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RELATION OF FEED CONSUMED TO FOOD PRODUCTS PRODUCED BY FATTENING CATTLE

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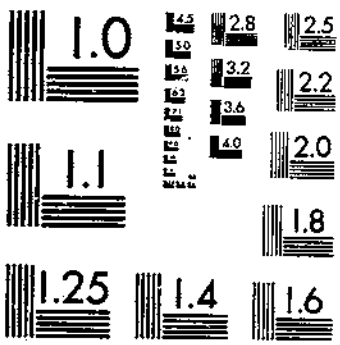

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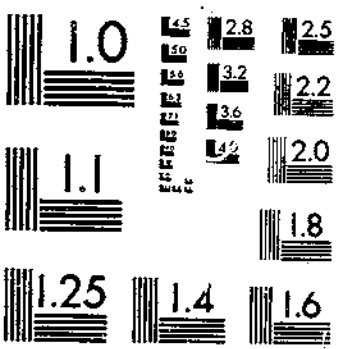

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NATIONAL BUREAU OF STANDARDS-1963-A

Technical Bulletin No. 900 • September 1945

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Relation of Feed Consumed to Food Products Produced by Fattening Cattle[1]

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INTRODUCTION

To meet the needs for food during the war and immediate postwar periods, all of our productive resources must be used effectively. It is important that every possible effort be made to obtain the most effective utilization of available feed supplies. This involves distributing wise proportions of them to the classes of livestock and systems of management that convert feed most efficiently into food products, so far as this distribution is consistent with the War Food Program as a whole. At the same time, every effort must be made to increase production efficiency in the conversion of feeds into essential livestock products.

In meeting this challenge, cattle feeders particularly are considering such questions as the following: How do cattle during the fattening period compare with hogs or dairy cows in the efficiency with which they convert feed grains and high-protein feeds into food? Are some systems of management now used in fattening cattle more desirable than others, considering the total contribution of each to the wartime food supply? How much of the total supply of concen-

[1] Submitted for publication May 15, 1945.

[2] The author is indebted to many persons connected with the Bureau of Animal Industry, the State Agricultural Colleges, and public stockyards who have contributed to this study. C. W. Crickman, R. D. Jennings, A. V. Nordquist, and C. L. Harlan, Bureau of Agricultural Economics, assisted in outlining the problems considered and in making the estimates of the number of cattle grain-fattened and the length of the feeding period.

trates should be used for cattle-feeding operations? Should the total number of cattle fed be increased or decreased?

This bulletin brings together the results of research on three phases of cattle fattening in the Corn Belt. From these results it attempts to disclose: (1) A picture of the cattle-feeding enterprise, including the number of animals that are grain-fattened annually, the quantity of concentrates that is utilized, and the gain in live weight produced during the fattening period; (2) the relationships between the quantity of feed utilized in fattening cattle and the quantity of food produced in terms of live weight, edible weight, and edible nutrients; and (3) the implications of these relationships in connection with cattle fattening in the Corn Belt.

Estimates of the number of cattle that were grain-fattened and the length of the feeding periods during the five feeding years from October 30, 1938 to September 30, 1943 are based on market records and survey information obtained from cattle feeders in the Corn Belt States. The estimates of gain and feed requirements, which are so constructed as to be consistent with the kind of cattle fattened and the length of the feeding period are based on: (1) Records obtained from cattle feeders by State agricultural experiment stations and the United States Department of Agriculture and (2) data obtained from experiments conducted by State agricultural experiment stations and by the United States Department of Agriculture.

All of these records, in turn, were supplemented by the judgment of specialists in the agencies referred to and of other persons who are familiar with the details of cattle fattening in the Corn Belt States.

Experimental data were used chiefly as a basis for the section dealing with relationships between the quantity of feed fed and the quantity of food produced. A 3-year experiment conducted by the Iowa Agricultural Experiment Station and designed to analyze the relationships between feed and live-weight gain during the fattening period for calves, yearlings, and 2-year-olds, provided the data on feed-gain relationships used in the analysis. This experiment also furnished data on grade, dressing percentages, and composition of the carcasses at the beginning and end of the fattening period, for representative animals used in the experiment. With the cooperation of members of the staff of the Bureau of Animal Industry engaged in meat investigations, estimates for these items at certain intervening points during the fattening period were derived from other studies. The procedure is given in detail in the Appendix (p. 27). Further experimental work is needed to furnish more complete and reliable data on changes that occur in the animal during the fattening period but the estimates used here appear to be congruent and specialists in the Bureau of Animal Industry feel that they are fairly satisfactory.

The scope of this study is limited to physical relationships involved in producing human food by the fattening of cattle. Costs and returns are important to the individual feeder but in periods when food is scarce and such production resources as feed and labor are likely to be inadequate to meet all requirements, it may be necessary to make adjustments in the economic relationships. This may be done through the development of price programs to facilitate maximum production of essential food in accordance with physical relationships. This

maximum is clearly indicated through an analysis of the physical relationships.

CATTLE FEEDING AN INTEGRAL PART OF CORN BELT FARMING

Many farms in the Corn Belt are large and a relatively high proportion of the land is used to grow the so-called fattening grains (corn and barley) compared with the acreage used for high-protein grains and roughages (such as oats and alfalfa). This results in a substantial surplus of fattening grains over the quantity needed on the average Corn Belt farm for fattening the litters of the number of brood sows that can be handled to advantage and for feeding the poultry flock and the farm work stock.

Cattle feeders in the Corn Belt feed part of this surplus, together with a considerable quantity of roughage, to feeder cattle that have been raised on western ranges and farm pastures. Many of the cattle raised on these rough feeds, for which often there is no good alternative use, are not fat enough to yield beef of desirable quality if they are slaughtered without being finished by the feeding of concentrates. Cattle feeders make an important addition to both the quality and the quantity of our food supply by fattening those cattle that are of feeder grade. Moreover, the fattening of cattle facilitates a more even distribution of the slaughter of cattle and therefore of the supply of beef throughout the year.

Four Million Cattle Grain-Fattened Annually in Corn Belt

In the 11 Corn Belt and border States about 4 million cattle were annually put on grain feed preparatory to being marketed, from 1938–39 to 1942–43 (table 1). The exact number varies from year to year, of course. It is estimated that in the feeding year that began October 1, 1938, slightly less than 4 million head of cattle were fed in the Corn Belt, whereas more than 4.6 million head were fed in 1942–43.

About 29 percent of the cattle that were grain-fattened in the Corn Belt during that period were so fattened in Iowa, 16 percent in Illi-

TABLE 1.—*Estimated number of cattle put on grain feed in the Corn Belt and border States, 1938–39 to 1942–43 (year beginning October 1)*[1]

State	1938–39	1939–40	1940–41	1941–42	1942–43
	1,000 head	*1,000 head*	*1,000 head*	*1,000 head*	*1,000 head*
Ohio	169	160	156	159	161
Indiana	198	228	216	234	226
Illinois	681	726	736	709	656
Michigan	105	112	99	103	119
Wisconsin	93	91	96	95	96
Minnesota	352	423	407	387	356
Iowa	1,095	1,211	1,305	1,290	1,389
South Dakota	118	135	139	169	208
Nebraska	408	420	470	461	580
Missouri	339	418	437	442	462
Kansas	253	251	313	397	426
Total	3,811	4,184	4,403	4,446	4,619

[1] These estimates are consistent with the estimates of the numbers of cattle and calves on feed by States as of January 1, published by the Bureau of Agricultural Economics, January 12, 1945.

nois, 11 percent in Nebraska, 9 percent in Missouri, 9 percent in Minnesota, 8 percent in Kansas, and 5 percent in Indiana. The remaining 13 percent were fed in Ohio, Michigan, South Dakota, and Wisconsin.

Approximately 22 percent of the cattle weighed less than 500 pounds each when put on feed; 37 percent weighed 500 to 750 pounds; and 41 percent weighed more than 750 pounds.

The average length of the grain-fattening period for all cattle fattened in the Corn Belt during that period was about 200 days. The best indications are that about 38 percent of the cattle fattened in the Corn Belt were "short-fed" (averaging about 120 days); about 44 percent were "medium-fed" (averaging about 225 days); and about 18 percent were "long-fed" (averaging about 300 days).

Calves were fed the longest period, averaging around 265 days. A large proportion of the calves were fed more than 300 days and some were fed more than a year. Such long-fed calves carry a high degree of finish when they are marketed. Feeders that had an initial weight of 500 to 750 pounds were fed an average of approximately 200 days. Although not so large a proportion of this group were fed for so long a period as calves, about 50 percent were fed an average of 225 days or more which indicates that they had a high degree of finish when they were marketed. Feeders that weighed more than 750 pounds when put on feed were fed an average of about 150 days. About one-third of the feeders that had weighed more than 750 pounds when put on feed were fed an average of around 200 days or more, which indicates that a large proportion are fed to a high degree of finish.

In general, the grain-fattening period is longest in the central part of the Corn Belt. In some areas on the fringe of the Corn Belt, cattle are fed for a long period, but considerable roughage is used with the concentrates during part or all of the time, hence the total gain in live weight is not so great as for a comparable length of feeding in the central Corn Belt.

About half of the annual number of cattle put on grain feed in the Corn Belt normally "go on feed" during the months of October

TABLE 2.—*Estimated average proportion of cattle put on grain feed in given periods of the feeding year in the Corn Belt, by States, 1938–39 to 1942–43 (year beginning October 1)*

State	1938–39 to 1942–43 average			
	Oct.–Dec.	Jan.–Mar.	Apr.–July	Aug.–Sept.
	Percent	*Percent*	*Percent*	*Percent*
Ohio	55	12	10	23
Indiana	50	15	10	22
Illinois	49	18	12	21
Michigan	59	9	7	25
Wisconsin	54	14	9	23
Minnesota	54	17	7	22
Iowa	48	21	10	21
South Dakota	60	19	8	13
Nebraska	52	24	11	13
Missouri	52	18	11	19
Kansas	51	18	12	19
Corn Belt	51	19	10	20

through December (table 2). About one-fifth go on feed from January through March, one-tenth from April through July, and the remaining one-fifth during August and September.

Estimated numbers of grain-fattened cattle that were marketed from the Corn Belt during the calendar years 1939–43 are given in table 3. These estimates are congruous with the estimates of the number of cattle put on grain feed to be marketed later, and of the length of feeding period. Normally about 25 percent of the grain-fattened cattle are marketed during the period January to March; 40 percent during April–July; and 35 percent during August–December.

TABLE 3.—*Estimated number of grain-fattened cattle marketed from the Corn Belt, by States, 1939–43*

State	1939	1940	1941	1942	1943
	1,000 head	*1,000 head*	*1,000 head*	*1,000 head*	*1,000 head*
Ohio	156	162	160	154	173
Indiana	174	224	222	227	240
Illinois	593	715	759	700	697
Michigan	96	113	104	99	136
Wisconsin	87	88	99	94	100
Minnesota	334	420	408	382	393
Iowa	1,018	1,159	1,310	1,261	1,499
South Dakota	110	133	157	167	218
Nebraska	383	432	467	463	597
Missouri	317	408	436	450	422
Kansas	256	239	302	388	434
Total	3,514	4,093	4,424	4,385	4,909

ANNUAL TOTAL GAIN OF FATTENING CATTLE

The annual total live-weight gain made by cattle that were fattened averaged about 1.5 billion pounds during the period 1938–39 to 1941–42 (table 4). About 28 percent of the gain was made by cattle that weighed less than 500 pounds each when put on grain feed, 38 percent by cattle that weighed 500 to 750 pounds when put on grain feed, and 34 percent by cattle that weighed more than 750 pounds at that time.

The greatest gains per head occurred among the cattle that were fed in the central Corn Belt. The grain-feeding period there is

TABLE 4.—*Estimated total gain in live weight, during the fattening period, of cattle put on grain feed in the Corn Belt, during the feeding years 1938–39 to 1941–42, by States, (year beginning October 1)*

State	1938–39	1939–40	1940–41	1941–42
	Million pounds	*Million pounds*	*Million pounds*	*Million pounds*
Ohio	61.0	57.6	55.6	56.7
Indiana	75.0	86.2	81.9	85.8
Illinois	254.8	280.5	288.6	274.6
Michigan	38.7	40.5	37.5	37.9
Wisconsin	31.4	31.9	33.0	32.3
Minnesota	118.7	143.5	144.7	141.5
Iowa	408.5	462.7	502.4	493.9
South Dakota	38.7	44.4	52.8	56.8
Nebraska	135.1	143.4	155.9	154.1
Missouri	115.3	139.4	147.6	145.0
Kansas	78.0	75.8	96.3	118.3
Total	1,355.2	1,505.9	1,596.3	1,596.5

longest and a larger proportion of the feed is in concentrates, than is true elsewhere in the Belt. For example, about 29 percent of the cattle that were fattened in the Corn Belt during this period were fed in Iowa, but approximately 31 percent of the gain in weight was produced there. In general, calves are fed longer and make greater gains per head than do the heavier feeders. Only 22 percent of the cattle that are fed in the Corn Belt are calves, whereas calves produce about 28 percent of the total gain.

