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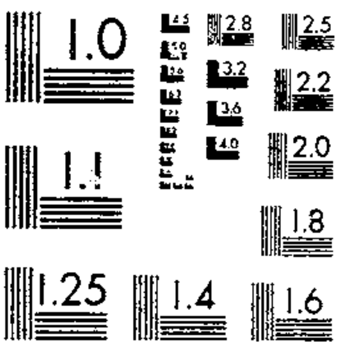

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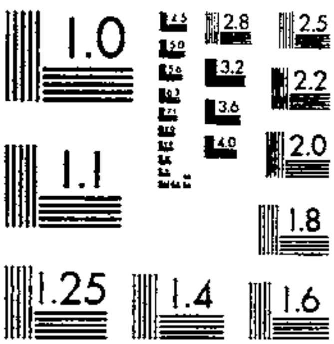

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Malnutrition of Young Cattle: Effect on Feed Utilization, Eventual Body Size, and Meat Quality

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SUMMARY

The effects of undernutrition and malnutrition of cattle between the ages of 6 months and 1 year were studied with 17 pairs of monozygotic twin beef-type cattle. Low, medium, and relatively liberal levels of protein were incorporated in a series of rations that provided low, medium, and liberal allowances of energy. The least liberal allowances of protein and energy were about 16 and 40 percent, respectively, of the allowances commonly accepted as the requirements for rapidly growing cattle.

At a caloric intake somewhat above the maintenance level, weight gain was directly related to the intake of protein. Animals on the lowest level of protein intake lost weight.

Animals were slaughtered when they reached an arbitrarily determined degree of fatness, usually within the "choice" range. The overall efficiency of co-twins was similar despite the extremely drastic restrictions in feed imposed on one member of the pair. Carcass grade and meat quality of co-twins at time of slaughter also were similar.

Although the study shows that cattle can recover successfully from a period of drastic undernutrition, the results of research reported in the literature show that cattle have been unable to recover fully from presumably greater nutritional stress than that imposed in our study. When drastic undernutrition of cattle is unavoidable, the situation can be alleviated to some extent by providing rough shelter and liberal quantities of the required minerals, carotene, and water.

INTRODUCTION

Seasonal decline in the quality and quantity of pasture or forage available for farm livestock results in young animals failing to gain and even losing weight in the fall and winter or in the seasons that follow low rainfall unless supplements are fed. Undernutrition from these causes is nearly a worldwide problem.[4] The feeding of supple-

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[4] In this bulletin the term undernutrition means deficient nutrition due to an inadequate intake of feed, although the quality may be high. Malnutrition means faulty nutrition due to an unbalanced intake of feed, although the quantity may be adequate.

ments ordinarily is expensive and many producers have long questioned whether or not the practice is economically justified. To obtain some basic information on this problem, studies of interrupted growth were started at the U.S. Department of Agriculture, Agricultural Research Center, Beltsville, Md., in 1950. Monozygotic (one-egg, or identical) twin cattle were used throughout these studies because of the statistical advantage of using pairs of animals that have identical inherited characteristics.[5]

In early studies at Beltsville, experimental animals were fed rations that were deficient in energy but otherwise met all the known nutrient requirements while their co-twins were fed full rations. In later studies some animals were fed rations that were deficient in both energy and protein or in either of these alone. As a rule, the period of undernutrition was 6 months, but in some cases it exceeded 6 months; in others it was as short as 3 months.

Without exception, these early studies showed that animals recovered rapidly from the regimens of underfeeding. This phenomenon was observed in rats by Osborn and Mendel (*15*)[6], who pointed out that growth of realimented animals frequently exceeds normal rates.

When differences in energy intake were great, animals that received the poorer rations usually reached slaughter condition later than did their co-twins. However, when the energy intake of co-twins was similar but the protein intake dissimilar, both co-twins invariably reached slaughter condition simultaneously. At time of slaughter, body size of the pair-member that received the poorer rations usually was similar to that of the better fed animal, and the quality of meat of co-twins seldom differed greatly. Differences in within-twin-pair hide quality were found to be insignificant. Overall feed requirements of co-twins per unit of gain in weight were nearly equal despite the wide differences in feeding. Apparently, animals gained weight more efficiently after the period of undernutrition than did their continuously well-fed co-twins.

This report deals with a continuation of studies to determine whether undesirable effects, including stunting, detectable at time of slaughter result from an interruption of growth caused by undernutrition or from extremely wide nutritive ratios similar to those of some forages during the winter season (*12*). In addition, throughout this study we gave attention to the question of whether or not several months of undernutrition result in a lowering of the overall level of efficiency at which cattle utilize their feed.

EXPERIMENTAL MATERIALS AND METHODS

Animals and Rations

Monozygotic twins were used in these trials because the absence of genetic differences between such co-twins greatly reduces the number of animals required to develop reliable information (*19*). The monozygotic origin of the animals was determined by a critical physical examination, confirmed later by a blood test of an antigenic type (*7*). The cattle were purebred, crossbred, or grade cattle

[5] The blood analyses to determine monozygosity were made by M. R. Irwin and associates, Department of Genetics, University of Wisconsin.

[6] Italic numbers in parentheses refer to Literature Cited p. 25.

of beef-type breeds plus two half-Guernsey pairs. The quarters occupied by the animals and details of their care were described in an earlier publication (*20*).

Restricted rations were fed when the animals were between 6 and 12 months of age; at the end of this period, each was fed as much of a liberal ration as it could consume readily. Each animal was slaughtered when members of a panel agreed that it had reached a grade either in or above the "choice" range or else at the highest grade the animal could be expected to reach within a reasonable time.

To insure an ample intake of vitamin A, each animal was given the minimum requirement of this vitamin in oil in addition to the carotene it obtained in the rations.

Rations 1, 2, and 3 had equal energy value and dry matter content but differed in protein value (table 1, at end of report). Ration 3 appeared to cause some bloating in one animal; therefore, to avoid any further bloating that might be ascribed to alfalfa, the alfalfa content was reduced from three-fourths to less than one-fourth of the ration, and the ration containing the smaller amount of alfalfa was designated 3A.

Ration 4, similar to the one designated by that number in an earlier trial (*22*), was formulated to permit animals to gain a pound per day. The two rations related to ration 4, namely 4A and 4B, provided energy equal to that of ration 4 but contained less protein than the latter. Ration 4B had a nutritive ratio of 1:17 and provided only a third of the protein allowed a rapidly growing calf according to the National Research Council Committee on Nutrition (*14*). Ration 7 was similar to ration 4 but was formulated to be fed more liberally than the latter. Rations 7A and 7B provided restricted levels of protein intake with a liberal caloric allowance.

