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EFFECTS OF FATNESS ON TENDERNESS OF LAMB

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Tenderness is one of the important components of palatability in meat. A reliable, easily applied guide to tenderness would be of great value to all who buy meat. A theory widely held for some time is that the fatter the animal the tenderer its meat will be. Conclusive evidence supporting this theory is lacking.

In some of the experiments set up to test this theory, the fatter or full-fed lamb was somewhat more tender than the limited-fed one, but in other experiments the limited-fed one was more tender. In view of the wide variations and even contradictory results found in these tests, it seems doubtful that fatness influences tenderness in lamb to any marked extent.

Neither fatness nor thinness can be used as a guide to tenderness in buying lamb.

No attempt was made to study the effect of fatness on factors of palatability other than tenderness.

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EFFECT OF FATNESS ON TENDERNESS OF LAMB

Sylvia Cover[1], A. K. Mackey[2], C. E. Murphey[3], J. C. Miller[4], H. T. Bass[5], C. L. Bell[6], and Carl Hamalainen[7].

Tenderness is one of the important components of palatability in meat. A reliable, easily applied guide to tenderness would be of great value to all who buy meat.

A theory widely held for some time is that the fatter the animal the tenderer its meat will be. Conclusive proof of this theory is lacking.

The early references in animal husbandry literature were not based on experimental evidence and so must be regarded as personal opinion. Armsby (1) in 1908 stated, "Experience has shown that the tenderness and palatability of the lean meat are notably greater when it is accompanied by considerable fat." Hall (13) in 1910 explained the association of marbling and tenderness by postulating that the increased tenderness results from a decrease in the elasticity of the connective tissue due to the deposition of fat therein. Bull (5) in 1916 considered that the main object for fattening an animal is to increase flavor, quality and tenderness of the lean meat, by the deposition of fat between the muscle fibers. Armsby (2) in 1917 and Henry and Morrison (17) in 1916 explained that a fat animal has fat deposited between the bundles of muscle fibers thus separating them, and that the lean from such an animal is more tender than the lean from an animal which has not been fattened. Helser (16) in 1929 expressed the opinion that well marbled meat is more tender and juicy than meat deficient in fatness. Hammond (14) in 1932, after showing that the correlation between marbling and tenderness for different muscles from the same carcass is not significant, stated, "No doubt such a correlation does exist with animals of different degrees of fatness."

Yet some evidence has been collected from research studies which may be used in support of the theory that fatness influences tenderness. Lowe (21), in her text, stated that the deposition of fat, either intramuscularly, intrafascicularly, or intracellularly, tends to lessen the toughness. She has collaborated in many microscopical studies of meat. Nelson, Lowe, and Helser (22), presented data to show that fresh beef from feeder animals required more force to shear than that from fattened animals. After fattening, the decrease in shear force amounted to 18% for calves, 30% for yearlings, and 22% for 2-year-olds. The results of the judges who scored the cooked rib roasts from these animals agreed with those from the mechanical tests, that the roasts from the fattened animals were more

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tender than the roasts from the lean animals. Hostetler, Foster, and Hankins (18), working with meat from Native and Grade yearling cattle, found the Grade cattle to be fatter and slightly but significantly more tender. Black, Warner and Wilson (3) using two grades of steers fed grain supplement on grass and grass alone, found that the rib samples of the supplement fed lots contained a higher percentage of fat (chemical) and were slightly more tender according to the standard judging committee (though mechanical tests of shearing strength of the raw rib muscle showed but little difference among the four lots). Trowbridge and Moffett (26) found there was a difference in the tenderness of the heifer and steer carcasses. The heifer carcasses were fatter and more tender. When comparable lots were fed to the same degree of fatness, the difference in tenderness disappeared. Foster and Miller (12), working with yearling steers, reported an association between fatness and tenderness.

Not all the evidence, however, supports this association between fatness and tenderness. Work with baby beef by Bull, Olson, and Longwell (6) indicated that no significant change in tenderness occurred with increased finish. The chief of the Bureau of Animal Industry (8) reported that though on the average, lambs sired by Southdown rams and out of Dorset x Merino ewes were less fat than lambs sired by Southdown rams and out of Dorset ewes or Dorset x Tasmanian Merino ewes, no appreciable difference in tenderness of the roasted legs was observed. Weber, Loeffel and Peters (27) in 1931 carried on feeding experiments with lambs in which after the lambs were killed, the legs were cooked, and then rated as to their tenderness by a judging committee. These lambs were killed at intervals of twenty-eight days. The investigators observed comparatively little difference in the tenderness of the samples from the various lots. Because the lambs were killed at intervals, the lambs killed last should have been the fattest, and so if tenderness and fatness are associated, these lambs should have had the highest tenderness scores. But, little difference was noted between the lots; hence one might conclude that very little or no relationship existed between fatness and tenderness in the test. Satorius and Child (23) found that the shear force of cooked adductor and longissimus dorsi muscles was the same for beef of the two grades, Medium and Good. Their comparisons were based on 15 animals from each of the two grades. Cover (9) found that roasts from fat beef were not always judged "tender" by a committee of experienced judges. A score below "tender" was reported for 6 out of 11 U. S. Choice carcasses when the standing rib roasts were cooked well-done at 125° C. The muscle tested was the longissimus dorsi, usually regarded as a tender muscle.

In considering these conflicting results from research, it must be remembered that these findings were supplemental observations, since the experiments were not planned primarily to observe the relationship between fatness and tenderness. Tenderness of meat is thought to be influenced by other factors, such as breeding, age, exercise, rate of gain, length of feeding period, aging in cooler, method of cooking, thickness of slicing cooked

meat, and gaining condition of the animal at the time of slaughter. It seemed likely that more reliable data could be secured if an experiment were planned especially for studying the relationship between fatness and tenderness. In this case it would be highly desirable to control as many as possible of the other factors which affect tenderness.

Controlling all the production variables which may influence tenderness is a considerable undertaking. A feeding procedure which is in accordance with the usual fattening practices may not be dependable when strict control of experimental conditions is necessary. Thus in the study reported here, several attempts were made before satisfactory procedures were developed. The difficulties encountered are presented for the benefit of research workers in this field.

PLAN OF EXPERIMENTS

For the first and second experiments (1937-8), wether lambs were selected for uniformity of type and size from the entire crop of lambs produced in one pasture, on one ranch, where the same blood lines had been used for 10 years. After a short rest period, 48 of them were selected for the first experiment and the remainder placed on pasture for use in the second experiment. In the first experiment 8 were killed immediately after coming off the range. The remaining 40 were then full-fed a ration of yellow corn, cottonseed meal, and alfalfa hay. After 6 weeks on feed, 8 lambs were killed and 8 more at each 2-week interval to the end of the test. Data were obtained on gains, carcass grades, separable fat and ether extract in the raw right leg, and on tenderness scores by weighted adjectives on the cooked left legs.