QUANTITY OF GRAIN USED FOR FATTENING CATTLE

About 11 billion pounds of grain (equivalent to 200 million bushels of corn) and about 275,000 tons of protein supplement were required annually during the period 1938–39 to 1941–42 to fatten the cattle that were put on grain feed in the 11 Corn Belt States (table 5).

TABLE 5.—*Estimated total quantities of grain and protein supplement used to fatten cattle put on grain feed during the feeding year in the Corn Belt, by States, 1938–39 to 1941–42 (year beginning October 1)*

State	Grain				Protein supplement			
	1938–39	1939–40	1940–41	1941–42	1938–39	1939–40	1940–41	1941–42
	Million pounds	*Million pounds*	*Million pounds*	*Million pounds*	*1,000 tons*	*1,000 tons*	*1,000 tons*	*1,000 tons*
Ohio	437	417	390	407	11.5	11.0	10.1	10.7
Indiana	562	648	606	636	14.5	16.8	15.5	16.4
Illinois	1,937	2,160	2,185	2,107	48.2	53.9	53.3	52.2
Michigan	283	293	276	265	7.5	7.8	7.3	6.9
Wisconsin	225	231	245	242	5.6	5.8	6.3	6.3
Minnesota	871	1,028	1,091	1,073	22.1	25.8	27.5	27.2
Iowa	3,113	3,564	3,874	3,795	75.2	86.2	93.2	91.3
So. Dakota	273	312	374	407	6.8	7.7	9.2	10.1
Nebraska	960	1,025	1,116	1,130	19.6	20.9	22.9	23.0
Missouri	759	914	970	955	22.0	26.7	28.3	28.2
Kansas	500	487	628	778	16.2	15.9	20.6	25.8
Total	9,920	11,079	11,755	11,795	249.2	278.5	294.2	298.1

About 25 percent of the grain was fed to calves, about 40 percent went to 500-750-pound feeders, and about 35 percent went to feeders that weighed 750 pounds and over at the beginning of the feeding period. Calves are usually fed more grain per head than are the older feeders. About 22 percent of the cattle fattened were calves but they consumed about 25 percent of the grain.

The quantity of protein fed is more difficult to estimate than the quantity of grain. There is apparently considerable variation in the quantity of protein used in the rations. Some cattle feeders do not use any protein supplement. Feed records indicate that relatively less protein per head is fed to calves than to heavier feeders; one reason may be that a relatively larger proportion of the calves are run on pasture for a part of the feeding period.

FATTENING CATTLE IN WARTIME

In wartime, feed and food generally are inadequate to meet all demands. Moreover, there is special need for livestock food products which can be produced with relatively small quantities of feed per unit of food produced. Milk, eggs, and pork are examples. Large

quantities of corn and other concentrates beyond those usually needed are required for producing these commodities as well as for essential industrial purposes.

To facilitate meeting these needs during this war it has been suggested that a considerable part of the 5.5 million tons of grain and the 275,000 tons of protein supplement which Corn Belt cattle feeders use annually, in adding about 1.5 billion pounds to the live weight of cattle slaughtered, be shifted to more essential uses.

In general, cattle that are being fattened have been rated below some other kinds of livestock in efficiency when converting feed concentrates into food. The reasons are that too frequently when this rating is made (1) full consideration is not given to the change that takes place in the food-nutrient content of the beef carcass during the fattening process and (2) the "long-fed" steers are compared with "whole milk" dairying. Usually only the gain in live weight of a steer is considered as the contribution of the fattening process, whereas, in fact, the dressing percentage has been increased and the finished carcass has been considerably improved in food-nutrient content. For instance, a comparison of the food-nutrient content of the carcass of a Medium to Good grade 600-pound feeder steer with that of the same kind of steer after it has been fattened to 950 pounds, indicates that although the fattened steer increased only 58 percent in weight, the increase in total calories was 149 percent; in fat, 196 percent; and in protein, 54 percent.

Taking account of the improvement in these phases that is made during the feeding process, a comparison of fattened cattle with other kinds of livestock in regard to edible product and food nutrients produced per 1,000 units of feed is given in table 6.

Some systems of cattle feeding, however, are not so efficient in the use of feed as the one discussed. When cattle are fed for a relatively long period to obtain a high finish and when they are full-fed on

TABLE 6.—*Comparison of edible product and food nutrients produced per 1,000 feed units by fattened cattle and other livestock* [1]

Class of livestock and kind of product	Yield per 1,000 units of feed consumed [2]			
	Edible product	Calories	Fat	Protein
	Pounds	*Thousands*	*Pounds*	*Pounds*
Fattened cattle:				
Food products [3]	76	157	36	8
Dairy cows:				
Whole milk	901	276	34	31
Butter [4]	69	212	51	2
Hogs:				
Pork and lard	135	349	80	13
Chickens:				
Eggs	165	113	18	20
Meat	103	83	12	19

[1] Data are based upon an unpublished report by R. D. Jennings of the Bureau of Agricultural Economics; also CHRISTENSEN, R. P. USING RESOURCES TO MEET FOOD NEEDS. U. S. Bur. Agr. Econ., 71 pp. 1943. [Processed.]

[2] The term "feed unit" as used here is 1 pound of corn or equivalent quantities of other feeds having the same feed value as a pound of corn.

[3] During the fattening period, assuming a Medium to Good grade 600-pound feeder steer fattened to 950 pounds. An allowance for pork and lard produced on feed wasted by cattle and consumed by hogs following them is included.

[4] Includes an allowance for pork and lard produced from skim milk.

concentrates throughout the feeding period to increase the daily rate of gain, the feed concentrates are used less efficiently. Moreover, the greater part of the increase in weight obtained by feeding cattle to the higher slaughter grades is in the form of fat. Cuts from carcasses of animals that have been fattened beyond the Good slaughter grade contain more fat than usually is eaten by the average person, as indicated by several studies and the opinions of several specialists in the field of nutrition. (See Appendix, p. 35.)

RELATIONSHIPS BETWEEN QUANTITY OF FEED CONSUMED AND FOOD PRODUCTS PRODUCED

The efficiency of the utilization of feed during the fattening period is indicated in several ways. Some of them are the relationships between the quantities of feed consumed and the gains in live weight, the gains in edible body, the gains in edible body nutrients, and the gains in calories. Related data on the feed consumed, the gains in live weight, the slaughter grade reached, the dressing yield, and the grade and composition of beef carcasses of steers, are available for setting up all of these relationships. Analyses of these relationships will indicate approximately the efficiency with which feed is utilized in the production of food and nutritive values at various stages in the feeding period.[3]

Relation of Slaughter Grade to Gain and Feed Consumed

Choice feeder steers would yield carcasses of Common to Medium grade if they were slaughtered without being fattened. A Choice feeder-steer calf requires about 400 pounds of gain to produce a Good or A carcass and an additional 200 pounds of gain to produce a Choice or AA carcass.[4] A Choice yearling feeder steer requires about 270 pounds of gain to produce a carcass that will be of Good grade, and an additional 170 pounds of gain to produce a Choice carcass. A Choice 2-year-old feeder steer requires about 200 pounds of gain to produce a Good grade carcass and an additional 150 pounds of gain to produce a Choice carcass (fig. 1). Experimental data indicate that there is considerable variation in the grade of carcass that Choice feeder steers would yield before being fattened and in the gain required by Choice feeder steers to produce Good grade and Choice grade slaughter animals. The report of the experiment that was used as a basis for this section specifies that: "The steers were graded as Choice feeders, or as Common to Medium steers for slaughtering. . . . The fattened steers were graded as Choice beef steers." *(7, p. 304)*.[5] The report also gives the gain made by Choice feeder steers in becoming Choice slaughter animals. The judgment of animal husbandrymen from the Corn Belt States was relied upon to a considerable extent in arriving at congruent average figures for the gain required by Choice feeder steers in order to become Good grade slaughter animals.

[3] Further information regarding the data used in this analysis, together with a brief description of the analytical procedure followed is given in the appendix (p. 2[illegible])

[4] Throughout this bulletin the degree of finish indicated by the grade names (Choice, Good, etc.) is that carried by the animal when it has reached the middle or average of the specified grade unless otherwise indicated. At several places in the discussion, however, it seemed desirable to definitely specify the degree of finish as the average of the grade to insure clarity.

[5] Italic numbers in parentheses refer to literature cited, p. 37.

The younger feeder cattle gain more in live weight per unit of feed than do the older feeder cattle, but they require more feed to reach comparable slaughter grades because they grow more during the fattening period. When fed a standard Corn Belt ration in dry lot, calves require about 3,330 pounds of total digestible nutrients, yearlings about 2,840 pounds of total digestible nutrients, and 2-year-old steers about 2,335 pounds of total digestible nutrients if they are to be fattened from Choice feeder grade to Choice slaughter grade. The increase in slaughter grade from Good to Choice requires 43.4

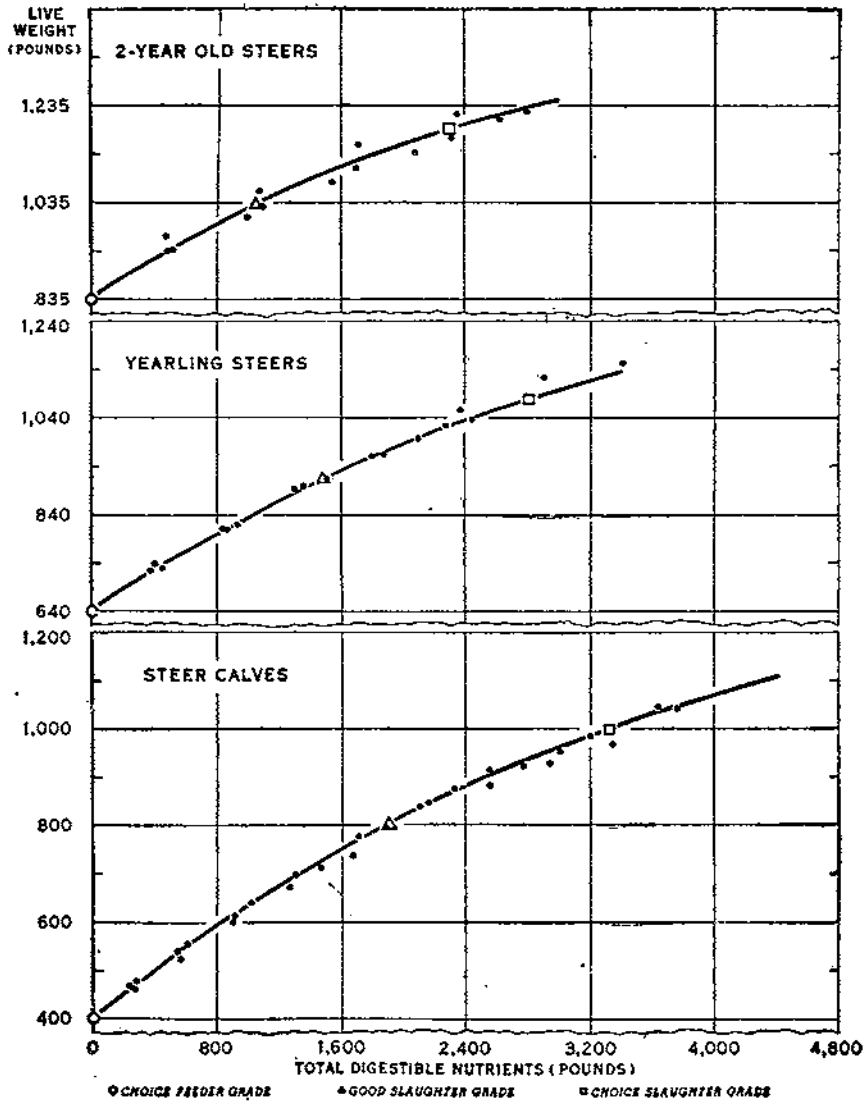

FIGURE 1.—Relation of live weight to total quantity of feed consumed throughout the fattening period.

percent of the total feed normally given to calves during the fattening period, 48.6 percent of the total given to yearlings, and 54.6 percent of the total given to 2-year-old steers.

Relation of Gain in Live Weight to Feed Consumed

The efficiency of feed utilization, as measured by the gain in live weight per 100 pounds of total digestible nutrients, declines from the beginning of the feeding period. Two measures of live-weight gain related to feed consumed are shown in figure 2.