Measurements of Body Size

Animals were weighed at weekly intervals after the morning feed allowance had been consumed. Body measurements of both pair-members were made at the beginning and at the end of the period of restricted feeding and at time of slaughter. If one member of the pair was slaughtered before the other, body measurements of both were made when the first animal was killed. Ninteen measurements similar to those described by Lush (*9*) were made of each animal in triplicate. Each animal was photographed while standing before a gridboard at the beginning and at the end of the period of restricted feeding and at time of slaughter. If one animal was slaughtered earlier than its co-twin, both were photographed when the first was killed.

Determinations of Meat Quality

Grading of the animals before slaughter and of the carcasses was done by a committee of three experienced judges.

Independent chemical analyses were made of the longissimus dorsi muscle and of the remaining edible portion of the 9th-10th-11th-rib cut. Organoleptic tests of meat quality were carried out to determine flavor and tenderness of the fat and lean meat of the rib cut.

EXPERIMENTAL RESULTS

Weight Changes During Undernutrition

Rations 1, 2, and 3 had equal caloric value but varied greatly in protein content. The animals fed ration 1 lost an average of 0.10 of a pound per day, whereas those fed rations 2 and 3 gained 0.13 and 0.31 of a pound per day, respectively (table 2). Protein intake was the factor that limited gain. Every calf gained weight on rations 4B and 7B, which were relatively low in protein content but were liberally supplied with energy. Gains in weight for calves fed rations 4A, 4, 7A, and 7 were comparable to gains expected of animals fed rations similar in energy value to these rations but more liberally supplied with protein. None of these four rations provided as much protein as is recommended by the National Research Council. Of these, ration 7, the most liberal, provided less protein than the generally accepted amount required for a calf to gain 2 pounds a day if the calf consumed the full allowance. Ration 7 has previously been reported as having resulted in gains equal to those of animals that had been fed liberal protein allowances (*22*). Hence in the experiment reported here, none of the rations fed was more liberally supplied with protein than was ration 7.

Aberdeen-Angus co-twin steers numbered 75 and 76 used in the study are shown in their relative size and condition at various stages of growth and feeding in figures 1, 2, and 3.

Steer No. 75, which received little more than enough energy for maintenance and a low allowance of protein, lost 0.12 of a pound a day for 6 months (fig. 1). Steer No. 76, on an energy allowance equal to that of its brother but with a relatively liberal amount of protein in the ration, gained 0.26 of a pound a day. At 1 year of age (fig. 2), the height of No. 75 was nearly as great as that of its co-twin, and its body length was only a little less, although the former animal had lost 22 pounds and the latter had gained 52 pounds in 6 months time.

These findings, together with information on additional pairs of identical twin cattle, recently have been evaluated by Winchester and Harvey (*23*) by use of multiple regression procedures to determine relationships among protein intake, energy intake, and growth. Their study showed that for each level of ingested energy, there exists a level of protein that is conducive to maximum weight gain. Protein and energy requirements for maintenance of growing cattle were also determined. A mathematical relationship among energy intake, nitrogen intake, and nitrogen retention was demonstrated.

Feed Economy and Growth After Undernutrition

The 6-month period of undernutrition did not impair the ability of calves to make rapid, economical gains (table 3). When energy intake during restriction was similar, co-twins reached slaughter condition simultaneously despite wide differences in protein intake during the period of underfeeding.

Pair-members differed very little in overall efficiency of energy utilization with the exception of pair Nos. 73 and 74 (table 4). Animal No. 73 consumed a greater overall amount of energy than did its co-twin, but was unique in having made relatively large gains on the feed it consumed during the period of restricted feeding.

Body Size and Carcass Composition at Time of Slaughter

Nineteen measurements of body size were made of each animal just prior to slaughter. These measurements did not indicate that ultimate body size or conformation were influenced by early under-

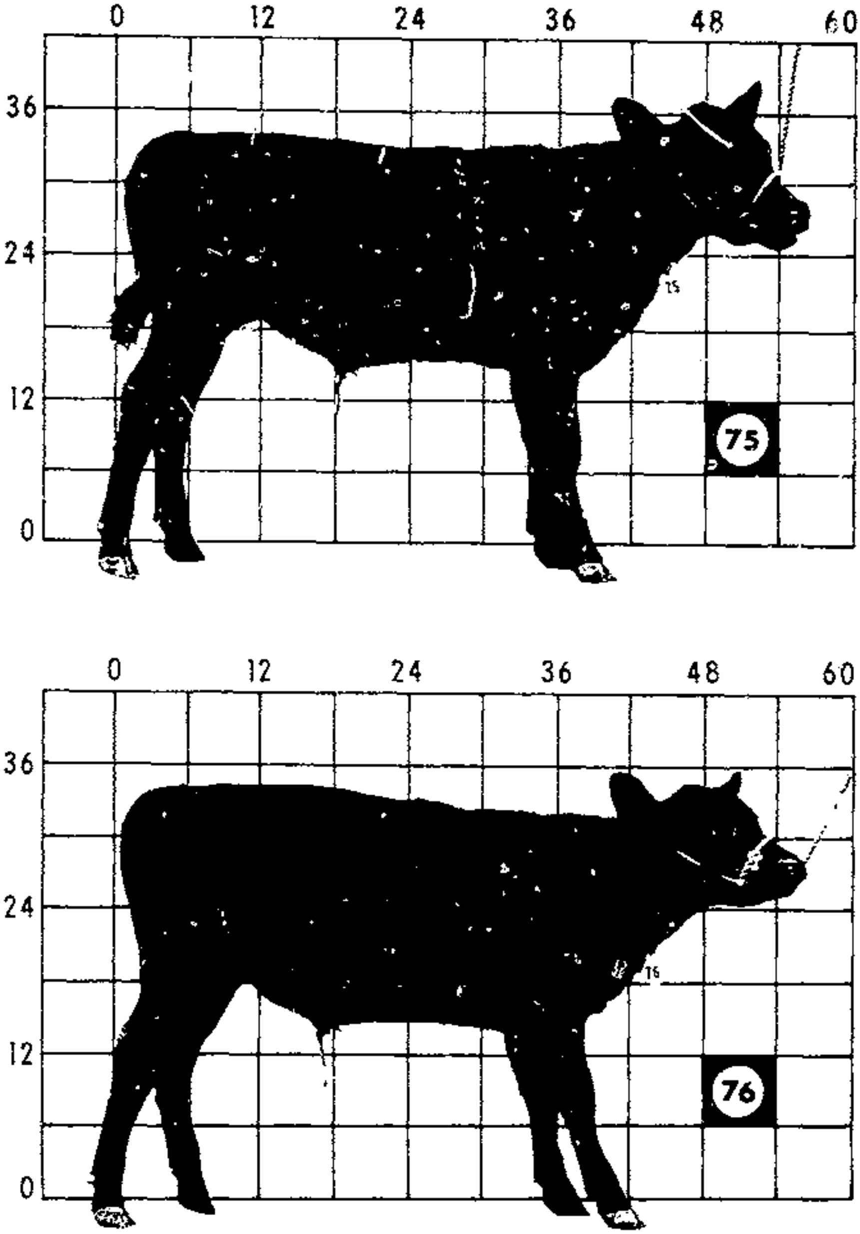

FIGURE 1.—Co-twins at age of 6 months when they were placed on restricted rations. Animal No. 75, weighing 252 pounds, was placed on ration No. 1; No. 76, weighing 238 pounds, was placed on ration No. 3.

nutrition. Some of these measurements together with body weights are given in table 5.

