THE UTILIZATION BY HUMAN SUBJECTS OF THE PHOSPHORUS OF BEEF HEART AND BEEF ROUND

by

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INTRODUCTION

Human balance experiments with different cuts of beef including loin, heel, round, and liver have shown little difference in the extent to which the phosphorus of these meats is used. The present study was made to supply similar data regarding the utilization of phosphorus from beef heart using beef round as a basis for comparison. Conditions were particularly favorable for this investigation since it was possible to secure equal quantities of both meats from the same animals, thus eliminating differences due to quality.

REVIEW OF LITERATURE

Studies of the Utilization of the Phosphorus of Meat

Very little work has been reported on the metabolism of the phosphorus of meat. A balance study on human subjects was made by the Department of Food Economics and Nutrition of Kansas State College (4) in which the utilization of phosphorus from beef loin and heel was observed. Approximate equilibrium for all subjects was maintained even though the intake was below the minimum requirement set by Sherman (17) as 0.88 gram of phosphorus per 70 kilograms of body weight per day. Long (10) using beef round and beef heart in a similar study found good utilization of the phosphorus from these cuts.

Sherman (17) states that within a few days the body tends to adjust its phosphorus metabolism to the intake. A preliminary period on the experimental diet is necessary to allow for this adjustment. He also states that with a low phosphorus intake, the effect of a deficiency of this element may be readily observed. He says: "If instead of exact equilibrium there is a very small negative balance, the total output may be taken as indicating approximately the maintenance requirement." It is generally accepted that the ability of human subjects to remain at approximate equilibrium on a low intake of phosphorus is indicative of a good source of the element, or its economical usage by the body, or both.

Meat with a high connective tissue content is associated with toughness which is believed to affect its utilization unfavorably. Mitchell (13) quotes Lehman to the effect that "it is the connective tissue fibers, rather than the muscle fibers to which the greater portion of the toughness of meat is due." Mitchell adds that in so far as the connective tissue consisting of elastin and collagen accounts for the toughness of meat, the content of these 2 proteins in meat can be correlated with the physical property of toughness. He also states (12) that "the relatively high biological values for liver, kidney, and

heart may also be associated with a relatively low content of connective tissue."

Factors Affecting the Utilization of Phosphorus

Calcium-Phosphorus Ratio.--Certain factors in the diet have been found to affect the utilization of phosphorus by the body. Orr and co-workers (14) determined the calcium and phosphorus intake and output of 2 children on a normal, a high-calcium, and a high-phosphorus diet. An excess of either mineral caused a lower retention of the other. They assumed this lowered retention to be a result of the precipitation of insoluble calcium phosphate in the intestine thereby rendering it less available to the body.

Irradiation.--No increased tendency to phosphorus retention was observed by Hart, Tourtellotte, and Heyl (7) when their single subject was irradiated for 20 minutes daily during a 20-day period. Nor did Kramer, Gillum, and Potter (9) find better utilization of phosphorus by 5 irradiated subjects than by a control group when they compared the retention of calcium and phosphorus from raw milk and ice cream made from sweetened condensed milk.

Effects of Sugars in the Diet.--Pronounced increases in the amount of calcium and phosphorus absorbed were observed by Bergeim (1) when lactose was added in the proportion of 25 per cent of the diet. He believed this to be

due to the increased lactic acid fermentation throughout the gastro-intestinal tract which made these minerals more soluble and consequently more available. The results were somewhat less marked for phosphorus than for calcium. No increase was observed with sucrose and various other carbohydrates at the 25 per cent level and only a slight increase when they were fed in amounts of 50 per cent of the diet.

Acid-Base Balance.--The acid-base balance is recognized as an important factor in the metabolism of phosphorus. Neutral diets are quite generally believed to be optimal for phosphorus retention, while basic diets are regarded as slightly less favorable, and acid diets as least desirable. Shohl, Bennett, and Weed (21) working with rats on a high calcium-low phosphorus diet, found such to be the case. Shohl and Sato (19, 20), studying mineral metabolism in infants, found a slightly decreased retention of phosphorus when either acid or alkali was added to the infants' formulae. Chaney and Blunt (3) noted a decided increase in phosphorus retention when 600-700 cc. of orange juice were included each day in the diets of children. They suggested, among various causes for this increase, the formation of an alkaline residue, but also such other factors as vitamins, the additional calcium and phosphorus supplied by the orange juice, and the stimulation of the flow of hydrochloric acid thus increasing the acidity in the duodenum and favoring

absorption of these minerals.

