THE EFFECT OF PHOSPHORUS ON THE QUALITY OF MEAT

by

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INTRODUCTION

Meat is one of the most common food substances occurring in the diet of the average individual. Since meat is one of the most extensively commercialized economic commodities, one would expect that much research work had been done on it. On the contrary, very little of a fundamental nature has been done.

Kansas State College is one of the few places where work of this nature is being conducted. For the past ten years the experiment station has been carrying on research on the factors influencing the quality and palatability of meat. Since the amount of meat eaten today depends on the palatability, one can readily see why it is important to study factors influencing it. The keeping quality is a vital factor to the meat packing industry as well as to the retailer.

Some study has been done at the college on the mineral constituents of muscle tissue, blood, and adipose tissue, and their relation to the shrinkage, palatability, and keeping qualities of the meat. Some observations seem to show that the mineral composition has some effect on the

shrinkage and keeping quality.

Since the study of mineral constituents in muscle tissue has been undertaken, it is desirable to see what effect different levels of phosphorus fed beef animals might have on the shrinkage, palatability, and keeping quality of the meat, as well as the effect on the bones of the animals.

REVIEW OF LITERATURE

Very little work has been done on the effects of feeding various amounts of minerals on the composition and quality of meat, and as a result the source of material is limited. Much work has been done on the effect of such feeding on both blood and bones, but in no case was a correlation made between the blood, bones, and meat.

The only data available on the effects of mineral composition on the quality of meat is that which was done at this college (1). Mineral balance studies were made both on expressed juice and residual tissue of the muscle tissue. In the pressed juice the lowest P/Ca ratios occurred in the tissue yielding the least juice and the highest ratio occurred in the tissue yielding the most juice.

Work was also done on color of meat by use of oxidation potentials.

According to Mitchell and Hamilton (2), the greatest factor affecting quality of meat is muscular exercise. Any attempts to modify the composition of lean by varying the ration fed were not successful, because the cellular protoplasm is capable of maintaining its composition in the face of a varying food supply. Their results show that the animals which are exercised produce more tender meat.

Francis and Trowbridge (3) show that phosphorus is found chiefly in the muscular or connective tissue, and that very little phosphorus is found in fat. The flesh of a thin animal contains more soluble phosphorus than that of a fat animal. The quantity decreases with increasing fatness even when it is expressed on a fat free basis.

Chatfield (4) found that beef is extremely variable in its composition. In order to give a correct basis for composition every constituent is figured on a fat free basis. The grade or class of beef and the type of cut, as well as its proportion of lean meat, visible fat, and bone must be known if a close estimate of chemical composition is required.

Moulton (5) showed that the composition of animals

should be compared on a fat free basis in order to make apparent the effects of age or abnormal development. On this basis he found that mammals show a rapid decrease in relative water content and increase in protein and ash content from earliest life until the time chemical maturity is reached. At this time nearly constant composition is shown. As a result of calculation on a fat free basis, the fatness of the individual has no effect on the composition.

Henderson and Weakley (6) found that inorganic phosphorus in the blood can be more easily reduced than can calcium, by the rations fed to animals. They show that rations containing less than 0.2 percent phosphorus will decrease the amount of inorganic phosphorus in the blood; animals fed 0.131 percent phosphorus continued to grow as well as did normal animals even though blood calcium was much below normal; rations which contain less than 0.35 percent calcium or less than 0.2 percent phosphorus give bones low in ash and consequently low in calcium and phosphorus.

Grollman (7) found that the amount of inorganic phosphorus in the blood depends on the amount of calcium present. By addition of calcium chloride more of the inorganic

phosphorus becomes non filterable and by further addition made to disappear. The amount of protein bound calcium is proportional to the protein concentration.

ANIMALS USED IN EXPERIMENT

The animals used in this experiment were eight steers all of which were about the same size and quality. Numbers 67, 75, 127, and 146 were placed on a low phosphorus ration, while animals 11, 99, 131, and 248 received a high phosphorus ration. The quantity of feed for each pair of animals, aside from the phosphorus supplement, was the same. The ration of prairie hay, cane silage, and grain mixture, containing equal parts ground tapioca roots, barley, and hominy, supplemented with a low phosphorus blood meal, was fed the steers. The low phosphorus steers received only that phosphorus which was in the ration, about 7.5 grams per day. The high phosphorus steers received in addition mono calcium phosphate to bring the amount of phosphorus fed them up to a minimum of 15 grams per day. The ration was supplemented with calcium carbonate so that each steer received calcium and phosphorus in the ratio of 2-1. The animals were paired, one high and one low phosphorus steer

making up the pair. In this way, it was easy to see the effect of the feeds on the animals as they stood in the lot. They were allowed to run loose in the pen at intervals during the day. During the time they were free in the pen, they were muzzled to prevent them from licking the ground and as a result getting any phosphorus or calcium which the dirt might contain. At no time could the animals get any feed other than what was fed them.

