels of Holstein Cows.

Animal No.	Carotene Intake		Plasma Vitamin A			Plasma Carotene		
	Gestation	Lactation	Gestation	Parturition	Lactation	Gestation	Parturition	Lactation
	Mcg./Lb. Live Wt.	Mcg./Lb. Live Wt.	mcg./100 ml. plasma			mcg./100 ml. plasma		
H- 6-2	76	36	18.0	13.6	22.9	183	82	178
-3	30	26	23.0	0	14.2	168	78	86
H- 1-1	83	69	14.1	12.2	15.0	174	180	126
-2	90	32	17.4	12.7	18.1	96	84	176
H- 1-3	32	—	13.5	6.7	—	48	45	—
H-11-1	85	32	22.0	9.4	18.7	132	15	104
H-10-1	86	76	20.8	6.4	16.8	168	106	104
-2	85	32	22.0	27.0	21.4	94	134	64
-3	30	—	20.1	26.4	—	45	38	—

*No lactation following early abortion.