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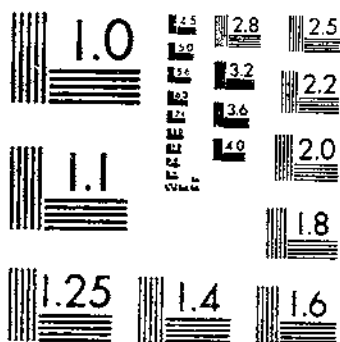
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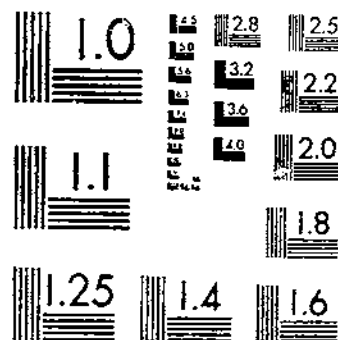
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RELATIVE EFFECTS OF CONTINUOUS AND INTERRUPTED GROWTH ON BEEF STEERS
WINCHESTER, C. F. HOWE, P. E. 1 OF 1

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**BEEF
STEERS**

By C. F. Winchester and Paul E. Howe

TECHNICAL BULLETIN No. 1108
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Relative Effects of Continuous and Interrupted Growth on BEEF STEERS

By C. F. WINCHESTER, animal physiologist, and PAUL E. HOWE, nutrition consultant,
Animal and Poultry Husbandry Research Branch, Agricultural Research Service

INTRODUCTION

It is commonly believed that beef calves utilize feed more efficiently when growth is continuous than when it is interrupted. Morrison (14)¹ advises that beef calves be fed to gain at least half a pound daily. Guilbert and associates (6), on the basis of a study of growth of beef calves during the dry season in California, stated: "From the standpoint of total feed required to produce a unit of product, greatest efficiency is obtained from a high plane of nutrition with continuous growth and development."

Nevertheless, systems of management that involve periods when growth of young cattle is retarded by varying degrees, or even periods during which the animals gain no weight, are fairly common. Probably most beef cattle undergo at least some growth retardation during their lives. Under many conditions, continuous growth can be maintained during the winter, or during or following a drought, only at great expense. To the beef producer confronted with a problem that involves the physiological influences as well as the economic effects of periods of retarded and interrupted growth, the question as to what possible harm may be done the animals by interruption of growth is of importance.

Because the levels of protein,

carotene, and phosphorus in range grasses decline as the plants mature, range forage becomes an increasingly less satisfactory feed for cattle as the season advances. Quantity and quality of the feed decline simultaneously. Therefore, it is of great importance to know the relative disadvantages of the restriction of feed nutrients, at least the major nutrients, to various levels for different periods of time. Such knowledge would enable producers to evaluate the feeds available, and to plan feeding programs to bring about satisfactory recovery from the effects of retardation.

In the research reported here, weight gains of beef steers were retarded between the ages of approximately 6 and 12 to 16 months by rations that varied in energy value from a level that maintained body weight up to one that provided for about 1 pound of gain a day. Because protein, carotene, and minerals were fed at levels adequate for rapid gains, retardation of growth may be assumed to have been due to the low-energy value of the rations rather than to a deficiency syndrome such as one that may occur when winter forage, deficient in nutrients other than those supplying energy, is consumed by cattle over a period of several months.

The research reported here was undertaken to determine some effects of a delay in growth on subse-

¹Italic numbers in parentheses refer to Literature Cited, p. 33.

quent performance of beef cattle. Data were compiled on the effects of growth interruption on subsequent

efficiency of feed utilization, quality of meat, and proportion of the carcass represented by lean meat.

EXPERIMENTAL METHODS AND MATERIALS

Animals used

Since both members of a pair of identical twins possess the same inherited characteristics, the use of identical twin cattle in research (one cotwin being used as the experimental animal and the other as the control) eliminates genetic differences between experimental and control animals and greatly reduces the number of individuals required for developing reliable information (3, 5, 7). However, identical twins are born to cows of the beef breeds perhaps no oftener than once in every 1,000 to 2,000 births, and the accumulation of even a small herd of identical twins is difficult.

Although 9 pairs of male twin calves were purchased for this study, only 6 pairs were found to be of the identical type; the other 3 pairs were fraternal twins. Data obtained with the identical twins are reported here, whereas those obtained with fraternal twins are not. Information compiled on a given pair of fraternal twins, by itself relatively insignificant, would

add little to the present report and tend to obscure such conclusions as might be drawn from the data obtained with the identical twins.

Whether or not the members of a given pair of twins were identical (of one-egg origin) was determined first by critical physical examination. Later, blood samples were taken from those sets of twins that appeared to be definitely identical, and the original diagnosis was confirmed by means of a blood test of an antigenic type (7, 10). Results of such a blood test are considered wholly reliable when the analysis indicates that the twins are not identical, and 90 percent reliable when it indicates that they probably are identical.

The six pairs of twins used in this study were, beyond reasonable doubt, identical twins. Five of the six pairs were purebred Aberdeen Angus and the other pair (Nos. 5 and 6) were Hereford \times Guernsey crossbreds.

Rations and feeding procedures

Table 1 shows the rations used in this study. These rations were designed to provide liberal allowances of all nutrients, other than those that supply energy, that are known to be required by cattle. One member of each pair of twins (experimental animal) was subjected to growth retardation by feeding it one of the low-energy rations, whereas the other member (control animal) was fed the liberal ration.

In order to insure an adequate protein supply, Blaxter and Mitch-

ell's (2) relatively liberal protein allowances for dairy heifers were approached or exceeded. The low-energy rations fed in these experiments were different, insofar as the proportions of the various nutrients are concerned, from a ration consisting solely of unsupplemented forage such as is consumed during winter seasons by some cattle on the range. Forage plus suitable supplements, however, would be similar in nutrient content to the rations fed in the trials. The level of en-

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

NUTRITIVE REQUIREMENTS

Item of comparison	Amount of feed	Dry matter	Total digestible nutrients	Protein	Calcium	Phosphorus ¹	Carotene
	Pounds	Pounds	Pounds	Pounds	Grams	Grams	Milligrams
For normal growth (14).....	-----	9. 1-11. 4	7. 2	0. 870	20. 0	15. 0	25.
For Holstein heifer (2).....	-----	11. 3	7. 4	. 925	21. 8	14. 4	-----

RATIONS USED IN THESE TRIALS

50 percent of a liberal ration in energy content:							
Maintenance ration (j):							
Linseed oil meal.....	1. 00	0. 91	0. 76	0. 297	1. 6	2. 8	-----
Barley.....	. 25	. 22	. 19	. 025	. 1	. 5	-----
Alfalfa hay (U. S. No. 2, Leafy).....	5. 50	4. 98	2. 77	. 578	36. 7	6. 0	62. 7
Total.....	6. 75	6. 11	3. 72	0. 900	38. 4	10. 3	62. 7
62 percent of a liberal ration in energy content:							
Maintenance ration.....	6. 75	6. 11	3. 72	0. 900	38. 4	10. 3	62. 7
Corn.....	1. 07	. 91	. 86	. 071	. 1	1. 3	1. 2
Total.....	7. 82	7. 02	4. 58	0. 971	38. 5	11. 6	63. 9
75 percent of a liberal ration in energy content:							
Maintenance ration.....	6. 75	6. 11	3. 72	0. 900	38. 4	10. 3	62. 7
Corn.....	2. 26	1. 92	1. 81	. 149	. 2	2. 8	2. 6
Total.....	9. 01	8. 03	5. 53	1. 049	38. 6	13. 1	65. 3
100 percent of a liberal ration in energy content:							
Maintenance ration.....	6. 75	6. 11	3. 72	0. 900	38. 4	10. 3	62. 7
Corn.....	4. 53	3. 85	3. 62	. 299	. 4	5. 5	5. 2
Total.....	11. 28	9. 96	7. 34	1. 199	38. 8	15. 8	67. 9

¹ Steers had free access to rock salt and to monosodium phosphate. The salt was kept in the paddock, the phosphate in the individual box stalls.

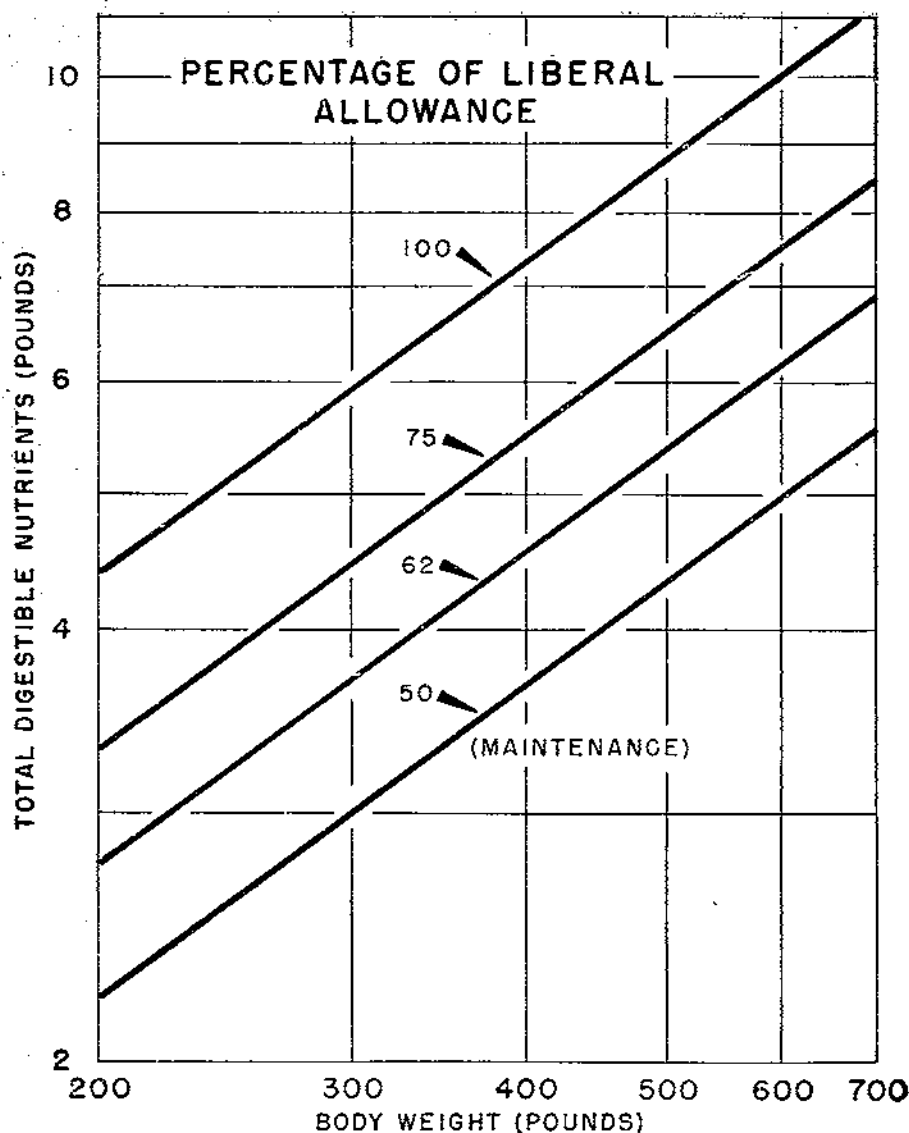


FIGURE 1.—Energy allowances in pounds of total digestible nutrients fed daily to steers through a size range of 280 to 690 pounds.

ergy allowed the control animals was approximately equal to Morrison's (14) "more liberal allowances." Feed allowances varied with the three-fourths power of body weight (4, 11).