According to Salter and Angier (16) considerable error may be made in the calculation of the acid-base balance of a diet. They state: "That calculation of the potential acidity or alkalinity of the diet cannot be made with great accuracy is apparent not only from considerations of possible natural daily variations in the composition of foodstuffs, but also from the differences in values to be found in the literature for individual foods. . . . . The difficulties of calculating exactly acid-base balance can be simplified greatly if the diet consists of only a few simple ingredients." The variation that may be secured for the excess acid content of 100 grams of lean beef is shown by the different values obtained by various workers expressed in terms of cc. of 0.1 N hydrochloric acid as follows: 16.50 (Sherman, 1927); 13.91 (Sherman, 1911); 13.00 (Salter and Angier, 1931); and 12.28 (Forbes, 1909).

Effect of Water.--Zucker, Johnson, and Barnett (24) state that the hydrogen ion concentration of the contents of the stomach and upper small intestine controls to a large extent the absorption of calcium and phosphorus. Foster and Lambert (6) found a higher acidity of the gastric juice of dogs when the secretion was abundant, and that water ingested with food excited a greater activity than water alone.

They cited the work of Pawlow who has shown with dogs that a greater flow of gastric juice may be induced by the ingestion of comparatively large amounts of water at one time (400-500 cc.) whereas small amounts (100-150 cc.) caused little or no increase in secretion.

Excretion of Phosphorus.--Under normal conditions the excretion of phosphorus by way of the urine has been stated by Shohl and Sato (20) to vary from 68.5 to 65.0 per cent while Hawk and Bergeim (8) find it to be 80.0 to 70.0 per cent. Sherman (17) states that the phosphorus excretion is largely by way of the intestine although wide variations may occur. Zucker, Johnson, and Barnett (24) interpret a greater urinary excretion as evidence of better absorption from the intestine.

A diet with a basic residue will, according to Shohl and Sato (20), cause more phosphorus to be excreted in the feces. Orr, Holt, Wilkins, and Boone (14) found considerable amounts of phosphorus diverted from the urine to the feces when a high calcium-low phosphorus diet was fed to rats. Crude fiber is thought by Sjollema (22) to increase but slightly the fecal and urinary phosphorus output of rabbits, while Bloom (2), working with rats, states that crude fiber did not lower the retention of phosphorus and did not appear to change the channel of excretion appreciably.

Loss of phosphorus through the skin was found by Taylor (23) to be so small as to lead him "to infer that there is no real cutaneous elimination of phosphorus in any form." Observations by Sherman, Gillette, and Pope (18) on the loss of phosphorus in the menstrual flow showed the output to be of minor consequence in the phosphorus metabolism.

PROCEDURE

Subjects.--Four normal young college women, all graduate students in the Department of Food Economics and Nutrition of Kansas State College, served as subjects. Their activities involved both laboratory and classroom work and varied little throughout the experiment.

Diet.--The meat to be tested was eaten with a basal ration of orange juice, purified butterfat, lactose, sucrose, and a special bread which contained a negligible amount of phosphorus. The diet was adequate in all respects except possibly for some deficiency of vitamin D which is not considered harmful to adults for a period as short as that covered by this experiment (7, 9). The food consumed daily by each subject is shown in Tables I and II.

Individual energy requirements were computed on the basis of 45 Calories per kilogram of body weight per day. The Calories supplied by the food were also calculated and