The experiment was started January 6, 1936. September 9, 1936, four of the animals were killed. The numbers were 67, 99, 131, 146. None of these animals showed a great deal of effect by the rations fed them except that the low phosphorus animals showed a lack of appetite. As for the outward appearance, no appreciable difference could be seen.

The remaining four animals were kept on their diet until December 9. At this time, they were slaughtered. In these animals a decided difference was shown. On foot, numbers 127 and 75, the low phosphorus steers, were not active at all as compared with the high phosphorus ones. Their hind legs were badly bent and they dragged their feet when they walked. Number 127 seemed to be effected the more of the two. It seemed as though its legs would break

every step it took. On analysis of the blood, there was a decided difference in the amounts of inorganic phosphorus.

METHODS OF TAKING SAMPLES

Samples of blood for analysis were taken when the animals were killed. The jugular was cut and a beaker of blood was obtained. Before clotting, samples were taken for determination of hemoglobin. Then the blood was allowed to clot, centrifuged, and the remainder of the chemical analysis determined on the serum.

The animals were dressed, split, and placed in the cooler at 36° C. Samples of muscle for chemical analysis were taken from the section of ribs, 9-11, five days after the animals were killed. The muscle used was the eye muscle, or the longissimus dorsi muscle as it is sometimes called. It was separated from the fat and bone and was put through a grinder twice to ensure complete grinding. Then the sample was placed in a cold room and kept at -9° F until analysis was made.

Fat samples for analysis were obtained from the same section from which the eye muscle was obtained. It was dissected from the lean and bone and placed in a cold room

at -9° F until analysis was made.

Bones for chemical analysis were taken from the fifth and thirteenth rib. They were separated from the muscle tissue, scraped, weighed, and placed in an oven at about 100° C to dry. When dried to constant weight, they were extracted first with 95 percent alcohol for about 24 hours, then with ether for 8 hours. After this time, the bones were ground fine enough to pass through a 20 mesh sieve. From this samples were taken for chemical analysis.

Analyses were made in duplicate and where good checks were not obtained, the analysis was repeated. Table 1 gives the percent of each constituent of the rib as could best be separated by dissection. Each portion was weighed and from the weights of each, the percents were calculated. The percent lean is determined by subtracting the sum of the others from 100. Thus, any evaporation taking place is represented as lean.

Table 1

PHYSICAL ANALYSES OF RIB CUTS

Animal number	Level	Wt. rib gms.	Percent eye	Percent lean
67	L	2876	24.8	33.2
99	H	2760	21.8	35.2
146	L	2408	23.5	33.7
131	H	2873	24.1	27.7
75	L	3865	21.1	37.0
248	H	4393	19.9	37.7
127	L	3671	20.8	38.0
11	H	3862	18.8	37.0

Table 1 (cont.)

Animal number	Percent bone	Percent fat	Percent gristle
67	17.2	23.7	1.10
99	18.5	23.5	1.00
146	18.9	22.7	1.20
151	18.0	29.0	1.20
75	15.1	26.2	0.60
248	14.8	26.7	0.90
127	12.9	27.9	0.40
11	17.9	23.4	2.90

CHEMICAL ANALYSES

Blood

Hemoglobin. This was determined by the spectrophotometric method. One c.c. of whole blood was added to 60 c.c. of 0.1 percent sodium carbonate in a 100 c.c. volumetric flask. The solution was shaken in order to get complete mixing. Then 0.1 percent sodium carbonate was added to the mark and the solution again mixed well. The concentration was determined on the spectrophotometer. The wave length used was 542. The factor is 1.165 mg. per c.c.