Figure 1 shows the energy allowances given animals through a size

range of 280 to 690 pounds at various energy levels.

The experimental animals were given rations supplying approximately 75, 62, and 50 percent of the energy supplied by a liberal ration. The animals fed the 62- and 50-percent rations were placed on these

rations at about 6 months of age; at 12 months of age they were again fed liberal rations. Two animals were placed on the 75-percent energy ration—one at 6 months of age and the other at 7. One was kept on the latter ration for about 10 months; the other for about 8 months. The control animals throughout the experiment, and the experimental animals after the period of restricted feeding ended, were allowed to eat as much as they could consume without digestive difficulties.

Although the rations were rich in carotene, additional allowances in amounts considered adequate to meet the animals' requirements (14), were given in the form of a concentrated solution of vitamin A

in oil. This was done in lieu of making carotene analyses of the feed.

Some of the steers were kept in box stalls from which they had direct access to individual paved paddocks. The others were kept in box stalls without individual paddocks from late afternoon until morning and, except during inclement weather, were kept during the remainder of the day in a yard free from grass and weeds. The steers were fed in the box stalls morning and evening under the supervision of an experienced herdsman. All unconsumed feed was weighed and accounted for. The animals were slaughtered when they reached about 1,000 pounds.

Measurements of body size

The animals were weighed at weekly intervals, usually between 9 and 11 a. m., following their morning feeding. Ordinarily, they were weighed only once, but if the result was much greater or less than was expected on the basis of earlier weighings, the weighing was repeated.

At the beginning of the period of low-energy allowances body measurements were made of all the animals except Nos. 1 to 4, which were about 9 months of age when first measured. Body size of both cotwins was measured at the end of

the retardation period and again when the unretarded steer reached slaughter weight (1,000 pounds). The retarded steer was measured when it in turn attained 1,000 pounds. Nineteen measurements, similar to those described by Lush (13), were made in triplicate.

Both members of each twin pair were photographed at the beginning and at the end of the low-energy feeding period, and when the unretarded cotwin reached slaughter weight. The retarded animal also was photographed just prior to slaughter.

Determination of carcass grades and meat quality

Carcasses were graded, both prior to and following slaughter, by committees made up of three experienced graders. Although personnel of the committees varied from time to time, the grades are all of approximately equal reli-

bility. Chemical analyses were made of the round and of the 9th-10th-11th-rib cut; and palatability tests, as well as mechanical shear tests of tenderness of meat, were carried out.

TABLE 2.—*Energy consumption and weight gain by six pairs of identical twin steer calves*

PERIOD OF REDUCED ENERGY INTAKE

Animal	Twin No.	Energy consumed ¹	Age of calves		Length of period	Body weight		Gain	Daily gain	Energy consumed			
			At beginning	At end		At beginning	At end			During period		Per pound of gain	
										TDN	Digestible calories ²	TDN	Digestible Calories ²
		Percent	Days	Days	Days	Pounds	Pounds	Pounds	Pounds	Pounds	Thousands	Pounds	Thousands
Control	2	93	170	478	308	360	838	478	1. 55	2, 808	5, 680	5. 9	11. 9
Experimental	1	75	170	478	308	366	689	323	1. 05	2, 104	4, 313	6. 5	13. 4
Control	4	90	221	432	211	340	676	336	1. 59	1, 657	3, 339	4. 9	9. 9
Experimental	3	73	221	432	211	342	570	228	1. 08	1, 248	2, 558	5. 5	11. 2
Control	5	95	182	365	183	360	690	330	1. 80	1, 554	3, 115	4. 7	9. 4
Experimental	6	62	182	365	183	354	460	106	0. 58	854	1, 775	8. 0	16. 7
Control	15	102	176	359	183	270	576	306	1. 67	1, 348	2, 793	4. 4	9. 1
Experimental	16	61	176	359	183	280	370	90	0. 49	681	1, 410	7. 6	15. 7
Control	17	101	180	363	183	340	618	278	1. 52	1, 510	3, 012	5. 4	10. 8
Experimental	18	48	180	363	183	324	340	16	-----	556	1, 165	-----	-----
Control	8	105	184	367	183	338	747	409	2. 26	1, 668	3, 332	4. 1	8. 1
Experimental	7	45	184	367	183	340	336	—4	-----	568	1, 198	-----	-----

PERIOD AFTER REDUCED ENERGY INTAKE UNTIL SLAUGHTER

Control	2	(3)	509	623	114	838	1,005	167	1.46	1,494	2,949	8.9	17.6
Experimental	1	(3)	509	699	190	689	1,006	317	1.67	2,384	4,685	7.5	14.8
Control	4	(3)	432	674	242	676	1,022	346	1.43	2,791	5,501	8.1	15.9
Experimental	3	(3)	432	674	242	570	1,024	454	1.88	3,075	6,087	6.8	13.4
Control	5	(3)	365	521	156	690	1,002	312	2.00	1,996	3,932	6.4	12.6
Experimental	6	(3)	365	597	232	460	990	530	2.28	2,828	5,569	5.3	10.5
Control	15	(3)	359	560	201	576	1,005	429	2.13	2,555	5,105	6.0	11.9
Experimental	16	(3)	359	652	293	370	1,002	632	2.16	3,612	7,126	5.7	11.3
Control	17	(3)	363	564	201	618	1,005	387	1.92	2,715	5,329	7.0	13.8
Experimental	18	(3)	363	634	271	340	1,008	668	2.46	3,301	6,476	4.9	9.7
Control	8	(3)	367	481	105	747	1,000	253	2.41	1,445	2,856	5.7	11.3
Experimental	7	(3)	367	619	243	336	1,000	664	2.73	2,810	5,518	4.2	8.3

¹ Expressed as proportion of that supplied by liberal ration, and for an animal of given size. The allowances varied with three-fourths of body weight (fig. 1). Also see parts D of figures 2 to 7. "Energy intake of cotwins expressed as percentage of a liberal ration."

² Digestible Calories=grams of digestible protein \times 5.65+grams of digestible fat \times 9.3+grams of digestible carbohydrate \times 4.1. The Calorie (written with a capital C) is equal to 1,000 calories.

³ Fed the liberal ration.

RESULTS

Growth during period of reduced energy intake

The caloric maintenance requirement of an animal of given size may be defined as the energy cost of normal, nonproductive, metabolic processes. As the term is used in this study, however, maintenance represents the level of energy required by a growing animal that is neither losing nor gaining weight. This implies that energy expenditures for walking and chewing, equal to perhaps 5 percent of the total maintenance requirement, are part of the energy cost of maintenance. The latter definition is satisfactory for the purpose of the present study because these same expenditures are involved in the maintenance of cattle under field conditions. The energy requirements of beef calves for maintenance were dealt with in an earlier paper (33). In that report it was shown that the energy requirement for maintenance as determined with 16 pairs of identical twin beef animals weighing between 200 and 800 pounds was about 38 percent of the total energy required when the animals were making gains of 2 pounds a day, and that the maintenance requirement varied with the two-thirds power of body weight.

As shown in table 2 (page 8), when energy intake was around 62 percent of that provided by a liberal ration weight gains were about half a pound a day; when energy intake was about 75 percent of that provided by a liberal ration weight gains were about 1 pound a day.

Growth curves (figs. 2 to 7) show that the response to increased energy allowances on the part of the animals that had been on restricted rations was rapid. This response suggests that even the calves that had been on maintenance rations for as long as 6 months had remained in good health. Controls

on liberal rations gained between $1\frac{1}{2}$ and $2\frac{1}{4}$ pounds daily during this period when their cotwins were on restricted intake.

Cumulative energy intake for the control and experimental animals (figs. 2 to 7, *B*) from the beginning of the trials until the animals weighed around 1,000 pounds was about the same. In some cases the animal that grew continuously consumed the greater amount; in other cases the experimental animal consumed more.

Digestible Calories were calculated as follows: Figures for digestible protein, fat, and carbohydrates (in grams) were multiplied, respectively, by the factors 5.65, 9.3, and 4.1, and the results were added together. While the values obtained by multiplying grams of TDN by the factor 4.38 ordinarily did not coincide with the calculated values, the differences were not great enough to permit the use of separate curves.

Energy allowances were based on body weight; therefore the energy intake of the animals increased as they gained weight (figs. 2 to 7, *C*). The maintenance rations increased slightly with the small increments in body weight (figs. 2 and 3, *C*).

An interesting comparison can be made between the growth curves (figs. 2 to 7) and the curves representing four measurements of body size (figs. 8, 9, and 10).

Even though weight gains were nearly or entirely arrested during the feeding of the maintenance rations, a definite tendency for continued skeletal growth on the part of animals Nos. 7 and 18 was observed. In general, this observation confirms the results of somewhat similar experiments reported by earlier workers (15, 16, 17, 29, 30, and 31).

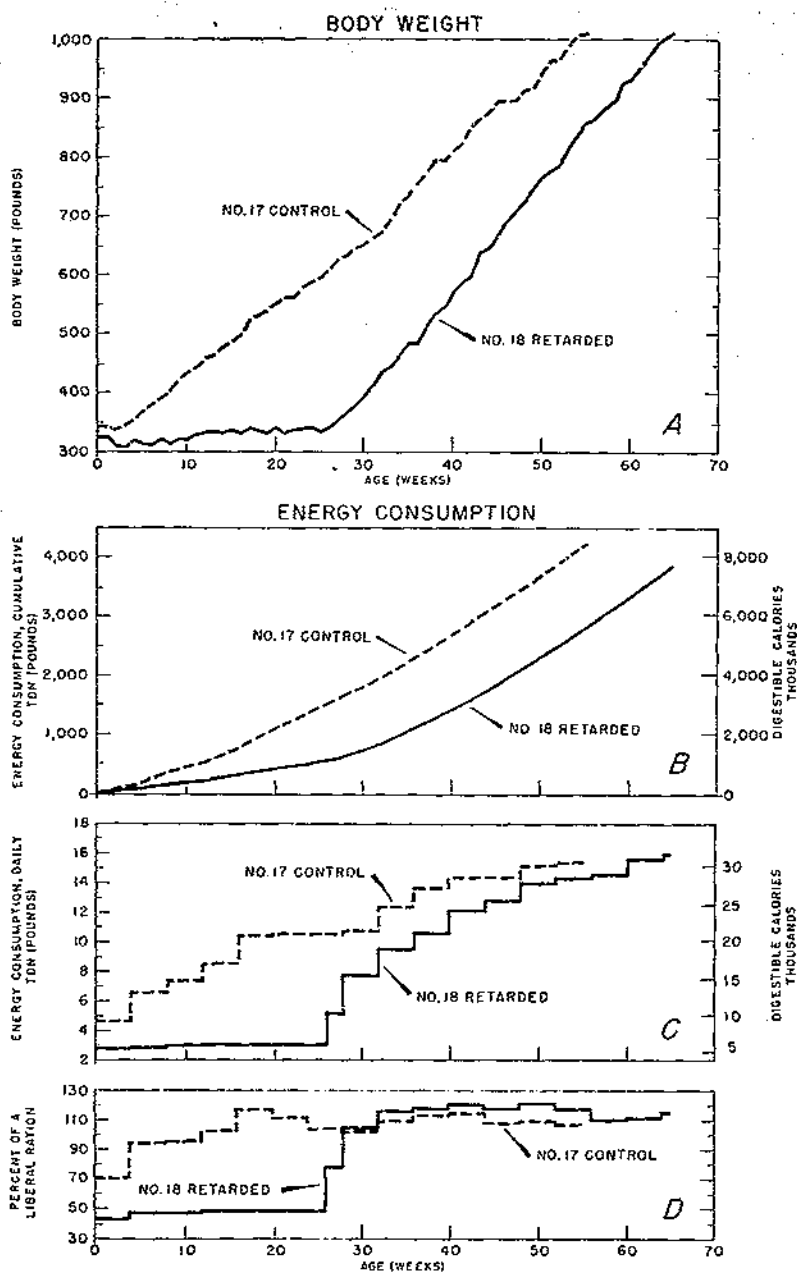


FIGURE 2.—Curves showing weight gained and energy ingested by twin steers Nos. 17 (control) and 18.

