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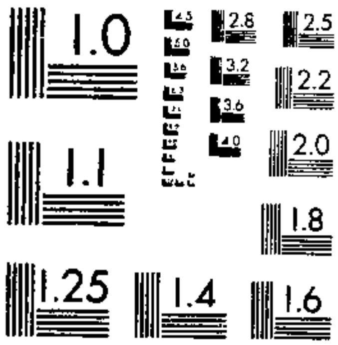

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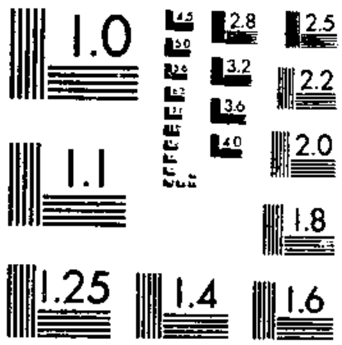

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Delayed Growth of BEEF CATTLE

By C. F. Winchester and N. R. Ellis

Technical Bulletin No. 1159

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ACKNOWLEDGMENTS

Grateful acknowledgment is made of generous contributions toward the success of the delayed-growth studies by many persons and agencies. Unfortunately, it is impossible to name all of the individuals and organizations that have aided in the work; for example, no complete record exists of the many channels through which information on our need for identical twins was carried to the public and information concerning twins reached us. Without such an exchange of information, studies with twin cattle would be impossible.

All samples of blood taken from the twin cattle were analyzed by M. R. Irwin and associates, Department of Genetics, University of Wisconsin, to aid in the determination of monozygocity.

All meat studies were made by members of the Meats Section, Animal and Poultry Husbandry Research Branch, Agricultural Research Service, under the supervision of R. L. Hiner and others. Chemical analyses of meat and feed samples were made by personnel of the Animal and Poultry Husbandry Research Branch. This work was done either under the supervision of W. R. Kauffman or by V. C. Scarborough; the latter also carried out many of the computations involved in the study. Some of the analyses of variance were carried out by W. R. Harvey, in charge, Livestock Research Staff, Biometrical Services. Studies of hide quality and some analyses of variance made in connection with this study were carried out by personnel of the Hides, Tanning Materials and Leather Section, Western Utilization Research Branch. Many of the measurements of body size were made by A. C. Cook, Animal and Poultry Husbandry Research Branch, who also gave generously of his time for other phases of the work.

The twin calves in the study were selected by George Beattie, Animal and Poultry Husbandry Research Branch, under whose direct supervision the animals were fed and cared for throughout the trials.

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Delayed Growth of BEEF CATTLE[1]

By C. F. Winchester and N. R. Ellis, *Animal and Poultry Husbandry Research Branch, Agricultural Research Service*

INTRODUCTION

Beef cattle seldom realize their full potentiality for rapid growth because of limitations imposed by environmental factors, especially nutrition. This is in evidence particularly in the range country, where more than 80 percent of the approximately 25 million beef calves dropped yearly in the United States are born. Under range conditions, grasses furnish excellent feed for cattle during the spring and early summer. But as summer progresses, grasses become increasingly poor feed because of maturing, drying, and weathering. By the beginning of winter, after exposure to rain and sun, some grasses are of little feed value, even to ruminants, except as a source of energy.

Young animals often cease gaining and frequently lose weight on dried, weathered forage. They do not begin to gain again until after the spring crop of grass has appeared.

Supplementary feeds are often used with forage. However, the cost of these supplements is relatively great, particularly when enough are fed to produce increments in body weight rather than merely to supply the nutrients essential to the maintenance of good health.

There is little doubt that cattle are harmed by a feeding regimen that, in addition to failing to supply sufficient energy to permit growth, also fails to supply such essential nutrients as protein, the required minerals, and carotene. Such a regimen is typical of many range areas. According to Hart (*9*),[2] after a season on such feed cattle "lose their efficiency of production. Full recovery is difficult or often impossible to obtain and, at best, is accomplished at an economic loss." On the other hand, earlier experiments (*10, 14, 15, 20, 21*) furnish some evidence that retardation caused principally by caloric restriction does not destroy the animal's potentiality for growth even when the caloric restriction lasts several months.

A question, then, of considerable economic importance is whether or not young cattle are harmed permanently if their growth is interrupted during seasons of feed shortage. There is also a question as to whether or not the possible harmful effects of a caloric allowance that is insufficient to produce gain in weight are mitigated if the cattle receive the essential nutrients in supplemental feeds.

In earlier studies (*22, 24, 26*) we found that steers that did not gain weight between 6 months and 1 year of age on rations that were adequate except for a deficiency in energy value later grew rapidly on liberal caloric

[1] Submitted for publication, May 18, 1956.

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

allowances. During the period from the beginning of reduced energy intake until slaughter the amount of feed required to produce a pound of gain was not increased by retardation. Neither the quality of meat nor the amount of muscle in the carcass was affected measurably by the period of limited caloric intake. The experiments were carried out with 6 pairs of monozygotic ("1-egg" or identical) twin beef steers (*23*). Such twins are rare. However, because of their identical inheritance they are much more valuable in research than an equal number of less closely related animals (*2*, *8*).

The outcome of these earlier experiments raised this question: What will be the later feed efficiency, quality of meat and hide, and proportion of muscle to fat and bone in carcasses of cattle that are weaned at 3 or 4 months of age and then are fed rations of various caloric values, including both maintenance and submaintenance rations, for 3 or 4 months? The experiments reported here were designed to cast some light on this question. The research was carried out at Beltsville, Md.

MATERIALS AND METHODS

Animals Used

Ten pairs of identical twin cattle were used in these experiments. The group included 6 pairs of heifers and 4 pairs of steers, and consisted of crossbred beef × dairy-type cattle as well as "high grade" and purebred beef animals.

A critical physical examination confirmed by a blood test of an antigenic type was the criterion of the monozygosity of each twin pair. The blood test is considered entirely reliable when it shows that a pair of twins is not monozygotic and 90 percent dependable when it indicates that a pair is of 1-egg origin.

Each animal was slaughtered when a committee found either (1) that it had reached a grade of Low Prime or (2) that its progress was so slow that it would not reach this grade within a reasonable time, that is, within 82 weeks after the end of the period of reduced energy intake.

Rations and Feeding Procedures

Table 1 lists the rations used in these feeding trials. The rations were made up of alfalfa hay, linseed oil meal, and, in some cases, cracked corn. They were designed to supply liberal amounts of the nutrients required by cattle with the single exception of sources of energy when energy was the factor limiting growth. One of each pair of twins (experimental animal) was fed a low-energy allowance from 3 to 6 months of age or from 4 to 8 months of age. Three animals were fed at a submaintenance level (ration 1), 3 were fed just enough to maintain body weight (ration 2), and 4 were fed at levels between maintenance and liberal (rations 3 and 4). During the period of restricted energy intake by these animals, their cotwins (control animals) were fed a liberal allowance (ration 5). The calves received no corn while they were on either submaintenance or maintenance rations. Protein was supplied in amounts roughly equal to or in excess of the levels recommended by the Committee on Animal Nutrition of the National Research Council (*6*) or by Morrison (*13*).

To insure ample intake of phosphorus, each animal had free access to monosodium phosphate in its box stall; each animal also had free access to sodium chloride in the form of rock salt.

The rations were presumably liberally supplied with carotene. However, sufficient vitamin A in oil was added to them to meet each animal's requirements for this nutrient. This was done to eliminate the necessity for making carotene analyses of the feed.