Not all co-twins were of equal grade at time of slaughter, but the animals that had been on the poorer rations had the higher grade carcass about half the time (table 6). Dressing percentages and

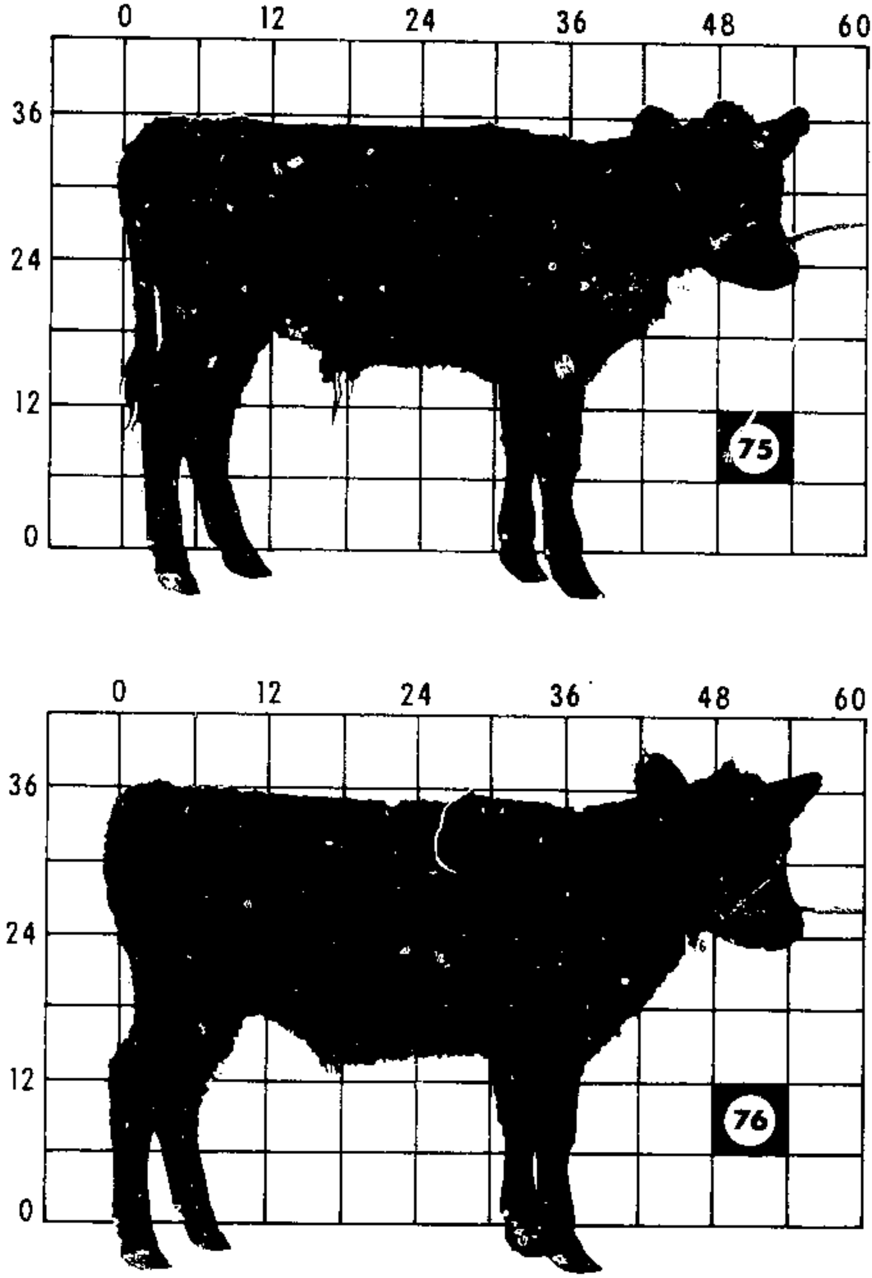

FIGURE 2.—Co-twins at age of 12 months after having been on restricted rations 1 and 3 respectively, the previous 6 months. At 12 months, No. 75 weighed 230 pounds; No. 76, 290 pounds.

carcass composition of co-twins were similar. Photographs of animals numbered 75 and 76 show that they were almost identical in appearance at time of slaughter (fig. 3). Carcasses of both were graded "average choice."