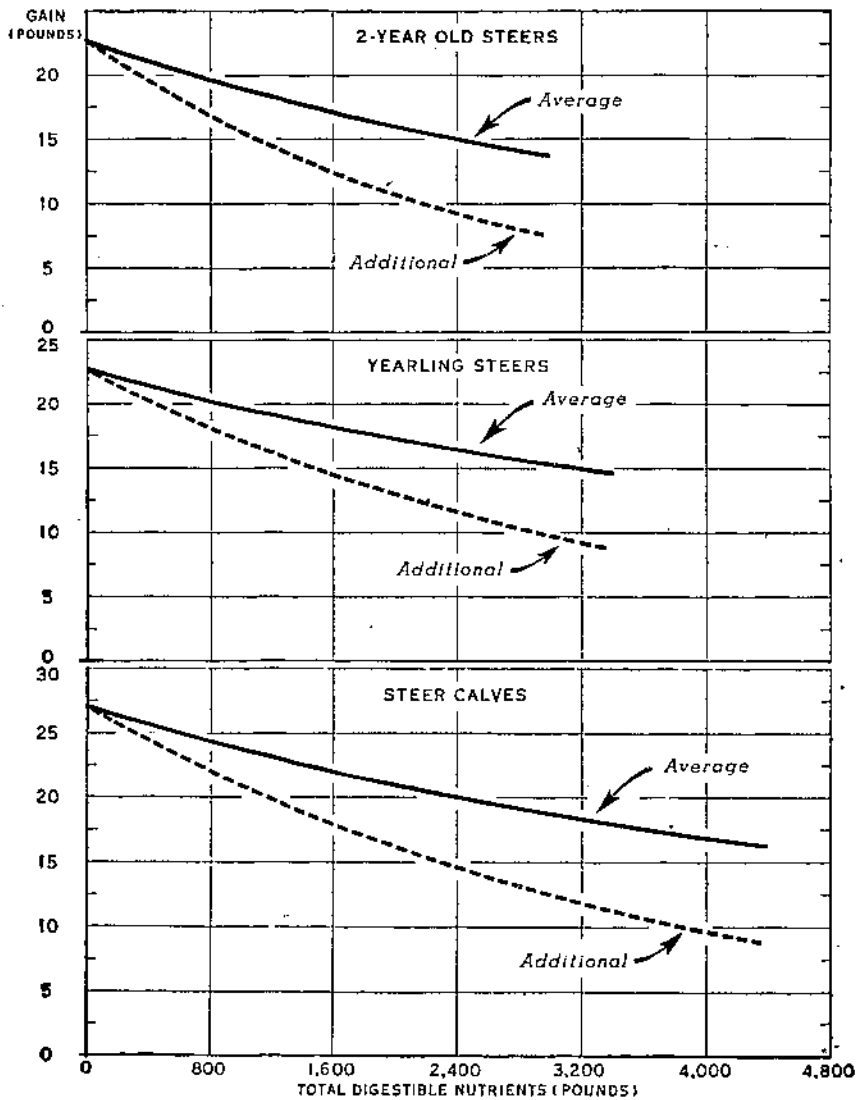

Figure 2.—Gain in live weight per 100 pounds of total digestible nutrients consumed throughout the fattening period.

Both measures indicate that the gain in live weight per 100 pounds of total digestible nutrients decreases as the animal grows and fattens. Axiomatically the *additional* gain per 100 pounds of total digestible nutrients decreases more rapidly than the *average* gain per 100 pounds of total digestible nutrients. The gain per unit of feed is greater, and the rate decreases less rapidly throughout the fattening period of calves than it does in the case of yearlings and 2-year-olds, as indicated by the curve showing the additional gain per unit of feed. During the fattening period of calves when they are at the stage of Good slaughter grade, they increase about 16.5 pounds in live weight for each 100 pounds of total digestible nutrients compared with about 11.4 pounds gain in live weight when they are at the stage of Choice slaughter grade—a decrease in efficiency of about 31 percent.

Comparable figures for gain in live weight of yearlings are about 15.1 pounds and 10 pounds, respectively, or a decrease in efficiency of about 34 percent. For 2-year-old steers, the decline in efficiency in the utilization of feed is even greater. Comparable figures for gain in live weight of 2-year-olds are about 15.2 pounds and 9.4 pounds respectively, or a decrease of 38 percent in efficiency.

But gain in live weight is probably not the most accurate measure of efficiency of feed utilization. As shown later, the efficiency of feed utilization, measured in pounds of edible nutrients and calories produced per unit of feed, probably increases during the first part of the feeding period.

Relation of Body Composition to Feed Consumed

In figure 3 the estimated weight of the component parts of the live animal in the case of calves, yearlings, and 2-year-old steers throughout the fattening period is compared with total feed consumed at comparable points. The edible part of the body (edible carcass plus edible offal) is the same thing as the edible lean meat and fat. Not quite half of the live weight is edible at the beginning of the feeding period; a large part of the gain in live weight that takes place during the feeding period occurs in the edible portion. Because of the greater growth in calves, a smaller part of the total increase in their live weight is edible compared with the increase in the older feeders, but a larger proportion of the increase in the edible portion is lean meat.

Relation of Gain in Edible Body to Feed Consumed

The decline in the efficiency in feed utilization throughout the feeding period, measured in terms of pounds of edible body produced per 100 pounds of total digestible nutrients, is small during the first part of the feeding period (particularly among calves) but the rate of decline is most rapid toward the end of the feeding period, especially among older cattle (fig. 4). Comparison of figures 1 and 4 suggests that the decline is relatively small until the animals become approximately Good slaughter grade.

An examination of the efficiency of producing edible lean (edible carcass lean plus the trimmed edible organs) and also of the separable fat (edible fat physically separable from carcass and organs plus

killing fats) indicate that the efficiency in producing edible lean meat declines rapidly from the beginning of the feeding period, and that the decline is more rapid in the case of older feeder cattle than in the case of calves (fig. 5). On the other hand, the efficiency in the production of fat increases during the first part of the feeding period for calves, yearlings, and 2-year-olds. The most efficient point in terms of separable-fat production is at about the time the animal

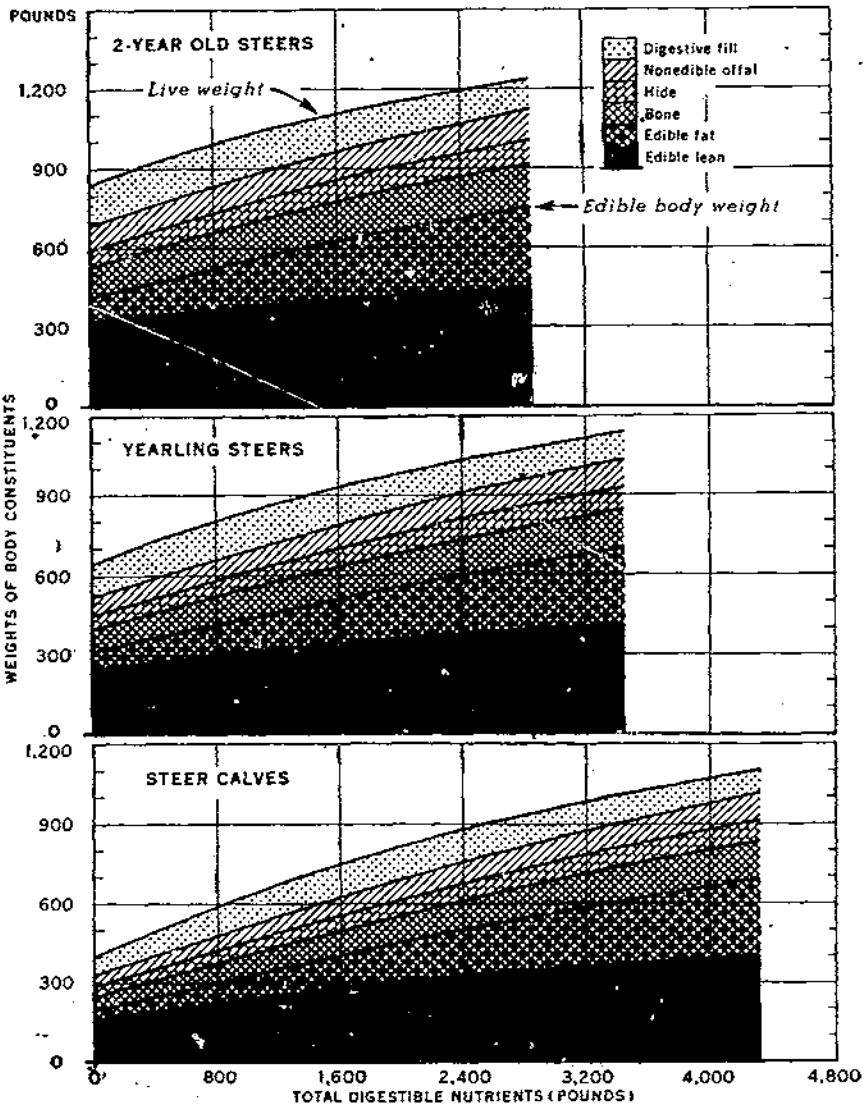

FIGURE 3.—Relation of weights of body constituents to total quantity of feed consumed throughout the fattening period. (The curves for live weight and edible body weight occupy the same relative positions also on the two lower graphs.)

is of Good slaughter grade in the case of 2-year-olds, about on the border between Good and Choice for yearlings, and on the border between Choice and Prime grade for calves.

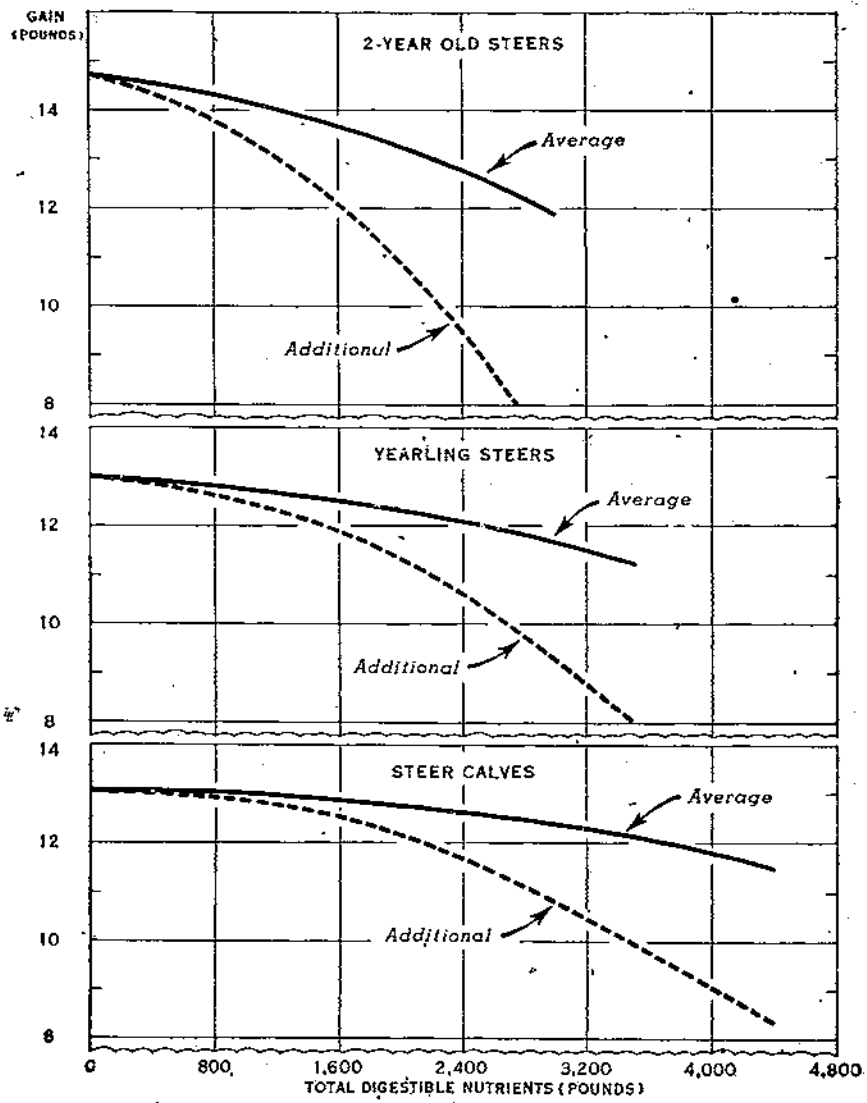

FIGURE 4.—Gain in edible body per 100 pounds of total digestible nutrients consumed throughout the fattening period.