In the second experiment the plan was revised to allow the use of the paired-eating method. At this time 32 of the lambs had been on full feed a total of 7 weeks. They were separated into two lots according to fatness as determined by handling. The fatter lambs were continued on full feeding and the others fed a ration containing the same feeds, but in amounts sufficient for maintenance only. At the end of 4 weeks after the change (total of 77 days on feed) both lots were killed. All of the full-fed lambs at this time were finished. The 8 fattest and the 8 thinnest carcasses were paired so that the greatest possible contrasts would be obtained in the first pairs. There were rather small differences in fatness between the last pairs. Data from this experiment show gains, carcass grades, separable fat in the raw right legs and tenderness by the paired-eating method on the cooked left legs.

In the third experiment (1938-9), the lambs were paired individually so that as they went on feed, they were as nearly comparable as possible in breed, body type and weight. One lamb of each pair was placed in a lot which received full feed so as to develop a high degree of finish. The other lamb of each pair was placed in a lot which received a smaller amount of similar feeds. An attempt was made to feed an amount sufficient only to keep them in a healthy and slightly gaining condition. Two pairs of lambs were killed at the same time, the fat ones having been judged

"fat" on the hoof before killing. In each pair the one which was limited-fed was expected to be thin because of limited feed only, and the other fat because of abundant feed only. In other words, the two lambs had the same predicted outcome on the same plane of nutrition. Data are reported on gains, carcass grades, separable fat in raw right legs and in the half carcasses, and tenderness by the paired-eating method on the cooked left legs.

In the fourth (1939-40), fifth (1940-1), and sixth (1941-2) experiments the lambs were fed individually, since feed intake and therefore gains and fatness of paired animals could not be adequately controlled in lot feeding. All of the lambs were run together in a lot 15x60 feet sheltered at one end, and with water and mineral (equal parts steamed bone-meal and salt) before them at all times. At feeding time the lambs were placed in individual sheltered pens bearing the same number as the lamb. The pens were just large enough to permit the lamb to stand and turn. They were adjacent and slatted so that the lambs were in close proximity and visible to each other during feeding. The lambs were fed from deep individual boxes attached to the end of the pen about one foot above the ground. All lambs were fed the same ration consisting of a concentrate mixture of nine parts yellow shelled corn and one part 43% protein cottonseed cake (pea size), plus chopped alfalfa hay. The concentrate was fed first, and after the lambs had consumed it the hay was placed in the same box. After the initial period required to get them on full feed, one member of each pair of lambs was full-fed, and the other member of the pair was fed just enough to make slight gains as determined by weekly weights. Those lambs which did not eat normally were discarded. The lambs were turned out in the exercise lot after each feeding. The same attendant cared for the lambs throughout the feeding period, and after the first few days the lambs showed no nervousness or indifference to feed, as might be expected of lambs being fed in individual pens. When the full-fed lamb was considered "fat," the pair was slaughtered. Data secured were gains, carcass grades, percentage separable fat in the leg and half carcass, and tenderness of the cooked leg by the paired-eating method, by scores from weighted adjectives, and by the mechanical shearing device. Some chemical determinations for collagen were made also. Collagen determinations were made because the presence of a large amount of connective tissue is one indication of tough meat. The quantity of connective tissue present is sometimes measured by determining the amount of one of its constituent proteins—collagen. If the lambs in a pair differed considerably in their collagen content, they were not well-paired.

Twin lambs were used in the fourth experiment. Since identical twins in lambs occur rarely, if at all (7), the twins used were of the same sex, similar in body type, size and weight. However, only five suitable pairs of twins were found. In the following year not a single pair of twin lambs was found which met the specifications. In the fifth experiment the lambs in a pair were taken from the same flock—a procedure approved by the geneticists acting as advisers for this project. The lambs were high grade

Rambouillets produced in the Del Rio country and were trucked to College Station in October. In the sixth experiment two pairs of high grade Rambouillet lambs from the Sonora station and one pair of Suffolk x Rambouillet cross-bred lambs from near Sonora were used. The lambs were selected and paired on the basis of similarity as to sex, breeding, conformation, weight, and fleece covering.

EXPERIMENTAL PROCEDURE

Weights of Lambs

For the first experiments, initial and final weights were based on an average of two successive day weights. For the last two experiments, three successive day weights were used. For the third, fourth, fifth and sixth experiments, the difference in initial weights between members of a pair was not more than two pounds except in a few cases.

Tests for Fatness

Carcass grades were secured because they help to give a picture of the lamb carcasses. Carcass grades are not an accurate indication of fatness, because fatness is only one of three factors used in determining whether the grade will be Choice, Good, Medium or Common. No thin carcass would be graded Choice, but a fat carcass might be graded Medium or Common if low enough in conformation and quality.

Physical separations into fat, lean and bone were made for the leg and half-carcass, and the percentage separable fat calculated. The leg was cut at the stifle joint and half-way between the rise of the pelvic arch and the point of the aitch bone. The cod and flank fat were removed before the separations were made. Values for separable fat seemed to be as good an indication of the fatness of the animal as the determination of ether extract, and were much more easily determined. The right side of the carcasses was used for these tests on raw meat.

Ether extractions were made for the leg only and in the first experiment only. The fat and lean were mixed and ground before sampling for moisture and ether extract determinations. Special procedures were necessary to obtain a homogeneous sample for analysis because of the excessive amounts of fat in some of the lambs. These determinations were so laborious that ether extractions were discontinued after the first experiment.

Tracings of the posterior surface of the rack were made during the first and second experiments. The tracings gave clear indications of the relative thickness of the fat covering on the backs of the paired lambs but were not suitable for use as a quantitative measure of fatness.

Length of Storage Period

In the first experiment two storage periods were used. After each slaughter 4 carcasses were stored for 7 days and the others for 14 days. In the remaining experiments, one storage period of 7 days was used.

Methods of Cooking

Oven temperature (9, 11) and the internal temperature to which the meat is cooked (24) have been shown to affect the tenderness. These factors were controlled by using a standardized cooking procedure. The legs were roasted on a rack in an uncovered pan without water, salt or flour, in an oven regulated at 150° C. until the internal temperature reached 76° C. The cuts from the left side of the carcass were used for cooking.

Methods of Testing Tenderness

Subjective tests were made on the semimembranosus muscle, which while still hot was dissected out and sliced into sections $\frac{3}{8}$ inch thick. The slices were cut into small samples approximately $\frac{3}{8}$x$\frac{3}{8}$x$\frac{1}{2}$ inch. It is well known that the thicker a roast is sliced, the greater the apparent toughness. This was the reason for having the samples for subjective tests as nearly uniform in size as possible.

Scores obtained from tests by weighted adjectives were used as the only measure of tenderness in the first experiment. The adjectives and weightings were: Very tough, 1.0-1.5; Tough, 1.5-2.5; Neutral, 2.5-3.5; Tender, 3.5-4.5; Very tender, 4.5-5.0. Each judge received on his plate three samples from each of the four roasts, making a total of 12 to be judged at one period. The samples for any particular judge were taken from the same position in the muscle and the same position in the slice. The 12 samples were placed on the plate of each judge according to a chart. The placing was the same for all judges, but was deliberately varied from time to time to prevent any judge from knowing which three of his samples came from the same roast. In later experiments where the scores by weighted adjectives were obtained only as supplemental data, the placing of the samples was determined by the method used for the paired eating method.