Inorganic Phosphorus. This fraction of phosphorus was determined on serum, as was the remainder of blood analyses. The determination was made by using Koch's (8) colorimetric method. One c.c. of serum was added to 4 c.c. 10 percent trichloracetic acid. The solution was filtered immediately and two c.c. were taken for determination. To this were added 0.4 c.c. ammonium molybdate reagent, and 0.16 c.c. 1, 2, 4 aminonaphtholsulfonic acid reagent and 3 cc. water. This solution was allowed to

stand five minutes and compared against a standard containing 0.024 mg. P which had been treated the same as the unknown.

Lipoid Phosphorus. This type of phosphorus was determined by the method of Man and Peters (9), the only differences being that 8 c.c. of the filtrate were used, and the standard contained 0.24 mg. phosphorus.

Total Phosphorus. Determination was made on 0.5 c.c. serum by the method of Koch (10). Care must be taken so that the phosphorus will not be volatalized.

Calcium. The method used was different from that which has been previously used in this station project. A method developed by Wang (11), with a few modifications, was used. Two c.c. of serum were added to 8 c.c. 10 percent trichloracetic acid. According to Wang (11), this mixture should stand 30 minutes. According to results obtained, it was found that this time of standing was not necessary because the same results were obtained by filtering after allowing to stand three minutes. A great advantage of this calcium method was in the wash liquid (equal parts alcohol, ether, and water) used for the calcium oxalate precipitate. This wash liquid allowed the calcium oxalate to settle to the bottom of the calcium tube leaving

Table 2

BLOOD ANALYSES

Animal number	Level	Grams per 100 c.c. Hb.	Milligrams per 100 c.c. serum	
			Inorg. P	Lip. P
67	L	13.06	3.80	2.80
99	H	14.92	7.91	4.10
146	L	15.13	4.30	3.30
131	H	12.50	5.58	4.70
75	L	13.04	2.97	2.20
248	H	14.44	7.50	2.00
127	L	15.49	3.99	2.20
11	H	14.32	9.52	2.10

Table 2 (cont.)

Animal number	Milligrams per 100 c.c. serum		Inorg. P/Ca
	Total P	Ca	
67	8.00	12.90	0.294
99	13.20	11.95	0.600
146	9.68	15.00	0.286
131	10.50	12.69	0.440
75	6.80	14.58	0.204
248	9.92	12.77	0.588
127	8.16	14.34	0.278
11	12.08	13.61	0.698

none of the precipitate floating on top of the solution which would be poured off during the decantation.

Muscle Tissue

Protein. A 1-3 gram sample was analyzed according to the method of A. O. A. C. (12). Eighteen grams of digestion mixture (HgO = 80 gs., $CuSO_4$ = 16 gs., K_2SO_4 = 1904 gs.) and 62.5 c.c. concentrated sulfuric acid were added and the mixture digested. Care must be taken at the start of digestion or the sample will be lost. After digestion add 400 c.c. water. This mixture must be cooled to at least room temperature before the sodium hydroxide is added.

Moisture. A 1½-3 gram sample was spread over the inner surface of a 7 cm. porcelain dish and placed in a vacuum desiccator over concentrated sulfuric acid. Weight was taken from time to time until constant.

Ash. The dried residue from the moisture sample was placed in the muffle and heated below dull redness until white. It was then cooled in a desiccator, and weighed.

Ether Extract. A 2-5 gram sample was spread on a thin layer of fat free cotton, folded, and placed in an extrac-

tion thimble and dried in a vacuum desiccator over concentrated sulfuric acid as long as the moisture samples were dried. Then the sample was extracted with anhydrous ether on a Bailey Walker apparatus for 72 hours. The ether was recovered and the flasks were dried in a vacuum oven 30 minutes, placed in a desiccator, cooled, and weighed.

Ether Extractable Phosphorus. Ether extract was analyzed for phosphorus as was the muscle tissue, except that after digestion, the mixture was transferred to a 50 c.c. volumetric flask and made up to volume. Then 20 c.c. of this solution were used for analysis.

Phosphorus. A 1-3 gram sample was taken. One c.c. concentrated sulfuric acid was added and the mixture allowed to stand for one hour. Five c.c. concentrated nitric acid were added and the mixture placed on a hot plate on low heat. The addition of nitric acid was repeated until the solution remained colorless when white fumes of sulfur trioxide occurred. The digest was then transferred to a 100 c.c. volumetric flask, diluted to the mark with distilled water and mixed well. Eight c.c. of the solution were placed in a 100 c.c. volumetric flask, neutralized with 1-1 ammonia, and 10 c.c. ammonium molybdate and 4 c.c. 1, 2, 4 aminonaphthol sulfonic acid were added. The solution was

diluted to the mark, mixed, and compared against a standard which contained 0.32 mg. phosphorus prepared the same way.