Thus it would appear that when cattle are being fattened to improve the quality and nutrient content of the meat, the greatest efficiency in producing fat is obtained when Choice 2-year-old feeder steers are fattened to about Good slaughter grade; when choice year-

ling feeders are fattened to High Good, or Low Choice slaughter grade; and when Choice feeder calves are fattened to Choice slaughter grade. However, if a part of the large quantity of edible fat produced by fattening animals to the higher slaughter grades is not consumed

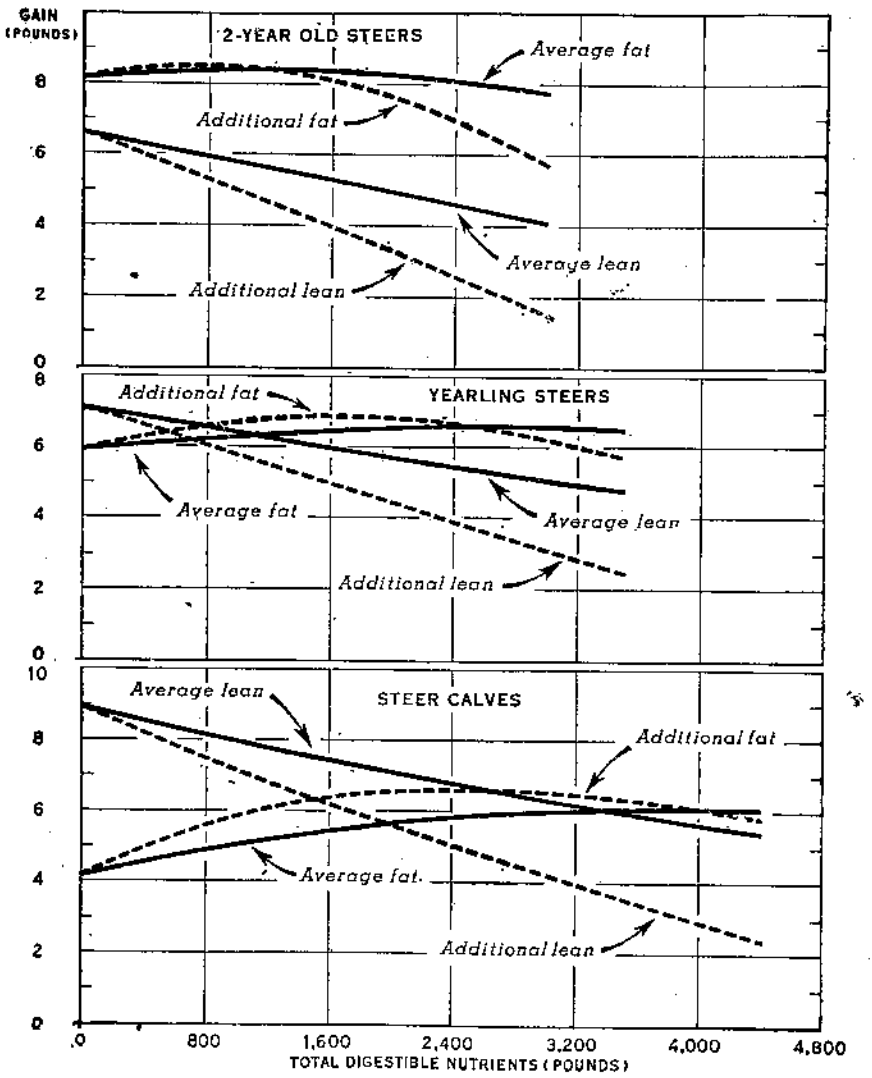

FIGURE 5.—Gain in edible lean and fat per 100 pounds of total digestible nutrients consumed throughout the fattening period.

as human food but is wasted, it would appear advisable, particularly when feed is scarce, to feed only to the slaughter grade at which the fat produced will be consumed by retail customers, even though additional finish could be efficiently produced.

As an indicator of efficiency in the utilization of feed, the gain in weight of the edible body per 100 pounds of feed consumed is more accurate than the gain in live weight because the clouding effects of digestible fill, hide, bone, and nonedible offal have been removed. But the edible body contains a large degree of moisture. Hence, a third and still more accurate measure of efficiency in feed utilization is found in the weight of the dry matter in the edible body.

Relation of Edible Body Composition to Feed Consumed

The estimated weights of the chemically determined constituents—crude protein, ash, ether extract (fat), and water—of the edible body of Choice grade feeder calves, yearlings, and 2-year-old steers, throughout the feeding period, are shown in figure 6. This chart indicates the large proportion of the edible body that is water, particularly when the animal is in thin condition. Edible bodies of younger feeders have the highest percentages of water. About two-thirds of the edible body of a Choice feeder calf is water at the beginning of the feeding period compared with about half when the animal has been fattened to Choice slaughter grade. The water content of the edible body of a Choice 2-year-old feeder steer is about 60 percent, and it is reduced to about 46 percent at Choice slaughter grade. The quantities of protein and ash in the edible body do not increase much during the fattening process, but the increase is relatively greater in young than in older animals.

Relation of Gain in Edible Body Nutrients to Feed Consumed

The efficiency in feed utilization throughout the feeding period, as indicated by both live-weight gain and edible-body gain per 100 pounds of total digestible nutrients consumed, declines from the beginning of the feeding period, but the efficiency in feed utilization as indicated by gain in edible body nutrients increases during the first part of the fattening period and then declines (fig. 7).[6] The point of greatest efficiency, as indicated by pounds of edible body nutrients, occurs in a 2-year-old steer just before it becomes of average Good slaughter grade; in a yearling when it goes just beyond the average of Good slaughter grade, and for a calf when it is about Choice slaughter grade.[7] As was shown by using the other two measures of efficiency, the efficiency in feed utilization is here shown to decline more rapidly among the 2-year-olds than among calves, after the maximum is reached.

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[6] Lacking more adequate terminology, the term edible body nutrients is used throughout this bulletin to mean edible crude protein, ash, and ether extract. Supporting evidence regarding the efficiency in feed utilization throughout the feeding period as here discussed is given in the appendix, p. 35.

[7] The point of greatest efficiency, at which the largest quantity of edible body nutrients is produced per 100 pounds of total digestible nutrients fed, is reached when the curve showing the average quantity of nutrients produced per unit of feed used crosses the curve showing the additional quantity of nutrients produced per unit of additional feed used. Before this point is reached, each additional unit of 100 pounds of total digestible nutrients fed produces more edible body nutrients than was produced on the average by all previous units of feed; this causes the average quantity of edible nutrients per 100 pounds of feed to increase. After the curves cross each other, each additional 100 pounds of total digestible nutrients fed produces a smaller additional quantity of edible body nutrients, causing a decline in the average quantity of edible body nutrients produced per unit of the feed used.

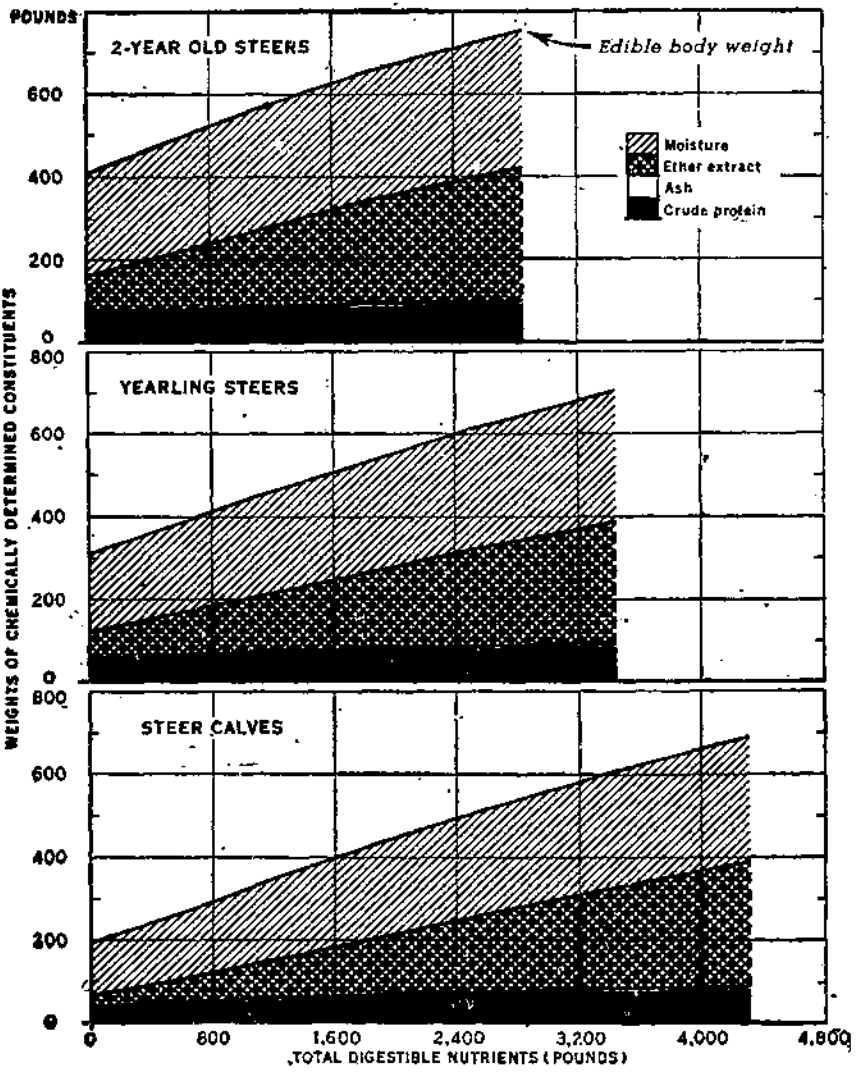

FIGURE 6.—Relation of weights of chemically determined constituents of the edible body to total quantity of feed consumed throughout the fattening period. (The curve for edible body weight occupies the same relative position also on the two lower graphs.)

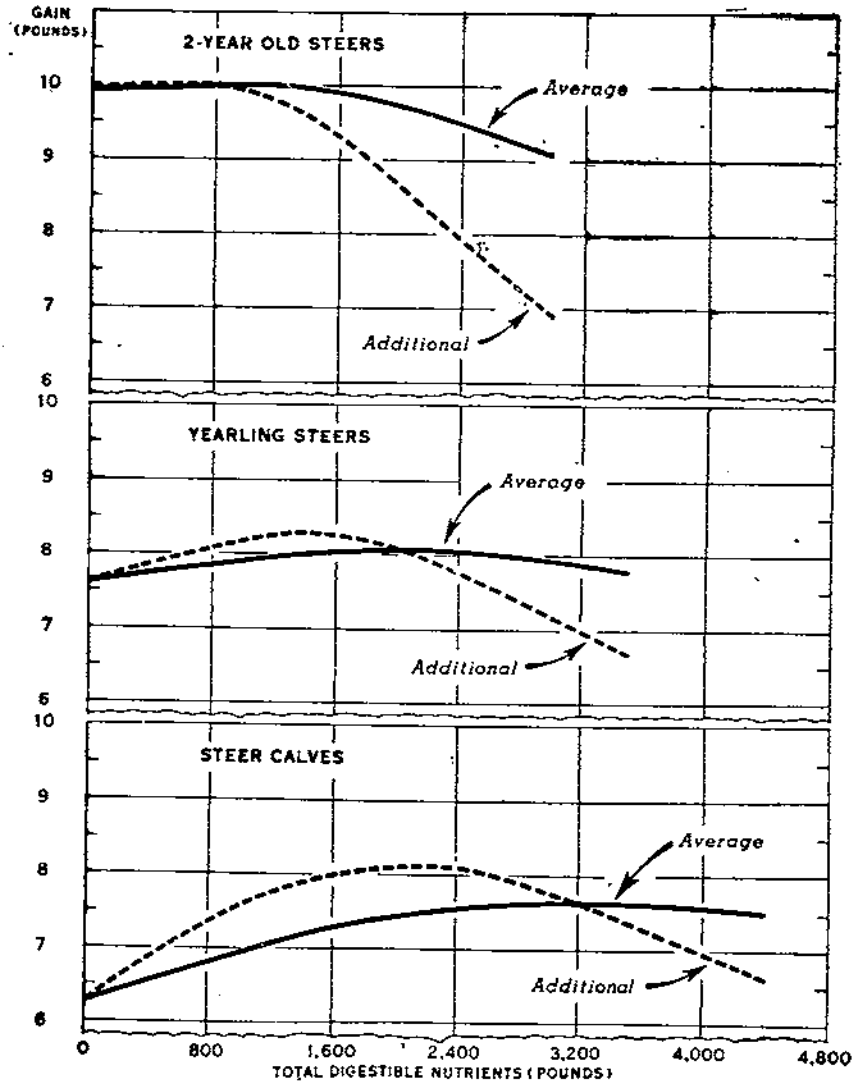

FIGURE 7.—Gain in edible body nutrients (crude protein, ash, and ether extract) per 100 pounds of total digestible nutrients consumed throughout the fattening period.

