A STUDY OF THE MINERAL CONSTITUENTS OF BLOOD, MUSCLE TISSUE, AND ADIPOSE TISSUE OF BEEF ANIMALS IN RELATION TO THE SHRINKAGE, PALATABILITY, AND KEEPING QUALITIES OF THE MEAT

by

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INTRODUCTION

Considering the extent to which meat is used in the human dietary, there is surprisingly little information concerning the factors which influence the quality of meat. In order to secure definite information regarding the factors which influence the quality of meat, a conference was held by the National Livestock and Meat Board at Chicago in the fall of 1924. At this meeting a committee was appointed which was to recommend that cooperative experimental work be carried out between the state agricultural experiment stations and the United States Department of Agriculture. The United States Department of Agriculture was later requested by this committee to make a resume of the work done on the factors which influence the production and quality of meat together with the recommendation of the Department's active participation in this project. This was accepted by the Secretary of Agriculture.

In the spring of 1925, at the meeting of the directors of the state agricultural experiment stations, this study of meat was included in the program for research work to be done under the provisions of the Purnell Act.

It was decided that this work should come under the title of, "A Study of the Factors which Influence the

Quality and Palatability of Meat." Certain phases of this work were to be done by the United States Department of Agriculture and other phases were to be taken up by various state experiment stations. The Kansas State Experiment Station was assigned the work relative to the quality and palatability of meat from steers full-fed in dry lot compared with meat from similar steers full-fed on bluestem grass.

Some observations made by the Kansas Station seemed to indicate that the mineral composition of the adipose tissue had a relation to the original water content of the meat and also to the shrinkage and keeping quality of the meat.

It is probably to be expected that the mineral composition might bear a decided relation to the keeping quality of meat since it has been shown that the ratio of certain mineral elements in living tissue has an effect upon the permeability.

Bancroft (1) observed that the character of an oil and water emulsion can be altered by altering the kind of emulsifying agent. That is by using soaps of Na, K, and other monovalent cations as emulsifying agents for oil and water, emulsions are formed consisting of drops of oil dispersed in water. In the opposite case when soaps of Ca, Mg, and other di- and trivalent cations are used in place of the monovalent cations, the reverse emulsions are formed consisting

of drops of water dispersed in oil.

Clowes (2) investigations undertaken as a result of the observations made by Bancroft show that the ratio of mineral elements play a very important part in living tissue. He divides the electrolytes into two main antagonistic groups. Included in the first group are acids and salts of di- and trivalent cations in which the cation is more reactive and more readily adsorbed than the anion. Included in the second group are alkalies, salts of monovalent cations, and di- and trivalent anions in which anion is more reactive. Mg which ordinarily belongs to the first group and K which ordinarily belongs to the second group in some cases revert to the opposite group.

The first group exerts a protective effect on physical and biological membranes and diminishes their permeability to water; that is, as shown by Bancroft, this group produces the water-in-oil type of emulsion. The second group has just the opposite effect, that of increasing the permeability of the membranes to water. This group, of course, forms the oil-in-water type of emulsion. Clowes also shows that a state of equilibrium may exist within narrow limits which may vary of permeability of the membranes. The protoplasm and protoplasmic film under ordinary conditions do not present any sharp differentiations of phase relations, that

is, the phases are very intimately related with one another. Therefore under certain conditions he shows that a system may be more permeable to oils, fats, lipins, and very impermeable to water. In the reverse condition the system may be very permeable to water and impermeable to oily substances.

These results of Clowes make it very desirable for one to know the mineral content of meat. In the case of mineral constituents of meat in relation to shrinkage and keeping qualities, there is considered here only the permeability of the substance to water. That is with an excess of Ca or Mg or both above a certain limit or a lowering of Na or K or both below a certain limit, it would be expected that the material would lose very little water under normal conditions of storing or ripening. However, in the opposite case, that of the ratio of monovalent cation to divalent cation above a certain limit it would be expected that the material would lose a much larger quantity of water, also the material would be more permeable to the action of bacteria, mold, and enzymes since the mobility of these agents is greater in a water medium. The chemical reaction brought about by bacteria, mold, and enzymes would cause an objectional flavor in the meat and also decomposition would occur in much less than the average time.

REVIEW OF LITERATURE

In an examination of the literature there was not a great deal of data found to be available on the complete mineral analysis of the muscle and adipose tissues. No data were found on the mineral analysis of muscle and adipose tissue in relation to shrinkage, palatability or keeping qualities. There was a great deal of data available on the analysis of blood, but none of these data were correlated with meat. There are many types of analyses of experimental animals which have no value to this particular phase of work.

Moulton (3) observed that partial starvation of beef animals did not cause an increase in water content of the lean when calculated to a fat-free basis, but that it did cause a decrease in the nitrogen and phosphorus of the lean when calculated to this basis.

Moulton also found that this partial starvation increased the water content and decreased the protein content of the blood.

In this article Moulton points out that it is important to calculate the data to a fat-free basis because the constituents vary due to the fatness of the animal, but erroneous ideas may be obtained if the data are calculated to a

water-free basis. That is, a very fat piece of meat might appear to give abnormal results because of this excess of fat though the chemical constituents of the non-fatty tissue were normal.

Moulton (4) found that the chemical composition of mammals changed with age, that there was a decrease in water content and an increase in ash and protein content. All compositions were calculated to a fat-free basis when comparisons were made showing the effects of age or abnormalities. The fatness of an animal had no effect on the results when these results were calculated to a fat-free basis. Abnormal results for water were obtained in cases of edema, under development, and atrophy.

Ritchie, Moulton, Trowbridge, and Haigh (5) found that age or plane of nutrition had little if any effect on the ash of the lean or ash of the fat of the rib when calculated to a fat-free basis. Neither did they have much effect on the total phosphorus in the round and rib as the plane of nutrition was lowered. The total nitrogen in the lean flesh of the round, rib, and loin did not change noticeably with the condition of the animal, but did increase as the animal increased in age.

Chatfield (6) found that the per cent of ash, protein, and fat varied with various cuts. The results of analyses

for similar cuts from different animals were fairly uniform in most cases when these results were calculated to a fat-free basis as suggested by Moulton. There was, however, some variation in the results with degree of fatness of the animal even though the results were calculated to a fat-free basis.