Calcium. A 25 gram sample was taken for analysis and was treated according to the method of Stearns (13), the only difference being that the whole sample was used for the analysis. Five c.c. of concentrated sulfuric acid were added to the muscle and allowed to stand about an hour before nitric acid was added. After the sample was oxidized, it wss heated for some time to remove some of the sulfuric acid, as it interfered with the precipitation of calcium oxalate.

Table 3 (cont.)

Animal number	Moisture	Ash	Phosphorus	Calcium	P/Ca
67	74.58	1.11	0.175	0.00570	30.8
99	74.05	1.09	0.181	0.00784	23.1
146	74.53	1.08	0.177	0.00498	35.5
131	75.85	1.02	0.184	0.00800	23.0
75	72.85	0.95	0.175	0.00496	35.2
248	73.88	0.99	0.178	0.00532	33.5
127	72.95	1.04	0.178	0.00588	30.4
11	74.12	0.99	0.183	0.00611	30.0

Table 4

ANALYSIS OF RIBEYE IN PERCENT (FAT FREE BASIS)

Animal number	Level	Protein	Moisture	Ash
67	L	22.02	75.50	1.12
99	H	22.60	75.80	1.11
146	L	22.04	75.50	1.09
131	H	22.02	77.40	1.08
75	L	21.58	74.90	0.98
248	H	21.00	75.50	1.02
127	L	22.02	74.60	1.06
11	H	21.48	75.90	0.92

Table 4 (cont.)

Animal number	Phosphorus	Ether extractable phosphorus	Calcium	P/Ca
67	0.177	0.00175	0.000577	30.8
99	0.185	0.00146	0.000800	23.1
146	0.179	0.00169	0.000505	35.5
131	0.188	0.00116	0.000815	23.0
75	0.180	0.00193	0.000511	35.2
248	0.182	0.00130	0.000545	33.4
127	0.182	0.00112	0.000603	30.0
11	0.187	0.00230	0.000625	30.0

Adipose Tissue

Protein, Ether Extract, Moisture, Ash, and Phosphorus. The determinations for these were made as in ribeye.

Calcium. A 25 gram sample was placed in a silica dish, and heated in an oven at 100° C for several hours. It was then placed on a hot plate on low heat, a wick of filter paper placed in the melted fat and the wick lighted. This oxidized most of the organic matter. The dish was then

placed in a muffle below dull redness and heated until white, removed, cooled, and dissolved in 5 c.c. 1-1 hydrochloric acid. The solution was filtered and calcium was determined as in muscle tissue.

Table 5

ANALYSIS OF ADIPOSE TISSUE IN PERCENT

Animal number	Level	Protein	Ether extract	Moisture	Ash
67	L	11.28	64.32	24.78	0.49
99	H	10.35	69.70	19.86	0.45
146	L	12.56	58.20	28.20	0.43
131	H	9.09	69.10	20.70	0.40
75	L	6.44	78.91	14.31	0.13
248	H	4.07	87.70	8.73	0.14
127	L	4.32	84.85	11.21	0.19
11	H	4.50	84.40	11.57	0.20

Table 5 (cont.)

Animal number	Phosphorus	Calcium	P/Ca
67	0.0506	0.0223	2.27
99	0.0565	0.0421	1.34
146	0.0686	0.0216	3.17
131	0.0621	0.0321	1.93
75	0.0277	0.0096	2.91
248	0.0347	0.0112	2.20
127	0.0263	0.0117	2.25
11	0.0325	0.0137	2.39

Table 6

ANALYSIS ON ADIPOSE TISSUE IN PERCENT (FAT FREE BASIS)

Animal number	Level	Protein	Moisture	Ash	Phosphorus	Calcium	P/Ca
67	L	31.60	69.40	1.37	0.141	0.0625	2.26
99	H	34.20	65.50	1.48	0.186	0.1390	1.34
146	L	30.00	67.50	1.03	0.164	0.0517	3.17
131	H	29.40	67.00	1.29	0.201	0.1040	1.93
75	L	30.52	68.00	0.61	0.131	0.0455	2.91
248	H	33.05	70.90	1.23	0.205	0.0910	2.26
127	L	46.60	72.40	1.25	0.173	0.0772	2.25
11	H	43.50	72.70	1.25	0.210	0.0860	2.44

Pressed Juice from Ribeye

Volume. One hundred grams of ground ribeye were pressed to determine the volume of juice per sample. The muscle was mixed with filter paper pulp and placed in layers between filter papers in the cylinder. A felt pad was placed at each end. These precautions were taken in order to keep the tissue from squeezing out of the cylinder.