Considering the protein and ether extract individually, the quantity of crude protein produced per unit of feed declines from the beginning of the feeding period, as does the quantity of lean meat (fig. 8). The efficiency in producing ether extract increases during

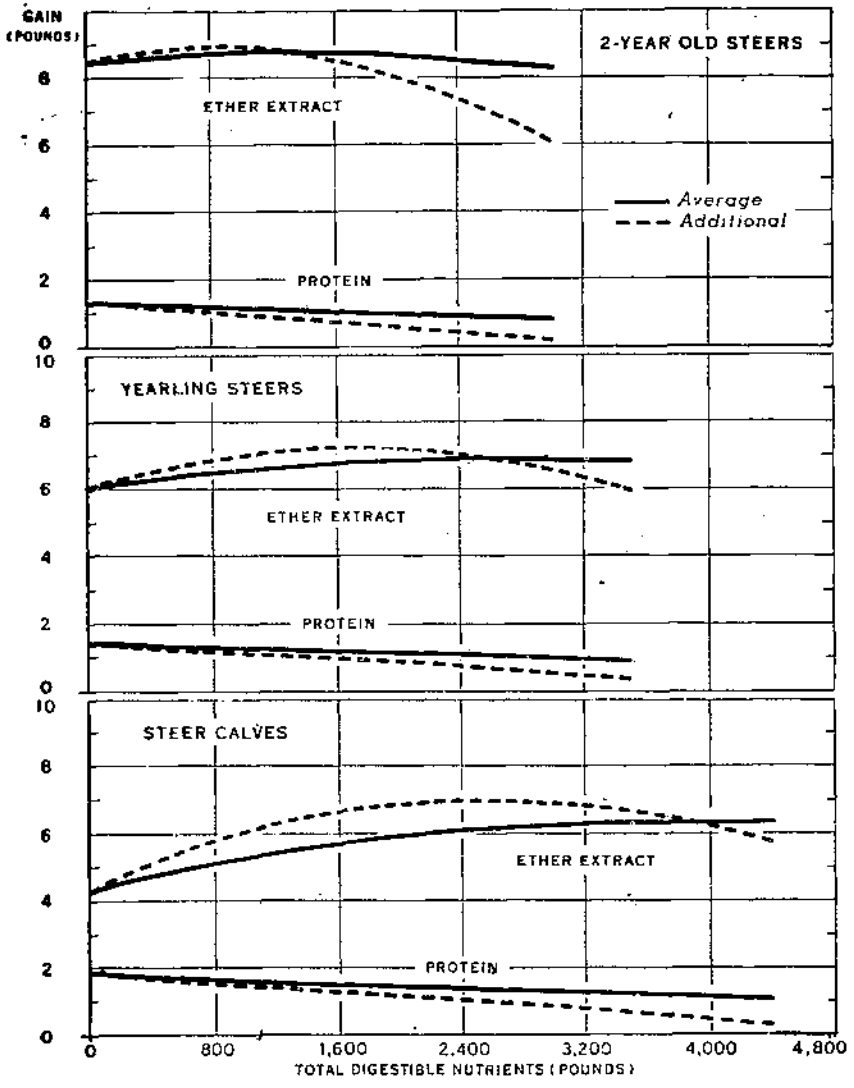

FIGURE 8.—Gain in edible crude protein and edible ether extract per 100 pounds of total digestible nutrients consumed throughout the fattening period.

the first part of the feeding period and then declines, as in the case of separable fat. The maximum efficiency in terms of ether extract for the 2-year-olds occurs just as they go beyond the average of the Good slaughter grade. Yearlings are close to the average of the Choice slaughter grade before the point of greatest efficiency of pro-

ducing ether extract is attained, and calves beyond the average of the Choice slaughter grade.

Relation of Calories Produced to Feed Consumed

As a choice feeder steer fattens the number of calories produced by the animal per 100 pounds of digestible nutrients consumed increases during the first part of the fattening period and then declines, about as do the pounds of edible body nutrients produced per 100 pounds of total digestible nutrients consumed (fig. 9). But the greatest efficiency,

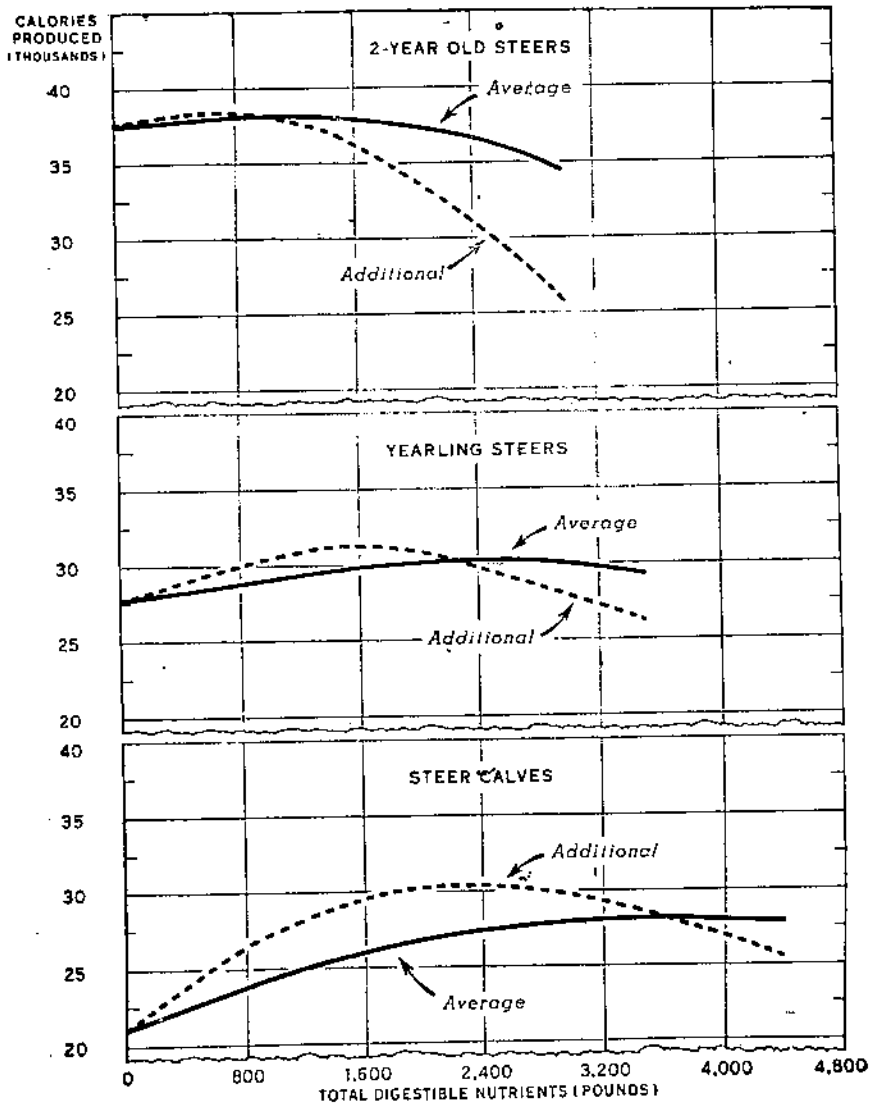

Figure 9.—Calories produced per 100 pounds of total digestible nutrients consumed throughout the fattening period.

when measured in calories, is reached a little later in the fattening period than when the efficiency is measured in pounds of edible body nutrients. Maximum efficiency, measured in calories, is reached by a 2-year-old Choice feeder steer at about the time the animal is of Good slaughter grade. Choice yearling feeder steers have reached Good to Choice slaughter grade, and Choice feeder steer calves have become Choice to Prime slaughter grade when they have reached their maximum efficiency in feed utilization as measured in calories.

Once the maximum efficiency in food production, measured in calories, has been reached, the efficiency declines more rapidly for the 2-year-old steers than for younger feeder animals. This has been demonstrated by using other measures of efficiency as well. Until they are highly finished, however, the older feeder steers produce more calories per unit of feed than do younger animals.

Discussion of Efficiency Measures

Although gain in edible body nutrients—protein, ash, and ether extract—and in calories, per unit of feed consumed, more accurately portrays what is produced with the feed utilized than do either live weight gain or edible body gain, it still may not be entirely adequate as a measure of efficiency. The various constituents produced may not be given the proper weight when pounds of each are added or converted to calories, to obtain a total. Possibly protein should be weighted more heavily than ether extract; were it given a heavier weight, the point of greatest efficiency in producing edible nutrients or calories would be shifted toward an earlier point in the feeding period (indicating an advantage in "shorter feeding") and the decline after the maximum is reached would be more sharp. Moreover, calves would compare more favorably with older feeders in respect to efficiency in utilization of feed. As no one measure is entirely adequate it is important that the efficiency in producing each constituent be considered closely, along with the efficiency in producing the total edible nutrients or calories. It must be remembered, furthermore, that the constituents are joint products; one cannot be produced without the other even though they can be produced in varying proportions at the same time.

RELATIONSHIP BETWEEN GAIN IN LIVE WEIGHT AND FOOD PRODUCTS PRODUCED

The gain in live weight only partially and somewhat inadequately indicates the gain in food products produced by a given quantity of feed. In addition to the gain in live weight during the fattening period, there is a considerable increase in the food-nutrient content of the beef carcass. In table 7 estimates of the gain in live weight and selected indicators of food production are given for Choice feeder steer calves, yearling steers, and 2-year-old steers, from the beginning of the feeding period until these animals have reached the average of Good grade and the average of Choice grade slaughter animals.

This facilitates a comparison. The percentage increase in lean meat and crude protein is slightly less than the percentage gain in live weight but the percentage increase in fat is considerably greater

than the percentage gain in live weight. From the beginning of the feeding period until the animals reach the average of the Good slaughter grade the percentage increase in pounds of edible nutrients ranges from about twice the percentage gain in live weight for the steer calves to nearly three times the percentage gain in live weight for the 2-year-olds. Animals fed to the middle of the Choice slaughter grade show an even greater disparity in the same direction between the increase in edible nutrients and the increase in the gain in live weight. The percentage increase in calories is greater than the percentage increase in edible nutrients. The average animal, when placed on grain feed in the Corn Belt, is thinner and therefore is graded lower than a Choice feeder, and an even greater percentage increase in nutrients and calories than in gain in live weight would be obtained by feeding.

When comparing feeder cattle of different ages less difference is found in percentage increase in live weight and in edible body nutrients and calories in calves than in older animals. As calves grow more during the fattening period than do older animals, a larger part of the gain made while being fattened is in the form of bone and other nonedible products. Moreover, a larger proportion of the gain is protein which has a lower calorie content per pound than has ether extract.

TABLE 7.—*Estimated percentage increase in live weight, edible body, and edible body nutrients of Choice feeder steers fattened to reach the average of the Good and the average of the Choice slaughter grades*

Item	Estimated increase of Choice feeder steers fattened to:					
	Good slaughter grade			Choice slaughter grade		
	Calves	Yearlings	2-year olds	Calves	Yearlings	2-year olds
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Live weight	100	42	24	150	69	42
Edible body:	125	59	37	210	106	72
Lean	84	36	19	127	59	33
Fat	329	145	100	626	286	210
Edible-body nutrients:	206	97	65	375	187	135
Crude protein	82	35	18	122	56	31
Ash	76	34	15	120	53	26
Ether extract	312	148	102	653	294	216
Calories in edible product[1]	269	119	81	485	233	170

[1] Calculated on the basis of 1,814.4 calories per pound of crude protein, and 4,082.4 calories per pound of ether extract.

POSSIBILITIES FOR GREATER FOOD PRODUCTION IN CATTLE FATTENING

In normal times considerable feed is utilized in the Corn Belt in the production of high-quality slaughter cattle. As cattle are fattened to a high degree of finish the quantity of feed consumed per unit of gain increases. Of the 1.5 billion pounds of gain produced annually on cattle that were fattened in the Corn Belt from 1938–39 to 1941–42, an estimated 1.2 billion pounds, or about 80 percent, was produced before or by the time the animals reached the average of the Good

slaughter grade; the remaining 20 percent was produced on those animals that were fattened beyond the average of the Good slaughter grade after they reached the average of that grade. Some of the cattle that were grain fed for market were not carried to the average of the Good slaughter grade, and the gain they produced is a part of the 80 percent. The 80 percent also includes that part of the gain on the highly finished cattle which was produced before they reached the average of the Good slaughter grade.

These estimates are based upon the assumption that as an average for cattle fattened to or beyond the average of the Good slaughter grade on farms in the Corn Belt, the feeders weighing under 500 pounds at the beginning will become of Good slaughter grade after they have gained about 415 pounds; feeders with an initial weight of 500 to 750 pounds, after they have gained about 300 pounds; and feeders weighing over 750 pounds, after they have gained about 235 pounds.