TABLE 1.—*Nutritional requirements for growth, and composition of the rations used in these experiments (based on the requirements of a 400-pound calf)*

Items compared	Percentage of liberal ration [1]	Percentage of maintenance ration	Alfalfa hay	Linseed oil meal	Corn	Dry matter	Total digestible nutrients	Digestible protein
Recommended allowance:	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Morrison (*13*)						9.1–11.4	6.2–7.2	0.76–0.87
Guilbert and others (*6*)						10.8	7.0	0.90
Experimental rations: [2]								
1	36	75	2.5	1.9	0	4.0	2.7	.84
2	49	100	2.5	3.0	0	5.0	3.6	1.17
3	66	136	4.9	2.6	0.5	7.2	4.9	1.34
4	82	169	4.9	2.6	2.1	8.6	6.1	1.44
5	100	206	4.9	2.6	3.7	9.9	7.4	1.55
6	100	206	4.0	1.0	5.8	9.5	7.4	1.11

[1] Energy level of the liberal rations is 7.4 pounds TDN for a 400-pound calf (fig. 1).

[2] Rations 1 through 4 are examples of rations fed to the experimental animals during the period of reduced energy intake; ration 5 was fed to the control animals while their cotwins were on the restricted rations; and ration 6 was fed after the period of reduced energy intake ended.

The low-energy rations fed in these experiments differed in nutrient content from a ration made up entirely of mature range grasses such as is often available for winter grazing. However, forage can be supplemented so that it is comparable in nutritive value to the experimental rations.

A level of energy intake was adopted to serve as a criterion for use with animals of various sizes. This allowance varies with the three-fourths power of body weight and is nearly the same as Morrison's (*13*) "more liberal" allowance for dairy animals weighing from 150 to 200 pounds and for rapidly growing beef cattle weighing from 300 to 400 pounds (fig. 1). For animals weighing from 600 to 1,000 pounds, the allowance is an average of the allowances for growing beef cattle fed for rapid growth and for fattening yearlings given by the National Research Council (*6*) and by Morrison (*13*).

Tables 2 and 3 show how the energy consumed by the various animals compares with the allowances given in figure 1. Some of the animals were kept in box stalls from late afternoon until morning and the remainder of the time they were out of doors in a yard kept free of grass and weeds. The rest of the animals were kept in individual box stalls each of which had an adjoining paved paddock to which the animal had access at all times.

The rations were fed in the box stalls morning and evening under the supervision of an experienced herdsman. All unconsumed feed was weighed and recorded.

Measurements of Body Size

The animals were weighed at weekly intervals after they had consumed the morning feed allowance. Body measurements of both members of each pair of twins were made at the end of the period of reduced energy intake, at 1 year of age, and just before the control animal was slaughtered when its slaughter preceded that of its cotwin. Body measurements of the four experimental animals that were slaughtered later than their cotwins were made again just prior to slaughter. Nineteen measurements, similar to those described by Lush (*12*), were made in triplicate of each animal.

Both members of each pair of twins were photographed at the beginning and at the end of the period of reduced energy intake, and when the control animal reached slaughter condition. The four experimental animals that were slaughtered later than their cotwins were photographed again just prior to slaughter.

Determination of Meat Quality

A committee of three or more experienced judges graded the animals before slaughter, and the carcasses following slaughter. Members of the committee varied from time to time.

Determinations were made of the chemical composition of a section of the semitendinosus muscle of the round and of one of the longissimus dorsi from the right 9th-10th-11th-rib cut. Various organoleptic tests were made to determine palatability. In addition, an objective test to determine tenderness was made with the Warner-Bratzler machine.

RESULTS

Effects of Feed Intake on Growth

During the period of reduced energy intake, the "poorly fed" animals were fed rations that ranged from submaintenance through maintenance to three-fourths of a liberal ration (table 2). In these trials, as in previous experiments (*25*), maintenance refers to the level of energy required by an animal that is neither gaining nor losing weight.

At the end of the period of growth retardation, the experimental animals grew rapidly on a liberal ration (figs. 2

and 3). This was true even of those animals that received submaintenance rations on which they lost weight (fig. 2). The growth curves of calves fed just enough to maintain body weight (fig. 3) were similar to the growth curves of calves fed maintenance ration between the ages of 6 and 12 months in an earlier series of trials (*26*). Similar growth patterns were reported earlier by Waters (*21*).

Growth of cattle after retardation is similar to that observed in rats by Osborne and Mendel (*17*), who re-

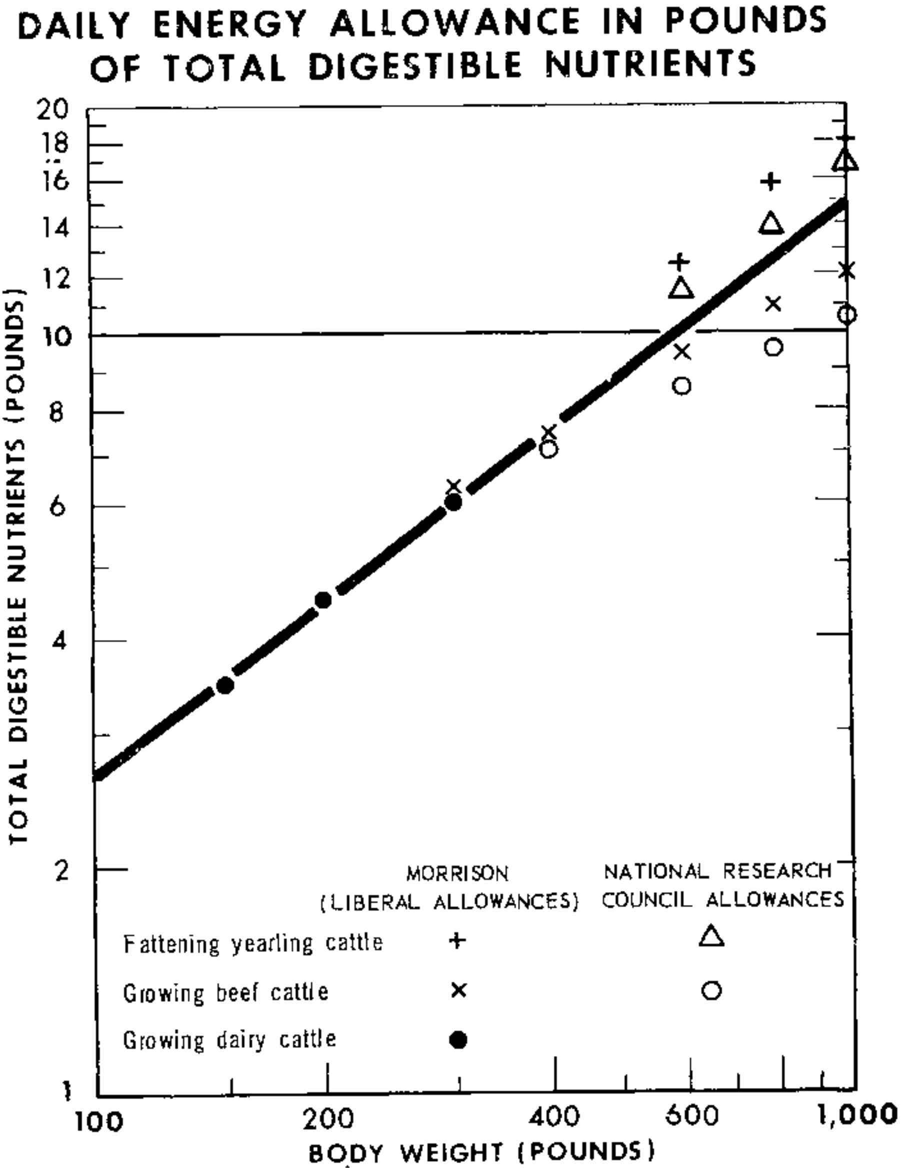

FIGURE 1.—The level of energy intake (pounds of total digestible nutrients) fed daily to animals of different sizes was based on recommendations of Morrison and the National Research Council.