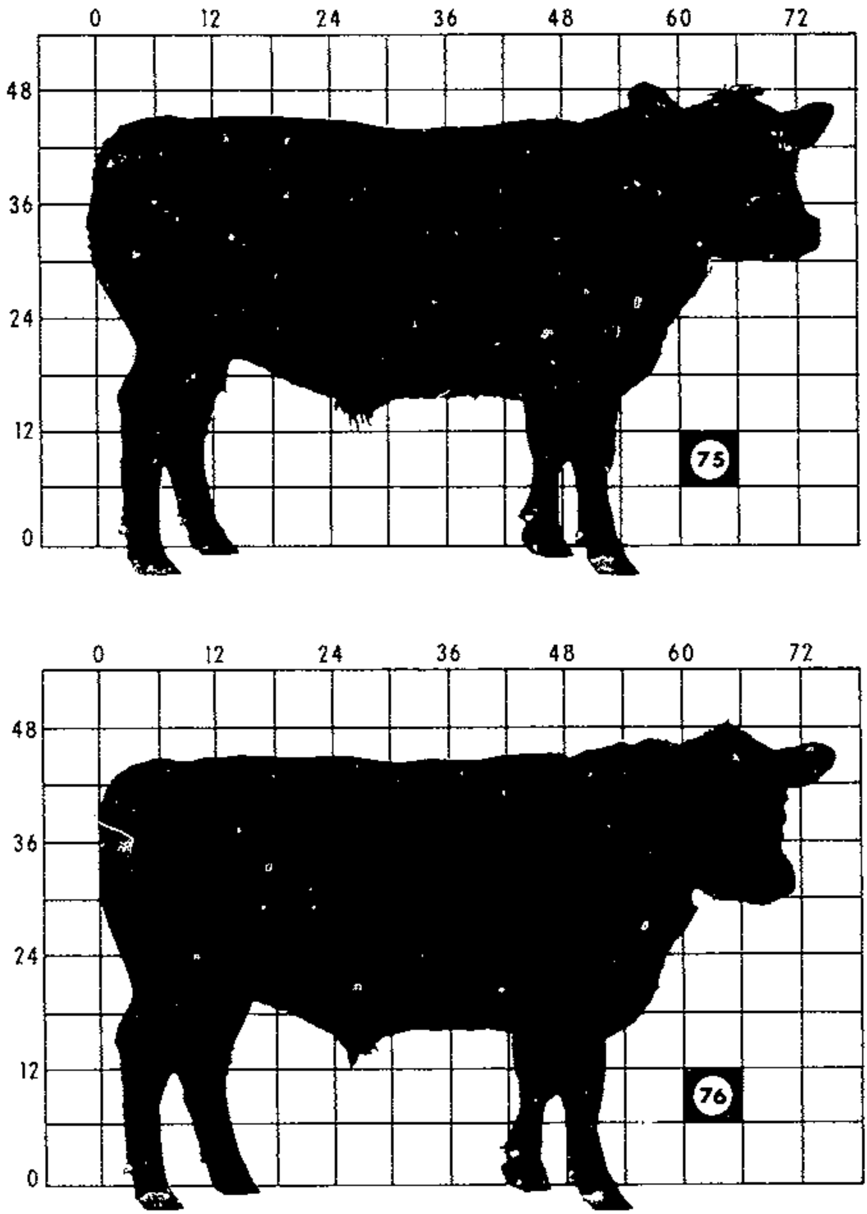

FIGURE 3.—Co-twins at age of 24 months after having been on good rations the previous 12 months. At this age, No. 75 weighed 900 pounds; No. 76, 932 pounds. Both animals were graded "average choice."

Meat Quality

Several organoleptic tests were made of the meat in the 9th-10th-11th-rib cut by specialists and a group of experienced meat judges using methods recommended by the committee on Methods of Cooking and Testing Meat for Palatability of the National Cooperative

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Meat Investigations Committee (*13*). Results of some of these tests show that meat quality was not greatly affected by the very unfavorable nutritional regimens to which some animals were subjected for 6 months during the early part of their lives. At slaughter time, the area of the rib eye (longissimus dorsi muscle) from a retarded animal was approximately equal to that of its co-twin (table 6).

The longissimus dorsi muscle in the 9th, 10th, and 11th ribs of some twin pairs was chemically analyzed together with the remaining edible portion of the 9th-10th-11th-rib cut (table 7).

DISCUSSION

Compensatory Growth After Undernutrition

The results reported here together with those reported in earlier publications demonstrate that young cattle can survive and recover from a season of relatively severe undernutrition lasting as long as 6 months (*20, 21, 22*). In 1915, Osborn and Mendel (*15*) reported that rats possess a remarkable ability to recover from undernutrition. More recently, McCance (*10*) reported similar recovery in pigs and cockerels. Relatively great efficiency in feed utilization following undernutrition has been reported by Crichton et al. (*2, 3, 4*) and by Wilson and Osbourn (*18*). In our trials, underfed animals utilized their feed with an overall efficiency equal to that of their co-twins. Similar results have been reported by Carroll et al. (*1*).

Results of the research reported here and of those reported earlier (*20, 21, 22*) fail to show that a season of undernutrition affects the quality of the meat unfavorably. In contrast with this finding, Carroll et al. (*1*) reported more intramuscular fat in the longissimus dorsi muscle of continuously well-fed cattle than in cattle subjected to restriction of protein and energy early in their lives. Our chemical analyses did not demonstrate that the composition of the meat of animals fed the poorest rations used in the experiment differed greatly from that of co-twins fed relatively favorable rations.

Significance of Data

In the continuous growth studies, even though treatments given the animals have differed greatly, co-twins invariably grew to the same body size and condition by the end of the experiment. Feed intake per unit of gain was likewise similar despite the dissimilarity of early treatment. For these reasons, statistical treatment of the experimental results was not carried out. The plan of the experiment was based upon an incomplete block design for identical twins that could have demonstrated significant differences had they existed.

The fact that undernutrition early in the life of cattle does not affect overall efficiency in the utilization of feed, eventual body size, or meat quality represents a finding of more than academic interest. Before studies of compensatory growth were started at various experiment stations in recent years, the possible harmful effect of interrupted growth occurring periodically in range cattle was a controversial subject. At present there appears to be general agreement that a period of nutritional stress early in the life of cattle, followed by a period of recovery has but little effect on the overall efficiency of utilizing feed or on the quality of the final product, namely meat. To demonstrate the latter point, the quality of meat of five pairs of twins is compared in table 8. One of the twins in each pair received a very low protein ration while its co-twin consumed a liberal amount of protein. Despite this difference in early feeding, meat of co-twins was similar in chemical composition.

Malnutrition Should Be Avoided

Although our experiments failed to demonstrate anatomical changes in cattle after a period of undernutrition and complete recovery, the results do not imply that it is desirable to winter cattle in a semistarved condition if it can be avoided. Undernutrition can be disastrous if it is too severe. Waters (*17*) and Joubert (*8*) have reported that prolonged undernutrition can cause stunting. Hart (*6*) has stated that after wintering under unfavorable conditions, cattle may lose their ability to recover fully, resulting in their being marketed at a financial loss. Schultz (*16*) has reported a similar failure of rats to recover fully from malnutrition. Thus, it has been amply demonstrated that animals should not be subjected to severe undernutrition if it can be avoided. However, situations arise in which cattle must be carried for several months on unsupplemented range forage. Under such conditions, some alleviation can be accomplished by providing rough shelter and ample quantities of the required minerals, carotene, and water.

TABLE 1.—*Rations used during period of restricted feeding* [1]

Ration constituents	Low-energy ration				Medium-energy ration [2]			High-energy ration [2]		
	Low protein	Medium protein	High protein	High protein	Low protein	Medium protein	High protein	Low protein	Medium protein	High protein
	1	2	3A	3	4B	4A	4	7B	7A	7
Digestible protein [3] ....percent..	2.4	5.1	10.1	10.7	3.9	6.2	6.6	3.3	4.9	6.6
Daily allowance for a 400-lb. calf pounds..	5.1	5.2	5.3	5.1	9.6	9.4	9.1	13.6	13.4	13.1
Ingredients by weight:										
Alfalfa meal...........percent..	3.6	33.9	22.5	74.3	12.5	19.8	27.0	3.7	15.4	27.0
Beet pulp..............do....	--------	--------	23.1	--------	38.0	32.8	27.7	44.8	36.2	27.7
Corncobs...............do....	28.5	17.3	--------	--------	--------	--------	--------	--------	--------	--------
Cornmeal...............do....	14.2	15.1	22.4	22.8	--------	13.4	26.9	--------	13.4	26.9
Cornstarch.............do....	14.2	8.7	--------	--------	9.0	4.5	--------	6.0	3.0	--------
Hay, rough, ground......do....	26.8	16.4	13.7	--------	29.0	22.7	16.4	34.9	25.6	16.4
Linseed meal...........do....	--------	--------	16.4	--------	--------	--------	--------	--------	--------	--------
Molasses...............do....	8.8	5.4	--------	--------	--------	--------	--------	--------	--------	--------
Sugar..................do....	--------	--------	--------	--------	8.5	4.2	--------	8.5	4.2	--------
Bonemeal, steamed.......do....	1.9	.8	.3	--------	--------	.2	.4	--------	.2	.4
Monosodium phosphate....do....	1.0	1.4	.6	1.8	2.0	1.4	.7	1.2	1.0	.7
Salt...................do....	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total.....................	100.0	100.0	99.9	100.1	100.0	100.0	100.1	100.1	100.0	100.1

[1] Total digestible nutrients (TDN) in ration 3A were 64 percent of dry matter; that of all other rations fed in the experiment, 67 percent. All rations were fed as ⅝-inch pellets.