Early Gains Most Efficient

It is calculated that the estimated 80 percent of the gain in live weight produced before or by the time the average of the Good slaughter grade was reached by cattle fattened in the Corn Belt required about 70 percent of the total quantities of grain and protein supplements that they consumed during the fattening period. The other 30 percent of the feed was required to produce the 20 percent of the gain in live weight in the highly finished animals after they had passed the middle of the Good slaughter grade.

Although the 30 percent of the concentrates, equivalent to about 60 million bushels of corn and 85,000 tons of protein supplement, utilized in fattening cattle in the Corn Belt beyond the average of the Good slaughter grade during the period studied produced about 300 million pounds gain in live weight, a relatively large part of this gain probably was not consumed as human food for it was largely fat in excess of what the average person consumes along with the lean meat.[8]

Probably about 45 percent of this gain in live weight produced before the average of the Good slaughter grade was reached was in the form of edible nutrients (edible crude protein, ash, and ether extract), and about 90 percent of the edible nutrients, or 40 percent of the gain in live weight, was consumed directly as human food in the form of beef (table 8). For Corn Belt cattle that were fattened beyond the average of the Good slaughter grade, about two-thirds of the gain produced after that point was in the form of edible body nutrients but probably only about 30 percent of the edible body nutrients, equivalent to about 20 percent of the gain in live weight, was consumed as human food in the form of beef. The percentage of edible nutrients that is consumed in the form of beef is small because little increase occurred in edible crude protein and ash and the

[8] This statement is based upon studies summarized in the appendix, p. 35. The quantity of fat relished along with lean varies considerably according to individual tastes. In making these calculations it was estimated that a little more fat would be consumed along with the lean in meat from a highly finished carcass than in meat from a medium finished carcass. To the extent that the fatter beef is served in places which cater to individuals who have above-average tastes for fat on highly finished beef, a larger proportion of the gain may be consumed as food than is indicated by these estimates.

quantity of fat deposited within the lean tissue is not very great even in the final stages of the fattening period. Most of the gain that is made after the middle of the Good slaughter grade is reached is in the form of fat that is in excess of what the average person will consume along with the lean meat. Some of this excess fat (killing fats, etc.) is utilized, however, in mixtures along with other lean meats.

TABLE 8.—*Estimated quantities of food nutrients produced from normal quantities of concentrates used for fattening cattle in the Corn Belt, with normal fattening practices, and with the practices adjusted so that no cattle would be fattened beyond the average of the Good slaughter grade*

Item	Unit	Normal fattening practices			Adjusted fattening practices [1]
		Before the average of the Good slaughter grade	After the average of the Good slaughter grade	Total	
Cattle fattened	Million head			4.0	5.7
Feed utilized:					
Grain	Billion lb.	7.7	3.3	11.0	11.0
Protein supplement	1,000 tons	190.0	85.0	275.0	275.0
Gain in weight:					
Live weight	Million lb.	1,200.0	300.0	1,500.0	1,700.0
Edible nutrients	do.	540.0	200.0	740.0	765.0
Edible nutrients consumed [2]	do.	480.0	60.0	540.0	680.0
Gain per hundredweight of grain:					
Live weight	Pounds	15.5	9.1	13.6	15.5
Edible nutrients	do.	7.0	6.1	6.7	7.0
Edible nutrients consumed [2]	do.	6.2	1.8	4.9	6.2

[1] Estimated, assuming normal (1938–39 to 1941–42) cattle-fattening pattern and practices except that no cattle would be fattened beyond the average of the Good slaughter grade.

[2] Consumed directly as food in the form of beef.

Assuming that only a small proportion of the additional nutrients produced when cattle are fattened beyond the Good grade is consumed directly as human food in the form of beef, then only a small quantity of additional human food is produced per unit of feed during this later period of feeding. After considering the normal distribution of cattle among the slaughter grades, as the animals come from feed-lots of the Corn Belt, it is estimated that in the gain produced before the average of the Good slaughter grade is reached, about 6 pounds of nutrients that will be consumed directly as human food in the form of beef are produced per 100 pounds of grain, whereas after the average of the Good slaughter grade is reached, only about 2 pounds of nutrients are produced per 100 pounds of grain fed.

MORE BEEF FROM SAME QUANTITY OF FEED

If the 60 million bushels of corn equivalent and the 85,000 tons of protein supplement that normally are used in the Corn Belt in a year to fatten cattle beyond the average of the Good slaughter grade were used to fatten additional cattle, about 1.7 million more animals could be fattened, assuming normal feeding and management practices (except that none of the cattle would be fed beyond the average of the Good slaughter grade).

This would result in the production of about 200 million more

pounds of gain in live weight of cattle, or about 140 million more pounds of nutrients to be consumed directly as food in the form of beef than were produced annually from 1938–39 to 1941–42 (table 8). The increase in live weight would be about 15 percent and the edible nutrients to be consumed as beef would be increased by about one-fourth.

If additional feeder cattle of satisfactory grades were not available, the feed that could be saved by not feeding any animals to a finish higher than the middle of Good slaughter grade probably should be used for feeding other kinds of livestock which would make more efficient use of the feed, if the aim is to get the greatest quantity of satisfactory human food from the supply of feed.

The relative quantities of fat and protein produced during the fattening period can be adjusted somewhat by varying the age of cattle to be fattened and by adjusting the feeding practices. As calves produce more protein per unit of feed during the fattening period than do the older cattle, more protein can be obtained by fattening a relatively large number of calves. However, calves require more feed to produce a carcass of satisfactory slaughter grade. Therefore, when concentrates are scarce, more calories can be produced, or more animals can be improved in slaughter grade, with a limited quantity of feed if older cattle are used for fattening.

Feeding practices play an important part in determining the rate of gain and therefore the composition of the gain, during the fattening period. Experimental data indicate that animals that are given limited feedings of concentrates during part or all of the feeding period continue to grow but put on less fat than if given a full feeding of concentrates, with the result that a greater proportion of the total gain is in the form of protein.

Other possibilities of producing more food for humans with the feed available for fattening cattle have been demonstrated by feeding experiments and by the experience of farmers. These have been adequately covered in other studies and are too numerous to discuss here. They fall into two broad and somewhat overlapping categories—adjustments in making up the rations and more efficient feeding. Where roughage and pasture are available, considerable quantities can be substituted for concentrates in the fattening of cattle, particularly in the case of the larger animals. In this way an increased number of cattle can be fattened and a larger quantity of beef for consumers obtained from a given quantity of concentrates. Moreover, still more cattle could be fattened with the same quantity of concentrates if the efficiency used in feeding and management is increased.

Economic and Physical Relationships

The foregoing analysis of relationships between the quantity of feed utilized to fatten cattle in the Corn Belt and the quantity of human food produced considers only the physical relationships involved. Relationships in terms of costs and returns involve a broad field, not touched upon in this analysis. But they must be given consideration when cattle-fattening programs are developed. When conflicts arise between physical and economic considerations, adjust-

ments should be made in accordance with the size of the supply of agricultural-production resources relative to the total food needs to be met. In wartime, feed is likely to be scarce relative to requirements for food, and every effort should be made to adjust economic relationships and incentives in such a way as to facilitate the maximum production of essential food products on the basis of the physical relationships involved.

SUMMARY

Fattening of cattle is an integral part of Corn Belt farming. Corn Belt farmers who fatten cattle from the western ranges and from farm pastures make a substantial contribution to the food supply. Normally, about 4 million head of cattle are fattened in the Corn Belt each year and about 1.5 billion pounds of live weight is added to these cattle. About 11 billion pounds of grain (equivalent to about 200 million bushels of corn) and 275,000 tons of protein supplement are normally utilized annually in this fattening process.

The food for human consumption that is produced from the feed utilized in fattening cattle is greater than is indicated by the gain in live weight. During the fattening process the percentage dressing yield and the percentage nutrient content of the whole carcass is materially increased. This fact is frequently overlooked when comparisons are made between the efficiency of feeding cattle for fattening and the efficiency of feeding other kinds of livestock.

Efficiency in feed utilization in fattening cattle varies considerably. It varies according to the age or weight of cattle at the beginning of the period and according to the degree of finish they carry at the end.

Efficiency in feed utilization during the fattening period, measured by the aggregate quantity of edible protein, ash, and fat produced per unit of feed, increases slightly until approximately Good slaughter grade is reached. The maximum efficiency of feed utilization for animals that are heavy when the feeding begins, is reached at a lower slaughter grade than for calves. The point of maximum efficiency, as indicated by pounds of edible body nutrients, occurs in a 2-year-old steer just before it becomes of average Good slaughter grade; in a yearling when it goes just beyond the average of the Good slaughter grade, and for a calf when it is about Choice slaughter grade.

The gains made per unit of feed as an animal becomes highly finished is smaller than at earlier stages of the process and a considerable part of the edible product produced by this finish is not eaten by the retail customers. The excess fat in the carcass of the highly finished animal is likely to be wasted (left on the plate) or diverted to other less essential uses.

Cattle that are fattened in the Corn Belt to Choice or Prime slaughter grade gain an average of about 6 pounds of edible protein, ash, and fat (that is later consumed in the form of beef) per 100 pounds of grain fed during the part of the fattening period that comes before the animals reach the average of the Good slaughter grade. During the rest of the fattening period they gain an average of about 2 pounds of edible protein, ash, and fat (that is later consumed in the form of beef) per 100 pounds of grain consumed.

Of the total gain in live weight during the normal fattening period of cattle in the Corn Belt about 80 percent is produced before and about 20 percent is produced after the animals reach the average of the Good slaughter grade. The 80 percent includes the gain to average Good slaughter grade on higher finished animals, the gain on those that are carried just to that point, and the gain on those that are not carried up to that point. Normally, about 70 percent of the concentrates used in fattening cattle in the Corn Belt is required for the 80 percent of the gain produced before the animals reach the average of the Good slaughter grade, and about 30 percent is used for the 20 percent of gain produced after the average of the Good slaughter grade has been reached.

If no cattle were fattened in the Corn Belt beyond the average of the Good slaughter grade (the point at which the carcass contains about the maximum quantity of fat that the average person will consume along with the lean meat), about 1.7 million additional head of cattle could be fattened annually with the concentrates normally used to fatten cattle in the Corn Belt. This would result in an estimated increase above normal production of about 15 percent in live weight and of about 25 percent in the aggregate quantity of protein, ash, and fat produced for human food—which would be consumed directly in the form of beef.

When cattle-fattening programs are being made the costs and probable returns should be considered as well as physical relationships. But in time of war when supplies of feed are not likely to be adequate to produce all the livestock products that are urgently needed, the economic considerations and incentives should be adjusted, so far as possible, to facilitate the maximum possible production of essential food products. This maximum is clearly indicated through an analysis of the physical relationships.

APPENDIX

Source of Data Used and Methods of Analysis of Relationship of Feed Consumed to Food Produced in the Fattening of Cattle

A 3-year series of feeding experiments with calves, yearlings, and 2-year-old steers, conducted at the Iowa Agricultural Experiment Station, is the principal basis for the analysis in this study of the production of food as related to the consumption of feed. The State report of the experiments contains complete data by monthly periods on feed-live-weight gain relationships and these data form the groundwork for this analysis (*4* and *7*). Two objects of these experiments, as stated by the authors (*4, p. 241; 7, pp. 303–304*) were: "1. To find out the relative economy of feeding two-year-olds, yearlings, and calves for market. 2. To note the feed consumption, gains of the cattle, feed requirements, finish . . . and yield and character of the carcasses of cattle of different ages."

The steers used in the 3-year series of experiments showed a preponderance of Hereford blood and were graded as Choice grade feeder steers or as Common to Medium grade slaughter steers. They were put in dry lot late in the fall and were hand-full-fed twice daily, the ration being shelled corn, linseed oil meal, and alfalfa hay the first 2 years; corn silage was added the third year. At the close of the feeding period the animals were graded as Choice grade slaughter steers.

To facilitate the comparison of feed used and gain made during the fattening period all feeds were converted to a total digestible-nutrient basis, using factors given by Morrison (*10*).

The data from the experiments are reported as averages for the various lots of cattle. The number of head per lot for each of the 3 years is shown in the following tabulation:

	Steers per lot		
	2-year-olds	*Yearlings*	*Calves*
1925–26 experiment	7	8	8
1926–27 experiment	7	8	10
1927–28 experiment	8	8	12

The method here used in fitting the curves (for figure 1, page 9 of this bulletin) to the experimental data is given in detail in the 1939 Year Book of Agriculture, (*6, p. 465*). The equation is $w = A - Be - kf$ in which:

w is the live weight after any quantity of feed, f, has been consumed; A is the maximum live weight attainable as a result of growth, but not as a result of fattening; B is the total gain in live weight made in reaching the maximum live weight; e is the base of the natural system of logarithms; k is a constant which is a measure of the rate of decrease in the efficiency of feed utilization; and f is the quantity of feed that is required for attaining any live weight, w.