TABLE 2.—*Energy intake and gain (or loss) in weight by 10 calves during a period of reduced energy intake, as compared with their identical twins on a liberal ration*

Animal	Twin No.	Sex	Breed or cross	Age: At start of period	Age: At end of period	Body weight: At start of period	Body weight: At end of period	Body weight: Gain (+) or loss (—) in weight per day	Energy intake during period: Percentage of liberal ration	Energy intake during period: TDN	Energy intake during period: Digestible calories [1]	Energy intake per pound of gain: TDN	Energy intake per pound of gain: Digestible calories [1]
				Days	*Days*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Millions*	*Pounds*	*Millions*
Control	23	Female	Angus	91	182	174	244	+0.77	73	305	627	4.4	9.0
Experimental	24					170	150	—.22	35	119	249	......	......
Control	38	do	do	123	249	200	318	+.94	73	494	982	4.2	8.3
Experimental	37					[2] 260	232	—.22	36	232	484	......	......
Control	26	Steer	Hereford × Angus-Guernsey.	113	239	212	336	+.98	76	536	1,100	4.3	8.9
Experimental	25					224	206	—.14	36	213	445	......	......
Control	22	do	Hereford × Guernsey.	92	184	205	271	+.72	72	339	692	5.1	10.5
Experimental	21					211	208	—.03	42	178	374	......	......
Control	19	Female	Angus	92	183	113	184	+.81	74	242	496	3.3	6.7
Experimental	20					114	140	+.28	47	134	282	......	......
Control	30	Steer	Milking Shorthorn.	126	252	220	350	+1.03	77	557	1,137	4.3	8.7
Experimental	29					228	252	+.19	49	311	657	......	......
Control	31	Female	Hereford × Shorthorn.	92	183	160	266	+1.16	87	365	739	3.4	7.0
Experimental	32					156	198	+.46	58	214	441	5.1	10.5

Control	36	Steer	Hereford × Shorthorn.	93	188	192	340	+1.56	88	454	917	3.1	6.2
Experimental	35					200	270	+.74	61	284	588	4.1	7.9
Control	34	Female	Hereford × Guernsey.	93	187	196	332	+1.45	89	457	924	3.4	6.8
Experimental	33					206	330	+1.32	73	383	780	3.1	6.3
Control	28	do	Hereford × Guernsey.	93	201	200	334	+1.24	89	530	1,055	4.0	7.9
Experimental	27					198	290	+.85	74	412	840	4.5	9.1

[1] Digestible calories = milligrams of digestible protein × 5.65 + milligrams of digestible fat × 9.3 + milligrams of digestible carbohydrates × 4.1.

[2] One cotwin, accepted by its dam, weighed 60 pounds more when the trial began than its pair mate that was "pail fed" from birth to weaning. The "pail fed" animal was fed a liberal ration, and its cotwin was fed a submaintenance ration.

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TABLE 3.—*Energy intake and gain in weight by 10 animals on a liberal ration for the period from the end of reduced energy intake until slaughter, as compared with their continuously well-fed identical twins*

Animal	Twin No.	Age: At start of period	Age: At end of period	Body weight: At start of period	Body weight: At end of period	Body weight: Daily gain in weight	Energy intake, During period: Percentage of liberal ration	Energy intake, During period: TDN	Energy intake, During period: Digestible calories [1]	Energy intake, Per pound of gain: TDN	Energy intake, Per pound of gain: Digestible calories [1]
		Days	*Days*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Millions*	*Pounds*	*Millions*
Control	23	182	559	244	797	1.47	98	3,328	6,583	6.0	11.9
Experimental	24		645	150	833	1.48	96	3,850	7,592	5.6	11.1
Control	38	249	653	318	979	1.64	94	4,075	8,021	6.2	12.1
Experimental	37			232	967	1.82	93	3,771	7,410	5.1	10.1
Control	26	239	656	336	1,118	1.87	95	4,658	9,190	6.0	11.8
Experimental	25		698	206	1,134	2.01	96	4,806	9,492	5.2	10.2
Control	22	184	674	271	1,055	1.60	92	4,839	9,422	6.2	12.0
Experimental	21		757	208	1,132	1.61	91	5,690	11,202	6.2	12.1
Control	19	183	757	184	852	1.16	93	4,782	9,383	7.2	14.0
Experimental	20			140	819	1.18	93	4,539	8,939	6.7	13.2
Control	30	252	770	350	1,311	1.86	91	6,010	11,803	6.2	12.3
Experimental	29			252	1,249	1.92	96	5,952	11,674	6.0	11.7
Control	31	183	701	266	997	1.41	88	4,776	9,423	6.5	12.9
Experimental	32			198	996	1.54	90	4,655	9,156	5.8	11.5
Control	36	188	539	340	1,101	2.17	94	3,796	7,488	5.0	9.8
Experimental	35		692	270	1,130	1.71	89	5,080	9,926	5.9	11.5

Control	34	187	697	332	965	1.24	86	4,711	9,266	7.4	14.6
Experimental	33			330	1,030	1.37	89	4,995	9,823	7.1	14.0
Control	28	201	705	334	1,043	1.41	90	5,107	10,056	7.2	14.2
Experimental	27			290	1,017	1.44	93	5,023	9,862	6.9	13.6

[1] Digestible calories = milligrams of digestible protein × 5.65 + milligrams of digestible fat × 9.3 + milligrams of digestible carbohydrates × 4.1.