Tenderness by the paired eating method (10) was used as the main test for tenderness in all the experiments except the first. In this method a sample from the limited-fed lamb was compared with an identical sample from the full-fed lamb. The judges recorded on a judging sheet which sample of the pair was more tender. The total number of paired samples tested and the number in favor of the full-fed lamb were used for calculating the tenderness-percentage. In the results for the full-fed lamb, therefore, a tenderness-percentage above 50 indicates that the majority of the judgments were in favor of the full-fed lamb, but a tenderness-percentage below 50 indicates that the majority of the judgments were in favor of the limited-fed lamb. The tenderness-percentages were calculated for each pair individually and for the group as a whole.

The mechanical shearing device was used in the last 3 experiments. A one-inch core was cut from a definite place in a particular muscle and the pounds of stress required to shear across the core of meat were obtained. Tough meat gives higher shear values than does tender meat.

Collagen Tests

Analyses for collagen were made by two methods, a modification of the soluble nitrogen method of Bogue (4) and a modification of the gelatin-tannate method of Spencer, Morgulus and Wilder (25). Meat for the determinations was obtained from the circles of cooked meat left from the shearing tests and from similar positions in the raw muscle. The pieces were shaved as thin as possible with a sharp knife and macerated in a mortar. Enough acetone was added to cover the meat completely, and the meat was ground until thoroughly saturated with acetone. The mixture was allowed to stand overnight at room temperature. The acetone evaporated, leaving a slightly moist powder which was spread on a shallow, enameled pan and placed in a gentle current of air from a fan. When it was crisp and dry, it was transferred to a mortar and ground. The product was a fine lightweight powder having a meaty odor. It was transferred to a weighing dish and placed in a desiccator. After 3 or 4 days it had reached constant weight and was stored at room temperature until the analyses could be made conveniently. About 0.5 gram of the dry meat powder, weighed accurately, was transferred to a 50 ml. centrifuge tube. About 15 ml. distilled water were added and the mixture autoclaved at 15 pounds pressure for 2 hours, to convert the insoluble collagen into soluble gelatin. While still hot, the mixture was centrifuged and the clear liquid decanted. To the solid material, hot distilled water was added, the mixture stirred vigorously for about one minute, centrifuged, and the liquid decanted. This procedure was repeated twice more.

The combined decantates were used in the two methods. Soluble nitrogen was determined in the decantate by the Kjeldahl procedure and expressed as grams soluble nitrogen per 100 grams total nitrogen in the dry meat powder. The procedure for the gelatin-tannate method is as follows: The four decantates were collected directly into a 250 ml. centrifuge bottle, acidified with 1 ml. 10% H_2SO_4 and 10 ml. 10% tannic acid reagent. The bottle was left in the refrigerator (6-10°C) overnight to complete the precipitation. The next day the fluffy, sticky precipitate was centrifuged, the clear liquid decanted, and the bottle inverted to drain for several minutes. To the gelatin-tannate precipitate in the bottom of the bottle was added 1 ml. 10% NaOH and 10-15 ml. hot distilled water. The precipitate dissolved completely, giving a brown solution in which the nitrogen was determined by the Kjeldahl procedure. The results were calculated as grams of gelatin tannate-nitrogen per 100 grams total nitrogen.

RESULTS

First Experiment. Lambs Fed in One Lot, Not Paired

No increase in tenderness scores was noted with increase in length of feeding period (Table 1). Only the tenderness scores of the three judges present at each judging period were used. When these scores were analyzed by variance, it was found that there was no significant difference in tenderness between killings nor between storage periods, but significant differ-

Table 1. First experiment. Lambs lot fed, not paired

Days on feed	Live weight in pounds		Average daily gain (pounds)		Separable fat in leg percentage	Ether extract in leg percentage	Tenderness score*	
	Initial	Final	Entire feeding period	Last 2 weeks			Stored 1 week	Stored 2 weeks
				A. Means For Groups				
0	70.31	.....	.....	.....	7.30	12.0	4.0	4.0
42	70.72	85.53	0.355	0.355	10.45	17.3	4.1	3.8
56	73.03	93.47	0.365	0.435	11.26	17.2	4.1	3.9
70	65.81	88.94	0.370	0.174	12.69	18.0	3.9	4.0
84	72.19	100.88	0.330	0.502	11.27	16.3	4.0	4.1
98	69.18	105.43	0.370	0.388	14.90	19.6	4.0	3.8
				B. Ranges Within Group				
0	57.75—84.25	.....	.....	.....	5.44— 8.94	8.7—15.1	3.0—4.9	3.6—4.7
42	57.50—81.00	76.50— 98.25	.202—.506	.202— .506	7.53—12.46	13.9—19.9	3.8—4.7	3.6—4.0
56	57.25—91.00	79.50—117.25	.246—.469	.286— .750	8.85—13.53	13.6—19.4	3.6—4.6	3.6—4.3
70	59.00—78.00	78.50— 97.50	.207—.461	—.125—+.482	9.89—16.63	13.9—22.9	3.4—4.4	3.8—4.2
84	58.50—88.25	79.50—121.00	.244—.405	.339— .714	7.58—17.47	13.3—22.7	3.8—4.2	3.8—4.3
98	57.25—82.00	98.00—115.50	.270—.518	.250— .607	11.64—16.71	17.1—22.7	3.8—4.3	3.7—4.1

*Average of the scores of the three judges present each judging period.

ences were obtained between carcasses regardless of method of handling. However, a correlation based on the tenderness scores and the percentage ether extract of all of the individual carcasses was not significant, either when the scores of the three judges present at each judging period were used, or when the mean scores of all of the judges were used.

That the lambs in the beginning differed greatly in tenderness is indicated by the fact that the range for the first period of slaughter includes the lowest and highest tenderness scores for the legs in the entire experiment (Table 1, B, Stored 1 Week).

A highly significant difference between the scores of different judges seemed to indicate that different standards of tenderness were used by the different judges. The method of testing tenderness, therefore, was changed in subsequent experiments.

There were difficulties in the production side of the project also. The range (Table 1, B) in percentage ether extract of the legs in the first period of slaughter shows that one of these lambs was fatter before it was placed on feed than some of those slaughtered in the next four periods after they had been on feed for some time. The means for the groups (Table 1, A) show the average separable fat and ether extract apparently remained almost stationary from the 42nd day through the 84th day of the feeding. This indicates that the average fatness of the lambs was not increasing during this period. The average daily gains made by these animals in the last two weeks before slaughter were very erratic. (Table 1, A and 1, B).