Phosphorus. Determination was made as in the whole muscle except that it did not require as much nitric acid to oxidize the sample.

Calcium. The method used for determination was the same as that used for muscle tissue.

Table 7

DATA ON JUICE FROM RIBEYE

Animal number	Level	Volume	Phosphorus per c.c.	Calcium per c.c.	P/Ca
67	L	47.00	0.00189	0.000146	12.90
99	H	45.00	0.00188	0.000166	11.92
146	L	44.00	0.00178	0.000159	11.20
131	H	36.00	0.00170	0.000129	13.20
75	L	39.00	0.00180	0.000146	12.30
248	H	38.00	0.00178	0.000138	12.90
127	L	34.00	0.00175	0.000157	11.10
11	H	37.00	0.00178	0.000172	10.40

Table 8

PRESS DATA ON COOKED RIBEYE

Animal number	Level	Volume juice c.c.	Volume fat c.c.
67	L	33	1
99	H	29	2
146	L	32	1
131	H	29	2
75	L	27	1
248	H	30	1
127	L	29	1
11	H	28	2

Bones

Ash. Determinations of ash were made on one gram samples. The samples were placed in tared porcelain dishes, heated below dull redness in the muffle until the samples appeared light grey. They were then cooled and weighed.

Calcium. Three tenths gram of powdered bone was

placed in a small beaker and 5 c.c. of 0.5 normal hydrochloric acid were added. This mixture was allowed to stand for a short time. Then the mixture was filtered through a number 42 Whatman filter paper into 100 c.c. volumetric flasks. The filter paper and beaker were washed with distilled water to ensure complete transference of the sample. Distilled water was added to mark, mixed well and a 20 c.c. portion taken for analysis of calcium. The method used for the determination of calcium was the method of Kramer and Howland (14).

Phosphorus. Determinations were made on 20 c.c. of the bone solution according to the method of Kramer and Howland (14).

Carbon Dioxide. Carbon dioxide was determined on a one gram sample. The bone powder was placed in a 250 c.c. dropping funnel and the apparatus arranged so carbon dioxide free air would be drawn through. Above the large dropping funnel was a 60 c.c. dropping funnel which contained carbon dioxide free 5 normal hydrochloric acid. The carbon dioxide liberated from the bones passed through a solution of silver sulfate which removed any hydrochloric acid that came over. Then the carbon dioxide came in contact with the sodium hydroxide. After the carbon dioxide

was all liberated, the sodium hydroxide solution was washed into a 250 c.c. volumetric flask and an excess of neutral saturated barium chloride added. A 50 c.c. portion of the clear solution was titrated against N/10 hydrochloric acid and the amount of carbon dioxide in the bones calculated.

Table 9

ANALYSIS OF BONES

Animal number	Percent Ash	Percent Calcium	Percent CO_2	Percent Phosphorus	Ca/p
67	55.93	20.20	3.15	9.12	2.20
99	57.38	19.65	2.78	9.25	2.12
146	54.32	18.45	3.15	9.08	2.03
131	59.06	19.80	3.04	11.10	1.78
75	55.70	18.18	3.47	7.97	2.28
248	60.93	20.78	3.83	9.70	2.14
127	53.21	18.65	3.77	8.12	2.30
11	60.68	20.14	3.77	9.63	2.19

Table 9 (cont.)

Animal number	Residual Ca/p	$Ca_3(PO_4)_2/CaCO_3$
67	1.90	6.40
99	1.85	7.30
146	1.71	6.35
131	1.54	8.03
75	1.89	5.14
248	1.78	5.57
127	1.88	4.75
11	1.74	5.60

ELECTRICAL WORK ON RIBEYE

Resistance. Measurements were made on the ribeys. The electrodes were placed on the eye muscle in different locations such as central and medial. Resistance was also determined on the 9th and 11th ribs in the fresh sample and on the 6th and 12th ribs of the ripening sample and on the 9th and 11th ribs after ripening.