- A, Growth curves from 26 weeks of age until time of slaughter.
- B, Cumulative energy intake: In pounds of total digestible nutrients, and in digestible Calories.
- C, Daily energy intake: In pounds of TDN, and in digestible Calories.
- D, Energy intake of cotwins expressed as percentage of a liberal ration.

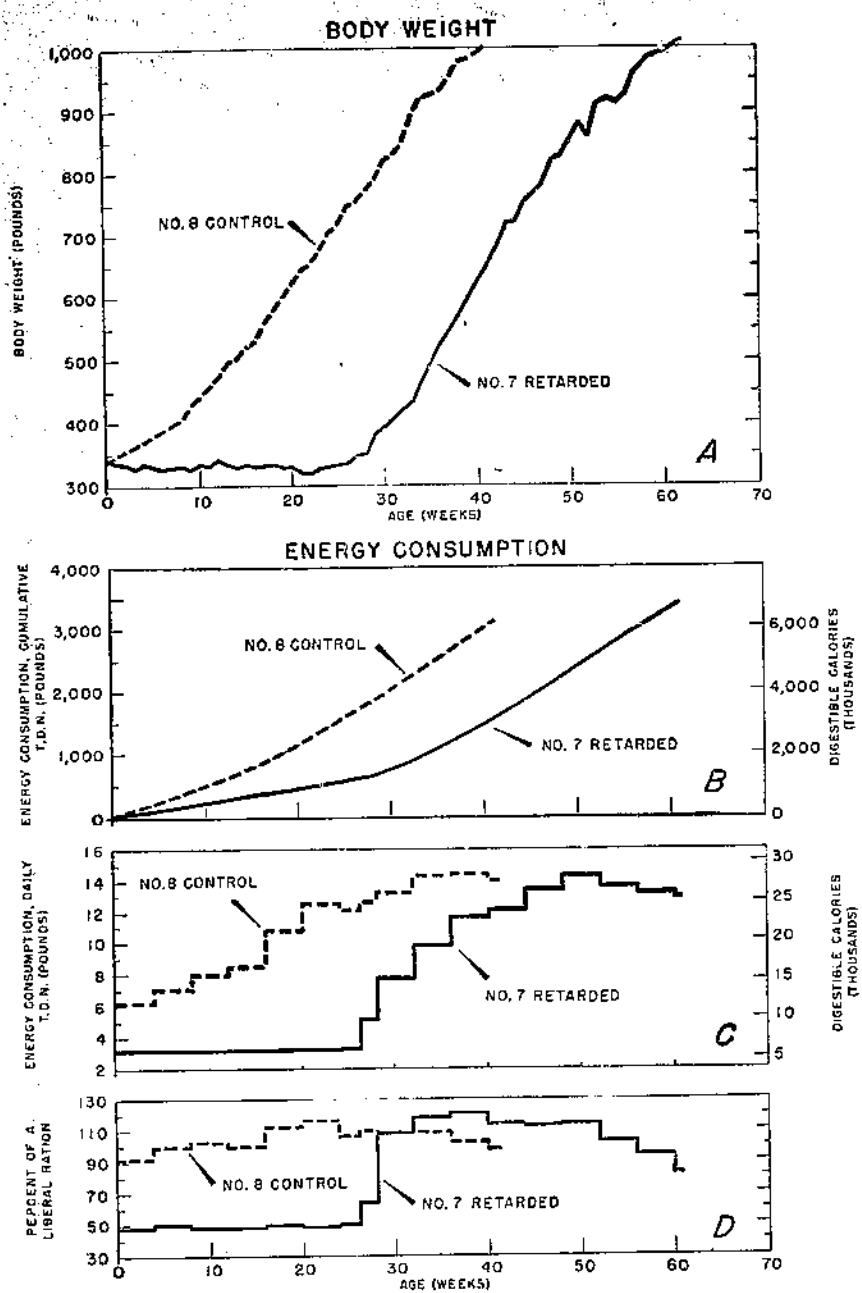


FIGURE 3.—Curves showing weight gained and energy ingested by twin steers Nos. 8 (control) and 7.

- A, Growth curves from 26 weeks of age until time of slaughter.
- B, Cumulative energy intake: In pounds of TDN, and in digestible Calories.
- C, Daily energy intake: In pounds of TDN, and in digestible Calories.
- D, Energy intake of cotwins expressed as percentage of a liberal ration.

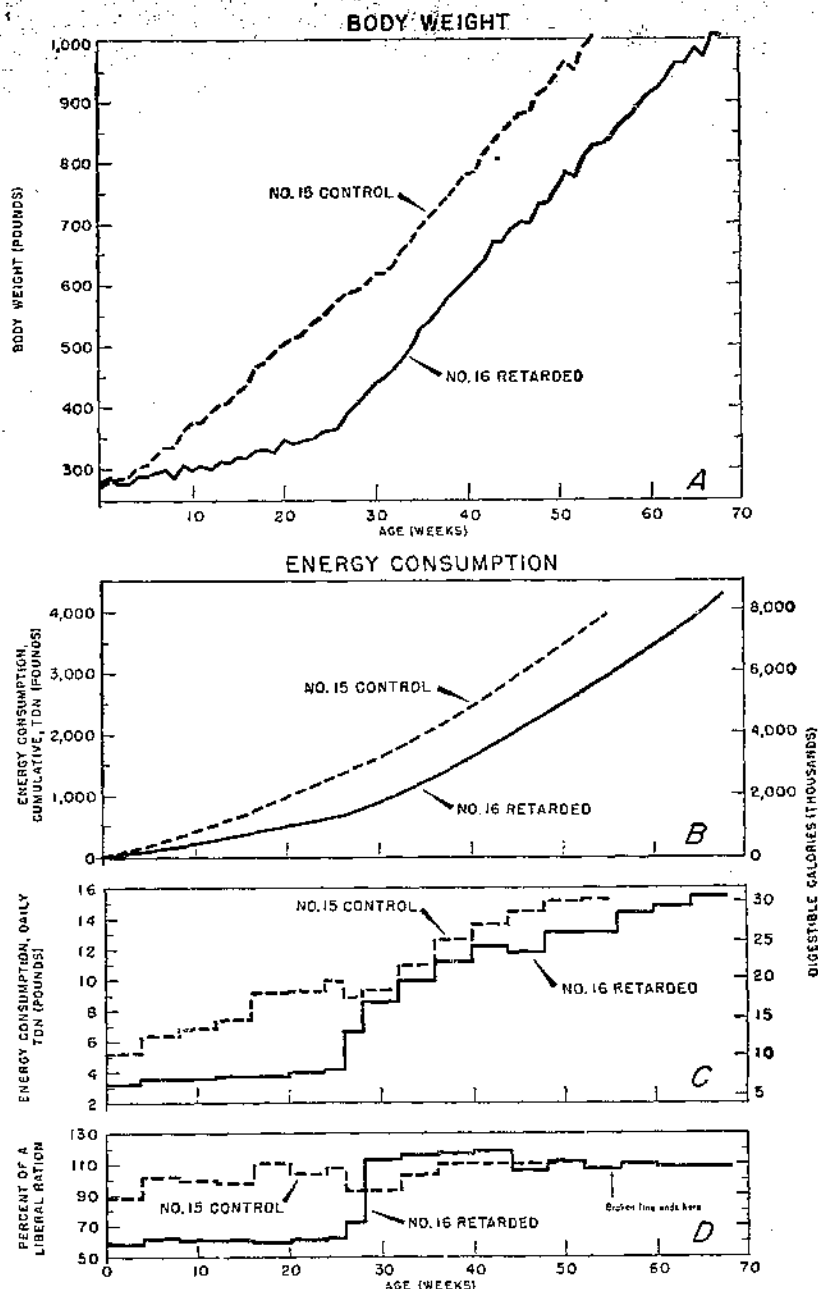


FIGURE 4.—Curves showing weight gained and energy ingested by twin steers Nos. 15 (control) and 16.

A, Growth curves from 25 weeks of age until time of slaughter.

B, Cumulative energy intake: In pounds of total digestible nutrients, and in digestible Calories.

C, Daily energy intake: In pounds of TDN, and in digestible Calories.

D, Energy intake of cotwins expressed as percentage of a liberal ration.