[2] If all rations were consumed, the medium-energy ration provided for a possible daily gain of 1 pound per day; high-energy, for a gain of 2 pounds per day.

[3] Determined by the equation $D=42.64\ (P-5)^{0.215}$, where D=apparent digestibility of the protein and P=protein content (dry basis) as suggested by Mitchell (*11*). Morrison (*12*) was source of information on protein content or the ingredients utilized. The equation did not permit the estimation of digestible protein of ration No. 1, various batches of which ranged from 5- to 6-percent crude protein or 2.1- to 3.4-percent digestible protein.

TABLE 2.—*Rations utilized during restricted feeding and their effect on body weight*

Animal No.	Sex[1]	Breed or[2] cross	Rations fed[3]	Rations consumed[4]			Period of restricted feeding	Body weight		
				Daily mean	In proportion to liberal rations[5]: Digestible protein	In proportion to liberal rations[5]: Digestible energy		Start of period	End of period	Daily gain
			No.	*Pounds*	*Percent*	*Percent*	*Days*	*Pounds*	*Pounds*	*Pounds*
46	S	A	1	4. 3	14	42	179	302	279	−0. 13
45[6]	S	A	2	4. 5	39	41	179	298	318	. 11
95	S	H	1	4. 6	16	39	182	370	334	−. 20
96	S	H	2	4. 7	30	40	182	370	342	−. 15
91	S	A	1	4. 2	17	39	189	310	300	−. 05
92	S	A	2	4. 3	28	40	189	292	360	. 36
75	S	A	1	3. 6	16	39	188	252	230	−. 12
76	S	A	[7] 3A	3. 5	53	40	188	238	290	. 28
93	S	A	1	5. 7	16	38	182	494	490	−. 02
94	S	A	3A	5. 7	57	39	182	474	540	. 36
89	S	A	1	5. 2	17	40	182	420	400	−. 11
90	S	A	3A	5. 4	58	41	182	420	442	. 12
47	F	A	2	4. 6	37	40	181	324	352	. 16
48[6]	F	A	3	4. 6	65	40	181	312	388	. 42
87	S	A	2	3. 7	27	38	189	252	272	. 11
88	S	A	[7] 3A	3. 6	50	39	189	252	312	. 32
69	S	A	2	4. 4	30	40	180	300	330	. 17

See footnotes at end of table.

TABLE 2.—*Rations utilized during restricted feeding and their effect on body weight*—Continued

Animal No.	Sex [1]	Breed or [2] cross	Rations fed [3]	Rations consumed [4]			Period of restricted feeding	Body weight		
				Daily mean	In proportion to liberal rations [5]			Start of period	End of period	Daily gain
					Digestible protein	Digestible energy				
70	S	A	[7] 3	4. 2	65	42	180	290	356	0. 37
83	F	A	4B	5. 8	24	56	203	290	340	. 25
84	F	A	4A	7. 8	40	66	203	310	468	. 78
73	F	H × G	4B	8. 6	31	66	216	370	506	. 63
74	F	H × G	4A	10. 2	46	75	216	380	570	. 88
65	F	H	4B	8. 3	26	52	208	538	584	. 22
66	F	H	4	12. 4	55	70	208	530	820	1. 39
72	F	A	4B	6. 3	29	61	175	296	322	. 15
71	F	A	4	8. 3	60	75	175	290	412	. 70
68	S	A	4A	9. 0	42	70	208	324	508	. 88
67	S	A	4	8. 9	54	69	208	302	530	1. 10
79	F	A	4A	7. 8	43	72	189	270	416	. 77
80	F	A	4	7. 5	53	70	189	260	422	. 86
85	F	H × A	7B	5. 6	16	48	210	326	400	. 35
86	F	H × A	7A	7. 9	32	64	210	320	496	. 84
77	F	A × G	7B	8. 4	25	71	175	352	392	. 23
78	F	A × G	7	10. 9	66	83	175	334	554	1. 26

[1] Symbols for sex: F, female; S, steer.

[2] Symbols for breed: A, Aberdeen Angus; H, Hereford; G, Guernsey.

[3] See table 1 for ration composition.

[4] All animals consumed approximately the full allowances except those on ration 4B, which provided enough energy for a daily gain of 1 pound and those on rations 7, 7A, and 7B, which provided enough energy for a daily gain of 2 pounds.

[5] Protein and energy actually consumed between the ages of 6 and 12 months expressed as a percentage of liberal allowances. As used here, liberal allowances for a 400-pound animal are 0.9 of a pound of digestible protein and 14.7 therms of digestible energy, or 7.4 pounds of TDN per day. Energy requirements are assumed to vary with the 0.7 power of body weight, and this factor was used to express protein intake in terms of liberal consumption.

[6] Some information on these pairs is given in an earlier publication (*22*).

[7] Because ration No. 3 had tended to cause bloat in animal No. 70, ration No. 3A was substituted for No. 3 during the final 35 days of restriction. Similarly, ration No. 3 was fed to animals numbered 76 and 88 for the first 55 and 28 days of the trials, respectively, and then was replaced by ration No. 3A.