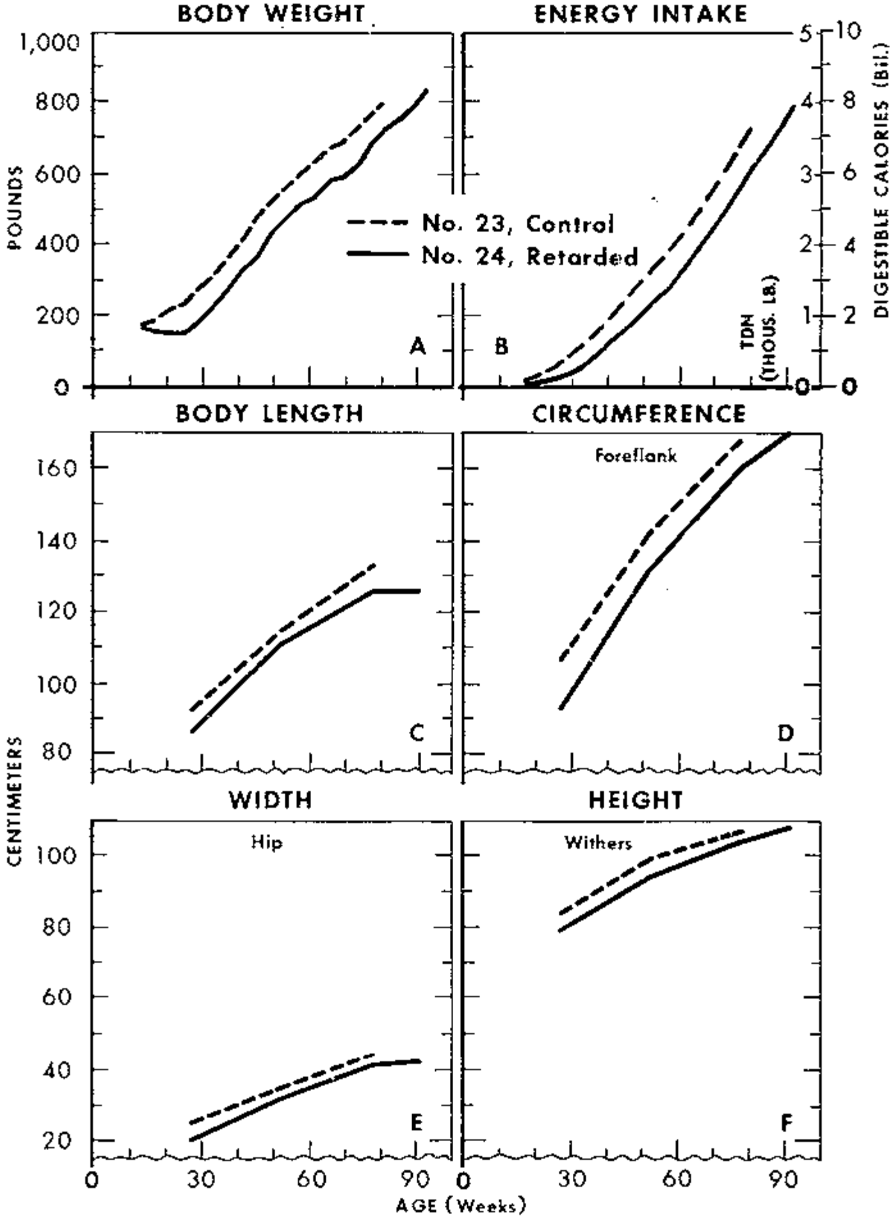

FIGURE 2.—Curves showing gain in body weight, energy consumption, and four body measurements of identical twin heifers. Twin No. 24 (experimental animal) was fed a submaintenance ration from 13 to 26 weeks of age; No. 23 was its cotwin control.

ported that after interruption: "Growth . . . is resumed at a rate normal for the size of the animals at the time . . . frequently it actually exceeds the usual progress."

Even though the growth curves show that the experimental animals, after interruption of growth, made gains comparable to those of their cotwin controls, a question remains as to

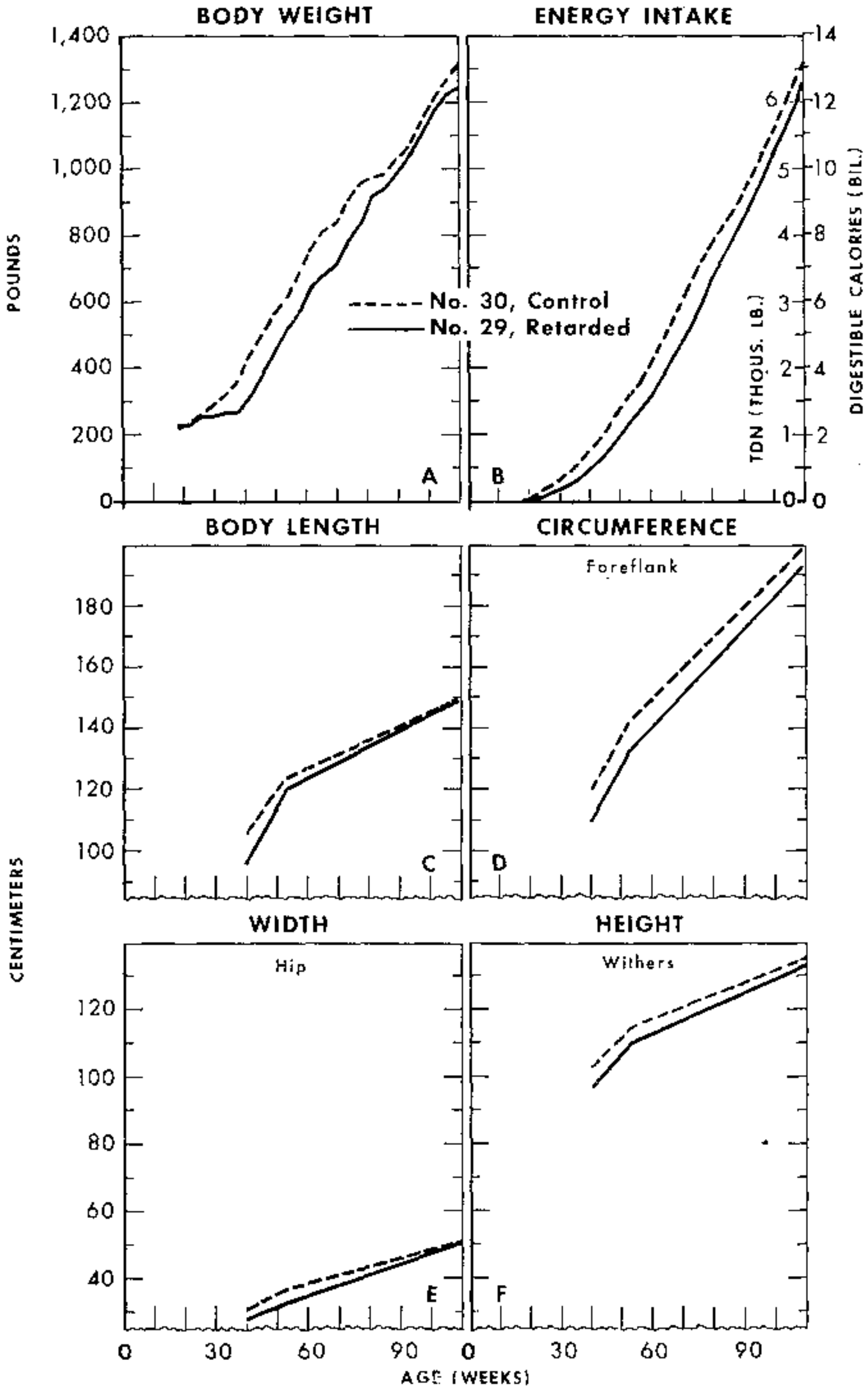

FIGURE 3.—Curves showing gain in body weight, energy consumption, and four body measurements of identical twin steers. Twin No. 29 (experimental animal) was fed near the level of maintenance from 18 to 36 weeks of age; No. 30 was its cotwin control.

whether or not the period of interrupted growth affected body conformation adversely. In experiments at the Missouri station (*14*), animals fed so that growth was retarded for various periods up to several years developed chests that were narrow as compared with those of well-fed animals. The narrow chests became increasingly apparent during the third and fourth years of the animals' lives.

A comparison of body-measurement curves of cotwins (figs. 2 and 3) shows no evidence that conformation of the animals at nearly full size was changed by a relatively short period of retardation; in fact, at slaughter the similarities between cotwins were much more striking than the differences. When an experimental animal had a smaller heart girth than its control cotwin, its body weight was also less.

This similarity was observed also in earlier experiments that included two pairs of calves in which one member of each pair was subjected to maintenance feeding for 6 months (*26*).

Effects of Delayed Growth on Economy of Feed Utilization

It is logical to assume that a delay in growth would increase the energy that an animal must ingest to reach a given weight. One factor that seemingly would add to the total feed requirement is the energy needed for maintenance for the additional time a retarded animal would require to reach a given weight. A second factor is the inefficiency of weight gains that might be expected after an interruption of growth.

Although it is well known that cattle fail to make efficient use of feed after retardation of growth under some range and experimental conditions (*3, 5, 7, 9*), lack of efficiency in use of feed was not observed during the recovery phase in these experiments. Cumulative curves of energy intake (figs. 2–*B* and 3–*B*) indicate that the feed required to produce an animal of given size was not increased even when the growth of young calves was interrupted for 3 to 4 months. Also, table 4 shows that the energy required per pound of gain was not increased by interruption of growth. These results are similar to results observed in an earlier study (*26*) in which steers fed maintenance rations for 6 months required practically no more feed per pound of grain than did their cotwin controls.

Effects of Delayed Growth on Quality of Carcass and Meat

When body measurements of cotwins at time of slaughter are compared, their most striking characteristic is their great similarity. A comparison of four body measurements is given in table 5. The small differences between cotwins tend to disappear when mean values are determined for the two groups (experimental animals and control animals), and it seems likely that the differences were caused more by chance than by dissimilarities in nutrition. The general appearance of both members of twin pairs was similar at time of slaughter despite the drastic treatment given some of the experimental animals. The pair of twins (Nos. 23 and 24) shown at various stages of growth in figure 4 is an example.