Oxidation Potential. This was determined on a sample of the ribeye using the mercurous bromide-normal potassium

half cell and a platinum electrode. The platinum electrode was placed in the sample of the meat and a salt bridge contact made to complete the circuit through the tissue. The potential was measured directly by use of a portable potentiometer.

Quinhydrone Potential. This potential was measured against N/10 KCl calomel cell. A small amount of quinhydrone was placed in a hole in the meat and the platinum electrode placed in the quinhydrone. Then KCl was run into the meat and potential was measured by use of the portable potentiometer. From this the pH was determined.

Table 10

ELECTRICAL DATA ON RIBEYE (FRESH)*

Animal number	Rib number	Heat resistance	Rib No. 12 Oxidation potential	Rib No. 12 Quinhydrone potential	pH
67	9	665	+0.2004	+0.3571	6.00
	11	460			
99	9	440	+0.1664	+0.3466	6.20
	11	393			
146	9	810	+0.1999	+0.3571	5.96
	11	435			
131	9	635	+0.1792	+0.3406	6.20
	11	601			
75	9	214	+0.1909	+0.3571	5.92
	11	333			
248	9	195	+0.1454	+0.3586	5.93
	11	328			
127	9	506	+0.1454	+0.3446	6.13
	11	536			
11	9	281	+0.1459	+0.3541	6.00
	11	267			

* Potentials are compared to the standard hydrogen electrode taken as zero potential.

Table 11

ELECTRICAL DATA ON RIBEYE (RIPENING SAMPLE)*

Animal number	Before ripening: Rib number	Before ripening: Meat resistance	After ripening: Rib number	After ripening: Meat resistance	After ripening: Oxidation potential	After ripening: Quinhydrone potential	pH
67	6	202	9	132	+0.1039	+0.3411	6.13
	12	141	11	114			
99	6	234	9	156	+0.1459	+0.3446	6.10
	12	182	11	123			
146	6	410	9	121	+0.1159	+0.3296	6.55
	12	174	11	121			
131	6	498	9	180	+0.1214	+0.3181	6.69
	12	254	11	194			
75	6	190	9	185	+0.1400	+0.3491	6.12
	12	314	11	192			
248	6	288	9	135	+0.1394	+0.3591	5.92
	12	248	11	166			
127	6	330	9	208	+0.1574	+0.3476	6.16
	12	520	11	310			
11	6	160	9	112	+0.1644	+0.4096	5.05
	12	214	11	143			

* Potentials were determined on rib number 12 and were compared to the standard hydrogen electrode taken as zero potential.

MECHANICAL SHEAR ON RIBEYE

Shear was determined on a core from each of the samples. The shear machine was run by an electric motor and recorded the pounds of pressure necessary to cut through the core. As many readings as possible were taken, usually four or five, and then averaged.

Table 12

MECHANICAL SHEAR ON RIBEYE

Animal number	Level	Fresh		Ripened	
		Uncooked	Cooked	Uncooked	Cooked
67	L	25.60	15.3	18.4	13.9
99	H	16.35	13.4	16.8	14.7
146	L	18.60	12.2	14.3	10.8
131	H	15.80	30.5	12.8	24.6
75	L	16.75	18.8	23.0	16.5
248	H	14.00	14.7	13.7	13.2
127	L	18.80	12.5	19.1	14.0
11	H	10.80	13.6	13.0	13.2

RIPENING AND SHRINKAGE TESTS

Cores from the ribeye about one inch long and about one inch in diameter were placed in tared porcelain dishes and weighed. The samples were then placed in a cooler at about 36° F and kept for three weeks. The samples were weighed from time to time, and then at the end of three weeks. The reason they were weighed at several times was to see if there was any appreciable difference in loss between samples from the low and high phosphorus animals at any time during the test.

Sections of rib cuts, 6-12, were weighed and placed in the cooler at 36° F and allowed to hang for three weeks. The ribs were weighed at the end of one, two, and three weeks to determine moisture loss. Calculations for shrinkage were made by considering the size of the section. The grams lost were divided by the surface ratio.