Thieler, Green, and Du Toit (7) observed effects on year old cattle raised to adult weight on rations which varied in content of calcium, phosphorus, sodium, potassium, and chlorine. No mineral analyses were made on tissue. On the analysis of blood, it was found that a great excess of calcium over phosphorus in the diet seemed to lessen the phosphorus in the blood. A diet high in phosphorus seemed to increase the calcium in the blood. Phosphorus deficiency showed up principally in the inorganic phosphorus of the blood which dropped very low. The other phosphorus fractions in the blood were within a normal range. A variation in the diet of sodium, potassium, and chlorine seemed to produce no change in the blood.

EXPERIMENTAL

Animals Used

Since the material for analysis was available from the cooperative meat investigations project carried on at this

station, it was decided to make a rather complete analysis of the blood, and of the muscle and adipose tissues of a particular cut from all of the animals slaughtered for the fall of 1931.

There were eighteen animals used in this work. Twelve yearling steers (17 to 18 months of age at time of slaughter) were fed alike during the winter of 1930-31 and on May 1, 1931, were divided into three lots. Lot 1 consisting of five head was full-fed ground corn, cottonseed meal, and alfalfa hay in the dry lot until the latter part of September when they were slaughtered. Lot 2 consisting of five head was full-fed ground corn and cottonseed meal on bluestem grass pasture during this same period. Lot 3 consisting of the last two head in this group of twelve steers was turned out on bluestem grass until the time of slaughter toward the latter part of October. Lot 4 consisting of two head of short horn heifers about eighteen months old at time of slaughter was purchased from George Andrews living at Iola, Allen County, Kansas, through the cooperation of Dan Braum, county agent. These heifers had been on bluestem grass pasture (low phosphorus) and were the two best animals from this pasture. A number of the other animals from this same pasture were showing signs of the phosphorus deficiency disease. Lot 5 consisting of two head of Hereford heifers

about one year old at time of slaughter was purchased from A. C. Dick of LaHarpe, Kansas, also through the cooperation of Dan Braum. These heifers had been on grass pasture similar to Lot 4, but had received bone meal in their salt. None of the cattle from this pasture was showing symptoms of phosphorus deficiency. Lot 6 consisted of two animals commonly known as dark cutters. The rib cuts from these two animals were secured by the Nebraska station. None of the meat from the Kansas station showed this characteristic known as dark cutting.

Table I

DESCRIPTION OF SAMPLES

Sample No.	Animal No.	Lot No.	Feed
1	66	1	Full feed in dry lot
2	103		
3	107		
4	82		
5	84		
6	83	2	Full feed on grass
7	104		
8	72		
9	80		
10	86		
11	37	3	Manhattan pasture grass alone
12	106		
13	A.1	4	S. E. Kansas pasture grass alone
14	A.2		
15	D.1	5	S. E. Kansas pasture grass with bone meal supplement
16	D.2		
17	22	6	(Nebraska dark cutters)
18	23		

Methods of Securing Samples

All of the animals in lots 1, 2, and 3 were slaughtered at the college and blood samples taken from the jugular vein at this time. The blood samples were taken in glass covered fruit jars containing ammonium citrate as an anti-coagulant. A few drops of a dilute solution of formaldehyde were added as a preservative and the samples then sealed and stored in the refrigerator until analyzed. The carcasses were dressed, split, and hung in the cooler at 35 degrees F for 120 hours. At the end of this period, the carcasses were cut up and from the left side the rib cut including the sixth, seventh, and eighth ribs was taken for cooking tests conducted by the Department of Home Economics and the rib cut including the ninth, tenth, and eleventh ribs was taken for chemical analysis.

On this cut taken for chemical analysis, the bone and connective tissue were removed and discarded. All of the adipose tissue was removed from this cut (except that which was contained within the separate muscles due to marbling) for chemical analysis. The eye muscle (longissimus dorsi) was removed for chemical analysis. The rest of the muscular tissue was discarded. This adipose tissue and eye muscle were ground separately, sealed in glass covered fruit jars

and stored at -20 degrees F. until analyzed.

Lots 4 and 5 were slaughtered at Iola, Kansas, and the samples brought to the Kansas station the following day. Samples of blood and of muscle and adipose tissues were taken the same as lots 1, 2, and 3.

Lot 6 was slaughtered at Omaha (Armour's). The rib cuts (6-12 ribs) were sent to the Kansas station where they were prepared for analysis as described above. No blood samples were obtained from this lot.

Chemical Analysis

The whole blood was analyzed for phosphorus, calcium, sodium, potassium, and chlorine. The plasma from four of the steers was also analyzed for these same constituents.

The muscle tissue was analyzed for water, fat, protein, ash, phosphorus, calcium, magnesium, sodium, and potassium.

The adipose tissue was analyzed for water, fat, protein, ash, phosphorus, calcium, sodium, and potassium.

In each case the analyses of these samples were made in duplicate. A repetition was made on all analyses where good agreement was not secured.

Blood. The common micro methods for blood analysis are acceptable in nearly all work on blood; however, the results do not agree always with methods using larger amounts of

blood and following through with accepted procedures such as given in Methods of Analysis (8). It was for this reason that the latter procedure was followed in the hope of securing more exact determinations.

Calcium. 100 c. c. of blood were pipetted into a 12 cm. porcelain dish and placed in an air oven at 60 degrees C. After coagulation and partial drying, the temperature was raised very slowly to about 150 degrees C. When the sample was thoroughly dried and faintly charred, it was removed from the oven and placed on an electric heating unit and heated below dull redness while a gas flame was applied carefully to the top surface. By this procedure the danger of loss from splattering and of swelling over the dish was avoided when the sample was placed later in the muffle. When charring was complete, the sample was removed to the muffle and ignited at a temperature below dull redness. This ash was taken up in dilute HCl, filtered, and completely washed. Calcium was precipitated in the form of the oxalate from a 5% acetic acid solution as outlined by Scott (9).

This method of precipitation was necessary because of the large excess of iron and phosphorus over calcium. The precipitate of calcium oxalate was filtered, washed several times with hot H_2O, then with dilute NH_4OH solution, and then thoroughly washed with hot H_2O. This precipitate was

then washed from the filter paper into the beaker from which precipitation occurred, 5 c. c. of 1:1 H_2SO_4 added, heated nearly to boiling, titrated with N/50 $KMnO_4$, finally adding the filter paper and completing the titration.