It seemed wise to examine the method of selection critically. The lambs for the first killing had been selected by weight as follows: After the weight of the lambs had been arranged in order from the lightest to heaviest, the fourth from the lightest lamb was selected, and counting from it every sixth lamb was chosen. While this method of selection was expected to give a representative sample of the fatness of the entire lot of lambs at the beginning of the experiment, perhaps other variables, present in a group of 48 lambs even from the same flock, were large enough to defeat the original purpose. Lambs for the later killings were selected on the basis of gains. At killing time, the average daily gains in pounds for all of the **live lambs for the preceding two week period** were arranged in order from the smallest to the largest. The third from the smallest gainer was selected, and counting from it every fifth lamb was selected for the second killing, and every fourth for the third killing. Then the second from the smallest gainer was selected, and counting from it every third lamb was selected for the fourth killing, every second for the fifth killing, and all that were left were used for the sixth killing. (Because one died during the test there were only 7 in the sixth killing). Thus the lowest and the highest gainers in each two-week period were left alive until the last killings. No distinction was possible between gains caused by fatness and those caused by growth. Gains made previous to the last period were disregarded. This method gave a representative sample of

Table 2. First experiment. Individual lamb records arranged in the order in which they were selected for killing

Animal number	Days on feed	Live weight in pounds		Average daily gain in pounds		Carcass grade	Separable fat in leg** percentage	Ether extract in leg** percentage	Tenderness score***	
		Initial	Final	Entire feeding period	Last 2 weeks				Stored 1 week	Stored 2 weeks
2799	0	57.75	.....	.....	.....	Common	5.47	8.66	4.3	.....
2768	0	60.25	.....	.....	.....	Common	6.04	13.53	.....	4.7
2826	0	66.25	.....	.....	.....	Common	7.44	9.14	4.9	.....
2774	0	68.25	.....	.....	.....	Common	5.44	11.23	.....	3.8
2848	0	72.50	.....	.....	.....	Medium	8.94	13.01	3.0	.....
2831	0	75.25	.....	.....	.....	Medium	7.96	11.85	.....	3.8
2821	0	78.00	.....	.....	.....	Medium	8.89	13.29	3.9	.....
2825	0	84.25	.....	.....	.....	Medium	8.24	15.09	.....	3.6
2843	42	76.50	85.00	0.202	.....	Good	12.22	19.88	3.9	.....
2856	42	73.50	85.50	0.286	.....	Choice	10.06	17.49	.....	3.8
2773	42	73.00	85.50	0.298	.....	Good	11.46	18.91	4.7	.....
2817	42	81.00	94.75	0.327	.....	Good	12.46	19.35	.....	3.6
2814	42	66.50	81.50	0.357	.....	Good	10.32	16.74	3.9	.....
2818	42	60.75	77.25	0.393	.....	Medium	7.53	14.00	.....	4.0
2790	42	57.50	76.50	0.452	.....	Good	10.36	18.49	3.8	.....
2852	42	77.00	98.25	0.506	.....	Good	9.16	13.88	.....	3.6
2851	56	77.75	91.50	0.246	0.286	Good	10.16	16.55	3.6	.....
2847	56	67.00	83.50	0.295	0.286	Choice	10.37	16.06	.....	3.6
2864	56	80.50	102.00	0.384	0.357	Good	12.39	18.62	4.4	.....
2862	56	69.75	90.50	0.371	0.375	Good	10.23	15.56	.....	4.3
2867	56	70.75	90.00	0.344	0.429	Choice	11.25	19.44	4.6	.....
2806	56	91.00	117.25	0.469	0.446	Choice	13.33	18.95	.....	3.9
2873	56	57.25	79.50	0.397	0.554	Good	8.85	13.61	.....	3.6
2804	56	70.25	93.50	0.415	0.750	Good	13.53	18.70	3.6	.....
2886	70	59.00	78.50	0.279	—0.125*	Medium	12.72	16.78	3.6	.....
2800	70	78.00	92.50	0.207	—0.107*	Choice	9.89	13.89	3.4	.....
2813	70	68.25	90.75	0.321	—0.036*	Choice	16.63	22.90	.....	4.0
2888	70	65.00	82.00	0.243	0.018	Good	14.52	20.21	.....	3.8
2837	70	59.00	84.25	0.361	0.339	Medium	11.23	15.91	4.4	.....
2807	70	63.00	89.50	0.379	0.393	Good	12.59	18.00	.....	4.2
2860	70	69.00	96.50	0.393	0.429	Good	12.19	17.55	4.2	.....
2751	70	65.25	97.50	0.461	0.482	Choice	11.78	18.68	.....	4.0

2858	84	58.50	90.75	0.384	0.339	Medium	9.12	14.23	.....	4.3
2879	84	58.75	79.50	0.247	0.357	Medium	8.14	13.38	4.0	.....
2778	84	88.25	121.00	0.389	0.393	Choice	17.47	22.73	4.1	.....
2752	84	73.00	94.50	0.256	0.500	Good	7.58	13.25	.....	4.2
2819	84	63.00	91.50	0.339	0.536	Good	10.21	14.15	4.2	.....
2824	84	80.75	112.00	0.372	0.554	Good	11.38	15.18	3.8	.....
2772	84	73.75	107.75	0.405	0.589	Choice	14.77	20.71	.....	4.0
2757	84	81.50	110.00	0.339	0.714	Good	11.51	16.54	.....	3.8
2786	98	72.50	99.00	0.270	0.250	Good	12.17	18.21	4.1	.....
2761	98	60.25	98.00	0.385	0.286	Good	11.64	17.40	.....	3.7
2859	98	82.00	115.50	0.342	0.321	Good	14.84	20.72	.....	3.7
2766	98	74.25	110.00	0.365	0.321	Choice	16.38	22.65	3.9	.....
2829	98	57.25	108.00	0.518	0.393	Good	14.08	19.70	.....	4.1
2896	98	70.00	98.50	0.291	0.536	Good	12.85	17.10	3.8	.....
2863	98	68.00	109.00	0.418	0.607	Choice	16.71	21.09	4.3	.....

*Loss instead of gain.
**Leg removed from carcass midway between point of aitch bone and rise of pelvic arch and perpendicular to the shank. Shank removed at stifle joint. Cod and flank fat trimmed off.
***Average of the scores of the three judges present each judging period.

gains at the time of killing, but such factors as weather might influence gains in a two-week period in a way not related necessarily to the fatness of the animal. Illustrations may be observed in Table 2. In the group killed after 42 days on feed, No. 2852 had the highest average daily gain but the lowest percentage ether extract. In the group killed after 70 days on feed, No. 2813 lost weight in the last two weeks, yet had the highest percentage ether extract.

Thus from the results of the first experiment it appeared that biological variations between animals, differences in standards of tenderness used by the judges, and the method of selecting fat and thin lambs were problems which had not been solved satisfactorily.

Second Experiment. Unpaired Lambs Fed in Two Lots. Carcasses Paired

When all the data were taken as one sample, a difference in tenderness between the full-fed and limited-fed lambs was obtained. Sixty-nine per cent of the paired judgments were in favor of the full-fed lamb (Table 3). The Chi-square was 14.9, which is highly significant since it was above 6.635.

However, when the data from the individual pairs were observed, it was noted that the lowest percentage of judgments in favor of the full-fed lamb were found not only in the two pairs having the least but also in the pair which had the greatest difference in fatness. Erratic data of this sort tend to discount the results of statistical analyses, because such analyses are valid only for homogeneous data, and these results appear to indicate that the data are not homogeneous.

Third Experiment. Lambs Paired, Fed in Two Lots

When all the data by the paired eating method in Experiment Three were taken as one sample, there was again a difference in tenderness between the full-fed and limited-fed lambs with 61% of the judgments in favor of the full-fed lambs (Table 4). This difference is highly significant (Chi-square 17).