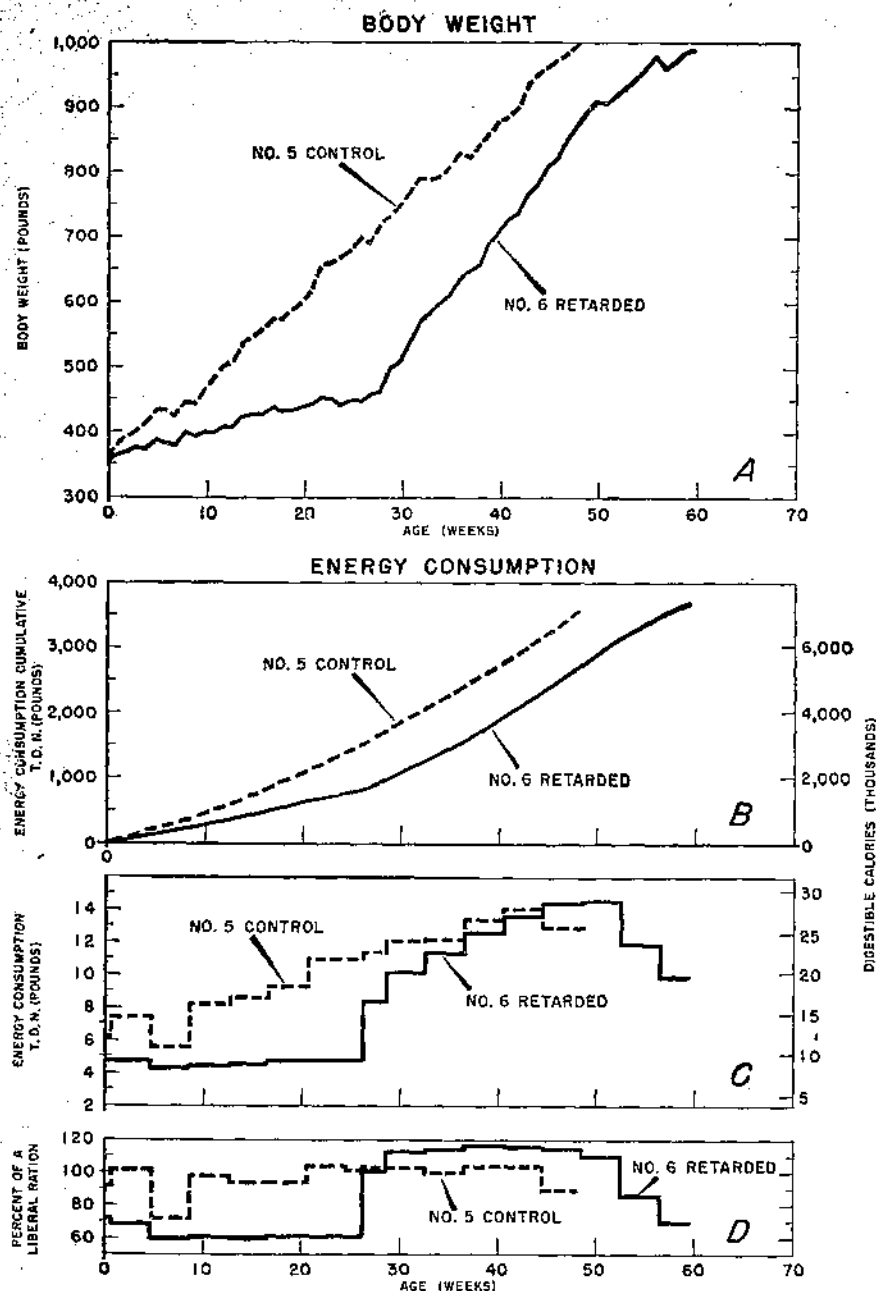


FIGURE 5.—Curves showing weight gained and energy ingested by twin steers Nos. 5 (control) and 6.

- A, Growth curves from 26 weeks of age until time of slaughter.
 B, Cumulative energy intake: In pounds of total digestible nutrients, and in digestible Calories.
 C, Daily energy intake: In pounds of TDN, and in digestible Calories.
 D, Energy intake of cotwins expressed as percentage of a liberal ration.

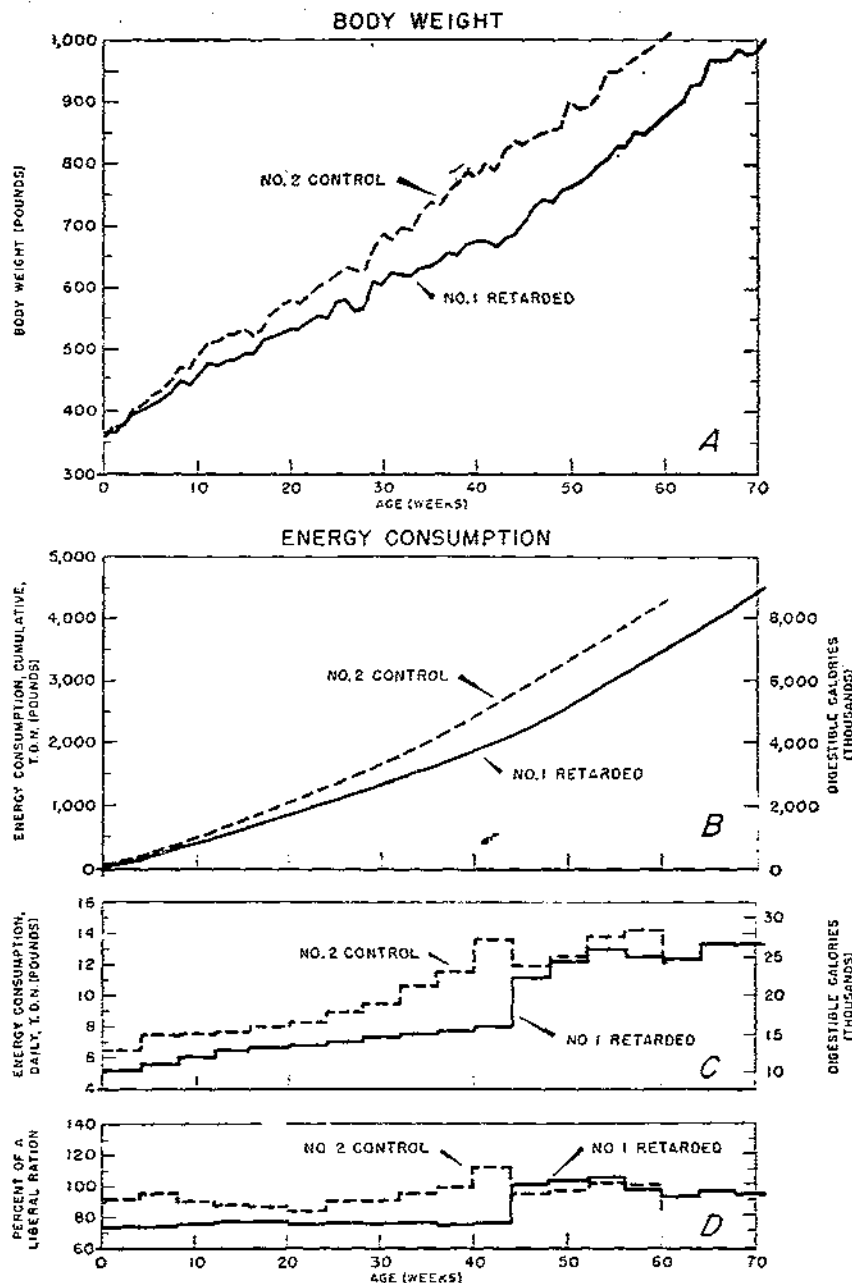


FIGURE 6.—Curves showing weight gained and energy ingested by twin steers Nos. 2 (control) and 1.

- A, Growth curves from 24 weeks of age until time of slaughter.
 B, Cumulative energy intake: In pounds of total digestible nutrients, and in digestible Calories.
 C, Daily energy intake: In pounds of TDN, and in digestible Calories.
 D, Energy intake of cotwins expressed as percentage of a liberal ration.

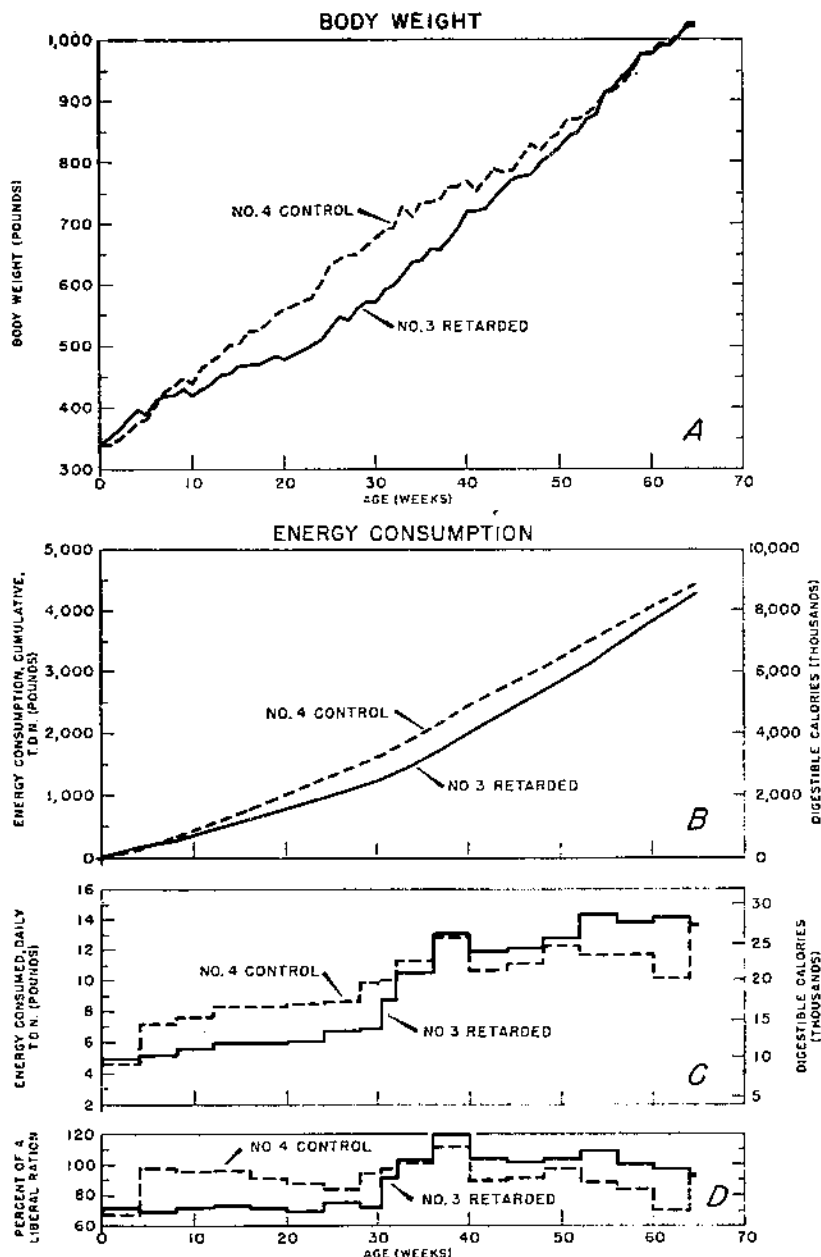


FIGURE 7.—Curves showing weight gained and energy ingested by twin steers Nos. 4 (control) and 3.

- A, Growth curves from age 31 weeks until time of slaughter.
B, Cumulative energy intake: In pounds of total digestible nutrients, and in digestible Calories.
C, Daily energy intake: In pounds of TDN, and in digestible Calories.
D, Energy intake of cotwins expressed as percentage of a liberal ration.