Phosphorus. 20 c.c. of blood were pipetted into a 250 c. c. beaker, 10 c. c. of $Mg(NO_3)_2$ solution (1000 gms. $Mg(NO_3)_2.6H_2O$ per liter) added, the material evaporated to dryness, ignited below dull redness in the muffle, the residue taken up in dilute HCl, filtered, and washed. Phosphorus was determined as outlined in Methods of Analysis (8a).

Chlorine. 10 c.c. of blood were pipetted into a 7 cm. porcelain dish, dried, and ignited as outlined under the determination of calcium. This ash was taken up with hot water, made faintly acid with dilute HNO_3, filtered, washed, and 1 c. c. of concentrated HNO_3 added. Chlorine was determined as outlined in Methods of Analysis (8b).

Sodium and Potassium. 10 c. c. of blood were pipetted into a 7 cm. porcelain dish, dried, and ignited as outlined under the determination of calcium. The residue was taken up in dilute HCl, filtered, and washed. Sodium and potassium were determined as outlined in Methods of Analysis (8c).

Plasma. The analysis of plasma was followed through as outlined under the analysis of blood.

Table II

MINERAL CONSTITUENTS OF BLOOD IN MILLIGRAMS PER 100 C.C.

Sample No.	Phosphorus	Calcium	Sodium	Potassium	Chlorine
1	18.72	9.88	267.44	50.83	297.47
2	20.32	9.60	276.49	51.40	304.73
3	17.05	8.80	283.65	38.36	264.82
4	22.10	9.69	269.64	37.13	268.45
5	25.00	9.59	256.51	71.04	250.32
6	20.20	8.27	278.71	51.40	277.52
7	24.07	9.97	272.65	48.19	281.15
8	24.07	7.67	263.54	58.17	302.91
9	18.67	7.82	257.94	53.80	270.26
10	23.44	10.74	241.31	58.75	253.94
11	21.06	7.81	275.28	32.83	233.99
12	23.03	7.55	269.64	34.17	214.04
13	21.78	9.87	270.61	43.64	301.10
14	18.88	8.53	268.08	50.24	288.40
15	13.99	8.28	250.00	65.84	273.89
16	18.88	10.31	256.59	52.64	290.22

Table III

RATIOS OF THE PER CENT OF THE MINERAL CONSTITUENTS OF BLOOD

Sample No.	P/Ca	Na/Ca	K/Ca	Na/K	(Na & K)/Ca
1	1.89	27.1	5.14	5.26	32.2
2	2.12	28.8	5.35	5.38	34.2
3	1.94	32.2	4.36	7.39	36.6
4	2.28	27.8	3.83	7.26	31.7
5	2.60	26.7	7.41	3.61	34.2
6	2.44	33.7	6.22	5.42	39.9
7	2.41	27.3	4.83	5.66	32.2
8	3.14	34.4	7.58	4.53	41.9
9	2.39	33.0	6.88	4.79	39.9
10	2.18	22.5	5.47	4.11	27.9
11	2.70	35.2	4.20	8.39	39.5
12	3.05	35.7	4.53	7.89	40.2
13	2.21	27.4	4.42	6.20	31.8
14	2.21	31.4	5.89	5.34	37.3
15	1.69	30.2	7.95	3.80	38.1
16	1.83	24.9	5.11	4.87	30.0

Table IV

RATIOS OF THE CHEMICAL EQUIVALENTS OF THE MINERAL CONSTITUENTS OF BLOOD

Sample No.	PO_4/Ca	Na/Ca	K/Ca	Na/K	(Na&K)/Ca
1	3.66	23.6	2.63	8.94	26.2
2	4.11	25.1	2.74	9.15	27.8
3	3.76	28.0	2.23	12.56	30.2
4	4.42	24.2	1.96	12.34	26.2
5	5.04	23.3	3.79	6.14	27.1
6	4.73	29.4	3.18	9.21	32.6
7	4.67	23.8	2.47	9.62	26.3
8	6.08	30.0	3.88	7.70	33.9
9	4.63	28.7	3.52	8.14	32.2
10	4.22	19.6	2.80	6.99	22.4
11	5.23	30.7	2.15	13.26	32.9
12	5.91	31.1	2.32	12.41	33.4
13	4.28	23.9	2.26	10.54	26.2
14	4.28	27.3	3.02	9.08	30.3
15	3.27	26.3	4.07	6.46	30.4
16	3.54	21.7	2.62	8.28	24.3

Table V

MINERAL CONSTITUENTS OF PLASMA IN MILLIGRAMS PER 100 C.C.

Sample No.	Phosphorus	Calcium	Sodium	Potassium
4	15.14	12.47	323.49	23.56
5	17.64	12.32	343.23	31.85
9	16.60	11.90	328.19	15.84
10	15.82	13.79	341.37	24.92

Table VI

RATIOS OF THE PER CENT OF THE MINERAL CONSTITUENTS OF PLASMA

Sample No.	P/Ca	Na/Ca	K/Ca	Na/K	(Na&K)/Ca
4	1.21	25.9	1.89	1.37	27.8
5	1.43	27.9	2.59	1.08	30.4
9	1.39	27.6	1.33	2.07	28.9
10	1.15	24.8	1.81	1.37	26.6

Table VII

RATIOS OF THE CHEMICAL EQUIVALENTS OF THE MINERAL CONSTITUENTS OF PLASMA

Sample No.	PO_4/Ca	Na/Ca	K/Ca	Na/K	(Na&K)/Ca
4	2.34	22.6	0.968	2.33	23.6
5	2.77	24.3	1.330	1.84	25.6
9	2.69	24.0	0.681	3.52	24.7
10	2.23	21.6	0.927	2.33	22.5

Muscle Tissue (Longissimus Dorsi).

Preparation of sample for the determination of Calcium, Magnesium, Sodium, and Potassium. A 105 gram portion of the sample was weighed into a 12 cm. porcelain dish, spread evenly over the inner surface, and dried in the same manner as outlined for the determination of calcium on blood except that it was possible to raise the temperature more rapidly. This material was charred carefully and ignited as outlined under the determination of calcium on blood. The ash was taken up in dilute HCl, filtered, and completely washed into a volumetric flask. An aliquot of the filtrate, equivalent to 5 grams of sample, was measured out for the determination of sodium and potassium. The remaining filtrate, equivalent to 100 grams of sample, was taken for the determination of calcium and magnesium.

Calcium. Calcium was determined as outlined under the analysis of blood.