Carcass grades of the experimental animals (growth interrupted by a period of reduced energy intake) and of their cotwin controls either were the same or differed by no more than two-thirds of a grade (table 6). When differences existed, as often as not the carcass of the animal that had been retarded was judged superior. Mean dressing percentages of the experimental animals and the control animals were equal (table 7).

Chemical analyses were made of two muscles—the longissimus dorsi in the region of the 9th, 10th, and 11th ribs; and a small portion of the semitendinosus (part of the round cut). Results of the analyses show that the differences between members of a pair were not great, and the mean analytical values obtained are nearly the same

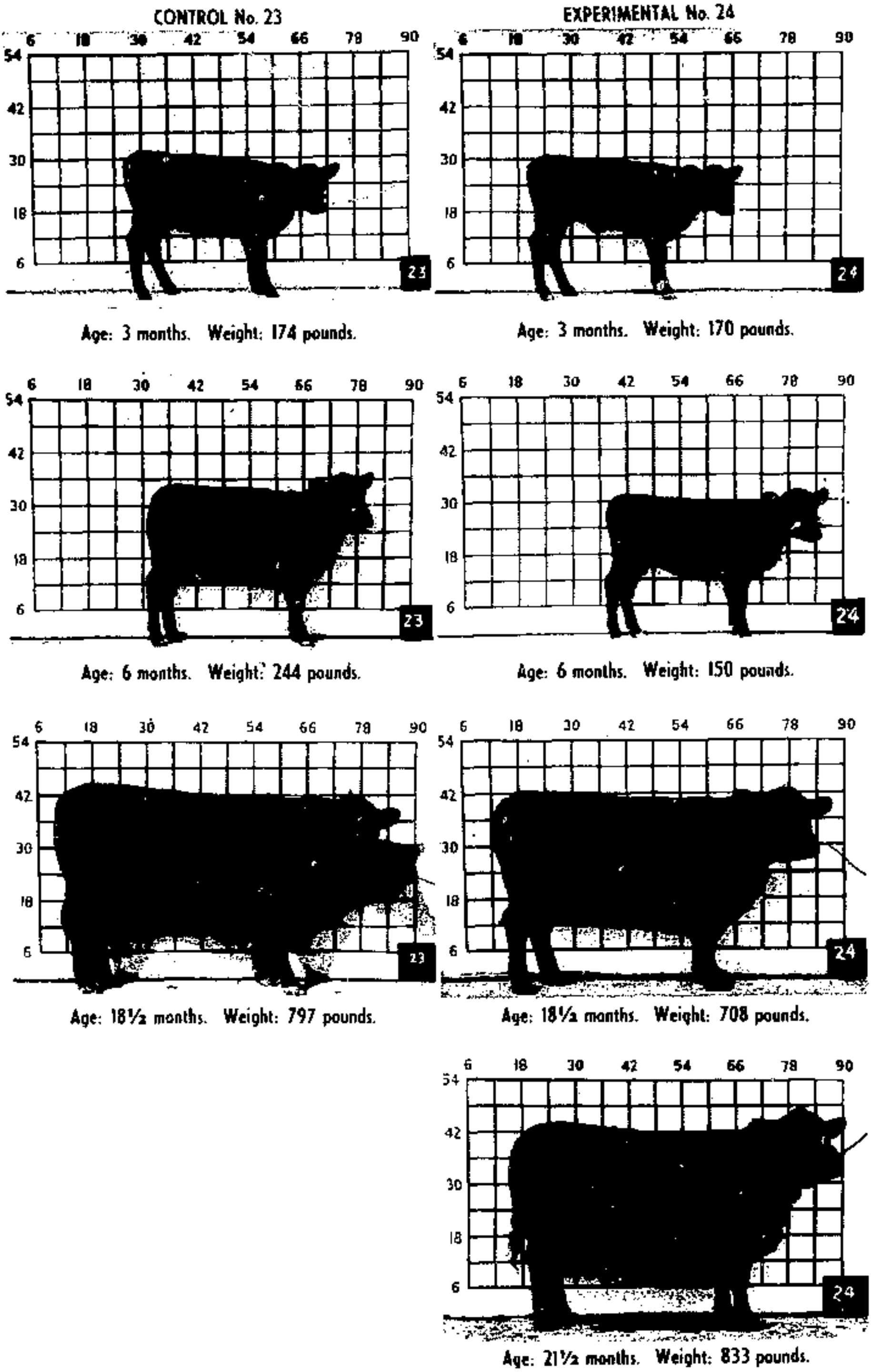

FIGURE 4.—Identical twin heifers No. 23 (control) and No. 24 (experimental) at various stages of growth.

Table 4.—Energy intake and gain in weight by 10 pairs of identical twin cattle for the entire experimental feeding period

Animal	Twin No.	Age		Body weight			Energy intake			
							During period		Per pound of gain	
		At start of period	At end of period	At start of period	At end of period	Daily gain in weight	TDN	Digestible calories [1]	TDN	Digestible calories [1]
		Days	*Days*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Millions*	*Pounds*	*Millions*
Control	23	91	559	174	797	1. 33	3, 633	7, 209	5. 8	11. 6
Experimental	24		645	170	833	1. 20	3, 962	7, 841	6. 0	11. 8
Control	38	123	653	200	979	1. 47	4, 569	9, 035	5. 8	11. 6
Experimental	37			[2] 260	967	1. 32	4, 003	7, 893	5. 7	11. 3
Control	26	113	656	212	1, 118	1. 67	5, 194	10, 290	5. 7	11. 4
Experimental	25		698	224	1, 134	1. 56	5, 018	9, 936	5. 5	10. 9
Control	22	92	674	205	1, 055	1. 46	5, 178	10, 114	6. 1	11. 9
Experimental	21		757	211	1, 132	1. 38	5, 868	11, 576	6. 4	12. 6
Control	19	92	757	113	852	1. 11	5, 023	9, 878	6. 8	13. 4
Experimental	20			114	819	1. 06	4, 673	9, 221	6. 6	13. 1
Control	30	126	770	220	1, 311	1. 69	6, 567	12, 940	6. 0	11. 9
Experimental	29			228	1, 249	1. 58	6, 262	12, 330	6. 1	12. 1
Control	31	92	701	160	997	1. 37	5, 141	10, 162	6. 1	12. 1
Experimental	32			156	996	1. 36	4, 869	9, 597	5. 8	11. 4
Control	36	93	539	192	1, 101	2. 04	4, 251	8, 405	4. 7	9. 2
Experimental	35		692	200	1, 130	1. 55	5, 364	10, 514	5. 8	11. 3
Control	34	93	697	196	965	1. 27	5, 168	10, 190	6. 7	13. 2
Experimental	33			206	1, 030	1. 36	5, 379	10, 603	6. 5	12. 9

Control	28	93	705	200	1,043	1.38	5,637	11,111	6.7	13.2
Experimental	27			198	1,017	1.34	5,434	10,701	6.6	13.1
Mean:										
Control animals									6.0	12.0
Experimental animals									6.1	12.0

[1] Digestible calories = milligrams of digestible protein × 5.65 + milligrams of digestible fat × 9.3 + milligrams of digestible carbohydrates × 4.1.

[2] One cotwin, accepted by its dam, weighed 60 pounds more when the trial began than its pair mate that was "pail fed" from birth to weaning. The "pail fed" animal was fed a liberal ration, and its cotwin was fed a submaintenance ration.