The equations of the curves for the three ages of Choice feeder steers are:

For calves, $w = 1446 - 1049e^{-.0002571f}$

For yearlings, $w = 1446 - 805e^{-.0002811f}$

For 2-year-olds, $w = 1446 - 610e^{-.0003721f}$

In arriving at the estimated dressing yield and body composition, the author used several sources of information. Iowa Agricultural Experiment Station Bulletin 272 (*7*) contains some data on dressing yield and body composition at the beginning and end of the feeding period for the three ages of steers reported in Iowa Bulletin 271. These data were utilized in establishing the estimates of dressing yield at the beginning and end of the feeding period. The estimates of dressing yield and body composition at various points during the fattening period were made on the basis of unpublished data of experiments made by North Dakota and Michigan and on data in the Journal of Agricultural Research (*9*), Illinois Bulletin 501 (*5*), United States Department of Agriculture Circular 549 (*3*), a bulletin published by a large packing Company, (*12*), unpublished data from one of the large packers on yields of edible offal, and the judgment of research workers in the Bureau of Animal Industry.

In the study here reported, the dressing percentage (warm carcass) was assumed to be represented by a curve directly correlated with live weight. This relationship was indicated by unpublished North Dakota and Michigan data. The warm-carcass dressing percentage was used because all of Hopper's equations on relationships in factors of composition are based upon warm dressing percentages (*9*).

The percentages of edible offal are based upon unpublished data from a large packing company, and upon data from a bulletin published by another large packing company in April 1943 (*12*). In making calculations based on data from these sources a straight-line relationship with live weight throughout the feeding period was assumed. The percentage composition of the edible organs, etc., is the weighted average of the composition of the tongue, tripe, liver, and heart, as given in United States Department of Agriculture Circular 549 (*3*). The weights of the edible organs at the beginning and end of the feeding period are based upon the data from the two packing companies mentioned above. In the author's calculations, the change throughout the feeding period was assumed to be a straight-line relationship with empty body weight. The proportional relationships of edible offal to live weight at the beginning and at the end of the feeding period were assumed to be the same for calves, yearlings, and 2-year-olds because there were insufficient data to allow for estimates for each; any error introduced by this assumption would be very small.

The assumptions of the author, the method of calculating the body composition throughout the fattening period, and further notes on the source of data are outlined below. The estimates of feed consumption, slaughter grade, dressing yield, and body composition at specified liveweight intervals during the fattening period are given in the tables that follow.

Physically separable fat in carcass was estimated by the author, with the assistance of certain workers in the Bureau of Animal Industry, on the basis

of slaughter grade, dressing percentage, and body composition. Separable fat was assumed to be a straight-line relationship with live weight. This relationship was indicated by unpublished data from Michigan experiments.

Ether extract in the carcass was calculated by the author from separable fat in the carcass, using Hopper's equation 2, table 5.

Crude protein, moisture, and ash in the carcass were calculated from Hopper's table 9 for given age of animal and were changed from ether extract free basis to include ether extract. The ash was adjusted slightly by workers in the Bureau of Animal Industry to improve congruity.

The figures for crude protein in the animal may be slightly low for the first part of the fattening period and may be slightly high for the latter part of the period, because of the ages of animals Hopper used in his analysis. In his summary (of the Missouri data which formed the basis for his table 9), Hopper included the composition of some steers that were less than 7 or 8 months old. Before cattle have reached chemical maturity the protein and ash content of the body is relatively low, compared with the content after chemical maturity has been reached at about 7 or 8 months of age. The inclusion of the chemically immature animals would influence the slope of Hopper's regression line of protein content of the body on age of the animal, and would result in a relatively lower figure for protein content for younger animals and a relatively higher figure for protein content for older animals in his table 9.

Were Hopper's data recalculated to exclude the chemically immature animals, the results probably would not be sufficiently different to alter any conclusions in a study of cattle fattening as related to food production. Since the actual protein content of the animal would be slightly higher at the beginning and slightly lower at the end of the fattening period than calculated by Hopper, a curve showing the actual quantity of protein produced per 100 pounds of total digestible nutrients fed would decline slightly faster than is shown by the figures which were used here, and this would tend to accentuate rather than negate the conclusions reached.

Bone was calculated from ash, using Hopper's equation (unpublished): Bone, (carcass) $=$ 3.67314 $\times$ Ash, (carcass) $+$ .85825.

Lean is the residual between 100 and physically separable fat and bone.

Ether extract in the edible carcass was calculated from ether extract in carcass, using Hopper's equation (unpublished): Ether extract (edible carcass) $=$ 1.14424 $\times$ ether extract, (carcass) $-$ 3.29418.

Physically separable fat in the edible carcass was calculated from ether extract in edible carcass using Hopper's equation (unpublished): Fat, (edible carcass) $=$ .93126 $\times$ ether extract (edible carcass) $+$ .92522.

Crude protein, moisture, and ash in the edible carcass was calculated the same as for the carcass, as indicated above.

TABLES

TABLE 9.—*Choice feeder steer calves: Estimated feed consumption, slaughter grade, dressing yield, and body composition at specified live-weight intervals during the fattening period*

Item	Average live weight per head in pounds							
	400 [1]	500	600	700	800	900	1,000 [2]	1,100
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Total digestible nutrients consumed	0	402	837	1,326	1,886	2,541	3,328	4,316
Carcass:								
Weight—warm	207.6	260.5	316.8	379.4	448.8	526.5	611.0	701.8
Physically separable:								
Lean	144.1	173.7	201.8	231.3	261.5	291.3	321.6	348.9
Fat	22.8	37.8	57.0	81.6	112.2	150.0	195.5	249.2
Bone	40.7	49.0	58.0	66.5	75.1	85.2	93.9	103.7
Chemically separable:								
Ether extract	31.1	48.3	70.0	97.4	131.2	172.7	222.2	280.3
Crude protein	37.1	45.6	53.1	60.6	68.6	76.4	84.0	91.0
Moisture	128.8	153.9	178.6	204.2	229.6	255.4	280.7	303.9
Ash	10.6	12.7	15.1	17.2	19.4	22.0	24.1	26.6
Edible portion of carcass: [3]								
Weight	166.9	211.5	258.8	312.9	373.7	441.3	517.1	598.1
Physically separable fat	23.1	37.2	55.4	78.9	108.4	144.8	189.3	241.7
Chemically separable:								
Ether extract	23.1	37.9	56.9	81.6	112.7	151.2	198.1	253.7
Crude protein	30.0	36.3	42.2	48.4	54.6	60.9	67.0	72.3
Moisture	112.2	135.4	157.5	180.4	203.6	226.0	248.5	268.3
Ash	1.6	1.9	2.2	2.5	2.8	3.2	3.5	3.8
Edible offal:								
Organs, etc. (trimmed)	17.6	21.5	25.3	29.0	32.4	35.6	38.8	41.7
Ether extract	.8	1.2	1.6	2.0	2.5	3.1	3.7	4.4
Crude protein	3.4	4.1	4.8	5.4	6.0	6.5	7.0	7.4
Moisture	13.2	16.0	18.7	21.3	23.6	25.6	27.7	29.5
Ash	.2	.2	.2	.3	.3	.4	.4	.4
Cevil, ruffle, and other fats	9.0	13.0	17.8	23.2	29.4	36.4	43.9	52.2
Ether extract	8.39	12.13	16.63	21.72	27.58	34.18	41.31	49.23
Crude protein	.15	.22	.30	.37	.47	.58	.66	.78
Moisture	.45	.64	.85	1.09	1.32	1.60	1.89	2.14
Ash	.01	.01	.02	.02	.03	.04	.04	.05
Bone, total body	55.2	67.1	78.8	90.9	103.2	115.5	127.4	138.1
Hide	32.0	39.5	46.8	53.9	60.8	67.5	74.0	80.3
Nonedible offal, including blood	46.9	53.3	59.8	66.2	73.3	83.2	92.3	103.5

[1] Common to Medium slaughter grade.
[2] Choice slaughter grade.
[3] Carcass minus the bone.

TABLE 10.—*Choice feeder steer calves: Estimated dressing yield and body composition at specified live-weight intervals during the fattening period*

Item	Average live weight per head in pounds							
	400	500	600	700	800	900	1,000	1,100
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Carcass:								
Dressing—warm [1]	51.9	52.1	52.8	54.2	56.1	58.5	61.1	63.8
Physically separable: [2]								
Lean	69.4	66.7	63.7	61.0	58.3	55.3	52.6	49.7
Fat	11.0	14.5	18.0	21.5	25.0	28.5	32.0	35.5
Bone	19.6	18.8	18.3	17.5	16.7	16.2	15.4	14.8
Chemically separable: [2]								
Ether extract	15.0	18.5	22.1	25.7	29.2	32.8	36.4	39.9
Crude protein	17.8	17.5	16.8	16.0	15.3	14.5	13.7	13.0
Moisture	62.1	59.1	56.4	53.8	51.2	48.5	45.9	43.3
Ash	5.1	4.9	4.7	4.5	4.3	4.2	4.0	3.8
Edible portion of carcass: [3]								
Physically separable fat	13.8	17.6	21.4	25.2	29.0	32.8	36.6	40.4
Chemically separable: [2]								
Ether extract	13.8	17.9	22.0	26.1	30.2	34.3	38.3	42.4
Crude protein	18.0	17.2	16.3	15.4	14.6	13.8	13.0	12.1
Moisture	67.2	64.0	60.8	57.7	54.5	51.2	48.1	44.9
Ash	1.0	.9	.9	.8	.7	.7	.6	.6
Edible offal:								
Organs, etc. (trimmed) [1]	4.4	4.3	4.2	4.1	4.1	4.0	3.9	3.8
Ether extract	5.0	5.6	6.2	6.9	7.7	8.6	9.5	10.5
Crude protein	19.2	19.1	18.9	18.7	18.5	18.3	18.1	17.9
Moisture	74.8	74.3	73.9	73.4	72.8	72.1	71.4	70.7
Ash	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.9
Caul, ruffle, and other fats [1]	2.2	2.6	3.0	3.3	3.7	4.0	4.4	4.8
Ether extract	93.2	93.3	93.4	93.6	93.8	93.9	94.1	94.3
Crude protein	1.7	1.7	1.7	1.6	1.6	1.6	1.5	1.5
Moisture	5.0	4.9	4.8	4.7	4.5	4.4	4.3	4.1
Ash	.1	.1	.1	.1	.1	.1	.1	.1
Bone, total body [4]	17.00	16.66	16.27	15.85	15.39	14.85	14.28	13.62
Hide [4]	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3

[1] Percentage of live weight.
[2] Constituents equal 100 percent.
[3] Carcass minus the bone.
[4] Percentage of empty body weight.

TABLE 11.—*Choice feeder yearling steers: Estimated feed consumption, slaughter grade, dressing yield, and body composition at specified live-weight intervals during the fattening period*

Item	Average live weight per head in pounds					
	640 [1]	740	840	940	1,040 [2]	1,140
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Total digestible nutrients consumed	0	467	1,011	1,652	2,436	3,442
Carcass:						
Weight—warm	334.7	394.4	461.2	538.6	625.0	717.1
Physically separable:						
Lean	217.6	244.6	272.2	301.7	331.7	359.3
Fat	51.9	76.2	106.6	145.0	192.0	247.6
Bone	65.2	73.6	82.4	91.9	101.3	110.2
Chemically separable:						
Ether extract	65.5	92.5	126.0	168.1	219.2	279.2
Crude protein	58.3	65.5	72.8	80.6	88.4	95.5
Moisture	193.9	217.3	241.0	266.2	291.3	314.1
Ash	17.0	19.1	21.4	23.7	26.1	28.3
Edible portion of carcass: [3]						
Weight	269.5	320.8	378.8	446.7	523.7	606.9
Physically separable fat	50.4	73.3	102.2	139.0	184.4	238.8
Chemically separable:						
Ether extract	51.5	75.5	106.0	144.8	192.9	250.4
Crude protein	45.9	51.7	57.5	63.7	69.8	75.3
Moisture	169.8	191.0	212.4	235.0	257.5	277.4
Ash	2.3	2.6	2.9	3.2	3.5	3.8
Edible Offal:						
Organs, etc. (trimmed)	28.1	31.7	35.2	38.4	41.5	44.3
Ether extract	1.4	1.8	2.3	2.8	3.5	4.2
Crude protein	5.4	6.0	6.6	7.2	7.6	8.0
Moisture	21.0	23.6	25.9	28.0	30.0	31.7
Ash	.3	.3	.4	.4	.4	.4
Caul, ruffle, and other fats	14.4	19.8	25.9	32.9	40.8	49.4
Ether extract	13.42	18.47	24.22	30.83	38.31	46.49
Crude protein	.25	.34	.41	.53	.65	.74
Moisture	.72	.97	1.24	1.51	1.80	2.12
Ash	.01	.02	.03	.03	.04	.05
Bone, total	87.9	99.8	111.6	124.1	136.5	147.3
Hide	49.9	56.3	63.0	69.6	75.9	82.1
Nonedible offal including blood	69.3	74.2	80.4	88.9	98.3	108.0

[1] Common to Medium slaughter grade.
[2] Choice slaughter grade reached at 1080 pounds.
[3] Carcass minus the bone.