Magnesium. Magnesium was determined in the filtrate from the determination of calcium as outlined in Methods of Analysis (8d).

Sodium and Potassium. Sodium and potassium were determined as outlined under the analysis of blood.

Phosphorus. Phosphorus was determined on a 1.5-3.0 gram portion of the sample as outlined under the analysis

of blood with the following notes: The material was taken almost to dryness with repeated applications of $MgNO_3$ solution or concentrated HNO_3. The precaution was taken each time to wash down the sides of the beaker and thoroughly moisten all of the material with the reagent. The difficulty normally encountered of charring or rapid combustion was hereby overcome upon ignition of the material in the muffle.

The procedures for the determinations of moisture, fat, ash, and protein are those in use for the past several years by W. L. Latshaw of this station.

Moisture. A 3 to 5 gram portion of the sample was spread in a thin layer over the inner surface of a 7 cm. porcelain dish, placed in a vacuum oven, and partially dried at a pressure of 75 m. m. of Hg and a temperature of 60 degrees C. for four hours. The dish containing the sample was then removed to a vacuum desiccator and dried over concentrated sulfuric acid to constant weight.

Ash. The material remaining from the determination of moisture was completely ignited below dull redness in the muffle, removed, placed in a desiccator, allowed to cool, and then weighed.

Fat (Ether Extract). A 3 to 5 gram portion of the sample was spread in a thin layer over the surface of a thin

sheet of fat-free absorbent cotton, then rolled, placed in an extraction thimble, and dried along with the sample for moisture. This dried sample was then extracted 72 hours with anhydrous ether, otherwise the procedure was that outlined in Methods of Analysis (8e).

Protein. A 2 to 3 gram portion of the sample was placed in an 800 c. c. Kjeldahl flask, 18 grams of digestion mixture (HgO = 80 grams, $CuSO_4$ = 16 grams, and K_2SO_4 = 1904 grams) and 62½ c.c. of concentrated H_2SO_4 were added. The material was digested for three hours, cooled, and 400 c. c. of water added, otherwise the procedure was that outlined in Methods of Analysis (8f).

Table VIII

CONSTITUENTS OF MUSCLE TISSUE
(LONGISSIMUS DORSI) IN PER CENT

Sample No.	Water	Fat	Protein	Sodium	Potassium
1	70.95	5.19	22.34	0.082	0.312
2	70.17	6.36	22.00	0.081	0.343
3	73.01	4.08	21.38	0.066	0.324
4	72.55	4.19	21.73	0.070	0.324
5	71.11	6.37	21.73	0.057	0.303
6	72.44	5.79	21.72	0.056	0.320
7	72.65	2.17	23.56	0.073	0.323
8	72.94	2.70	22.44	0.073	0.333
9	70.64	6.08	21.47	0.057	0.355
10	74.09	3.00	22.13	0.051	0.371
11	75.09	1.78	22.25	0.069	0.361
12	74.79	1.95	22.56	0.069	0.355
13	74.28	1.33	22.78	0.052	0.370
14	75.07	2.49	21.87	0.065	0.332
15	75.34	0.71	22.53	0.076	0.363
16	75.24	0.78	21.88	0.068	0.341
17	72.63	5.11	22.44	0.069	0.323
18	71.93	5.40	22.78	0.069	0.337

Table VIII (cont)

Sample No.	Calcium	Magnesium	Phosphorus	Ash
1	0.00536	0.0168	0.224	1.21
2	0.00653	0.0236	0.222	1.12
3	0.00603	0.0258	0.214	1.16
4	0.00541	0.0209	0.209	1.13
5	0.00580	0.0247	0.218	1.09
6	0.00642	0.0236	0.214	1.07
7	0.00635	0.0280	0.228	1.21
8	0.00531	0.0262	0.226	1.14
9	0.00629	0.0236	0.216	1.07
10	0.00557	0.0246	0.229	1.15
11	0.00546	0.0247	0.225	1.11
12	0.00609	0.0243	0.220	1.12
13	0.00682	0.0263	0.232	1.16
14	0.00700	0.0271	0.209	1.08
15	0.00988	0.0282	0.219	1.12
16	0.00707	0.0279	0.218	1.10
17	0.00390	0.0237	0.215	1.12
18	0.00539	0.0250	0.211	1.08

Table IX

CONSTITUENTS OF MUSCLE TISSUE ON THE FAT-FREE BASIS IN PER CENT

Sample No.	Water	Protein	Sodium	Potassium
1	74.83	23.56	0.086	0.329
2	74.93	23.49	0.086	0.366
3	76.11	22.29	0.069	0.338
4	75.72	22.68	0.073	0.338
5	75.95	23.21	0.061	0.324
6	76.84	23.04	0.059	0.339
7	74.26	24.08	0.075	0.330
8	74.96	23.06	0.075	0.342
9	75.21	22.86	0.061	0.378
10	76.38	22.81	0.053	0.382
11	76.45	22.65	0.070	0.368
12	76.27	23.00	0.070	0.362
13	75.28	23.09	0.053	0.375
14	76.99	22.43	0.067	0.340
15	75.87	22.69	0.077	0.366
16	75.83	22.05	0.069	0.344
17	76.54	23.62	0.073	0.340
18	76.03	24.08	0.073	0.356

Table IX (cont)

Sample No.	Calcium	Magnesium	Phosphorus	Ash
1	0.00565	0.0177	0.236	1.28
2	0.00697	0.0252	0.237	1.20
3	0.00629	0.0269	0.223	1.21
4	0.00565	0.0218	0.218	1.18
5	0.00619	0.0264	0.233	1.16
6	0.00681	0.0250	0.227	1.13
7	0.00649	0.0286	0.233	1.24
8	0.00546	0.0269	0.232	1.17
9	0.00670	0.0251	0.230	1.14
10	0.00574	0.0254	0.236	1.19
11	0.00556	0.0251	0.229	1.13
12	0.00621	0.0248	0.224	1.14
13	0.00691	0.0267	0.235	1.18
14	0.00718	0.0278	0.214	1.11
15	0.00995	0.0284	0.221	1.13
16	0.00713	0.0281	0.220	1.11
17	0.00411	0.0250	0.227	1.18
18	0.00570	0.0264	0.223	1.14