TABLE 3.—*Feed utilization and gain in weight during recovery feeding—age 12 months to slaughter*

Animal No.	Rations used in restricted feeding	Recovery feeding period	Body weight			Feed consumed in recovery period—mean daily	
			Start of recovery period	End of recovery period [1]	Daily gain	Grain mixture [2]	Alfalfa hay
	No.	*Days*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
46	1	419	279	961	1. 63	([3])	([3])
45	2	419	318	963	1. 54	([3])	([3])
95	1	356	334	1, 048	2. 03	12. 5	2. 8
96	2	356	342	994	1. 85	11. 9	2. 7
91	1	350	300	990	1. 97	11. 3	2. 7
92	2	350	360	964	1. 74	11. 0	2. 5
75	1	370	230	932	1. 90	10. 8	2. 1
76	3A	370	290	900	1. 65	10. 6	2. 1
93	1	293	490	1, 010	1. 77	12. 8	3. 6
94	3A	293	540	1, 004	1. 58	12. 7	3. 6
89	1	420	400	1, 028	1. 52	12. 4	2. 9
90	3A	420	442	1, 010	1. 36	12. 5	2. 9
47	2	378	352	944	1. 57	([4])	([4])
48	3	378	390	949	1. 48	([4])	([4])
87	2	447	272	1, 050	1. 74	12. 9	2. 0
88	3A	447	312	1, 051	1. 65	13. 0	2. 0
69	2	315	330	935	1. 92	10. 8	2. 7
70	3	315	356	955	1. 90	11. 4	2. 7

83	4B	391	340	997	1. 68	13. 0	1. 8
84	4A	328	468	981	1. 56	13. 5	1. 8
73	4B	391	506	1, 037	1. 36	14. 1	2. 1
74	4A	294	570	1, 048	1. 63	14. 0	2. 2
65	4B	237	584	1, 069	2. 05	14. 0	2. 9
66	4	175	820	1, 056	1. 35	13. 4	3. 2
72	4B	255	322	733	1. 61	10. 0	2. 0
71	4	255	412	746	1. 31	9. 7	2. 0
68	4A	273	508	1, 091	2. 14	14. 7	2. 7
67	4	273	530	1, 095	2. 07	14. 7	2. 7
79	4A	322	416	987	1. 77	12. 5	2. 1
80	4	322	422	984	1. 75	12. 5	2. 1
85	7B	384	400	986	1. 53	12. 6	1. 8
86	7A	321	496	1, 018	1. 63	13. 5	1. 8
77	7B	401	392	1, 090	1. 74	12. 4	2. 2
78	7	350	554	1, 065	1. 46	11. 9	2. 2

[1] Final weight in feedlot.

[2] Mixture consisted of the following constituents by weight: corn, 50 percent; oats, 30 percent; bran, 10 percent; and linseed meal, 10 percent.

[3] During the 288 days immediately following restricted feeding, animals numbered 45 and 46 received 13.7 and 14.7 pounds per day, respectively, of a pelleted ration consisting of the following ingredients by weight: alfalfa meal, 43.6 percent; corn cobs, 26.2 percent; corn starch, 27.0 percent; monosodium phosphate, 0.5 percent; and salt, 1 percent. During the final 131 days, these animals received, respectively, 9.8 and 12.0 pounds of corn; 5.9 and 5.5 pounds of alfalfa hay; and 4.8 pounds of grass hay containing 3 percent digestible crude protein (DCP) and 40 percent total digestible nutrients (TDN).

[4] During the 205 days immediately following restricted feeding, animals numbered 47 and 48 received 15.0 and 15.1 pounds per day, respectively, of the pelleted ration described in footnote 3. During the final 173 days, these animals received 14.2 and 13.9 pounds, respectively, of the mixture described in footnote 2, plus 4.5 pounds of alfalfa hay.

TABLE 4.—*Feed utilization and gain in weight by animals during experiment—6 months to slaughter*

Animal No.	Ration fed	Length of experimental period	Body weight		Daily gain	Feed intake per pound of gain		
			Start	End		Digestible energy	TDN	Digestible protein
	No.	*Days*	*Pounds*	*Pounds*	*Pounds*	*Therms*	*Pounds*	*Pounds*
46	1	598	302	961	1. 09	14. 0	7. 2	0. 85
45	2	598	298	963	1. 10	14. 3	7. 5	. 93
95	1	538	370	1, 048	1. 28	11. 3	5. 8	. 81
96	2	538	370	994	1. 17	12. 0	6. 1	. 90
91	1	539	310	990	1. 26	10. 3	5. 3	. 75
92	2	539	292	964	1. 26	10. 2	5. 0	. 76
Mean	1	558	327	1, 000	1. 21	11. 9	6. 1	. 80
Mean	2	558	320	974	1. 18	12. 2	6. 2	. 86
75	1	558	252	932	1. 22	10. 4	5. 3	. 75
76	3A	558	238	900	1. 19	10. 6	5. 4	. 83
93	1	475	494	1, 010	1. 08	13. 9	7. 1	. 98
94	3A	475	474	1, 004	1. 11	13. 7	6. 9	1. 12
89	1	602	420	1, 028	1. 02	14. 8	7. 9	1. 07
90	3A	602	420	1, 010	. 99	15. 4	7. 9	1. 25
Mean	1	545	389	990	1. 11	13. 0	6. 8	. 93
Mean	3A	545	377	971	1. 10	13. 2	6. 7	1. 07
47	2	559	324	944	1. 11	13. 9	7. 1	. 88
48	3	559	312	949	1. 14	13. 4	6. 9	. 93
87	2	636	252	1, 050	1. 25	12. 0	6. 1	. 88
88	3A	636	252	1, 051	1. 26	12. 1	6. 1	. 93

69	2	495	300	935	1.28	10.4	5.3	.79
70	3	495	290	955	1.34	10.2	5.2	.84
Mean	2	563	292	976	1.21	12.1	6.2	.85
Mean	3	563	285	985	1.25	11.9	6.1	.90
83	4B	594	290	997	1.19	12.8	6.5	.87
84	4A	531	310	981	1.26	13.1	6.7	.87
73	4B	607	370	1,037	1.10	15.9	8.2	1.05
74	4A	510	380	1,048	1.31	13.4	6.9	.87
Mean	4B	600	330	1,017	1.14	14.4	7.4	.96
Mean	4A	520	345	1,014	1.28	13.2	6.8	.87
65	4B	445	538	1,069	1.19	13.7	7.0	.90
66	4	383	530	1,056	1.37	13.1	6.7	.89
72	4B	430	296	733	1.02	12.2	6.3	.82
71	4	430	290	746	1.06	12.5	6.4	.87
Mean	4B	438	417	901	1.10	13.0	6.6	.86
Mean	4	406	410	901	1.22	12.8	6.6	.88
68	4A	481	324	1,091	1.59	11.1	5.7	.75
67	4	481	302	1,095	1.65	10.7	5.5	.76
79	4A	511	270	987	1.40	11.1	5.7	.74
80	4	511	260	984	1.42	11.0	5.6	.76
Mean	4A	496	297	1,039	1.50	11.1	5.7	.74
Mean	4	496	281	1,040	1.54	10.8	5.6	.76
85	7B	594	326	986	1.11	13.1	6.7	.87
86	7A	531	320	1,018	1.31	12.3	6.3	.80
77	7B	576	352	1,090	1.28	12.8	6.6	.85
78	7	525	334	1,065	1.39	12.1	6.2	.85