However, when the individual data are examined, it is noted that in about one-fourth of the pairs the limited-fed lamb was the more tender. Moreover the difference in fatness between full-fed and limited-fed lambs is not significantly correlated with their tenderness-percentages. This may be observed without calculation from Table 4, in which the pairs of lambs are arranged in order of difference in fatness. The expected order for the corresponding tenderness-percentages is not apparent. Furthermore, after grouping the pairs having a difference in fatness of above 10%, those having a difference of 5-10%, and those having less than 5%, the percentage of judgments in favor of the full-fed lamb does not show the expected descending order. Thus there was no increase in unanimity of judgments in favor of the full-fed lamb as the difference in fatness increased. It seems reasonable to expect that it would have occurred if degree of fatness is an important factor in tenderness.

Table 3. Second Experiment. Unpaired Lambs Fed in Two Lots, Carcasses Paired.

Carcass number		Live weight in pounds				Average daily gain in pounds				Carcass grade		Separable fat in leg percentage	Tenderness by paired eating method	
		Initial		Final		Entire period after change		Last two weeks					Total number paired samples	Percentage in favor of full-fed
Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed—Limited fed = Diff.		
2767	2894	107.0	82.0	111.0	83.0	+.143	+.036	+.182	+.091	Choice	Common	21.93—10.50=+11.43	14	57
2802	2845	106.5	90.0	123.0	87.0	+.589	—.107	+.545	—.273	Choice	Common	19.80— 9.50=+10.50	10	95
2823	2763	104.0	82.0	119.0	78.5	+.536	—.125	+.727	—.318	Choice	Common	16.38— 8.91=+ 7.47	14	71
2865	2889	98.5	78.0	112.5	76.5	+.500	—.054	+.500	—.227	Choice	Common	15.28— 8.49=+ 6.79	12	78
2820	2803	107.0	89.0	119.0	89.0	+.429	.000	+.273	.000	Choice	Medium	17.10—11.19=+ 5.91	14	86
2754	2866	92.0	87.5	100.0	89.5	+.286	+.072	.000	+.182	Choice	Medium	16.70—11.30=+ 5.40	12	83
2760	2788	111.0	87.5	126.5	94.5	+.554	+.250	+.455	+.318	Choice	Common	13.62—10.90=+ 2.72	14	36*
2791	2805	101.5	94.5	116.5	98.0	+.536	+.125	+.773	+.182	Good	Medium	13.93—12.42=+ 1.51	12	54
Mean.....	.....	103.4	86.3	115.9	87.0	.....	.....	.....	.....	.....	.....	16.84—10.38=+ 6.46	102**	69***

*The limited-fed lamb was more tender.
**Total.
***Calculated from totals of paired samples.

Table 4. Third Experiment. Lambs Paired, Lot Fed.

Carcass number		Carcass grade		Separable fat in leg percentage	Separable fat in carcass percentage	Tenderness by paired eating method		
						Total number of paired samples	Percentage in favor of full-fed	
Full fed	Limited fed	Full fed	Limited fed	Full fed — Limited fed = Diff.	Full fed — Limited fed = Diff.		Individuals	Groups
3036	3035	Choice	Common	22.40 — 7.73 = +14.67	26.71 — 11.32 = +15.39	18	31*	
3026	3027	Choice	Medium	23.34 — 10.17 = +13.17	29.54 — 16.52 = +13.02	18	39*	54
3015	3016	Choice	Common	20.67 — 8.99 = +11.68	27.79 — 9.94 = +17.85	18	58	
3058	3056	Good	Common	21.26 — 10.69 = +10.57	25.48 — 12.10 = +13.38	16	94	
3068	3067	Choice	Good	23.35 — 13.48 = + 9.87	31.42 — 20.11 = +11.31	18	56	
3066	3059	Choice	Common	19.36 — 9.86 = + 9.50	29.68 — 12.77 = +16.91	18	86	
3069	3070	Choice	Common	21.10 — 11.65 = + 9.45	25.48 — 14.61 = +10.87	18	33*	
3024	3025	Good	Common	22.81 — 13.37 = + 9.44	31.90 — 17.39 = +14.51	18	72	
3023	3022	Choice	Medium	22.51 — 13.38 = + 9.13	33.46 — 19.45 = +14.01	18	53	
3040	3041	Good	Medium	23.01 — 15.04 = + 7.97	26.84 — 19.84 = + 7.00	18	67	65
3033	3032	Choice	Medium	20.69 — 14.08 = + 6.61	27.80 — 21.25 = + 6.55	18	94	
3085	3086	Choice	Common	17.98 — 11.54 = + 6.44	22.93 — 14.09 = + 8.87	16	66	
3076	3077	Choice	Common	18.90 — 12.51 = + 6.39	26.58 — 15.71 = +10.87	18	69	
3045	3044	Good	Common	19.72 — 13.77 = + 5.95	23.54 — 17.66 = + 5.88	18	69	
3082	3079	Choice	Good	21.63 — 16.30 = + 5.33	25.29 — 20.74 = + 4.55	18	83	
3073	3072	Good	Medium	19.18 — 14.15 = + 5.03	25.27 — 19.11 = + 6.16	18	31*	
3007	3006	Choice	Good	20.04 — 15.29 = + 4.75	25.93 — 20.31 = + 5.62	18	25*	
3012	3013	Good	Common	18.26 — 13.84 = + 4.42	26.31 — 16.63 = + 9.68	18	61	
3009	3008	Choice	Medium	16.95 — 13.39 = + 3.56	23.42 — 20.65 = + 2.77	18	83	56
3097	3096	Choice	Common	15.85 — 12.32 = + 3.53	22.20 — 14.92 = + 7.28	18	56	
3083	3080	Good	Good	17.12 — 19.10 = — 1.96	22.74 — 22.47 = + 0.27	18	53	
Mean.....				20.29 — 12.89 = + 7.40	26.68 — 17.02 = + 9.66	374**	61***	

*The limited-fed lamb was more tender.
**Total number of paired samples.
***Calculated from totals of paired samples.

Table 5. Third Experiment. Weights and Gains of Paired Lambs Fed in Two Lots.

Carcass number		Live weight in pounds				Average daily gain entire period pounds		Days on feed
		Initial		Final				
Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	
3036	3035	75.0	73.0	109.0	74.0	.354	.010	96
3026	3027	76.0	78.0	111.0	87.0	.232	.060	151
3015	3016	60.0	58.0	96.0	55.0	.290	—.024*	124
3058	3056	58.0	60.0	92.0	69.0	.309	.082	110
3068	3067	70.0	72.0	108.0	85.0	.292	.100	130
3066	3059	73.0	72.0	109.0	71.0	.277	—.008*	130
3069	3070	75.0	73.0	99.0	75.0	.250	.021	96
3024	3025	72.0	76.0	101.0	102.0	.162	.145	179
3023	3022	85.0	81.0	128.0	95.0	.250	.081	172
3040	3041	46.0	48.0	87.0	73.0	.285	.174	144
3033	3032	71.0	71.0	96.0	65.0	.214	—.051*	117
3085	3086	59.0	62.0	80.0	64.0	.191	.018	110
3076	3077	67.0	70.0	100.0	59.0	.241	—.080*	137
3045	3044	48.0	48.5	94.0	77.5	.305	.192	151
3082	3079	66.0	66.0	100.0	85.0	.236	.132	144
3073	3072	69.0	70.0	90.0	85.0	.122	.087	172
3007	3006	77.0	77.0	108.0	81.0	.301	.039	103
3012	3013	66.0	65.0	104.0	72.0	.277	.051	137
3009	3008	65.0	67.0	86.0	74.0	.169	.056	124
3097	3096	67.0	66.0	79.0	64.0	.116	—.019*	103
3083	3080	57.0	57.0	95.0	81.0	.325	.205	117
Mean.....		66.8	67.2	98.7	75.9			

*Loss instead of gain.