Table X

RATIOS OF THE PER CENT OF THE MINERAL CONSTITUENTS OF MUSCLE TISSUE

Sample No.	P/Ca	Na/Ca	K/Ca	Na/K
1	41.8	15.30	58.2	0.263
2	34.0	12.40	52.5	0.236
3	35.5	10.95	53.7	0.204
4	38.6	12.94	59.9	0.216
5	37.6	9.83	52.2	0.188
6	33.3	8.72	49.8	0.175
7	35.9	11.50	50.9	0.226
8	42.6	13.75	62.7	0.219
9	34.3	9.06	56.4	0.161
10	41.1	9.16	66.6	0.137
11	41.2	12.64	66.1	0.191
12	36.1	11.33	58.3	0.194
13	34.0	7.62	54.3	0.141
14	29.9	9.29	47.4	0.196
15	22.2	7.69	36.7	0.209
16	30.8	9.62	48.2	0.199
17	55.1	17.69	82.8	0.214
18	39.1	12.80	62.5	0.205

Table X (cont)

Sample No.	(Na&K)/Ca	Mg/Ca	(Na&K)/(Ca&Mg)
1	73.5	3.13	17.8
2	64.9	3.61	14.1
3	64.7	4.28	12.3
4	72.8	3.86	15.0
5	62.1	4.26	11.8
6	58.6	3.68	12.5
7	62.4	4.41	11.5
8	76.5	4.93	12.9
9	65.5	3.75	13.8
10	75.8	4.42	14.0
11	78.8	4.52	14.3
12	69.6	3.99	14.0
13	61.9	3.86	12.7
14	56.7	3.87	11.6
15	44.4	2.85	11.5
16	57.9	3.95	11.7
17	100.5	6.08	14.2
18	75.3	4.64	13.4

Table XI

RATIOS OF THE CHEMICAL EQUIVALENTS OF THE MINERAL CONSTITUENTS OF MUSCLE TISSUE

Sample No.	PO_4/Ca	Na/Ca	K/Ca	Na/K
1	81.0	13.32	29.8	0.447
2	65.9	10.80	26.9	0.401
3	68.8	9.54	27.5	0.347
4	74.8	11.27	30.7	0.367
5	72.8	8.56	26.7	0.320
6	64.5	7.60	25.5	0.298
7	69.5	10.02	26.1	0.384
8	82.5	11.98	32.1	0.372
9	66.4	7.89	28.9	0.274
10	79.6	7.98	34.1	0.233
11	79.8	11.01	33.8	0.325
12	69.9	9.87	29.8	0.330
13	65.9	6.64	27.8	0.240
14	57.9	8.09	24.3	0.333
15	43.0	6.70	18.8	0.355
16	59.7	8.38	24.7	0.338
17	106.7	15.41	42.4	0.364
18	75.7	11.15	32.0	0.349

Table XI (cont)

Sample No.	(Na&K)/Ca	Mg/Ca	(Na&K)/(Ca&Mg)
1	43.1	5.16	7.00
2	37.7	5.95	5.44
3	37.0	7.05	4.61
4	42.0	6.36	5.69
5	35.3	7.02	4.41
6	33.1	6.06	4.69
7	36.1	7.26	4.36
8	44.1	8.12	4.83
9	36.8	6.18	5.14
10	42.1	7.28	5.09
11	44.8	7.44	5.32
12	39.7	6.57	5.25
13	34.4	6.36	4.69
14	32.4	6.37	4.39
15	25.5	4.69	4.48
16	33.1	6.51	4.42
17	57.8	10.01	5.24
18	43.2	7.64	4.99

Adipose Tissue. The procedures for all determinations made on adipose tissue are those in use for the past several years by W. L. Latshaw of this station.

Preparation of sample for the determination of Calcium, Sodium, and Potassium. A 50 gram portion of the fatty tissue was placed in a 12 cm. porcelain dish and dried in an air oven at a temperature of 110 degrees C. for about sixteen hours. The sample was then removed to a hot plate (low heat), a wick of ashless filter paper inserted in the melted fat, and lighted. The charred mass remaining from this preliminary burning was then placed in a slightly warm muffle and ignited at a temperature just below dull redness. The ash was dissolved in dilute HCl, filtered, and thoroughly washed into a volumetric flask.

Calcium. One half of the filtrate from above, equivalent to 25 grams of sample, was taken for the determination of calcium as outlined in Methods of Analysis (8g), except that N/50 $KMnO_4$ was used in place of N/10 as directed.

Sodium and Potassium. The remaining one half of the filtrate from above, equivalent to 25 grams of sample, was taken for the determination of sodium and potassium as outlined under the analysis of blood.

Phosphorus. Phosphorus was determined on a 4 to 5 gram portion of the fatty tissue as outlined in the analysis of lean tissue.

Moisture. A 2 to 5 gram portion of the sample was dried as outlined in the analysis of lean tissue.

Ash. The material remaining from the determination of moisture was completely ignited at a temperature below dull redness with the same precautions as given in the preparation of sample in the determinations of calcium, sodium, and potassium. The porcelain dish containing the ash was then removed from the muffle, cooled in a desiccator, and weighed.

Fat (Ether Extract). A 2 to 2½ gram portion of the sample was dried and extracted as outlined in the analysis of lean tissues.

Protein. Protein was determined on a 2 to 2½ gram portion of the sample as outlined in the analysis of lean tissues.

Table XII

CONSTITUENTS OF ADIPOSE TISSUE IN PER CENT

Sample No.	Water	Fat	Protein	Sodium
1	12.27	84.08	3.25	0.031
2	11.97	84.44	3.59	0.026
3	12.19	84.59	3.43	0.031
4	10.90	86.53	2.84	0.029
5	10.45	87.23	2.56	0.027
6	10.69	85.89	3.97	0.030
7	11.74	84.70	3.40	0.029
8	10.80	85.92	2.91	0.024
9	11.51	85.19	3.40	0.031
10	11.04	85.11	2.93	0.028
11	14.34	79.14	6.56	0.038
12	16.89	74.79	8.17	0.042
13	11.40	84.17	4.22	0.029
14	15.39	80.48	4.78	0.039
15	17.10	76.60	5.53	0.054
16	12.87	81.48	4.19	0.034

Table XII (cont)