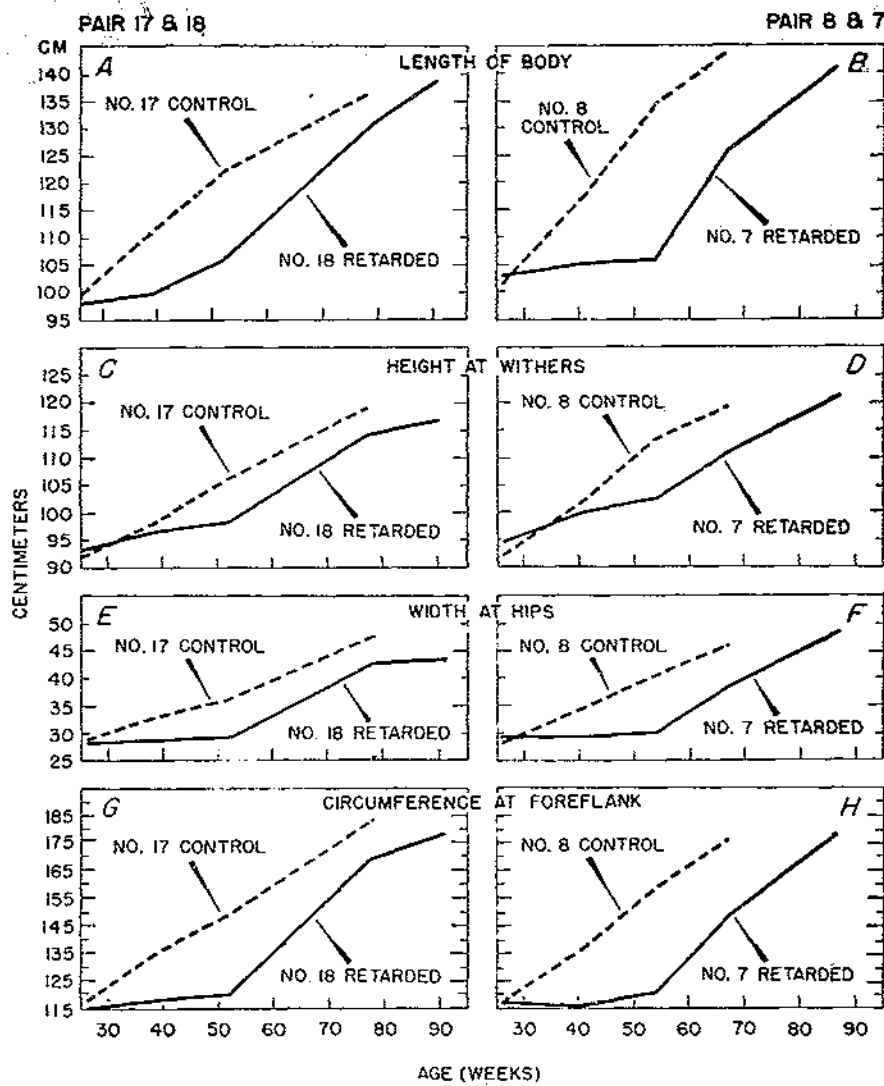


FIGURE 8.—Four body measurements of two pairs of twins. Steers Nos. 17 and 8 were the controls; steers Nos. 18 and 7 had been kept on maintenance rations for 6 months between the ages of 6 and 12 months.

Growth following period of reduced energy intake

Subsequent weight gains were not retarded by the 6 months' low-energy regimen. Figures 2 to 7 (part 4) show that weight gains of the retarded calves for some time after restricted feeding ended either equaled or exceeded those of

the controls. This appears to be a confirmation of Waters' (32) statement that "an animal that is below the normal size at a given age, through poor nourishment, apparently has the capacity, when liberally fed, to compensate for this loss,

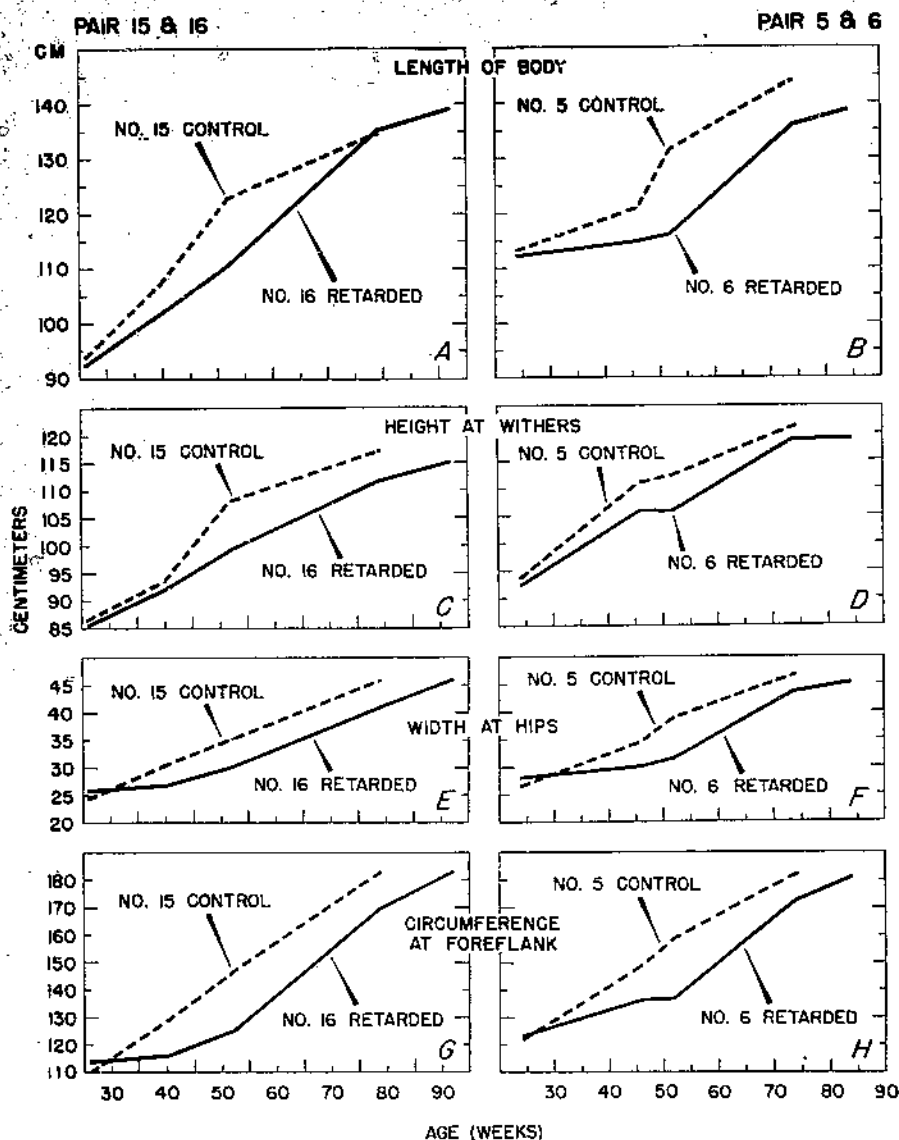


FIGURE 9.—Four body measurements of two pairs of steers. Steers Nos. 15 and 5 were the controls. Nos. 16 and 6 were fed only about 62 percent of the energy allowance provided by a liberal ration between the ages of 6 and 12 months.

in a measure at least, by an increased rate of gain."

Skeletal growth of the experimental animals, after the period of limited energy intake ended was either as rapid as, or more rapid

than, that of the controls (figs. 8, 9, and 10).

Photographs of the steers were taken at various stages of growth; figure 11 showing the identical twin steers Nos. 17 and 18 is an example.

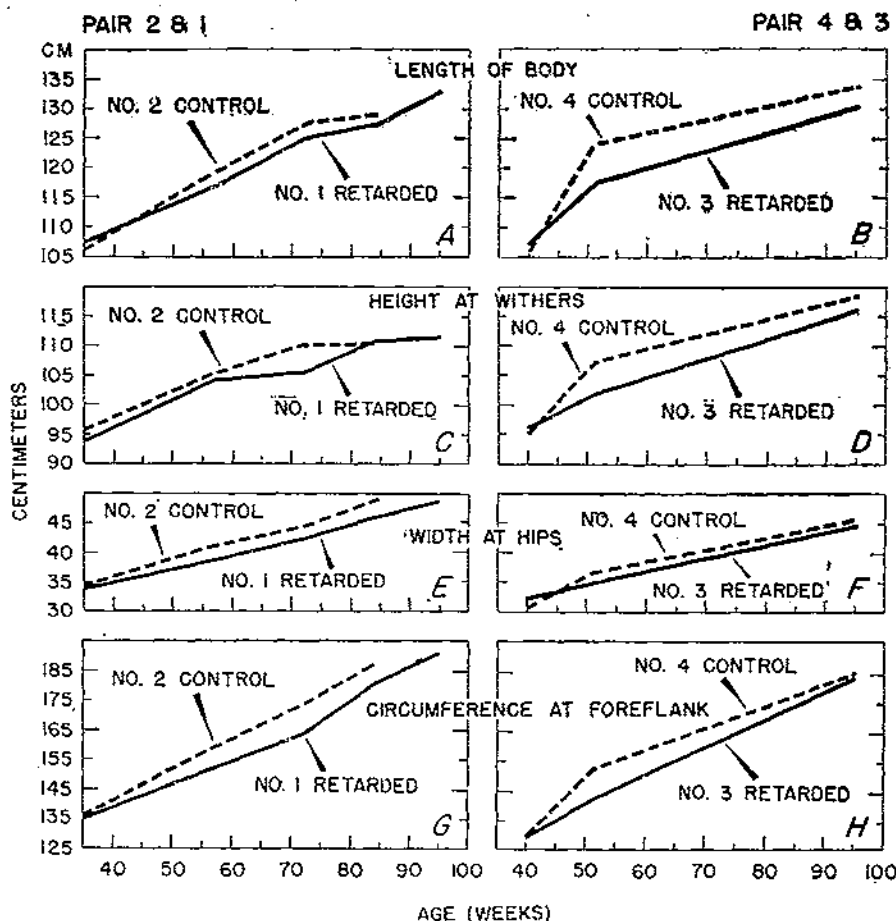


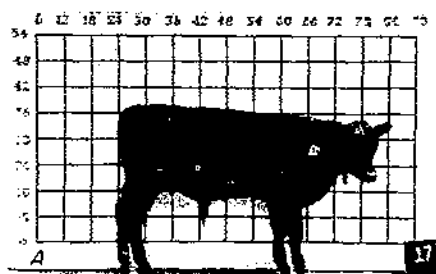
FIGURE 10.—Four body measurements of two pairs of steers. Steers Nos. 2 and 4 were the controls. Steer No. 3 was on 75 percent of a liberal ration for 7 months between the ages of 7 and 14 months, steer No. 1 for 10 months between the ages of 6 and 16 months.

The pictures show that even though No. 18 gained practically no weight between the ages of 6 months and 1 year, skeletal size did increase somewhat during this time.

Four body measurements of the control and retarded animals, at about time of slaughter, are compared in table 3. These data not

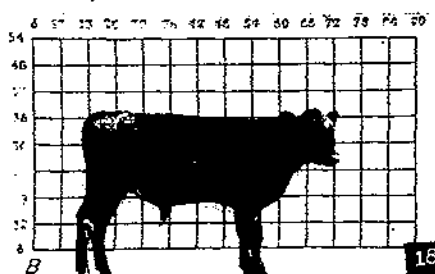
only show that differences in body measurements were small when the cotwins were of about equal weight at time of slaughter, but also that neither the retarded animals nor their cotwins invariably excelled so far as a given measurement is concerned.

Control animal No. 17

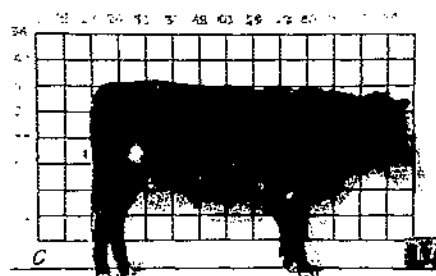


Age: 6 months.
Weight: 340 pounds.