Initial and final weights and average daily gains of these paired lambs are given in Table 5. Not all of the full-fed lambs gained as well as could be desired. It may be noted that some of the limited-fed lambs lost weight during the test.

Fourth, Fifth, and Sixth Experiments. Paired Lambs Fed Individually

In these tests the paired judgments in favor of the full-fed lamb were 57%, 38%, and 58% respectively (Table 6). When the three experiments were taken as one sample, 49% of the paired judgments were in favor of the full-fed lamb and 51% in favor of the limited-fed lamb. This ratio of 49:51 does not differ significantly from a 50:50 ratio and indicates no difference in tenderness between full-fed and limited-fed lambs. This finding is based on 14 pairs of lambs and on 164 paired judgments.

When the individual data are examined the percentages of paired judgments in favor of the full-fed lamb are very erratic, ranging from 9% to 97% in Experiment Four, from 8% to 81% in Experiment Five, and from 33% to 83% in Experiment Six.

The scores from weighted adjectives were obtained by using the following weightings: 5 = very tender, 4 = tender, 3 = neutral, 2 = tough, and 1 = very tough. The scores of full-fed and limited-fed lambs respectively averaged 3.9, 3.7 in Experiment Four; 3.6, 3.8 in Experiment Five; 3.7,

Table 6. Experiments Four, Five, and Six. Lambs Fed Individually.

Carcass number		Carcass grade		Percentage separable fat		Tenderness of the semimembranosus (cooked)						Shear of adductor muscle pounds			
				Leg	Carcass	Paired eating method		Scores from weighted adjectives**		Mechanical shear in pounds		Raw		Cooked	
Full fed	Limited fed	Full fed	Limited fed	Full fed — Limited fed = Diff.	Full fed — Limited fed = Diff.	Total number of paired samples	Percentage in favor of full-fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed
Fourth Experiment. Twin Lambs															
700	699	Choice	Common	24.3 — 13.6 = +10.7	33.2 — 15.4 = +17.8	14	75	3.7	3.2	.....	.....	20.6	15.6	24.4	22.9
703	702	Choice	Good	22.3 — 15.3 = + 7.0	29.3 — 19.6 = + 9.7	16	75	3.2	2.6	.....	.....	20.0	17.0	26.8	27.6
3296	3431	Good	Medium	15.2 — 9.8 = + 5.4	22.1 — 13.3 = + 8.8	16	9**	4.1	4.7	.....	.....	25.3	22.6	16.0	16.0
689	708	Good	Medium	15.2 — 12.5 = + 2.7	21.0 — 16.8 = + 4.2	16	97	4.5	3.6	.....	.....	11.3	12.5	20.2	22.3
3210	3209	Choice	Good	14.2 — 14.3 = — 0.1	23.3 — 17.7 = + 5.6	12	25**	4.0	4.3	.....	.....	17.1	15.0	19.8	14.8
		Mean.	.....	18.2 — 13.1 = + 5.1	25.8 — 16.6 = + 9.2	.....	57	3.9	3.7	.....	.....	18.9	16.5	21.4	20.7
Fifth Experiment. Paired Lambs from Same Flock															
2999	2998	Good	Common	28.4 — 9.1 = +19.3	33.5 — 14.6 = +18.9	16	28**	3.5	3.9	23.5	26.0	.....	.....	.....	.....
3614	3615	Choice	Common	29.3 — 12.8 = +16.5	33.2 — 17.5 = +15.7	12	21**	3.9	4.6	24.0	17.9	.....	.....	.....	.....
5	5A	Choice	Common	18.4 — 8.6 = + 9.8	23.1 — 10.7 = +12.4	16	44**	3.5	3.5	16.9	32.1	.....	.....	.....	.....
3248	3200	Choice	Common	22.0 — 13.4 = + 8.6	31.6 — 17.8 = +13.8	8	81	4.0	3.4	16.6	19.8	.....	.....	.....	.....
3613	3612	Choice	Common	23.0 — 14.6 = + 8.4	29.4 — 19.1 = +10.3	12	8**	3.1	4.1	30.4	21.0	.....	.....	.....	.....
2978	2979	Choice	Medium	17.9 — 11.6 = + 6.3	23.8 — 13.7 = +10.1	8	75	3.4	3.0	16.2	21.3	.....	.....	.....	.....
		Mean.	.....	23.2 — 11.7 = +11.5	29.1 — 15.6 = +13.5	.....	38**	3.6	3.8	21.3	23.0	.....	.....	.....	.....
Sixth Experiment. Paired Crossbred Lambs															
2	2A	***	***	18.7 — 12.1 = + 6.6	25.8 — 15.2 = +10.6	6	83	3.8	3.3	.....	.....	.....	.....	19.4	22.4
3	3A	***	***	19.7 — 11.1 = + 8.6	27.1 — 13.9 = +13.2	6	58	3.5	3.3	.....	.....	.....	.....	18.4	19.8
5	5A	***	***	15.6 — 6.5 = + 9.1	19.3 — 10.0 = + 9.3	6	33**	3.7	3.7	.....	.....	.....	.....	17.0	18.3
		Mean.	.....	18.0 — 9.9 = + 8.1	24.1 — 13.0 = +11.0	.....	58	3.7	3.4	.....	.....	.....	.....	18.3	20.2
Summary of Individually Fed Lambs															
		Mean.	.....	20.3 — 11.8 = + 8.5	26.8 — 15.3 = +11.4	164	49**	3.7	3.6	.....	.....	.....	.....	.....	.....

*Adjective weightings: Very tough, 1.0 — 1.5; Tough, 1.5 — 2.5; Neutral, 2.5 — 3.5; Tender, 3.5 — 4.5; Very tender, 4.5 — 5.0.
**The limited-fed lamb was more tender.
***Carcasses not graded but full-fed would have graded Good or better while limited-fed were thin and blue.