Sample No.	Potassium	Calcium	Phosphorus	Ash
1	0.038	0.0255	0.037	0.22
2	0.035	0.0228	0.036	0.24
3	0.040	0.0219	0.037	0.22
4	0.034	0.0202	0.034	0.31
5	0.032	0.0178	0.036	0.23
6	0.033	0.0197	0.031	0.20
7	0.030	0.0210	0.033	0.20
8	0.034	0.0222	0.032	0.26
9	0.037	0.0273	0.042	0.30
10	0.036	0.0237	0.039	0.28
11	0.052	0.0277	0.050	0.29
12	0.060	0.0301	0.054	0.33
13	0.033	0.0240	0.035	0.24
14	0.042	0.0317	0.042	0.27
15	0.054	0.0271	0.053	0.34
16	0.047	0.0149	0.038	0.28

Table XIII

CONSTITUENTS OF ADIPOSE TISSUE ON THE FAT-FREE BASIS IN PER CENT

Sample No.	Water	Protein	Sodium	Potassium
1	77.07	20.41	0.193	0.239
2	76.93	23.07	0.167	0.225
3	79.10	22.26	0.201	0.260
4	80.92	21.08	0.215	0.252
5	81.83	20.05	0.211	0.251
6	75.76	28.14	0.213	0.234
7	76.73	22.22	0.190	0.196
8	76.70	20.67	0.170	0.241
9	77.72	22.96	0.209	0.250
10	74.14	19.68	0.188	0.242
11	68.74	31.45	0.182	0.249
12	67.00	32.41	0.167	0.238
13	72.01	26.66	0.183	0.208
14	78.84	24.49	0.200	0.215
15	73.08	23.63	0.231	0.231
16	69.49	22.62	0.184	0.254

Table XIII (cont)

Sample No.	Calcium	Phosphorus	Ash
1	0.160	0.232	1.38
2	0.147	0.231	1.54
3	0.142	0.240	1.43
4	0.150	0.252	2.30
5	0.139	0.282	1.80
6	0.140	0.220	1.42
7	0.137	0.216	1.31
8	0.158	0.227	1.85
9	0.184	0.284	2.03
10	0.159	0.262	1.88
11	0.133	0.240	1.39
12	0.119	0.214	1.31
13	0.152	0.221	1.52
14	0.162	0.215	1.38
15	0.116	0.226	1.45
16	0.080	0.205	1.51

Table XIV

RATIOS OF THE PER CENT OF THE MINERAL CONSTITUENTS OF ADIPOSE TISSUE

Sample No.	P/Ca	Na/Ca	K/Ca	Na/K	(Na&K)/Ca
1	1.45	1.22	1.49	0.82	2.71
2	1.59	1.14	1.54	0.74	2.68
3	1.69	1.42	1.83	0.78	3.24
4	1.68	1.44	1.68	0.85	3.12
5	2.02	1.52	1.80	0.84	3.31
6	1.57	1.52	1.68	0.91	3.20
7	1.57	1.38	1.43	0.97	2.81
8	1.44	1.08	1.53	0.71	2.61
9	1.54	1.14	1.36	0.84	2.49
10	1.65	1.18	1.52	0.78	2.70
11	1.81	1.37	1.88	0.73	3.25
12	1.79	1.40	1.99	0.70	3.39
13	1.46	1.21	1.38	0.88	2.58
14	1.32	1.23	1.32	0.93	2.56
15	1.96	1.99	1.99	1.00	3.99
16	2.55	2.28	3.15	0.72	5.44

Table XV

RATIOS OF THE CHEMICAL EQUIVALENTS OF THE MINERAL CONSTITUENTS OF ADIPOSE TISSUE

Sample No.	PO_4/Ca	Na/Ca	K/Ca	Na/K	(Na&K)/Ca
1	2.81	1.06	0.763	1.39	1.82
2	3.08	0.99	0.788	1.26	1.78
3	3.27	1.24	0.937	1.33	2.18
4	3.25	1.25	0.860	1.45	2.11
5	3.91	1.32	0.922	1.43	2.24
6	3.04	1.32	0.860	1.55	2.18
7	3.04	1.20	0.732	1.65	1.93
8	2.79	0.94	0.783	1.21	1.72
9	2.98	0.99	0.696	1.43	1.69
10	3.20	1.03	0.778	1.33	1.81
11	3.51	1.19	0.963	1.24	2.15
12	3.47	1.22	1.019	1.19	2.24
13	2.83	1.05	0.707	1.50	1.76
14	2.56	1.07	0.676	1.58	1.75
15	3.80	1.73	1.019	1.70	2.75
16	4.94	1.99	1.613	1.22	3.60

Shrinkage and Ripening Tests

On twelve of the animals, the right side was stored in the cooler at 35 degrees F. for approximately two weeks from the time of slaughter. At the end of this period, the sixth to twelfth ribs inclusive were cut out, and placed in the cooler again for shrinkage and ripening tests. The shrinkage was determined on this cut (sixth to twelfth ribs inclusive) for a period of storage of twenty days. That is, the rib cut was weighed immediately after being cut out from the right side, placed in the cooler, and weighed again at the end of twenty days.

Observations were then made as to the condition of the muscle and adipose tissues. The Department of Home Economics conducted cooking tests on this ripened sample the same as on the unripened sample.

Table XVI

GRADING CHART USED FOR FRESH AND RIPENED MEAT (COOKED)*

Factor	Phase	7	6	5
Aroma	Intensity	Very pronounced	Pronounced	Moderately pronounced
	Desirability	Very desirable	Desirable	Moderately desirable
Texture	Intensity	Very fine	Fine	Moderately fine
Flavor of fat	Intensity	Very pronounced	Pronounced	Moderately pronounced
	Desirability	Very desirable	Desirable	Moderately desirable
Flavor of lean	Intensity	Very pronounced	Pronounced	Moderately pronounced
	Desirability	Very desirable	Desirable	Moderately desirable
Tenderness	Intensity	Very tender	Tender	Moderately tender
Juiciness	Quantity of juice	Very juicy	Juicy	Moderately juicy
	Quality of juice	Very rich	Rich	Moderately rich

* Department of Home Economics (Dr. Kramer)

Table XVI (cont)

4	3	2	1
Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible
Slightly desirable	Neutral	Slightly undesirable	Undesirable
Slightly coarse	Coarse	Very coarse	Extremely coarse
Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible
Slightly desirable	Neutral	Slightly undesirable	Undesirable
Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible
Slightly desirable	Neutral	Slightly undesirable	Undesirable
Slightly tough	Tough	Very tough	Extremely tough
Slightly dry	Dry	Very dry	Extremely dry
Slightly rich	Perceptible	Slightly perceptible	Imperceptible