TABLE 5.—*Body size at time of slaughter*

Animal No.	Ration fed	Body weight [1]	Height at withers	Length of body	Circumference at foreflank
	No.	*Pounds*	*Centimeters*	*Centimeters*	*Centimeters*
46	1	961	114	135	182
45	2	963	114	136	186
95	1	1,048	124	135	189
96	2	994	124	136	184
91	1	990	115	133	186
92	2	964	114	133	186
Mean	1	1,000	118	134	186
Mean	2	974	117	135	185
75	1	932	115	127	185
76	3A	900	113	127	182
93	1	1,010	115	134	191
94	3A	1,004	115	136	191
89	1	1,028	120	132	184
90	3A	1,010	117	132	181
Mean	1	990	117	131	187
Mean	3A	971	115	132	185
47	2	944	113	130	180
48	3	949	113	130	181
87	2	1,050	120	122	194
88	3A	1,051	121	122	194
69	2	935	111	125	180
70	3	955	112	125	182
Mean	2	976	115	126	185
Mean	3	985	115	126	186
83	4B	997	114	128	196
84	4A	981	116	131	194
73	4B	1,037	120	138	184
74	4A	1,048	121	138	187
Mean	4B	1,017	117	133	190
Mean	4A	1,014	118	134	190
65	4B	1,069	119	136	186
66	4	1,056	117	136	184
72	4B	733	102	120	170
71	4	746	103	120	171
Mean	4B	901	110	128	178
Mean	4	901	110	128	178
68	4A	1,091	122	134	194
67	4	1,095	122	134	197
79	4A	987	114	127	186
80	4	984	113	127	187

See footnote at end of table.

TABLE 5.—*Body size at time of slaughter*—Continued

Animal No.	Ration fed	Body weight [1]	Height at withers	Length of body	Circumference at foreflank
	Number	*Pounds*	*Centimeters*	*Centimeters*	*Centimeters*
Mean	4A	1, 039	118	130	190
Mean	4	1, 040	118	130	192
85	7B	986	118	132	189
86	7A	1, 018	120	132	187
77	7B	1, 090	121	141	191
78	7	1, 065	120	139	184

[1] Final weight in feedlot.

TABLE 6.—*Grade and composition of carcass and quality of meat*

Animal No.	Ration fed	Grade	Carcass				Meat quality [3]				
			Dressed [1]	Composition [2]			Tenderness	Desirability of flavor (rib)		Area of eye-of-rib cut (longissimus dorsi muscle)	
				Muscle	Fat	Bone		Fat	Lean		
	No.		*Percent*	*Percent*	*Percent*	*Percent*				*Sq. in./100 lb.*	*Sq. in.*
46	1	Average choice	65	52.4	34.1	13.5	6.4	5.8	6.4	1.31	12.6
45	2	do	67	51.4	34.9	13.7	5.8	5.8	5.4	1.20	11.6
95	1	do	64	47.6	37.1	15.3	5.8	5.0	6.0	1.03	10.8
96	2	Low choice	63	49.0	34.6	16.4	5.8	5.4	6.0	1.06	10.5
91	1	Average choice	64	53.7	32.1	14.2	6.8	5.8	6.6	1.21	12.0
92	2	do	64	55.1	30.6	14.3	6.6	5.8	6.0	1.20	11.6
Mean	1		64	51.2	34.4	14.3	6.3	5.5	6.3	1.18	11.8
Mean	2		64	51.8	33.4	14.8	6.1	5.7	5.8	1.15	11.2
75	1	Average choice	62	48.1	36.3	15.5	6.4	6.0	6.6	1.19	11.1
76	3A	do	61	48.5	34.7	16.8	6.0	6.2	6.8	1.16	10.4
93	1	High choice	66	48.0	35.5	16.5	6.6	6.0	6.6	1.43	14.4
94	3A	do	66	47.5	38.2	14.3	6.8	6.2	6.8	1.18	11.8
89	1	do	67	51.2	33.1	15.7	6.6	6.2	6.4	1.41	14.5
90	3A	do	66	51.0	32.9	16.1	7.0	6.4	6.6	1.47	14.8
Mean	1		65	49.1	35.0	15.9	6.5	6.1	6.5	1.34	13.3
Mean	3A		64	49.0	35.3	15.7	6.6	6.3	6.7	1.27	12.3
47	2	Low choice	66	43.8	43.7	12.5	6.0	5.0	6.2	1.22	11.5
48	3	do	65	44.3	42.8	13.0	5.6	5.6	5.8	1.02	9.7

87	2	High choice	63	51. 1	35. 0	13. 8	6. 2	6. 0	6. 2	1. 06	11. 1
88	3A	Average choice	62	48. 0	37. 0	15. 0	6. 4	6. 2	6. 6	. 93	9. 8
69	2	do	59	54. 0	29. 2	16. 8	6. 0	6. 0	6. 0	1. 49	13. 9
70	3	do	60	55. 2	29. 8	14. 9	6. 2	5. 8	5. 6	1. 53	14. 6
Mean	2		63	49. 6	36. 0	14. 4	6. 1	5. 7	6. 1	1. 25	12. 2
Mean	3		62	49. 2	36. 5	14. 3	6. 1	5. 9	6. 0	1. 16	11. 4
83	4B	Low prime	65	42. 8	43. 3	13. 9	6. 6	6. 2	6. 8	1. 17	11. 7
84	4A	do	66	39. 0	48. 2	12. 8	6. 2	5. 4	6. 2	1. 40	13. 7
73	4B	High good	61	44. 1	41. 8	14. 1	6. 0	6. 0	6. 2	1. 23	12. 8
74	4A	Low choice	59	44. 6	40. 5	14. 9	6. 4	6. 4	6. 0	1. 04	10. 9
Mean	4B		63	43. 4	42. 6	14. 0	6. 3	6. 1	6. 5	1. 20	12. 2
Mean	4A		62	41. 8	44. 4	13. 8	6. 3	5. 7	6. 1	1. 21	12. 3
65	4B	Low choice	62	46. 7	34. 4	18. 9	6. 8	5. 8	6. 2	. 81	8. 7
66	4	do	61	47. 0	36. 6	16. 3	6. 0	6. 0	6. 2	. 96	10. 1
72	4B	Average choice	60	45. 2	38. 9	15. 8	6. 2	6. 0	5. 8	1. 26	9. 2
71	4	Low choice	60	51. 4	33. 5	15. 0	6. 0	5. 6	5. 8	1. 31	9. 8
Mean	4B		61	46. 0	36. 6	17. 6	6. 5	5. 9	6. 0	1. 00	9. 0
Mean	4		60	49. 2	35. 0	15. 6	6. 0	5. 8	6. 0	1. 11	10. 0
68	4A	Low choice	61	52. 3	29. 1	18. 6	5. 8	6. 0	6. 4	1. 06	11. 6
67	4	do	62	53. 9	29. 0	17. 0	6. 2	6. 2	5. 8	1. 30	14. 2
79	4A	Top choice	62	53. 0	31. 5	15. 4	5. 8	5. 8	6. 2	1. 40	13. 8
80	4	do	61	53. 4	31. 8	14. 8	5. 8	5. 6	6. 0	1. 29	12. 7
Mean	4A		62	52. 6	30. 3	17. 0	5. 8	5. 9	6. 3	1. 22	12. 7
Mean	4		62	53. 6	30. 4	15. 9	6. 0	5. 9	5. 9	1. 29	13. 4

See footnotes at end of table.