Table 7. Experiments Four, Five, and Six. Weights and Gains of Paired Lambs Fed Individually

Lamb or carcass number		Live weights in pounds				Average daily gain in pounds				Days on feed
		Initial		Final		Entire period		Last two weeks		
Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	
Fourth Experiment—Twin Lambs										
700W	699W	66.5	64.0	106.0	82.0	.299	.136	+.250	—.036	132
703E	702E	76.0	73.5	117.0	92.0	.328	.148	+.179	+.286	125
3296E	3431E	41.5	45.5	95.0	69.0	.366	.161	+.321	+.107	146
689E	708E	72.0	75.5	111.5	89.5	.316	.112	+.536	+.071	125
3210W	3209W	76.5	70.5	113.5	90.0	.266	.140	+.357	+.071	139
Fifth Experiment—Paired Lambs										
2999	2998	62.3	63.1	96.0	73.0	.237	.070	+.250	+.167	142
3614	3615	57.4	55.4	101.0	66.5	.323	.082	+.306	+.306	135
5	5A	54.7	56.0	93.0	69.5	.270	.096	+.278	+.111	142
3248	3200	57.8	54.8	100.0	68.0	.330	.103	+.222	+.083	128
3613	3612	59.7	56.3	95.0	70.0	.261	.101	+.361	+.250	135
2978	2979	62.2	61.4	98.5	71.0	.284	.075	+.361	+.083	128
Sixth Experiment—Paired Crossbred Lambs										
2	2A	42.0	43.0	112.0	67.0	.673*	.231	Not	Not	104
3	3A	67.0	68.0	99.0	69.0	.356	.011	avail-	avail-	90
5	5A	64.0	62.0	88.0	62.0	.231	.000	able	able	104

*Unusually high daily gain. This pair was Suffolk x Rambouillet. They were big growthy lambs but thin when placed on feed. Forty-five lambs of this breeding, fed experimentally by the Animal Husbandry Department in the same year, gained 0.548 pounds per head daily during an 84 day period.

Table 8. Chemical Tests for Collagen in Raw and Cooked Semimembranosus Muscle.

Carcass number		Raw (right)				Cooked (left)			
		Grams soluble nitrogen per 100 grams total nitrogen		Grams gelatin-tannate nitrogen per 100 grams total nitrogen		Grams soluble nitrogen per 100 grams total nitrogen		Grams gelatin-tannate nitrogen per 100 grams total nitrogen	
Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed	Full fed	Limited fed
2999	2998	11.4	11.4	8.8	8.7	13.2	12.5	7.9	9.3
3614	3615	12.0	10.9	8.4	7.5	11.7	11.5	8.0	8.4
5	5A	11.4	11.0	8.5	8.1	12.7	12.2	8.6	9.4
3248	3200	.....	.....	.....	.....	9.1	9.8	7.3	7.4
3613	3612	11.5	12.3	8.8	8.3	11.7	11.4	8.4	8.2
2978	2979	.....	.....	.....	.....	9.6	10.1	6.8	7.1
Mean...	.....	11.6	11.4	8.6	8.2	11.3	11.3	7.8	8.3

3.4 in Experiment Six (Table 6). These values indicate little difference between paired samples. Even the small differences in the averages were not consistently in favor of the full-fed lamb.

Shear values are the pounds of stress required to shear across a one-inch core of meat. Tender meat gives lower shear values than does less tender meat. The average shear values for full-fed and limited-fed respectively were: 21.4, 20.7 pounds in Experiment Four; 21.3, 23.0 pounds in Experiment Five; 18.3, 20.2 pounds in Experiment Six (Table 6). These values indicate little difference in tenderness between paired samples. Even the small differences in the averages were not consistently in favor of the full-fed lamb.

Weights and gains of the paired lambs fed individually are given in Table 7. None of these lambs lost weight during the test.

The chemical determinations for collagen by both methods are given in Table 8. Since the soluble nitrogen method measures not only the gelatin nitrogen but other soluble nitrogen compounds as well, the collagen values by this method are higher than those by the gelatin-tannate method. Little difference between the full-fed and limited-fed lambs was found. The small differences observed are probably within experimental error. Spencer, Morgulus, and Wilder (25) reported values for raw biceps femoris (a muscle in the hind leg) ranging from 7.4 to 14.5% within their control group of 8 rabbits. The values in Table 10 for raw muscle from 8 lambs and cooked muscle from 12 lambs fall within a much narrower range. The values appear to be close enough to indicate that in respect to collagen content, the lambs in the fifth experiment were fairly well paired.

Re-examination of Results from Third Experiment

After the data on the individually fed lambs had been obtained, and it was noted that some of the pairs had to be discarded because they did not eat well under the experimental conditions, it occurred to the authors that the lambs which did not gain in Experiment Three might also be discarded. When this was done 16 of the original 21 pairs of lambs were left. The tenderness-percentage then dropped from 61 to 57% and was no longer highly significant. The data from the selected lambs (Table 9) are slightly in favor of the fatter lambs, but still are not consistent. The range in tenderness-percentage is 25-94%, as wide as that found with the individually fed lambs.

Results from Combined Data

When the selected data from the paired lot-fed lambs were combined with those from the individually-fed lambs, a total of 30 pairs was obtained. For all of these pairs only 54% of the total judgments were in favor of the full-fed lamb, while 46% were in favor of the limited-fed lamb. In view of the wide variations and the contradictory results found in each of these four tests, it seems doubtful that fatness influences tenderness in lamb to any marked extent.

Both carcass grades and tenderness scores were obtained for some of the animals in the present study. The totals include 13 Choice carcasses, 17 Good, 8 Medium and 8 Common. In the scores used here 4 = tender and 3 = neutral. The tenderness scores for Choice, Good, Medium and Common respectively averaged 3.8, 3.9, 3.8, and 4.0. These data indicate that the tenderness scores were not influenced by the grade of the carcass. Hunt (19) reported tenderness scores for legs of lamb using a score card in which 6 = tender, 5 = slightly tender, and 4 = slightly tough. In only 2 of his lots did the carcass grades include both Choice and Common. The scores he reported for Choice and Common respectively were: Lot III, 6.00 and 5.75; Lot IV, 4.00 and 5.75. It is apparent that in Lot III the leg from the Choice carcass was only slightly more tender than the one from the Common carcass, while in Lot IV the leg from the Choice carcass was not only less tender than the one from the Common carcass but was graded slightly tough. His results then appear to be as contradictory as those obtained in the present study. If, as seems likely, his Choice carcasses were fatter than his Common carcasses, these data lend support to the idea advanced here that fatness does not influence tenderness in lamb to any marked extent.

The relationship between carcass grade and fatness observed in lambs from the present study is shown in Tables 10 and 11. In Table 10 the fatness was determined by the separable fat in the carcass. In this table it may be noted that within each carcass grade there were animals which differed considerably in fatness. The ranges within carcass grades were: Choice 22%-33%, Good 17%-33%, Medium 13%-21%, and Common 9%-