Table XVII

PALATABILITY OF FRESH RIB ROAST (COOKED)*

Sample No.	Aroma Int:Des	Texture Int	Flavor of fat Int:Des
1	4.7:5.8	4.7	5.0:5.7
2	4.2:6.0	4.2	4.7:6.2
3	5.3:5.6	4.9	4.5:5.7
4	5.4:6.3	4.5	5.0:5.9
5	5.1:5.7	4.0	4.9:6.0
6	5.2:6.0	5.2	5.2:5.8
7	4.0:6.0	4.3	4.7:5.5
8	4.7:5.2	4.7	4.4:5.0
9	4.9:6.1	4.6	5.2:6.1
10	5.1:6.1	5.3	5.3:6.3
11	4.4:5.3	4.6	4.3:4.9
12	4.5:4.7	4.5	4.3:3.2
13	4.4:5.1	5.0	5.3:4.9
14	4.6:3.9	5.1	4.9:2.9
15	4.4:5.1	4.9	4.7:5.0
16	4.4:5.9	4.9	4.6:5.7
17	5.2:6.2	4.7	4.5:6.2
18	5.3:5.5	4.8	5.3:6.2

* Department of Home Economics (Dr. Kramer)

Table XVII (cont)

Sample No.	Flavor of lean Int:Des	Tenderness Int	Juiciness Quant:Qual
1	5.2:6.3	6.3	5.8:5.7
2	5.2:6.2	6.0	5.3:5.3
3	5.0:6.1	6.1	6.0:5.8
4	5.5:6.3	6.0	6.6:6.2
5	5.4:6.4	6.1	6.1:5.6
6	5.2:6.2	5.5	5.5:5.7
7	5.0:5.4	5.7	5.0:4.4
8	4.3:5.5	5.2	4.7:4.3
9	5.5:6.3	6.3	6.3:5.5
10	5.6:6.5	6.4	6.6:6.3
11	4.7:5.7	5.0	5.0:4.7
12	4.2:4.0	6.2	5.0:4.5
13	4.7:5.6	5.1	5.0:4.4
14	5.2:4.3	4.3	4.6:4.3
15	5.2:6.0	5.3	5.6:5.3
16	5.1:6.1	6.2	5.3:5.1
17	5.0:5.3	6.0	6.3:5.2
18	5.5:5.5	5.7	6.7:6.0

Table XVIII

PALATABILITY OF RIPENED RIB ROAST (COOKED)*

Sample No.	Aroma Int:Des	Texture Int	Flavor of fat Int:Des
1	5.1:5.0	4.7	4.9:5.6
2	4.9:5.7	5.1	4.7:5.6
3	5.1:4.9	5.1	4.7:5.6
6	4.9:4.7	4.4	4.7:4.9
7	5.1:5.7	4.3	4.3:4.6
8	5.0:4.4	4.7	5.0:3.9
11	4.6:5.4	4.8	4.9:4.9
12	4.9:4.0	5.1	4.3:3.7
13	4.3:3.8	5.3	4.8:2.0
14	inedible - unfit to eat		
15	5.0:3.2	4.5	4.7:2.7
16	4.5:4.8	5.3	4.5:3.5

* Department of Home Economics (Dr. Kramer)

Table XVIII (cont)

Sample No.	Flavor of lean Int:Des	Tenderness Int	Juiciness Quant:Qual
1	5.6:6.1	6.2	5.9:6.0
2	5.1:5.9	6.1	6.0:6.0
3	5.3:6.0	6.0	5.9:5.6
6	5.1.5.9	5.3	5.7:5.3
7	5.0:5.3	6.1	5.9:5.6
8	4.3:5.5	5.0	4.9:5.0
11	5.0:5.7	6.1	5.9:5.1
12	4.6:5.3	5.6	4.3:3.7
13	4.8:3.5	5.0	4.3:3.8
14	inedible - unfit to eat		
15	5.3:2.2	4.4	4.3:3.2
16	4.8:3.8	4.8	4.8:4.5

Table XIX

SHRINKAGE OF MEAT IN PER CENT*

Sample No.	Shrinkage 120 hours (dressed carcass)	Shrinkage 20 days (right rib cut, 6th to 12th)	Shrinkage upon Fresh (left rib cut, 6th to 8th)	Cooking Ripened (right rib cut 6th to 8th)
1	1.675	4.2	7.3	7.5
2	1.547	4.4	7.5	8.1
3	1.964	4.0	8.5	7.7
4	1.725		8.1	
5	1.116		7.9	
6	2.308	4.2	7.6	8.7
7	1.571	4.2	9.2	10.1
8	1.879	4.2	9.3	8.7
9	1.397		8.5	
10	1.558		7.8	
11		5.1	8.6	8.8
12		6.8	9.6	8.8
13		7.3	8.2	7.1
14		9.0	10.7	8.5
15		8.5	7.7	8.6
16		7.3	9.0	8.5
17			6.4	
18			6.0	

* Shrinkage upon ripening obtained from the Department of Animal Husbandry (Mackintosh, D. L. and Bratzler, L. J.) and the Department of Chemistry (Latshaw, W. L.). Shrinkage upon cooking obtained from the Department of Home Economics (Dr. Kramer).

Table XX

PHYSICAL ANALYSIS OF RIB CUTS

Sample No.	Per cent of left fresh rib cut		Weight of right rib cut before ripening (grams)
	Adipose tissue (subcutaneous)	Musclar tissue	
1	34.90	51.02	10,030.
2	29.25	57.31	11,400.
3	27.85	57.66	10,659.
4	30.43	55.43	
5	36.62	51.33	
6	28.00	57.35	9,773.
7	28.53	57.59	11,163.
8	29.58	56.36	10,688.
9	29.52	55.57	
10	29.39	56.06	
11	16.28	64.17	7,705.
12	11.41	66.55	7,000.
13	20.81	58.00	5,983.
14	22.92	57.40	7,140.
15	28.32	52.27	5,795.
16	28.73	50.61	6,442.