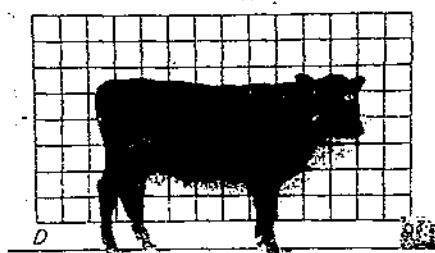
Experimental animal No. 18



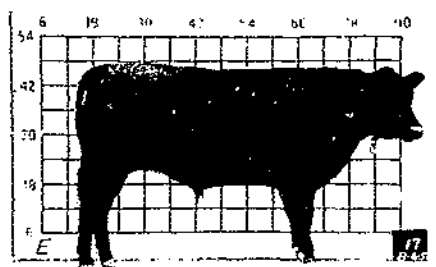
Age: 6 months.
Weight: 324 pounds.



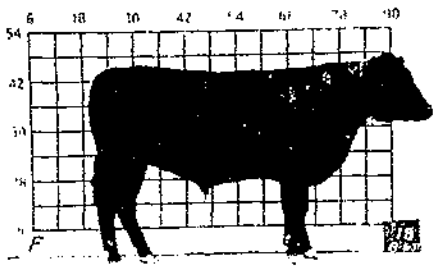
Age: 12 months.
Weight: 618 pounds.



Age: 12 months.
Weight: 340 pounds.

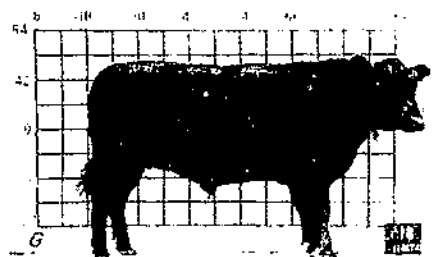


Age: 19 months.
Weight: 1,000 pounds.



Age: 19 months.
Weight: 832 pounds.

FIGURE 11.—Identical twin steers Nos. 17 (control) and 18, at various stages of growth.



Age: 21 1/2 months.
Weight: 1,000 pounds.

TABLE 3.—*Body measurements at time of slaughter*

Animal	Twin No.	Height at withers	Length of body	Circumference at foreflank	Width at hips
		<i>Centimeters</i>	<i>Centimeters</i>	<i>Centimeters</i>	<i>Centimeters</i>
Control.....	2	110	129	187	49
Experimental.....	1	113	133	191	48
Control.....	4	118	134	185	45
Experimental.....	3	116	130	184	44
Control.....	5	121	144	177	46
Experimental.....	6	119	138	176	45
Control.....	15	117	135	183	46
Experimental.....	16	115	139	182	46
Control.....	17	119	136	183	47
Experimental.....	18	117	139	178	44
Control.....	8	120	144	176	46
Experimental.....	7	121	141	179	48
Mean:					
Control.....		118	137	182	46
Experimental.....		117	137	182	46

Relative economy of gains made by unretarded and retarded animals

Energy intake and weight gains during the entire trial are summarized in table 4 in which a comparison is made, in the last 2 columns, of the relative energy utilization per pound of gain by the retarded and the unretarded animals. The difference is not striking in any case and, although mean energy intake per unit gain of the retarded animals was greater than that of the controls, the difference was only 3 percent.

The retarded animals with one exception were slaughtered later than their cotwin controls. As is shown by table 4, little more energy was required to produce a 1,000-pound animal when growth was retarded than when it was continuous. The explanation may be that the animals whose growth was retarded for a time gained more economically

after restricted feeding ended than did the control animals during this same time (figs. 12 and 13, parts *A* and *B*). Perhaps a comparison more logical than that shown in *A* and *B* is that shown in *C* and *D* where energy costs of gains, above maintenance (33), are plotted. A comparison on a still different basis is made in *E* and *F*, wherein relative energy requirements are compared at equal body size, but at different ages. The retarded animals tended to gain more economically than did the controls until the steers approached slaughter weight.

In figures 12 and 13, numbers representing energy values increase from top to bottom of each figure, therefore the nearer the top of the figure a point is, the greater the economy it represents.

Effects of reduced energy intake on dressing percentages and quality of meat

Carcass grades of the controls and their retarded cotwins were, with a single exception, the same;

and in the exceptional case the difference was not large (table 5).

TABLE 4.—*Energy consumption and weight gain during entire trial*

Animal	Twin No.	Age of animal		Length of period	Body weight		Amount of gain	Daily gain	Energy consumed			
		At beginning of trial	At end of trial		At beginning of trial	At end of trial			During entire trial		Per pound of gain	
									TDN	Digestible Calories ¹	TDN	Digestible Calories ¹
		<i>Days</i>	<i>Days</i>	<i>Days</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Thousands</i>	<i>Pounds</i>	<i>Thousands</i>
Control.....	2	170	592	422	360	1, 005	645	1. 53	4, 302	8, 629	6. 7	13. 4
Experimental.....	1	170	668	498	366	1, 006	640	1. 28	4, 488	8, 998	7. 0	14. 0
Control.....	4	221	674	453	340	1, 022	682	1. 50	4, 447	8, 840	6. 5	13. 0
Experimental.....	3	221	674	453	342	1, 024	682	1. 50	4, 323	8, 645	6. 3	12. 7
Control.....	5	182	521	339	360	1, 002	642	1. 89	3, 550	7, 047	5. 5	11. 0
Experimental.....	6	182	597	415	354	990	636	1. 53	3, 682	7, 344	5. 8	11. 5
Control.....	15	176	560	384	270	1, 005	735	1. 91	3, 900	7, 898	5. 3	10. 7
Experimental.....	16	176	652	476	280	1, 002	722	1. 52	4, 262	8, 545	5. 9	11. 8
Control.....	17	180	564	384	340	1, 005	665	1. 73	4, 225	8, 341	6. 4	12. 5
Experimental.....	18	180	634	454	324	1, 008	684	1. 51	3, 857	7, 641	5. 6	11. 2
Control.....	8	184	472	288	338	1, 000	662	2. 30	3, 113	6, 188	4. 7	9. 3
Experimental.....	7	184	610	426	340	1, 000	660	1. 55	3, 378	6, 716	5. 1	10. 2
Mean:												
Control.....							672		3, 923	7, 824	5. 8	11. 6
Experimental.....							671		3, 998	7, 982	6. 0	11. 9

¹ See footnote 2, table 2.

TABLE 5.—*Grade and physical composition of carcasses of control and retarded steers*

Animal	Twin No.	Energy intake during restricted period ¹	Carcass grade	Area of eye muscle (longissimus dorsi) of rib cut	Carcass composition:					
					Percentage basis ²			Pound basis ³		
					Muscle	Fat	Bone	Muscle	Fat	Bone
		Percent		Sq. in.	Percent	Percent	Percent	Pounds	Pounds	Pounds
Control.....	2	93	Prime.....	10. 6	52. 3	33. 5	14. 2	322	206	87
Experimental.....	1	75	Prime.....	12. 0	49. 7	35. 9	14. 4	316	228	92
Control.....	4	90	Prime (low).....	10. 7	59. 4	24. 7	15. 9	369	154	99
Experimental.....	3	73	Prime (low).....	11. 4	55. 9	27. 6	16. 5	347	171	102
Control.....	5	95	Good.....	10. 6	57. 3	25. 7	17. 0	323	145	96
Experimental.....	6	62	Good.....	10. 6	54. 2	28. 3	17. 5	302	158	98
Control.....	15	98	Choice (high).....	12. 6	50. 2	32. 9	16. 9	308	202	104
Experimental.....	16	61	Choice (high).....	10. 6	52. 7	30. 7	16. 6	320	187	101
Control.....	17	101	Choice (high).....	14. 4	58. 5	25. 9	15. 7	368	163	99
Experimental.....	18	48	Prime.....	13. 6	59. 8	26. 0	14. 1	374	163	88
Control.....	8	105	Good.....	10. 7	59. 6	24. 3	16. 1	345	141	93
Experimental.....	7	45	Good.....	12. 0	62. 4	20. 8	16. 8	402	134	108

¹ Expressed as a proportion of the energy supplied by liberal ration.

² Equations derived by Hankins and Howe (8) have been used to estimate the physical composition of the dressed carcasses. The equations are as follows:

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

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

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

³ Carcass composition, pound basis = composition, percentage basis \times cold weight of carcass.

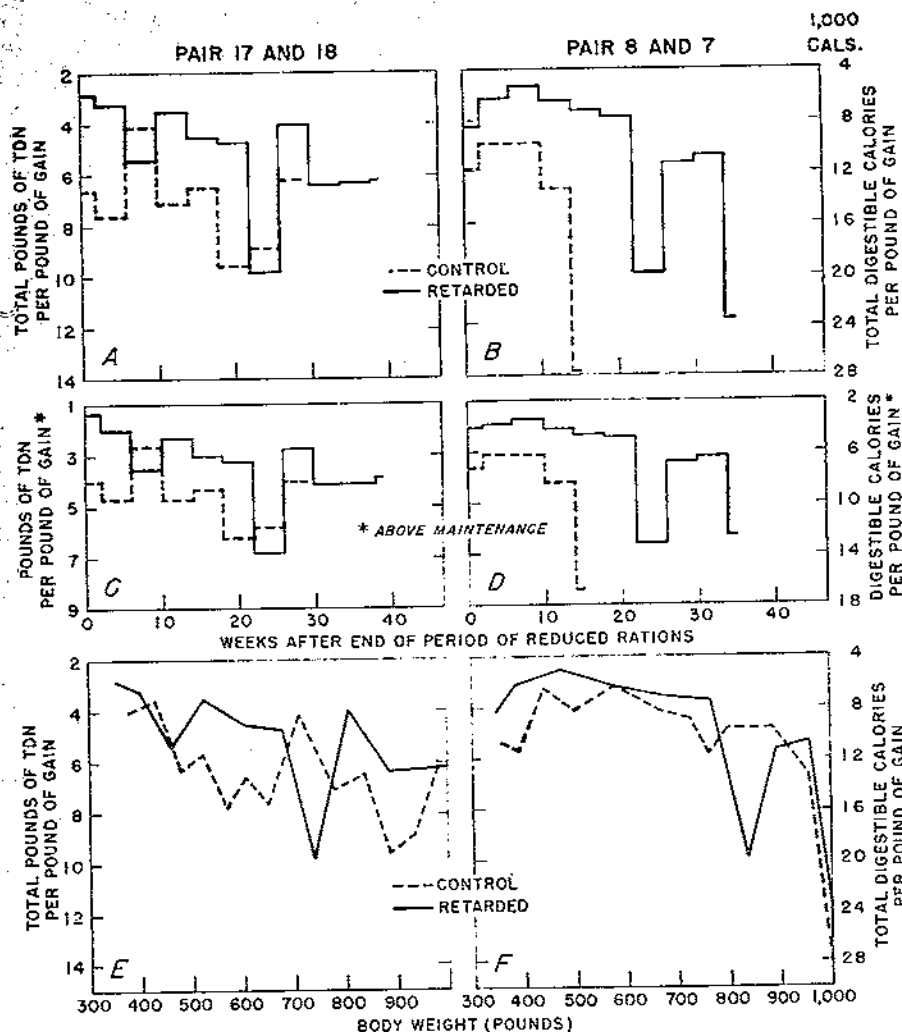


FIGURE 12.—Relative economy of gains of two pairs of twin steers after the end of the period during which one member of each pair was on restricted energy intake. For 26 weeks steer No. 18 had been restricted to an energy intake equal to 48 percent of that supplied by a liberal ration, steer No. 7 to 45 percent. The other member of each pair served as a control. In A through D, the animals were of equal age, but not of equal weight; in E and F they were of equal weight, but not of equal age.