Table 13

PERCENT SHRINKAGE ON CORE OF BEEF

Animal number	Level	4 days	14 days	3 weeks
67	L	31.20	60.25	64.25
99	H	32.00	59.50	64.40
146	L	31.90	60.00	64.00
131	H	28.20	55.20	61.40
75	L	25.82	56.85	65.20
248	H	28.47	59.60	66.75
127	L	27.73	56.90	66.00
11	H	26.00	54.80	64.90

Table 14

SHRINKAGE ON RIB CUTS (6-12)

Animal number	Level	Grams shrink / surface ratio		
		1 week	2 weeks	3 weeks
67	L	243	408	555
99	H	200	341	490
146	L	226	504	504
131	H	213	259	405
75	L	177	328	426
248	H	157	289	373
127	L	208	366	480
11	H	212	364	469

COOKING TESTS ON FRESH AND RIPENED RIB ROASTS

A section of ribs, 6-8, from each animal was set aside for six days after the animals were slaughtered and was then cooked by the Food Economics and Nutrition Department. The same section of ribs from the right side of the carcass was ripened three weeks and then cooked. A committee of seven sampled the cooked beef and judged it according to the

following factors: Aroma, texture, flavor of fat, flavor of of lean, tenderness, and juiciness. The phase of the various factors was judged as to intensity and desirability, number 7 being the most desirable and number 1 being the least desirable to the palate. Table 15 gives the results of the committee.

Table 15

PALATABILITY OF FRESH SAMPLES (COOKED)*

Animal number	Level	Aroma Int.	Aroma Des.	Texture Int.	Flavor of fat Int.	Flavor of fat Des.
67	L	4.4	5.1	5.1	4.2	5.2
99	H	4.6	5.0	5.3	4.4	5.3
146	L	4.4	4.5	5.4	4.7	5.3
131	H	4.4	4.7	4.7	4.3	5.2
75	L	4.9	5.0	5.0	4.4	5.4
248	H	5.1	5.0	4.7	4.9	4.4
127	L	5.0	5.1	5.0	4.5	5.1
11	H	4.7	5.7	5.0	4.5	4.0

* Department of Food Economics and Nutrition. Miss McMillan.

Table 15 (cont.)

Animal number	Flavor of lean		Tenderness	Juiciness	
	Int.	Des.	Int.	Quan.	Qual.
67	4.9	6.1	6.1	5.6	4.7
99	5.1	6.1	6.6	5.7	5.2
146	5.4	4.8	6.2	5.5	4.7
131	5.0	4.7	4.4	5.6	4.9
75	5.1	5.6	5.4	5.4	4.9
248	5.3	5.1	6.1	6.1	5.1
127	5.2	5.2	6.2	5.9	4.9
11	5.1	5.1	6.1	6.0	5.1

Table 16

PALATABILITY OF RIPENED SAMPLES (COOKED)

Animal number	Level	Aroma Int.	Aroma Des.	Texture Int.	Flavor of fat Int.	Flavor of fat Des.
67	L	5.2	4.4	5.4	5.6	4.0
99	H	5.0	5.6	5.8	5.0	4.8
146	L	4.6	4.8	5.0	5.0	4.4
131	H	5.4	5.0	5.6	5.6	5.2
75	L	5.1	5.3	5.6	4.4	5.7
248	H	5.0	5.3	5.0	4.7	5.9
127	L	5.1	5.3	5.5	3.1	5.0
11	H	4.7	5.1	5.3	5.0	4.3

Table 16 (cont.)

Animal number	Flavor of lean		Tenderness	Juiciness	
	Int.	Des.	Int.	Quan.	Qual.
67	5.4	4.6	5.0	5.4	5.0
99	5.4	4.6	5.8	6.2	5.8
146	4.8	4.4	4.6	5.0	4.8
131	5.2	4.2	5.2	5.8	5.6
75	4.9	5.9	6.0	5.7	5.1
248	5.6	5.7	6.4	6.1	5.4
127	4.6	6.0	6.4	6.0	5.1
11	5.1	5.4	6.1	5.9	4.9

Table 17

COOKING LOSSES*

Animal number	Level	Before ripening		After ripening	
		Percent total loss	Percent drippings	Percent total loss	Percent drippings
67	L	8.70	1.17	8.87	1.82
99	H	11.08	1.87	7.70	1.31
146	L	11.80	1.50	10.26	1.39
131	H	10.61	1.28	9.54	2.20
76	L	13.50	2.99	14.22	3.94
248	H	12.91	3.21	13.74	4.06
127	L	11.85	2.17	8.23	1.93
11	H	12.50	2.08	11.00	2.32

* Department of Food Economics and Nutrition. Miss McMillan.