TABLE 6.—*Grade and composition of carcass and quality of meat*—Continued

Animal No.	Ration fed	Grade	Carcass: Dressed [1]	Carcass: Composition [2]: Muscle	Carcass: Composition [2]: Fat	Carcass: Composition [2]: Bone	Meat quality [3]: Tenderness	Meat quality [3]: Desirability of flavor (rib): Fat	Meat quality [3]: Desirability of flavor (rib): Lean	Meat quality [3]: Area of eye-of-rib cut (longissimus dorsi muscle)	Meat quality [3]: Area of eye-of-rib cut (longissimus dorsi muscle)
	Number		*Percent*	*Percent*	*Percent*	*Percent*				*Sq. in./100 lb*	*Sq. in.*
85	7B	Low choice	64	45. 3	41. 1	13. 5	6. 0	5. 8	6. 4	1. 31	12. 9
86	7A	Average choice	63	45. 7	39. 4	14. 9	6. 0	5. 6	5. 6	1. 39	14. 2
77	7B	Low choice	60	51. 3	33. 3	15. 4	5. 8	4. 8	6. 0	1. 13	12. 3
78	7	High good	58	52. 0	32. 9	15. 1	6. 4	6. 0	6. 4	1. 05	11. 3

[1] Dressed percentage$=\frac{\text{cold weight}}{\text{final weight in feedlot}}\times 100.$

[2] Computed through use of equations derived by Hankins and Howe (5), as follows: (a) Separable muscle of dressed carcass= 16.08+0.8 of a percent of separable muscle in the 9th-10th-11th-rib cut; (b) separable fat of dressed carcass=3.54+0.8 of a percent of separable fat in the 9th-10th-11th-rib cut; and (c) separable bone and tendon of dressed carcass=5.52+0.57 of a percent of the separable bone and tendon in the 9th-10th-11th-rib cut.

[3] Numbers 1 to 7 represent degrees of tenderness and desirability of flavor. In rating flavor, number 1 means that a desirable flavor is absent or that it is of such low intensity as to be imperceptible; 7, that the meat has a highly desirable flavor. In regard to tenderness, number 1 means the meat is extremely tough; 7, that it is very tender.

TABLE 7.—*Chemical composition of meat in the 9th-10th-11th-rib cut*

Animal No.	Ration fed	Rib eye (longissimus dorsi muscle)			
		Water	Ash	Protein	Ether extract
	No.	*Percent*	*Percent*	*Percent*	*Percent*
46	1	70.7	1.1	20.6	7.6
45	2	70.0	1.1	20.8	8.1
95	1	69.3	1.0	22.7	7.0
96	2	69.6	.9	21.8	7.7
91	1	69.5	1.0	21.1	8.4
92	2	69.6	1.0	20.7	8.6
Mean	1	69.8	1.0	21.5	7.7
Mean	2	69.7	1.0	21.1	8.1
75	1	66.6	1.1	21.1	11.2
76	3A	66.9	.9	20.3	11.9
93	1	71.1	1.0	21.6	6.3
94	3A	70.8	1.1	22.0	6.1
89	1	70.5	1.0	22.1	6.3
90	3A	69.2	1.0	22.6	7.2
Mean	1	69.4	1.0	21.6	7.9
Mean	3A	69.0	1.0	21.6	8.4
47	2	68.8	1.0	21.2	9.0
48	3	68.3	1.0	21.3	9.4
87	2	66.2	1.0	20.8	12.0
88	3A	66.7	1.0	20.5	11.7
Mean	2	67.5	1.0	21.0	10.5
Mean	3	67.5	1.0	21.0	10.6
83	4B	60.8	.8	19.5	18.9
84	4A	59.2	1.0	20.5	19.3
73	4B	65.0	1.0	21.4	12.6
74	4A	67.8	1.0	20.5	10.7
Mean	4B	62.9	1.0	20.4	15.8
Mean	4A	63.5	1.0	20.5	15.0
65	4B	69.3	1.0	20.2	9.5
66	4	70.6	1.1	21.0	7.2
79	4A	69.0	.9	20.6	9.4
80	4	69.6	1.0	21.7	7.8
85	7B	66.7	.9	20.4	12.0
86	7A	66.6	1.0	20.9	11.5
77	7B	68.0	.9	21.4	9.7
78	7	68.3	1.0	20.6	10.1

TABLE 8.—*Protein intake of 5 pairs of twin cattle and the composition of their meat*

Low Protein Intake

Item	Values obtained					Mean
Animals [1] (co-twins shown below) No.	75	93	89	65	77	------
Ration fed No.	1	1	1	4B	7B	------
Rib-eye muscle: [2]						
Water percent	66. 6	71. 1	70. 5	69. 3	68. 0	69. 1
Ash do	1. 1	1. 0	1. 0	1. 0	. 9	1. 0
Protein do	21. 1	21. 6	22. 1	20. 2	21. 4	21. 3
Ether extract do	11. 2	6. 3	6. 3	9. 5	9. 7	8. 6
Remaining edible part: [2]						
Water do	27. 8	32. 9	28. 0	39. 3	32. 6	32. 1
Ash do	. 6	. 5	. 4	. 6	. 6	. 5
Protein do	9. 6	9. 8	10. 5	11. 0	11. 0	10. 4
Ether extract do	62. 0	56. 7	61. 0	49. 2	55. 9	57. 0

Adequate Protein Intake

Item	Values obtained					Mean
Animal [1] No.	76	94	90	66	78	------
Ration fed No.	3A	3A	3A	4	7	------
Rib-eye muscle: [2]						
Water percent	69. 9	70. 8	69. 2	70. 6	68. 3	68. 9
Ash do	. 9	1. 1	1. 0	1. 1	1. 0	1. 0
Protein do	20. 3	22. 0	22. 6	21. 0	20. 6	21. 4
Ether extract do	11. 9	6. 1	7. 2	7. 2	10. 1	8. 5
Remaining edible part: [2]						
Water do	30. 6	29. 6	33. 3	33. 3	33. 5	32. 1
Ash do	. 5	. 4	. 5	. 5	. 5	. 5
Protein do	10. 4	8. 8	11. 6	10. 3	10. 6	10. 3
Ether extract do	58. 4	61. 2	54. 5	56. 0	55. 4	57. 1

[1] The pairs of twins are animals No. 75 and 76, 93 and 94, 89 and 90, 65 and 66, and 77 and 78.

[2] Meat of the 9th-10th-11th-rib cut.

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