Bone usually constituted a similar percentage of the carcasses of pair members, but there were some appreciable differences between co-twins in percentages of fat and muscle. Since in some cases the control was the fatter individual, and in other cases the retarded ani-

mal was fatter, the level of energy in the rations during the period of restricted feeding hardly could have been the cause of relative fatness of the carcasses. In 5 of the 6 pairs, the eye of the rib cut was fatter in the animal that had had the limited ration; in 4 of the 6 pairs

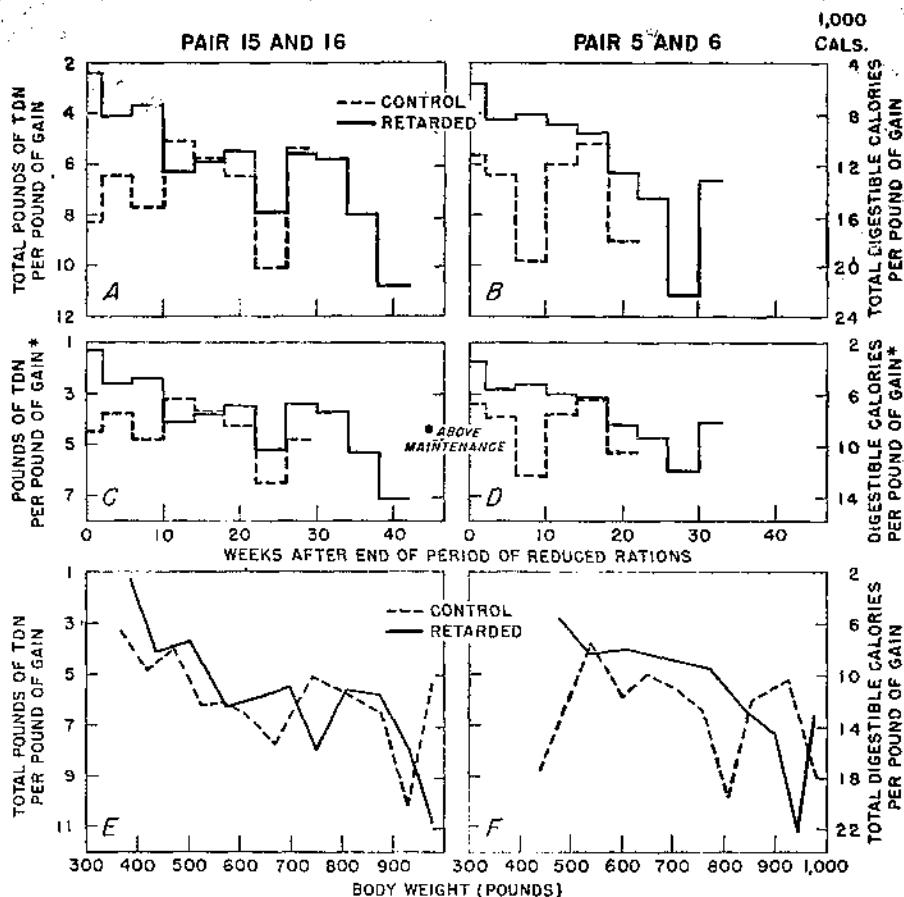


FIGURE 13.—Relative economy of gains of two pairs of twin steers after the end of the period during which one member of each pair was on restricted energy intake. For 26 weeks steer No. 15 had been restricted to an energy intake equal to 61 percent of that supplied by a liberal ration, steer No. 6 to 62 percent. The other member of each pair served as a control. In A through D, the animals were of equal age, but not of equal weight; in E and F, they were of equal weight, but not of equal age.

the remainder of the edible portion of the 9th-10th-11th-rib cut was fatter, as was also the semitendinosus of the round cut. While this may seem to indicate that reduced rations had a favorable influence on meat quality, we assume that the differences actually were due to chance. Area of the eye muscle of the 9th-10th-11th-rib cut was greater in some cases in the control and in other cases in the retarded member of a twin pair.

The differences between pairs shown in table 5 probably are due to inherited characteristics rather than to nutrition. As one would expect, those pairs that were purebred animals produced the more desirable carcasses, whereas the pair that carried the least beef blood produced the least desirable carcasses. For example, pair Nos. 4 and 3 (purebred Aberdeen Angus steers) were graded much higher than pair Nos. 5 and 6 (crossbred Hereford

Control

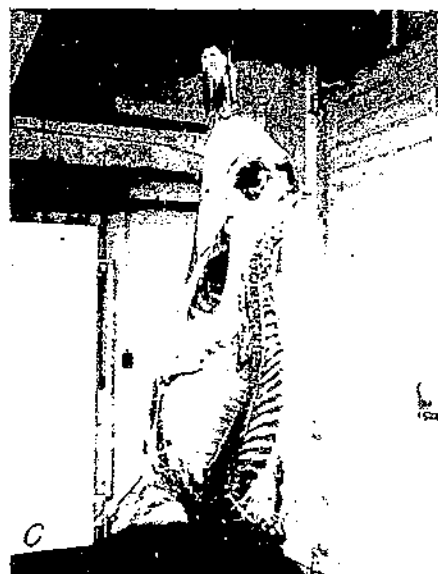
Experimental



A
Steer No. 17, purebred Aberdeen-Angus



B
Steer No. 18, cotwin of No. 17



C
Steer No. 8, purebred Aberdeen-Angus



D
Steer No. 7, cotwin of No. 8

FIGURE 14.—Carcasses of steers fed maintenance rations between the ages of 6 and 12 months compared with carcasses of their well-fed identical cotwins. Each of the animals weighed approximately 1,600 pounds at time of slaughter.

× Guernsey steers) even though the former actually were slightly less fat than the latter. This difference in grade was due to a difference in distribution of fat. In the purebred animals, desirable amounts of fat accumulated outside the ribs to produce carcasses of very good conformation; whereas, in the crossbred steers, fat tended to accumulate in greater amounts within the abdominal cavity.

Carcasses of control steers 17 and 8 are compared with those of their experimental cotwins in figure 14.

One member of each of these pairs was supplied energy at the maintenance level between ages 6 and 12 months. The figure shows that the cotwins, despite the differences in feeding, were similar in conformation when the animals reached 1,000 pounds.

Inheritance appears to have had an influence on the dressing percentages. The crossbred Hereford × Guernseys (pair Nos. 5 and 6) had the lowest dressing percentages of the lot (table 6).

TABLE 6.—Dressing percentages of the six pairs of steers

Animal	Twin No.	Final weight in feed lot	Weight, cold	Dressing percentage ¹
		<i>Pounds</i>	<i>Pounds</i>	
Control.....	2	1,005	616	61
Experimental.....	1	1,006	636	63
Control.....	4	1,022	622	61
Experimental.....	3	1,024	620	60
Control.....	5	993	563	57
Experimental.....	6	990	558	56
Control.....	15	1,005	613	61
Experimental.....	16	1,002	608	61
Control.....	17	1,005	629	63
Experimental.....	18	1,008	626	62
Control.....	8	1,000	579	² 58
Experimental.....	7	1,000	644	² 64

¹ Dressing percentage = $\frac{\text{Cold weight}}{\text{Final weight in feedlot}} \times 100$

² This relatively large difference is explained, in part, by the fact that the "fill" of No. 8 at slaughter was 40 pounds greater than that of No. 7.

The only conspicuous within-pair difference in dressing percentages was in pair Nos. 7 and 8; the higher of the two dressing percentages was that of the individual that had been on a maintenance ration for 6 months. Considered together, these facts seem to indicate that a period of restricted energy intake did not influence the dressing percentages adversely. Likewise, total lean

meat appears not to have been limited greatly by restricted energy intake (table 5).

Within reasonable limits quality of the meat is closely related to the level of fat in beef muscle. As an index of the relative quality of the meat of the retarded and control animals, analyses of two cuts of meat from each carcass are given in table 7. Of the muscles analyzed,

TABLE 7.—*Chemical composition of the semitendinosus of the round and of the 9th-10th-11th-rib cut*

Animal	Twin No.	Items compared	Semitendinosus of the round	9th-10th-11th-rib cut	
				Eye muscle (longissimus dorsi)	Remainder of edible portion of rib cut including separable fat
			Percent	Percent	Percent
Control	2	Water	73.6	70.4	33.6
		Ash	1.1	1.1	.5
		Protein	22.4	22.1	10.5
		Ether extract	2.8	6.6	55.9
Experimental	1	Water	71.8	66.7	36.5
		Ash	1.1	.9	.5
		Protein	21.0	19.8	10.6
		Ether extract	5.9	11.9	51.8
Control	4	Water	73.9	71.9	45.6
		Ash	1.1	1.0	.7
		Protein	22.4	21.6	13.7
		Ether extract	2.0	4.9	39.7
Experimental	3	Water	73.6	71.7	35.8
		Ash	1.1	1.0	.5
		Protein	22.6	21.8	10.6
		Ether extract	2.3	5.0	52.8
Control	5	Water	73.8	73.5	49.0
		Ash	1.0	1.0	.7
		Protein	21.9	22.2	14.8
		Ether extract	2.5	2.8	35.2
Experimental	6	Water	74.2	74.0	40.2
		Ash	1.1	1.0	.6
		Protein	20.5	22.0	12.5
		Ether extract	3.9	2.4	46.6
Control	15	Water	74.6	72.7	45.4
		Ash	1.1	1.0	.7
		Protein	21.1	21.2	14.6
		Ether extract	2.9	3.9	38.4
Experimental	16	Water	73.7	71.6	38.6
		Ash	1.1	1.0	.5
		Protein	22.2	21.6	11.1
		Ether extract	2.9	5.2	49.7
Control	17	Water	73.9	73.5	47.2
		Ash	1.1	1.1	.7
		Protein	22.7	22.8	15.2
		Ether extract	2.4	1.3	36.3
Experimental	18	Water	74.3	73.1	44.5
		Ash	1.1	1.1	.6
		Protein	21.7	22.1	13.8
		Ether extract	2.6	3.4	41.0
Control	8	Water	75.0	73.6	40.8
		Ash	1.1	1.1	.6
		Protein	22.2	23.3	13.4
		Ether extract	1.9	2.3	45.6
Experimental	7	Water		72.5	54.4
		Ash		1.1	.8
		Protein		22.2	16.0
		Ether extract		4.2	28.5

those of the steers that were subjected to growth interruption were not less fat than those of their cotwins that grew continuously. This suggests that, by this criterion, the meat of the retarded animals was not inferior to that of their controls.