Table 9. Selected* Animals from the Third Experiment

Carcass number		Degrees of fatness		Average daily gain entire feeding period pounds		Tenderness of semimembranosus (paired eating method)	
		Separable fat in leg	Separable fat in carcass				
Full fed	Limited fed	Full fed —Limited fed =Diff.	Full fed —Limited fed =Diff.	Full fed	Limited fed	Total paired judgments	Percentage in favor of full-fed
3036	3035	22.40 — 7.73 = +14.67	26.71 —11.32 = +15.39	.354	.010	18	31**
3026	3027	23.34 —10.17 = +13.17	29.54 —16.52 = +13.02	.232	.060	18	39**
3058	3056	21.26 —10.69 = +10.57	25.48 —12.10 = +13.38	.309	.082	16	94
3068	3067	23.35 —13.48 = + 9.87	31.42 —20.11 = +11.31	.292	.100	18	56
3069	3070	21.10 —11.65 = + 9.45	25.48 —14.61 = +10.87	.250	.021	18	33**
3024	3025	22.81 —13.37 = + 9.44	31.90 —17.39 = +14.51	.162	.145	18	72
3023	3022	22.51 —13.38 = + 9.13	33.46 —19.45 = +14.01	.250	.081	18	53
3040	3041	23.01 —15.04 = + 7.97	26.84 —19.84 = + 7.00	.285	.174	18	67
3085	3086	17.98 —11.54 = + 6.44	22.93 —14.09 = + 8.87	.191	.018	16	66
3045	3044	19.72 —13.77 = + 5.95	23.54 —17.66 = + 5.88	.305	.192	18	69
3082	3079	21.63 —16.30 = + 5.33	25.29 —20.74 = + 4.55	.236	.132	18	83
3073	3072	19.18 —14.15 = + 5.03	25.27 —19.11 = + 6.16	.122	.087	18	31**
3007	3006	20.04 —15.29 = + 4.75	25.93 —20.31 = + 5.62	.301	.039	18	25**
3012	3013	18.26 —13.84 = + 4.42	26.31 —16.63 = + 9.68	.277	.051	18	61
3009	3008	16.95 —13.39 = + 3.56	23.42 —20.65 = + 2.77	.169	.056	18	83
3083	3080	17.12 —19.10 = — 1.96	22.74 —22.47 = + 0.27	.325	.205	18	53
Mean.....		20.67 —13.31 = + 7.36	26.64 —17.69 = + 8.95	.254	.091	284***	57****

*All animals gained weight during the test.
**The limited-fed lamb was more tender than the full-fed one.
***Total.
****Calculated from totals of paired samples.

Table 10. Percentage of Separable Fat in the Carcass from Carcasses of Different Grades

Percentage separable fat	Number of carcasses			
	Choice	Good	Medium	Common
9	.....	.....	.....	1
10	.....	.....	.....	1
11	.....	.....	.....	1
12	.....	.....	.....	2
13	.....	.....	2	.....
14	.....	.....	.....	4
15	.....	.....	.....	2
16	.....	.....	2	1
17	.....	1	.....	4
18	.....	.....	.....	.....
19	.....	1	3	1
20	.....	3	1	
21	.....	1	1	
22	2	3		
23	4	1		
24	.....	.....		
25	3	2		
26	2	2		
27	2	.....		
28	.....	.....		
29	4	.....		
30	.....	.....		
31	2	1		
32	.....	.....		
33	3	1		
Total number of carcasses	22	16	9	17

Table 11. Percentage of Separable Fat in the Leg* from Carcasses of Different Grades.

Percentage separable fat	Number of carcasses			
	Choice	Good	Medium	Common
5	.....	.....	.....	2
6	.....	.....	.....	1
7	.....	1	2	2
8	.....	1	4	4
9	1	1	2	3
10	2	5	1	3
11	2	4	4	2
12	.....	7	3	3
13	2	3	2	5
14	2	4	2	1
15	2	4	1	
16	6	1		
17	4	1		
18	2	1		
19	2	3		
20	3	.....		
21	3	1		
22	4	1		
23	3	1		
24	1	.....		
25	.....	.....		
26	.....	.....		
27	.....	.....		
28	.....	1		
29	1			
Total number of carcasses	40	40	21	26

*Leg trimmed of flank and cod fat and shank removed at stifle joint.

19% separable fat in the carcass. Moreover carcasses of grades Good, Medium, and Common were found within the range 17%-19%, while the fattest Choice carcasses were no fatter than the fattest Good carcass. In Table 11 fatness was determined by the separable fat in the trimmed leg. In this table it may be noted that within each carcass grade there were animals which differed considerably in fatness. The ranges were: Choice 9%-29%, Good 7%-28%, Medium 7%-15% and Common 5%-14%. In this case carcasses of all grades (Choice, Good, Medium and Common) were found within the range of 9%-14% separable fat in the leg. This overlapping fatness for different carcass grades could be possible only in the presence of considerable variation in conformation and quality among the carcasses.

DISCUSSION

The question may be asked whether or not the fat lambs were really fat. In the report of the Chief of the Bureau of Animal Industry for 1938 a classification of lamb carcasses was reported based on percentage ether extract in the entire edible portion of the carcass and on percentage of separable fat in the untrimmed leg. No data for ether extract of the entire carcass were obtained in the present study, and the percentage separable fat in the leg was made on the leg from which the cod and flank fat as well as the shank had been removed. The data from the two studies, therefore, are not comparable. The authors know of no other suitable data for this comparison, but there can be little reasonable doubt of the fatness of those lambs in which the percentage of separable fat represented from $\frac{1}{4}$ to $\frac{1}{3}$ of the weight of the entire carcass (Tables 4, 6, 9, 10).

Hankins and Ellis (15) obtained coefficients of correlation between the tenderness of the roasted meat as measured by shearing strength and certain indexes of fatness. In lambs tenderness of the leg was correlated with fatness expressed both as the percentage of caul fat and the percentage of kidney fat. With one lot of cattle tenderness of the longissimus dorsi muscle was correlated with fatness expressed both as the percentage of ether extract in the longissimus dorsi and the percentage of ether extract in the entire edible portion of the 9-10-11 rib cut. In another lot of cattle which was grain fed in dry lot, fatness was expressed as ether extract in the longissimus dorsi muscle and correlated with tenderness of the same muscle. None of these five coefficients was even moderately high, and there was inconsistency among them as to sign. Hankins and Ellis concluded the evidence is strong that variations in tenderness are caused mainly by factors other than fatness. The relationships between tenderness and fatness in the present study were based on tenderness of the semimembranosus muscle in the leg and on separable fat both in the trimmed leg and in the entire carcass. The present study and that of Hankins and Ellis therefore supplement each other. Neither study showed evidence of a relationship between fatness and tenderness. It seems doubtful that such a relationship exists.

Fat deposited in and around the muscle is thought to improve the flavor and juiciness of the lean meat, but no attempt was made here to study the effect of fatness on factors of palatability other than tenderness.

SUMMARY AND CONCLUSIONS

When the study of the effect of degree of fatness on tenderness of lamb was begun, three problems became apparent: selecting comparable animals, producing differences in fatness and testing tenderness of the meat.

Six experiments are given in detail with critical appraisal of methods and results. It was found advisable to use paired lambs similar in sex, breeding, conformation, and fleece covering and differing by not more than two pounds in initial weight. One lamb of each pair was full-fed so that it would gain as rapidly as possible and the other limited-fed so that it would gain slightly and only enough to keep it in a healthy condition. Both lot feeding and individual feeding were used successfully, but it was necessary to discard some of the lot-fed pairs because the limited-fed lambs had lost weight by the end of the test. The paired-eating method was used for testing tenderness in paired lambs, but observations were recorded also from weighted adjectives, mechanical shear, and chemical analyses for collagen content.

The full-fed animal was somewhat more tender than the limited-fed one in some pairs, but in other pairs the limited-fed one was more tender. In view of the contradictory results from different pairs within each test, it seems doubtful that fatness influences tenderness in lamb to any marked extent.

Using fatness or thinness as an indication of tenderness may be regarded as of doubtful practical value in buying lamb.

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