TABLE 5.—*Effect of a period of reduced energy intake on body measurements at time of slaughter of 10 animals as compared with their continuously well-fed identical twins* [1]

Animal	Twin No.	Body weight	Height at withers	Length of body	Circumference at foreflank	Width at hips
		Pounds	*Centimeters*	*Centimeters*	*Centimeters*	*Centimeters*
Control	23	797	107	133	168	44
Experimental	24	833	108	126	170	42
Control	38	979	114	133	179	47
Experimental	37	967	113	134	178	46
Control	26	1,118	126	137	196	49
Experimental	25	1,134	124	142	193	49
Control	22	1,055	125	142	189	47
Experimental	21	1,132	127	146	190	48
Control	19	852	112	126	180	46
Experimental	20	819	110	128	175	44
Control	30	1,311	135	149	198	51
Experimental	29	1,249	133	149	193	50
Control	31	997	118	137	184	50
Experimental	32	996	118	136	182	48
Control	36	1,101	121	137	188	50
Experimental	35	1,130	122	147	195	50
Control	34	965	117	141	182	45
Experimental	33	1,030	119	140	190	49
Control	28	1,043	120	140	186	51
Experimental	27	1,017	120	140	182	50
Mean:						
Control		1,022	119	138	185	48
Experimental		1,031	119	139	185	48

[1] Figures given are means; those for weight each represent 2 or more weighings; those for body measurements each represent 3 measurements.

for the meat of the experimental animals and of the controls (table 8).

Organoleptic tests of the meat of the 9th-10th-11th-rib cut were made by a specialist assisted by a group of experienced judges of meat. The meat was prepared and graded according to methods recommended by the National Livestock and Meat Board (*16*). The results are given in table 9.

On the basis of these tests it seems evident that neither the experimental animal (interrupted growth) nor its cotwin control (continuous growth) can be pronounced superior to the other so far as meat quality is concerned. Factors that undoubtedly contributed to errors in the data are: (1) An elapsed time of as much as 5 months between the testing of the meat of pair members, and (2) the changing personnel comprising the meat-judging committee. However, in our estimation, the presence of these errors does not alter the conclusion reached.

In contrast with table 6, in which a comparison is made of the area of the eye muscle at the 12th rib and the estimated percentage of muscle, fat, and bone of the carcasses of all the experimental animals and their cotwin controls, table 10 makes a comparison on a somewhat different basis. In the latter table, some characteristics of the carcass, rib eye, and round for a group of 3 animals that had been fed submaintenance rations, another group of 3 animals that had been fed maintenance rations, and the two groups combined are compared with the corresponding groups of their cotwins.

No significant differences were found

TABLE 6.—*Effect of a period of reduced energy intake on the grade and physical composition of the carcasses of 10 animals as compared with their continuously well-fed identical twins*

Animal	Twin No.	Energy consumed during restricted period [1]	Carcass grade	Area of eye muscle (longissimus dorsi) of rib cut	Carcass composition [2]		
					Muscle	Fat	Bone
		Percent		*Square inches*	*Percent*	*Percent*	*Percent*
Control	23	73	Low Prime	11.7	55.7	32.0	12.3
Experimental	24	35	Prime	10.9	52.4	34.0	13.6
Control	38	73	Low Prime	11.0	53.4	31.2	15.5
Experimental	37	36	Prime	10.6	51.6	32.6	15.7
Control	26	76	Low Prime	11.6	49.8	35.5	14.6
Experimental	25	36	Low Prime	11.7	48.3	36.2	15.4
Control	22	72	Low Prime	11.4	51.8	32.9	15.2
Experimental	21	42	Choice	11.1	50.0	34.8	15.2
Control	19	74	Low Prime	13.7	50.2	35.9	13.9
Experimental	20	47	Low Prime	12.2	50.4	34.4	15.2
Control	30	77	Choice	12.2	52.1	30.9	16.9
Experimental	29	49	Low Choice	12.9	53.0	29.1	17.9
Control	31	87	Low Prime	14.0	52.9	32.9	14.2
Experimental	32	58	Prime	14.6	53.4	31.2	15.3
Control	36	88	Low Prime	12.2	52.4	32.5	15.1
Experimental	35	61	Top Choice	10.3	51.2	32.2	16.6
Control	34	89	Top Choice	12.1	47.0	38.1	14.9
Experimental	33	73	Low Prime	11.8	44.8	41.9	13.2
Control	28	89	Choice	13.9	50.4	35.7	13.8
Experimental	27	74	Choice	13.4	48.8	37.0	14.2
Mean:							
Control				12.4	51.6	33.8	14.6
Experimental				12.0	50.4	34.3	15.2

[1] Percentage of liberal ration.

[2] Equations derived by Hankins and Howe were used to estimate the physical composition of the dressed carcasses (see *26*). The equations are as follows:

Separable muscle of dressed carcass = 16.08 + 0.8 percent of separable muscle in 9th-10th-11th-rib cut.

Separable fat of dressed carcass = 3.54 + 0.8 percent of separable fat in 9th-10th-11th-rib cut.

Separable bone and tendon of dressed carcass = 5.52 + 0.57 percent of separable bone and tendon in 9th-10th-11th-rib cut.

Table 7.—*Effect of a period of reduced energy intake on the dressing percentage of 10 animals as compared with their continuously well-fed identical twins*

Animal	Twin No.	Final feed-lot weight	Cold weight of carcass	Dressing percentage [1]
		Pounds	*Pounds*	*Percent*
Control	23	797	501	63
Experimental	24	833	524	63
Control	38	979	588	60
Experimental	37	967	579	60
Control	26	1,118	700	63
Experimental	25	1,134	693	61
Control	22	1,055	652	62
Experimental	21	1,132	706	62
Control	19	852	540	63
Experimental	20	819	513	63
Control	30	1,311	787	60
Experimental	29	1,249	755	60
Control	31	997	636	64
Experimental	32	996	616	62
Control	36	1,101	650	59
Experimental	35	1,130	704	62
Control	34	965	579	60
Experimental	33	1,030	636	62
Control	28	1,043	661	63
Experimental	27	1,017	636	62
Mean:				
Control				62
Experimental				62

[1] Dressing percentage $= \frac{\text{Cold weight of carcass}}{\text{final feed-lot weight}} \times 100$.

between the groups with the exception of a significantly greater mean percentage of bone in the combined group of six poorly fed animals as compared with their cotwin controls. Table 10 shows that the mean age at slaughter of the six poorly fed animals was slightly greater than that of their cotwin controls. This raises a question as to whether or not the greater percentage of bone in the experimental animals is related more closely to their greater age at slaughter than to their early nutritional treatment.

Analyses of variance were carried out in an attempt to answer this question. The analyses indicate that the relationship between greater age at slaughter and greater percentage of bone in the 6 experimental animals that had received a highly restricted ration as compared with the cotwin control group approaches significance ($F=5.42$). The analyses also show that the significance of the mean difference between proportion of bone in the experimental animals as compared with their cotwin controls *decreased* when adjustment was made for the observed relationship between age at slaughter and percentage of bone. Results of the analyses suggest that the greater

TABLE 8.—*Effect of a period of reduced energy intake on the chemical composition of meat samples of 10 animals, as compared with their continuously well-fed identical twins*