Palatability tests were made of meat of the 9th-10th-11th-rib cut by a specialist with the assistance of a group of individuals, each of whom had had considerable experience in judging meat (18). Usually 2 to 4 months of time separated the testing of meat of cotwins, and the personnel comprising the testing group varied; therefore it would be expected that even though the meat of cotwins were exactly the same, there would be small differences in the scores for the pair members. Age differences between cotwins at time of slaughter varied

from 0 to 138 days. Although a difference in age could have influenced the tenderness of meat as well as quality of fat within the muscle, data given in table 8 show that such differences as existed between meat quality of cotwins were small. The mechanical shear test of tenderness (table 8, column 12) shows that differences measured by such tests, to which any significance can be attributed, existed only in pair Nos. 5 and 6 and pair Nos. 17 and 18; and in each of these cases it was the meat of the retarded animal that was the more tender. Our interpretation of the data in table 8 is that, so far as meat quality is concerned, rations as low as maintenance for as long as 6 months had no unfavorable effect on meat quality.

DISCUSSION

The growth curves of cattle on the range, with little or no supplementary feed, exhibit a peculiar cyclic pattern (fig. 15). Calves on Texas ranges gain weight rapidly during the spring and early summer until July. During the remainder of the summer, they gain less rapidly and either barely maintain weight or undergo a weight loss during the fall and winter (13). Knapp (12) reports that growth curves of range cattle in Montana follow a similar pattern, and points out that "this general staircase pattern of growth appears to be normal for cattle in the Great Plains area."

Is such a growth pattern accompanied by lower efficiency in the utilization of feed than that obtainable under conditions of continuous growth? Is the meat of animals whose growth has been interrupted inferior in quality to that of animals whose growth has not been interrupted? Does the carcass of an animal that did not grow continuously contain a smaller proportion

of lean meat than that of an animal that did grow continuously?

The data presented here suggest that retardation of growth during the period between ages 6 and 12 months did not adversely influence subsequent efficiency in feed utilization, quality of meat, or quantity of lean meat. Even though the time required by the individuals to reach slaughter weight (1,000 pounds) was increased by a period of reduced feed intake (in most cases by 2 or 3 months, and in one case by 4½ months) the total amount of feed required to produce a pound of beef was increased only slightly by the 6-month period of low-energy allowance. Apparently an increase in efficiency of feed utilization after the period of reduced energy intake ended accounts for the fact that so little difference was observed in the amounts of feed ultimately required to produce a unit weight of beef.

Results reported by earlier investigators indicate that animals fed rations low in energy but presum-

TABLE 8.—*Meat quality*¹

Animal	Twin No.	Intensity						Desirability			Tender-ness
		Aroma	Flavor of fat	Flavor of lean	Tender-ness	Richness	Quantity of juice	Aroma	Flavor of fat	Flavor of lean	Shear test ²
Control.....	2	4.8	4.0	5.0	5.2	5.6	5.6	6.0	5.8	6.6	12
Experimental.....	1	4.8	3.8	5.4	6.2	6.0	5.8	5.8	6.4	6.8	12
Control.....	4	5.0	3.2	5.2	5.6	5.4	5.8	6.2	5.8	6.2	12
Experimental.....	3	5.0	3.2	5.4	5.6	5.6	5.6	6.0	6.0	6.4	11
Control.....	5	5.2	3.8	5.0	5.4	4.6	5.0	6.7	5.8	6.0	14
Experimental.....	6	5.0	2.6	5.4	5.8	5.6	5.4	5.8	6.2	6.6	11
Control.....	15	5.0	3.8	5.2	5.2	5.6	5.4	5.6	5.8	6.4	13
Experimental.....	16	4.6	3.8	4.8	6.2	5.0	4.4	6.0	6.2	6.4	14
Control.....	17	5.0	3.2	5.0	5.0	5.6	5.2	6.0	6.2	6.4	13
Experimental.....	18	5.0	3.6	5.0	6.2	5.8	5.8	6.0	5.8	6.4	10
Control.....	8	5.2	4.2	5.4	5.0	5.0	5.6	6.0	5.8	6.4	13
Experimental.....	7	5.0	4.0	5.3	5.2	5.0	5.3	5.8	6.2	6.0	14

¹ The numbers 1 to 7 indicate the degree either of intensity or of desirability of factors such as aroma, flavor, or tenderness. Number 1 represents the absence of a desirable factor, i. e., the indications of its presence are of such low intensity as to be imperceptible. Number 1 in relation to the test of intensity of tenderness (4th

column under intensity) would indicate extremely tough meat; number 7 would represent very tender meat.

² Pounds of force per square inch required to shear a cylindrical section of meat having a diameter of 1 inch. Meat fibers were cut crosswise.

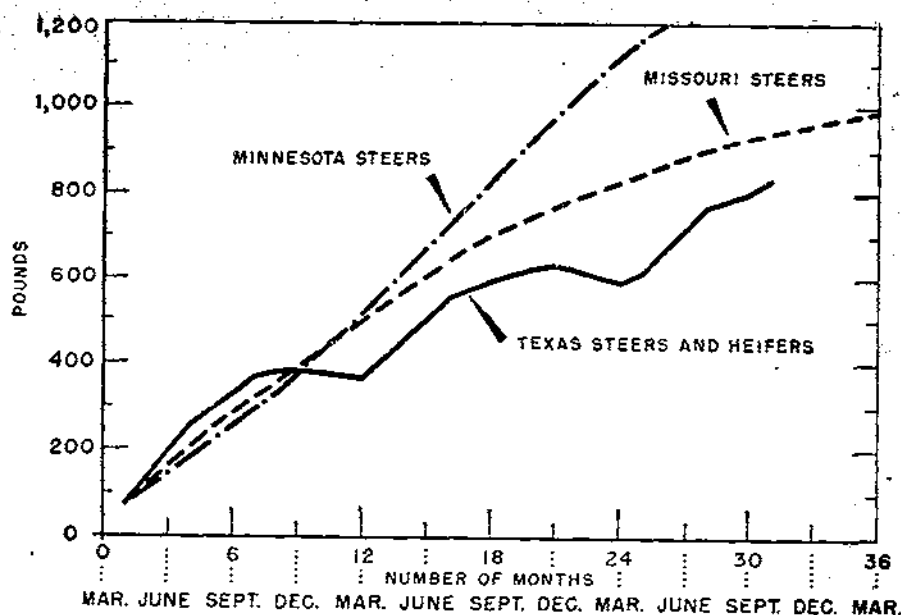


FIGURE 15.—Mean weight gains of beef cattle under different systems of feeding. The Texas cattle were on year-long pasture and received no feed except milk of their dams up to weaning time, and a very small amount of supplemental feed in very severe winters. The Minnesota steers were fed all the grain they would clean up quickly and all the roughage they would eat. The Missouri steers were fed to make good gains without any considerable amount of fattening. Months indicating age of calves refer to all three curves; months indicated by abbreviations refer to Texas curve only. (From "Normal Growth of Range Cattle" (13)).

ably otherwise adequate tend to make more efficient use of feed during recovery than do unretarded controls (9, 16, 29, 32).

The performance of adult steers fed rations equal to about half of maintenance for about 4½ months and subsequently fed fattening rations led Benedict and Ritzman (1) to the conclusion that: "Adult steers may be carried through the winter on extraordinarily low rations and subjected to heavy losses in weight without experiencing any permanent damage, and are able to resume their original weight and, indeed, can be fattened for market with subsequent high feeding."

In California (6), one group of steer calves was fed range forage plus concentrates from July to January in amounts sufficient to enable

them to gain 1 pound of weight daily, whereas a second group of steers, allowed only forage during this time, lost weight. From January to June, when growing pastures were available, the first group was fed no supplement, whereas the second group was given supplementary feed. The second group made greater gains during this time than the first group. Finally, from June to early September, both groups were given concentrates on a full-feed basis on the range. Whereas the total cost of concentrates for each of the two groups was similar, the first group returned considerably more profit than the second because of the greater gains made by the former and a somewhat higher selling price per pound. This research amply demonstrates

the usefulness of high-protein concentrates to supplement protein-deficient forage.

Workers at the Oklahoma station also have demonstrated the value of protein supplements when fed with native grasses during seasons of the year when deficiencies appear in range forage (21, 23, 25, 28). However, in one series of trials, greater profits were realized when 3-year-old steers were fattened on grass alone from early May to mid-September (136 days) than when they were fed grass plus supplements and marketed after they had grazed 106 days. Profits also were greater when grass was fed without supplements for 136 days than when this practice was followed for only 106 days (27). In general, the practice of feeding 3 pounds of oats per head per day to cattle on cottonseed cake plus forage or hay was found not to be profitable (19, 20, 22, 24). However, when fed in a trap, or holding pen, the feeding of oats did yield a profit (25). Protein pellets fed with grass during the summer increased weight gains and net profits to levels above those made with grass alone, but steers fed ground shelled corn instead of the protein pellets gained more weight and yielded a greater net profit than

did the steers that received the protein supplement (26).

A mathematical relationship between intake and weight gains has been shown to exist when experimental conditions are such that intake of energy is the factor limiting growth (33). On the basis of this relationship, the findings reviewed here, and the original data reported in this publication, it may be concluded that if feed prices are low enough to enable beef producers to feed for rapid, continuous gains throughout the year, this method is the more desirable since it makes possible the marketing of beef animals at the earliest age possible. However, it sometimes happens that prices of feeds, other than forage, are so high during a part of the year as to preclude the possibility of profits when such feeds are used except in limited amounts. In cases of this kind, retarded or even interrupted growth of cattle may be more profitable than continuous growth. It seems evident that young growing cattle can be carried for as long as 6 months at an energy level as low as maintenance, if the known nutritional needs aside from energy requirements for growth are met, without loss later either in efficiency of feed utilization or in meat quality.

SUMMARY AND CONCLUSIONS

A study was made, with six pairs of monozygotic (identical) twin steers, of the relative effects of continuous and of interrupted growth. The criterion of "one-egg" origin of the twins, upon which final reliance was placed, was a blood test of an antigenic type.

One member of each pair of twins was subjected to refardation of growth and the other was fed liberally. Two experimental animals were fed at each of the following energy levels: (1) Maintenance, or

about 50 percent of a liberal ration, (2) 62 percent of a liberal ration, and (3) 75 percent of a liberal ration. The two lower allowances were fed the steers for 6 months, between the ages of 6 and 12 months. The 75-percent ration was fed for a period somewhat longer than 6 months. At the end of the period of reduced feeding the retarded animals were fed a liberal ration; the controls were given liberal allowances throughout the experiment. The low-calorie rations were de-

ficient, so far as is known, only in energy.

The steers gained a pound a day on the 75-percent ration, 0.5 pound a day on the 62-percent ration, and neither gained nor lost much weight on the maintenance allowance.

After the period of reduced intake ended, all the retarded animals gained weight rapidly and economically.

Each steer was slaughtered when it reached a weight of about 1,000 pounds. Although in most cases the retarded animals reached slaughter weight from 10 to 20 weeks later than did their cotwins, the former attained this weight on approximately the same intake of energy as the later. This rather surprising result is explained by the fact that after reduced feeding

ended, the retarded animals made more economical gains than did their cotwins.

Carcass grades, and meat quality of the retarded animals were not lowered appreciably by the period of low-energy intake. The quantity of lean meat in the carcass was not decreased by interruption of growth.

It is concluded that under conditions of feed scarcity beef cattle between the ages of 6 and 12 months can be carried at an energy level as low as maintenance, if the nutritional needs other than those for energy are supplied, without loss later in efficiency of feed utilization, meat quality, or in the proportion of lean meat, as compared with fat and bone, in the carcass.

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