TABLE 12.—*Choice feeder yearling steers: Estimated dressing yield and body composition at specified live-weight intervals during the fattening period*

Item	Average live weight per head in pounds					
	640	740	840	940	1,040	1,140
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Carcass:						
Dressing—warm [1]	52.3	53.3	54.9	57.3	60.1	62.9
Physically separable: [2]						
Lean	65.0	62.0	59.0	56.0	53.1	50.1
Fat	15.5	19.3	23.1	26.9	30.7	34.5
Bone	19.5	18.7	17.9	17.1	16.2	15.4
Chemically separable: [2]						
Ether extract	19.6	23.4	27.3	31.2	35.1	38.9
Crude protein	17.4	16.6	15.8	15.0	14.1	13.3
Moisture	57.9	55.1	52.3	49.4	46.6	43.8
Ash	5.1	4.9	4.6	4.4	4.2	4.0
Edible portion of carcass: [3]						
Physically separable fat	18.7	22.8	27.0	31.1	35.2	39.4
Chemically separable: [2]						
Ether extract	19.1	23.6	28.0	32.4	36.8	41.3
Crude protein	17.0	16.1	15.2	14.3	13.3	12.4
Moisture	63.0	59.5	56.0	52.6	49.2	45.7
Ash	.9	.8	.8	.7	.7	.6
Edible offal:						
Organs, etc. (trimmed) [1]	4.4	4.3	4.2	4.1	4.0	3.9
Ether extract	5.0	5.7	6.5	7.4	8.4	9.4
Crude protein	19.2	19.0	18.8	18.6	18.4	18.2
Moisture	74.8	74.3	73.7	73.0	72.3	71.5
Ash	1.0	1.0	1.0	1.0	.9	.9
Caul, ruffle, and other fats: [1]	2.2	2.7	3.1	3.5	3.9	4.3
Ether extract	93.2	93.3	93.5	93.7	93.9	94.1
Crude protein	1.7	1.7	1.6	1.6	1.6	1.5
Moisture	5.0	4.9	4.8	4.6	4.4	4.3
Ash	.1	.1	.1	.1	.1	.1
Bone, total body: [4]	17.0	16.6	16.1	15.5	14.9	14.2
Hide [1]	7.8	7.6	7.5	7.4	7.3	7.2

[1] Percentage of live weight.
[2] Constituents equal to 100 percent.
[3] Carcass minus the bone.
[4] Percentage of empty body weight.

TABLE 13.—*Choice feeder 2-year-old steers: Estimated feed consumption, slaughter grade, dressing yield, and body composition at specified live-weight intervals during the fattening period*

Item	Average live weight per head in pounds				
	835 [1]	935	1,035	1,135 [2]	1,235
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Total digestible nutrients consumed	0	476	1,061	1,811	2,854
Carcass:					
Weight—warm	444.2	511.4	590.0	681.0	778.0
Physically separable:					
Lean	280.9	305.1	331.1	358.1	381.8
Fat	73.8	108.6	152.6	207.7	273.2
Bone	89.5	97.7	106.3	115.2	123.0
Chemically separable:					
Ether extract	92.0	130.0	177.8	237.3	307.7
Crude protein	77.1	83.6	90.4	97.5	103.5
Moisture	251.8	272.4	294.2	316.5	335.1
Ash	23.3	25.4	27.6	29.7	31.7
Edible portion of carcass: [3]					
Weight	354.7	413.7	483.7	565.8	655.0
Physically separable fat	70.6	103.1	144.9	197.9	262.0
Chemically separable:					
Ether extract	72.3	106.7	150.8	206.9	274.8
Crude protein	59.9	65.2	70.8	76.3	81.0
Moisture	219.5	238.6	258.6	278.9	295.3
Ash	3.0	3.2	3.5	3.7	3.9
Edible offal:					
Organs, etc. (trimmed):	36.7	39.9	43.0	45.7	48.3
Ether extract	1.8	2.3	2.9	3.6	4.5
Crude protein	7.0	7.6	8.1	8.5	8.8
Moisture	27.5	29.6	31.6	33.2	34.6
Ash	.4	.4	.4	.4	.4
Caul, ruffle, and other fats:	18.8	25.7	33.6	42.6	52.5
Ether extract	17.52	24.00	31.45	39.96	49.35
Crude protein	.32	.44	.54	.68	.84
Moisture	.94	1.23	1.58	1.92	2.26
Ash	.02	.03	.03	.04	.05
Bone, total	118.0	130.1	141.8	153.4	163.2
Hide	63.5	70.1	76.6	82.8	88.9
Nonedible offal including blood	92.8	95.7	101.1	109.0	116.0

[1] Common to Medium slaughter grade.
[2] Choice slaughter grade reached at 1185 pounds.
[3] Carcass minus the bone.

TABLE 14.—*Choice feeder 2-year-old steers: Estimated dressing yield and body composition at specified live-weight intervals during the fattening period*

Item	Average live weight per head in pounds				
	835	935	1,035	1,135	1,235
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Carcass:					
Dressing—warm [1]	53.2	54.7	57.0	60.0	63.0
Physically separable: [2]					
Lean	63.3	59.7	56.1	52.6	49.1
Fat	16.6	21.2	25.9	30.5	35.1
Bone	20.1	19.1	18.0	16.9	15.8
Chemically separable: [2]					
Ether extract	20.7	25.4	30.1	34.8	39.5
Crude protein	17.4	16.3	15.3	14.3	13.3
Moisture	56.7	53.3	49.9	46.5	43.1
Ash	5.2	5.0	4.7	4.4	4.1
Edible portion of carcass: [3]					
Physically separable fat	19.9	24.9	30.0	35.0	40.0
Chemically separable: [2]					
Ether extract	20.4	25.8	31.2	36.5	41.9
Crude protein	16.9	15.7	14.6	13.5	12.4
Moisture	61.9	57.7	53.5	49.3	45.1
Ash	.8	.8	.7	.7	.6
Edible offal:					
Organs, etc. (trimmed) [1]	4.4	4.3	4.2	4.0	4.0
Ether extract	5.0	5.9	6.9	8.0	9.2
Crude protein	19.2	19.0	18.8	18.5	18.2
Moisture	74.8	74.2	73.4	72.6	71.7
Ash	1.0	.9	.9	.9	.9
Caul, ruffle, and other fats: [1]	2.2	2.8	3.2	3.8	4.2
Ether extract	93.2	93.4	93.6	93.8	94.0
Crude protein	1.7	1.7	1.6	1.6	1.6
Moisture	5.0	4.8	4.7	4.5	4.3
Ash	.1	.1	.1	.1	.1
Bone, total body [4]	17.3	16.8	16.1	15.4	14.5
Hide [1]	7.6	7.5	7.4	7.3	7.2

[1] Percentage of live weight.
[2] Constituents equal 100 percent.
[3] Carcass minus the bone.
[4] Percentage of empty body weight.

PALATABILITY OF BEEF AS RELATED TO SLAUGHTER GRADE

In this part of the appendix pertinent information on palatability and associated factors of beef of different grades is summarized from reports on the subject.

Francis, Bull, and Carroll at Illinois Agricultural Experiment Station (*5, p. 137*) conclude: "In carrying Choice and Good feeders from a Good to a Choice finish, the additional carcass weight was made up largely of fat which, as already noted, is very expensive to produce. Furthermore, while this additional fat increases the grade of the carcass and improves the palatability of the beef, it usually is not eaten and therefore represents an economic waste of the extra corn used to produce it." It is not clear from the report how the determination was made of the quantity of fat that is usually eaten.

A report on a study conducted at the Iowa Agricultural Experiment Station, although concluding that fattening the animal improves the palatability, says that: "In the aroma and flavor of the fat, however, the committee favored the roasts without much finish. The additional fat on the roast seemed to add a very pronounced fatty odor and flavor, which was not pleasing to the majority of the committee." (*7, p. 320.*)

A report of the United States Department of Agriculture [6] on palatability of meats in relation to commercial grades contains considerable information based upon a study of 728 beef carcasses which were scored by judges on the basis of tenderness, richness, and quantity of juice, and desirability of flavor of the lean meat. The committee of judges indicated that more study is

[6] United States Department of Agriculture. REPORT OF COMMITTEE ON PALATABILITY OF MEATS IN RELATION TO THE COMMERCIAL GRADES. 48 pp., illus. 1937. [Processed.] (See pp. 9–10.)

needed on factors of grade and palatability but said that: "For grades Choice, Good, Medium, and Common the collective opinion of the judges was that the higher the grade the higher were the scores." The report then makes a statement that partially negates this conclusion: it says that, "when it is asserted that the higher the grade the higher were the scores for tenderness, richness or quantity of juice, or flavor of lean, *on the average* is meant." Considering the wide range of the scores as assigned by the judges and the low coefficients of correlation between fatness and measures of palatability, "little hope is held out that the grades can function as a certain aid to consumers who seek beef of superior quality in respect to the four items mentioned."

Trowbridge and Dyer (*11, p. 1*) at the Missouri Agricultural Experiment Station state that "Beef that grades 'good' is highly satisfactory beef."

An article in the Journal of Agricultural Science by E. H. Callow (*2, pp. 182, 183*), Cambridge University, London, England, on the food value of beef, indicates that palatability—as judged by texture, flavor, and juiciness—increased until the animal reached about Good slaughter grade, and then declined. "The data . . . show that the highest marks for palatability occur at a dressing-out percentage of 56." After considering the conditions under which the tests were made, and relating them to circumstances and activity of the average consumers, the author concludes: "The value of 58 (for dressing-out percentage) is tentatively suggested for war time."

Efficiency in Feed Utilization During the Fattening Period

Efficiency in feed utilization, as indicated by pounds of edible nutrients and calories produced per unit of feed consumed, by the Choice feeder steers used in the experiment which is the principal basis for the analysis in this study, increased during approximately the first third of the fattening period and, thereafter, declined. This indicated relationship is in accordance with experimental results and judgments of leading investigations of the subject.

Armsby, (*1, pp. 393, 395*) concludes that: "On the whole, the results of these experiments seem to indicate, if anything, a rather lower percentage utilization by the younger animals as compared with the older." His hypothesis on this question is that, ". . . the conversion of feed protein . . . into tissue requires a considerably greater relative expenditure of energy than does the conversion of surplus feed into fat, the difference representing what might be called the work of organization. . . ."

Hogan and associates at the Missouri Agricultural Experiment Station (*8, pp. 26, 27*) investigating Armsby's hypothesis that the percentage retention of net energy may increase with age, concluded that for hogs ". . . within reasonable limits, energy is stored more economically in the latter rather than in the earlier months of the feeding period." They also studied Haecker's Minnesota data on cattle and found it ". . . in essential agreement with ours, and that the more mature animals made gains in energy more economically than those that were younger." Haecker's data on cattle fattening, although inconclusive, indicate a gradual increase in efficiency in feed utilization until the latter part of the feeding period, when efficiency remains constant, or possibly declines.

Morrison (*10, p. 151*), when discussing the fattening process, says: "The fact that the proportion of fat in the gain made by an animal steadily increases during the fattening period is of much practical importance. It is the chief reason why the feed cost per pound of gain increases rapidly after an animal has become fairly well fattened. Such flesh contains much more fat and less water, and is correspondingly more expensive to produce.

"The fat animal also needs a greater proportion of its feed for maintenance than the one which is not yet well fleshed, because of two factors: First, the maintenance requirement of a fat animal per 1,000 lbs. live weight tends to be higher than for a thinner one; and second, the fat animal eats less feed per 1,000 lbs. live weight, consequently having less nutrients left for meat production after the maintenance requirements have been met."

These studies and authorities indicate that the more mature animals make gains in energy more economically than do the younger animals, but as the animal fattens its maintenance requirements increase and the consumption of feed decreases relative to live weight; this leaves less nutrients for the production of meat. Therefore, it does not appear improbable that efficiency in producing food nutrients would increase during the first part of the fattening period and thereafter decrease.

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For sale by the Superintendent of Documents, U. S. Government Printing Office
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