Animal	Twin No.	Items compared	Round cut [1]	9th-10th-11th-rib cut: Eye muscle [2]	9th-10th-11th-rib cut: Remaining edible portion [2]
			Percent	*Percent*	*Percent*
Control	23	Water	73.0	71.2	38.4
		Ash	1.1	1.1	.6
		Protein	21.7	21.8	10.9
		Ether extract	3.3	5.2	49.6
Experimental	24	Water	73.1	69.9	35.8
		Ash	1.1	1.0	.5
		Protein	22.4	21.4	10.9
		Ether extract	2.6	6.7	53.3
Control	38	Water	74.9	72.3	36.5
		Ash	1.1	1.1	.5
		Protein	21.4	22.2	10.8
		Ether extract	2.7	3.2	52.0
Experimental	37	Water	72.1	71.7	33.7
		Ash	1.2	1.1	.6
		Protein	23.4	21.6	10.6
		Ether extract	2.8	4.7	55.7
Control	26	Water	72.6	70.0	34.9
		Ash	1.1	1.0	.5
		Protein	21.7	20.9	9.7
		Ether extract	4.0	7.9	54.6
Experimental	25	Water	72.3	71.1	35.6
		Ash	1.0	1.0	.5
		Protein	23.2	22.3	10.7
		Ether extract	3.1	5.5	53.0
Control	22	Water	72.4	69.8	35.8
		Ash	1.1	1.0	.5
		Protein	22.2	20.7	10.0
		Ether extract	3.4	8.3	53.7
Experimental	21	Water	71.6	69.8	34.7
		Ash	1.0	1.0	.5
		Protein	21.2	21.3	10.1
		Ether extract	5.7	7.2	54.2
Control	19	Water	70.3	63.2	33.2
		Ash	1.1	.9	.5
		Protein	20.4	20.1	10.1
		Ether extract	6.8	15.3	55.8
Experimental	20	Water	71.5	66.2	31.2
		Ash	1.0	1.0	.5
		Protein	21.2	20.9	9.2
		Ether extract	5.3	11.6	58.4
Control	30	Water	72.4	71.2	42.3
		Ash	1.0	1.0	.6
		Protein	21.4	21.2	12.5
		Ether extract	4.4	5.9	44.4
Experimental	29	Water	74.4	69.7	37.3
		Ash	1.1	.9	.5
		Protein	21.6	21.0	11.0
		Ether extract	2.2	7.5	51.0

TABLE 8.—*Effect of a period of reduced energy intake on the chemical composition of meat samples, of 10 animals, as compared with their continuously well-fed identical twins*—Continued

Animal	Twin No.	Items compared	Round cut [1]	9th-10th-11th-rib cut: Eye muscle [2]	9th-10th-11th-rib cut: Remaining edible portion [3]
			Percent	*Percent*	*Percent*
Control	31	Water	73.6	70.4	35.2
		Ash	1.1	1.0	.4
		Protein	22.5	21.5	10.0
		Ether extract	2.2	6.2	54.2
Experimental	32	Water	72.7	70.1	37.9
		Ash	1.0	1.0	.5
		Protein	22.4	21.6	11.4
		Ether extract	2.9	6.4	50.2
Control	36	Water	74.1	71.0	39.2
		Ash	1.1	1.0	.6
		Protein	21.8	21.3	11.4
		Ether extract	2.5	6.5	48.4
Experimental	35	Water	73.1	71.0	37.6
		Ash	1.1	1.0	.5
		Protein	22.3	21.3	10.8
		Ether extract	2.8	6.0	50.6
Control	34	Water	73.0	68.8	27.8
		Ash	1.3	1.0	.4
		Protein	22.5	21.5	8.4
		Ether extract	2.6	8.4	62.8
Experimental	33	Water	71.8	69.1	30.5
		Ash	1.1	1.1	.4
		Protein	22.1	21.2	9.0
		Ether extract	4.1	7.5	59.6
Control	28	Water	71.8	70.1	27.0
		Ash	1.0	1.0	.4
		Protein	22.6	21.9	8.0
		Ether extract	3.9	6.3	64.3
Experimental	27	Water	72.7	68.5	31.5
		Ash	1.1	1.0	.5
		Protein	23.0	22.2	9.4
		Ether extract	2.8	7.6	58.5
Mean:					
Control		Water	72.8	69.8	35.0
		Ash	1.1	1.0	.5
		Protein	21.8	21.3	10.2
		Ether extract	3.6	7.3	54.0
Experimental		Water	72.5	69.7	34.6
		Ash	1.1	1.0	.5
		Protein	22.3	21.5	10.3
		Ether extract	3.4	7.1	54.4

[1] Semitendinosus muscle.
[2] Longissimus dorsi muscle.
[3] Remainder of edible portion of the 9th-10th-11th-rib cut, including separable fat.

percentage of bone in the experimental animals as compared with their cotwin controls more likely was due to greater age at slaughter than to early differences in nutrition.

The analyses of variance showed no significant relationship, when the two groups were treated separately, between the experimental animals and their cotwin controls in either the submaintenance or maintenance group.

Effects of Delayed Growth on Hides

An attempt was made to obtain analytical data on the hide of each animal slaughtered at the end of the experiment, but analysis of the hides of only 10 animals (5 pairs of twins) was feasible. Fortunately, 2 animals fed below the level of maintenance and 2 animals fed at the level of maintenance were included. A comparison of the data on the hides of these four experimental animals and their cotwin controls furnishes an index of the possible effects of a period of low energy feeding early in the life of an animal on the quality of its hide at slaughter. The results, given in table 11, show that a significant difference was found only in degree of tannage, or combined tannin per unit of hide substance. The table indicates that if the hides of the experimental animals were damaged by an early period of low energy intake, this damage was not detected after slaughter.

DISCUSSION

The data reported here indicate that mere interruption of growth is not necessarily responsible for failure of young cattle later to make quick, economical gains. These results are in agreement with some results reported by us at earlier dates (*22*, *24*, *26*). They are also in agreement with results reported recently by Bohman (*1*), who demonstrated that when gains by young beef cattle were restricted by the feeding of late-cut hay, as compared with gains of controls fed hay of the same variety cut at an earlier date, the animals were not permanently stunted. After 2 years, even though they were fed the same way the second winter as the first, the animals given the late-cut feed were as heavy as those fed the early cut hay.

Crichton and Aitken (*4*) concluded from recent tests with twin dairy heifers that: ". . . although level of feeding influences the rate of growth of dairy cows, it has little influence on ultimate size at maturity. Recovery in growth is very rapid when an animal moves from a low to a high plane of nutrition. . . . It is tentatively suggested that economy in food, especially concentrates, during the more costly period of winter feeding can be practiced without seriously affecting growth, provided there is good summer grazing." These results substantiate the results of the research reported here in which such drastic treatment as maintenance or even submaintenance caloric allowances given young calves did not lower ultimate carcass grades or meat quality.

In recent studies in Missouri (*18*), steers wintered on low-quality stack hay and minerals had more fat and less lean in their carcasses and received lower carcass grades after fattening for slaughter than steers wintered on more desirable rations. Presumably the ration of low-quality stack hay and minerals failed to provide caloric allowances sufficient for normal growth and in addition failed to supply all the essential nutrients. Results with these steers, therefore, are not directly comparable with the results reported in this publication.

The data cited, together with the results of the research reported here, suggest that consumption of winter forage or low-grade roughage by young cattle, even at intake rates too low to provide for growth, need not be followed by undesirable results if supplements compensate for the deficiencies

TABLE 9.—*Comparison of the quality of meat produced by 10 animals on limited caloric allowances for 3 or 4 months, and by their continuously well-fed identical twins* [1]