DISCUSSIONS OF RESULTS

Relation Between the Composition of Blood, Muscle Tissue, and Adipose Tissue

From the few samples analyzed the variations in the chemical composition of the whole blood do not seem to be reflected in the composition of either muscle or adipose tissue. Neither does there seem to be any correlation between the mineral composition of the muscle and adipose tissues. This is quite clearly shown by results obtained on sample Nos. 5 and 15. In the results for the analysis of blood (table 2) sample No. 5 contains the highest amount of total phosphorus of any of the samples, while sample No. 15 contains the lowest. In the adipose tissue (table 13) sample No. 5 is one of the highest in per cent of phosphorus while sample No. 15 contains about an average amount of phosphorus. In the muscle tissue (table 9) sample No. 5 is slightly above the average and No. 15 is next to the highest in phosphorus content. All of the other elements show this same lack of correlation.

This failure of the composition of the blood to be reflected in the composition of the other tissues may be explained in a measure because of the fact that in all cases studied, the composition of the blood fell within normal

limits. It is possible that if feeding practices were followed which would cause one of the mineral elements to be abnormally high or low in the blood, that this would be reflected in the composition of the other body tissues.

Relation Between the Composition and the Palatability of the Fresh Rib Roast

There seems to be no relation between the mineral composition of the meat and the palatability of the fresh cooked sample (table 17).

Relation Between the Composition and the Palatability of the Ripened Rib Roast (Keeping Qualities)

As indicated in the introduction, one of the reasons for undertaking this study was to see whether the poor qualities of the meat produced by animals grazing on herbage with unbalanced mineral content could be accounted for by an unbalanced mineral ratio in the meat. It was thought that the poor keeping qualities might be due to an increase in permeability resulting from an abnormally high amount of monovalent elements (sodium and potassium) compared to the amount of divalent elements (calcium and magnesium). The keeping qualities of the meat (table 18) from the animals on low phosphorus herbage were very poor as was expected. Of the two samples obtained from the animals on low phosphorus

herbage, one (No. 14) spoiled during the ripening process so that it was unfit for consumption. The other sample (No. 13) from this lot was of very poor quality at the end of the ripening period. This sample (No. 14) which spoiled during the ripening period, instead of having a high ratio of monovalent to di-valent minerals, was actually next to the lowest of eighteen samples tested both in the muscle tissue (table 10) and adipose tissue (table 14). The sample showing the highest ratio of monovalent to divalent minerals in the muscle tissue (table 10) was No. 1 which was one of the steers full-fed in the dry lot. This sample showed excellent keeping qualities. These results seem to indicate that there is little if any relation between the ratios of monovalent to divalent minerals in the meat and its keeping qualities.

In this connection it should be remembered that the results for the mineral analyses reported on these samples were made on the ash; for this reason the analyses give no indications as to the amount of any element which is combined with the organic material and that which is in the inorganic form. If it is the minerals that are combined in the organic form that have to do with permeability, it is possible that were methods devised to determine the amount of the mineral elements in this form, that some correlation

might be found between the keeping qualities of the meat and this organic form of the mineral.

Relation of Composition to Shrinkage

Since the shrinkage (loss of water) would depend to a considerable extent on the relative surface area of the meat and also to the per cent of this surface area covered by adipose tissue, it is evident that no direct comparison can be made between the larger cuts with relatively greater amounts of fat, obtained from the full-fed animals, and the smaller cuts obtained from the grass animals (table 20). In comparing the ten fairly uniform samples from the full-fed animals there seems to be no relation between loss of weight during ripening (table 19) and the mineral composition.

In the case of the smaller cuts from the grass-fed animals (table 20), it will be seen that the two animals (samples Nos. 13-14) that received the low phosphorus herbage lost much more weight during the ripening period (table 19) than the two animals (sample Nos. 11-12) which grazed in the pasture where there was no mineral deficiency. According to popular belief the keeping qualities of the meat as well as the shrinkage during ripening is limited almost entirely by the amount of fat covering the cut. If this

popular belief were true, then sample Nos. 13 and 14 from the animals receiving the low phosphorus herbage should have had higher keeping qualities than sample Nos. 11 and 12 from the animals on normal grass, for these samples on normal grass contained only 16.28 and 11.41 per cent of subcutaneous adipose tissue while sample Nos. 13 and 14 from animals on the phosphorus deficient grass contained 20.81 and 22.92 per cent of subcutaneous adipose tissue (table 20).

It is interesting to note that sample No. 14, which spoiled during the ripening process, showed the highest loss of water when the fresh portion was cooked (table 19). This high loss of water both upon ripening and cooking indicates that the water holding power of this sample of meat is different from that of the other samples. Just what causes this loose combination of water and tissue is difficult to explain.

The feeding of a limited amount of bone meal seemed to have very little effect on the quality of the meat produced, as samples 15 and 16 (tables 18 and 19) show about the same keeping qualities and shrinkage as did sample 13. Although samples 15 and 16 contained more fat (table 20), they were of lower quality (table 18) than samples 11 and 12 which were produced on normal grass. As in the case of the keeping

qualities of the meat, there appeared to be no direct correlation between the mineral composition of the samples and this loss of weight during cooking and ripening.

SUMMARY

1. Samples of blood from 16 animals were analyzed for phosphorus, calcium, sodium, potassium, and chlorine. Muscle tissue from these same animals was analyzed for water, fat, protein, ash, phosphorus, calcium, magnesium, sodium, and potassium. The adipose tissue from these animals was analyzed for water, fat, protein, ash, phosphorus, calcium, sodium, and potassium. Five of these animals were full-fed in the dry lot, five were full-fed on pasture, two were grazed on grass of normal mineral composition, two were grazed on grass of low phosphorus content, and two were grazed on grass of low phosphorus content, but were given a limited amount of bone meal.

The muscle tissue from two samples of meat commonly known as dark cutters, the method of feeding not known, was analyzed for water, fat, protein, ash, phosphorus, calcium, magnesium, sodium, and potassium.

2. Tables were prepared showing the percentage composition of these samples and the ratios of the various mineral constituents.

3. Tables were also included showing the palatability and keeping qualities of the meat which were determined in another experiment.

4. The ratios of the mineral composition to the palatability, keeping qualities, and shrinkage are discussed.

CONCLUSIONS

1. There seemed to be no correlation between the mineral constituents of meat and its palatability, shrinkage, and keeping qualities.

2. The poor keeping qualities of the meat from the animals receiving the low phosphorus herbage as compared to the meat from animals receiving herbage of normal mineral content indicates that the quality of the feed has a direct effect upon the quality of the meat.

3. More work is needed to determine just what characteristics of meat determine its keeping quality.

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