DISCUSSION OF RESULTS

The Relation of the Amount of Phosphorus in the Blood to that in Muscle, Adipose Tissue, and Bones

Since the amount of phosphorus in the ration was controlled, it was thought that the amount in the muscle tissue, adipose tissue, and bones might also be controlled. The inorganic phosphorus in the blood varied from 2-4 mg. per 100 c.c. blood in the low phosphorus animals and from 7-9 in the high phosphorus animals. In spite of the great variation, analysis of the muscle tissue showed no great variations in the amount of phosphorus. The adipose tissue seemed to be affected by the ration and showed that more phosphorus is deposited in the adipose tissue of the high phosphorus animals. The bones of the low phosphorus animals, numbers 127, 75, 67, and 146, showed less phosphorus than the high phosphorus animals. From this, one might conclude that the muscle tissue, when in need of phosphorus, gets it from the bones.

The Relation of Phosphorus to the Tenderness of Meat

In general, the low phosphorus animals proved to produce the less tender meat according to results obtained by the mechanical shear on fresh muscle tissue. Electrical resistance also seems to be a measure of tenderness. The resistance correlates with the mechanical shear. On cooked samples, there is no appreciable difference in tenderness.

Relation of Phosphorus to Shrinkage

In every case the rib cuts from the low phosphorus animals showed more ripening shrinkage (moisture loss) than did the high phosphorus ones. Number 11, however, by observation, seemed to show a greater effect from shrinkage. The reason for the loss in the low phosphorus animals may be that the protoplasm of the muscle cell is more permeable to water than where the phosphorus content is higher. Each section was in excellent condition, having an even mold over the surface. Core shrinkage agreed with the rib shrinkage in most cases.

The Relation between Fat, Protein, and Moisture in Muscle and Adipose Tissue

As the animals, both high and low phosphorus, were fattened the ration of protein to fat (ether extract) was diminished both in muscle and adipose tissue. As a result of the increase in fat, the percent moisture is decreased.

The Relation of Phosphorus to the Oxidation Potential of the Muscle Tissue

In three of the pairs of animals, the muscle tissue of the low phosphorus animals had a higher oxidation potential. This seems to indicate that the muscle tissue of the low phosphorus animals is more permeable to oxygen and as a result produced a brighter color.

The Relation of Phosphorus to the Ash and Phosphorus of Bone

The percent ash of the low phosphorus animals was less than that for the high phosphorus animals. The percent phosphorus is also less for the low phosphorus animals. The ratio of calcium phosphate to calcium carbonate and the

ratio of residual calcium to phosphorus are both lower for the low phosphorus animals.

Relation of Phosphorus to the Palatability of Fresh and Ripened Rib Roasts

There seemed to be no great difference in the palatability of the meat of the low and high phosphorus animals. The quality of the juice in the fresh cooked roasts from the high phosphorus animals, except 131, seemed to be slightly more desirable to the palate. In the ripened cooked roasts, the quantity of juice is slightly greater from the animals fed high phosphorus, and the juice is more desirable to the palate.

CONCLUSIONS

1. Low phosphorus rations cause the meat to be more permeable to water and as a result shrinkage is greater.

2. The ration does not seem to have much effect on the palatability of the meat. The quantity of juice is slightly greater in the high phosphorus animals and the quality of the juice is more desirable.

3. Low phosphorus seems to render the fresh and ripened uncooked meat less tender as is evidenced by mechanical shear and electrical resistance. This does not hold true in the cooked samples.

4. The amount of phosphorus fed did not change the content of phosphorus in muscle tissue. There is an indication that high phosphorus in the ration may cause a higher phosphorus content in the adipose tissue.

5. The ration had an effect on the content of ash and phosphorus in bones. The bones of the low phosphorus animals contained a smaller amount of ash and phosphorus than did the bones of the high phosphorus animals.

SUMMARY

1. A description of the animals used in the experiment is given, along with the ration given them.

2. Methods are given for preparing samples for chemical analysis. Methods of analysis of blood, muscle tissue, adipose tissue, juice, and bones are given.

3. Tables are given which show the results obtained by chemical analysis.

4. Ripening and shrinkage tests are made on samples from various animals and the results are given in tables.

5. Tenderness of the meat is determined.

6. Results of cooking tests are given which show the palatability of the various samples.

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