Animal	Twin No.	Intensity							Desirability			Tenderness (shear test) [2]
		Aroma	Texture	Flavor of—		Tenderness	Juice		Aroma	Flavor of—		
				Fat	Lean		Richness	Quantity		Fat	Lean	*Pounds*
Control	23	4.8	5.4	4.2	5.0	5.8	5.0	5.0	5.8	6.2	6.4	11.7
Experimental	24	5.2	4.6	2.8	4.8	6.8	5.8	6.4	5.8	6.4	7.0	7.2
Control	38	5.0	4.8	3.8	5.0	5.6	5.0	4.6	5.2	6.0	5.8	8.6
Experimental	37	5.2	5.4	3.8	5.2	5.4	4.6	5.0	5.2	6.0	5.8	11.0
Control	26	4.8	5.0	3.4	5.0	6.0	5.8	6.2	5.2	5.8	6.2	12.0
Experimental	25	4.8	5.2	3.8	5.0	5.6	6.0	5.6	5.8	5.6	6.6	12.9
Control	22	5.0	4.8	3.8	5.0	6.0	5.8	6.2	5.0	5.8	6.4	12.2
Experimental	21	4.8	4.5	4.0	4.8	5.0	5.2	5.8	6.0	6.0	6.0	17.3
Control	19	4.8	4.4	3.4	4.8	5.6	5.6	5.6	5.6	6.2	5.8	13.7
Experimental	20	4.8	5.0	3.2	5.0	6.0	5.6	5.8	5.4	6.2	5.8	16.7
Control	30	4.4	....	3.2	4.6	5.0	4.6	4.4	5.4	5.6	5.5	14.7
Experimental	29	5.0	4.8	3.4	4.8	4.4	4.8	4.8	5.4	5.8	5.8	14.9
Control	31	4.5	5.0	3.7	4.8	4.2	5.2	5.2	6.0	5.3	5.8	13.7
Experimental	32	5.2	5.4	3.8	5.0	5.2	5.6	5.8	5.8	5.8	6.4	13.1
Control	36	5.0	5.0	3.2	5.2	5.4	6.0	5.6	6.2	6.4	6.6	12.2
Experimental	35	4.4	5.2	3.8	4.8	5.6	5.8	6.0	6.0	6.2	6.4	13.7
Control	34	5.2	5.0	4.0	5.2	4.8	5.2	5.5	6.2	6.0	6.2	12.7
Experimental	33	4.5	4.3	6.0	4.8	4.2	5.0	5.2	6.0	6.0	6.0	12.7

Control	28	5.0	5.2	3.8	5.0	5.7	5.5	5.2	6.0	5.8	5.8	12.2
Experimental	27	5.2	5.2	3.8	5.0	5.0	5.8	4.7	6.0	5.7	6.2	15.5
Mean (first 6 pairs):												
Control	....	4.8	[3] 4.9	3.6	4.9	5.7	5.6	5.3	5.3	5.9	6.0	12.2
Experimental	....	5.0	[3] 4.9	3.5	4.9	5.5	5.6	5.6	5.6	6.0	6.2	13.3
Mean (all 10 pairs):												
Control	....	4.8	[3] 5.0	3.6	5.0	5.4	5.4	5.4	5.7	5.9	[4] 6.0	12.4
Experimental	....	4.9	[3] 5.0	3.8	4.9	5.3	5.4	5.5	5.7	6.0	[4] 6.2	13.5

[1] Numbers 1 to 7 indicate the degree of intensity and the degree of desirability of aroma, flavor, texture, and juiciness. Number 1 indicates the absence of a factor; that is, its presence is imperceptible. In the test for intensity of tenderness, number 1 indicates extremely tough meat; number 7, extremely tender meat.

[2] Pounds of pressure required per square inch to shear a cross-section sample of meat with a dull blade (cut made perpendicular to the fiber).

[3] Data for cotwins Nos. 29 and 30 were omitted from this calculation because data for twin No. 30 were not recorded.

[4] Difference approaches significance: $P<0.1$.

of the roughage. It appears that even if the loss of some body weight by calves on a submaintenance caloric allowance need not limit later gains by the calves, or impair the ultimate quality of the meat and hides. However, greater loss of body weight by a young calf than that reported here might have unfortunate effects, and it appears likely that the best practice is to avoid loss of weight by calves whenever possible.

TABLE 10.—*Composition of the carcasses of the experimental animals fed at or below maintenance, as compared with their continuously well-fed identical twins (control animals)*

Items compared	Submaintenance group (3 pairs)		Maintenance group (3 pairs)		Combined groups (6 pairs)	
	Control animals	Experimental animals	Control animals	Experimental animals	Control animals	Experimental animals
Mean age at slaughter...days..	616	665	734	761	675	713
Physical composition of the carcass:						
Muscle..........percent..	53	51	51	51	52	51
Fat...............do....	33	34	33	33	33	34
Bone..............do....	14	15	15	16	15	[1] 16
Rib eye:						
Area.......square inches..	11.4	11.1	12.4	12.1	11.9	11.6
Protein.........percent..	21.6	21.8	20.7	21.1	21.2	21.4
Ether extract.......do....	5.4	5.6	9.8	8.8	7.6	7.2
Round: [2]						
Protein............do....	21.6	23.0	21.3	21.3	21.5	22.2
Ether extract.......do....	3.3	2.8	4.9	4.9	4.1	3.6
Dressing percentage.....do....	61	61	62	62	62	62

[1] Significant: $P<0.02$.
[2] Portion of semitendinosus muscle.

TABLE 11.—*Some characteristics of the hides of 4 pairs of identical twins fed different rations* [1]

Items compared	Control animals	Experimental animals
Mean thickness of hides.......................centimeters..	602	588
Abrasion test: [2]		
Loss in weight..............................percent..	33	32
Loss in thickness..........................do....	36	35
Chemical analysis:		
Total ash...................................do....	0.9	0.9
Ether extract..............................do....	4.8	5.3
Water soluble matter.......................do....	11.8	11.4
Degree of tannage [3]......................do....	68.7	[4] 72.6

[1] 2 of the experimental animals were fed submaintenance rations and 2 were fed at the level of maintenance; their cotwin controls were fed a liberal ration.
[2] Abrasion on coarse sandpaper for 530 feet at the rate of approximately 3 feet per minute.
[3] Combined tannin × 100 ÷ hide substance.
[4] Significant: $P<0.05$.

SUMMARY AND CONCLUSIONS

Some effects of delayed growth were investigated with 10 pairs of identical twin beef cattle, of which 4 pairs were steers and 6 pairs were heifers. Probable monozygotic origin of the pairs was determined by physical examinations and blood tests of an antigenic type.

One member of each twin pair was fed a limited caloric allowance from 3 to 6 months of age or from 4 to 8 months of age. Three animals were fed submaintenance rations, 3 were fed just enough to about maintain body weight, and 4 were fed rations between maintenance and liberal levels. So far as is known, the low-caloric rations were deficient only in energy. During the period of low-caloric intake by the animals on the restricted rations their cotwin controls were continuously well-fed. At the end of this period, all animals were fed about as much as they were able to ingest without digestive disturbances.

Each animal was slaughtered when a committee decided either that it had reached the grade of Low Prime or that its progress was so slow as to preclude its reaching that grade within a reasonable time. Retarded animals made gains, per unit of feed ingested, equal to those of their cotwins even though some of the retarded animals were slaughtered later than their cotwins. This economy in feed utilization is explained by the fact that the retarded animals made more economical gains on full feed from the end of the period of low-caloric intake to slaughter than their cotwins made during the same period.

No evidence was observed that carcass grades, meat quality, or proportion of lean meat to fat were lowered by a delay in growth. A significant difference between the experimental animals that had received rations at and below the level of maintenance and their cotwin controls was observed in the percentage of bone. Whereas percentage of bone was greater in the experimental animals than in the controls, the results of analyses of variance suggest that this was more likely due to the greater age of the experimental animals at slaughter than to the early nutritional regimen. Hides of animals that had been fed at or below the level of maintenance combined significantly more tannin per unit of hide substance than did those of their cotwins. No other significant difference in hides of cotwins was found, and no evidence that the hides had been damaged by an early period of restricted feeding was obtained.

It is concluded that calves can be maintained without weight gain on rations that meet their nutritional needs, except their needs for energy, from 3 to 6 months of age or from 4 to 8 months of age without later loss in efficiency of feed utilization, quality of meat, or proportion of lean meat as compared with fat and bone in the carcass. These conclusions are similar to those reached earlier with cattle on maintenance rations from 6 to 12 months of age. The animals' potentiality for rapid growth is not diminished so far as could be observed even by caloric allowances *below* those required to maintain weight.

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