TABLE I

DAILY FOOD CONSUMPTION

Food	Beef Round Period															
	Subject A					Subject B				Subject C				Subject D		
	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base		Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base
	grams	gram	cc.	cc.		grams	gram	cc.	cc.	grams	gram	cc.	cc.	grams	gram	cc.	cc.
Orange juice mixture																	
Orange juice	1000.0	0.2046	--	56.1		1000.0	0.2046	--	56.1	1000.0	0.2046	--	56.1	1000.0	0.2046	--	56.1
Lactose	80.0	--	--	--		80.0	--	--	--	80.0	--	--	--	80.0	--	--	--
Sucrose	40.0	--	--	--		40.0	--	--	--	40.0	--	--	--	40.0	--	--	--
Bread																	
Cornstarch	120.0	--	--	--		120.0	--	--	--	120.0	--	--	--	120.0	--	--	--
Lactose	40.0	--	--	--		40.0	--	--	--	40.0	--	--	--	40.0	--	--	--
Dextri-maltose	15.0	--	--	--		15.0	--	--	--	15.0	--	--	--	15.0	--	--	--
Baking powder	3.0	--	--	--		3.0	--	--	--	3.0	--	--	--	3.0	--	--	--
Salt	3.0	--	--	--		3.0	--	--	--	3.0	--	--	--	3.0	--	--	--
Agar	5.0	--	--	--		5.0	--	--	--	5.0	--	--	--	5.0	--	--	--
Butterfat	32.0	--	--	--		32.0	--	--	--	32.0	--	--	--	32.0	--	--	--
Water (distilled)	80.0	--	--	--		80.0	--	--	--	80.0	--	--	--	80.0	--	--	--
Butterfat	20.0	--	--	--		43.2	--	--	--	47.7	--	--	--	55.0	--	--	--
Meat	113.6	0.2032	18.8	--		125.6	0.2247	20.8	--	127.8	0.2284	21.1	--	131.6	0.2359	21.8	--
Total excess base in food[1]				37.3					35.3				35.0				34.3
Minerals added																	
Calcium carbonate	0.3990	--				0.5175	--			0.5390	--			0.5765	--		
Ferric citrate	0.0241	--				0.0276	--			0.0281	--			0.0293	--		

1. Calculated as cc. of 0.1 normal solution of sodium hydroxide.

TABLE II

DAILY FOOD CONSUMPTION

Food	Beef Heart Period															
	Subject A				Subject B				Subject C				Subject D			
	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base	Weight	P	Excess 0.1 N Acid	Excess 0.1 N Base
	grams	gram	cc.	cc.	grams	gram	cc.	cc.	grams	gram	cc.	cc.	grams	gram	cc.	cc.
Orange juice mixture																
Orange juice	1000.0	0.2150	--	56.1	1000.0	0.2150	--	56.1	1000.0	0.2150	--	56.1	1000.0	0.2150	--	56.1
Lactose	80.0	--	--	--	80.0	--	--	--	80.0	--	--	--	80.0	--	--	--
Sucrose	40.0	--	--	--	40.0	--	--	--	40.0	--	--	--	40.0	--	--	--
Bread																
Cornstarch	120.0	--	--	--	120.0	--	--	--	120.0	--	--	--	120.0	--	--	--
Lactose	40.0	--	--	--	40.0	--	--	--	40.0	--	--	--	40.0	--	--	--
Dextri-maltose	15.0	--	--	--	15.0	--	--	--	15.0	--	--	--	15.0	--	--	--
Baking powder	3.0	--	--	--	3.0	--	--	--	3.0	--	--	--	3.0	--	--	--
Salt	3.0	--	--	--	3.0	--	--	--	3.0	--	--	--	3.0	--	--	--
Agar	5.0	--	--	--	5.0	--	--	--	5.0	--	--	--	5.0	--	--	--
Butterfat	32.0	--	--	--	32.0	--	--	--	32.0	--	--	--	32.0	--	--	--
Water (distilled)	80.0	--	--	--	80.0	--	--	--	80.0	--	--	--	80.0	--	--	--
Butterfat	15.0	--	--	--	38.0	--	--	--	42.0	--	--	--	49.3	--	--	--
Meat	151.4	0.3194	24.9	--	167.2	0.3527	27.6	--	170.0	0.3588	28.1	--	175.2	0.3689	28.9	--
Total excess base in food[1]				31.2				28.5				28.0				27.2
Minerals added																
Calcium carbonate	0.3990	--			0.5165	--			0.5380	--			0.5853	--		
Ferric citrate	0.0203	--			0.0233	--			0.0238	--			0.0247	--		

1. Calculated as cc. of 0.1 normal solution of sodium hydroxide.

the necessary adjustment for each subject made by varying the amount of butterfat used. The total intake and the distribution of Calories for each subject appears in Table III.

The meats used were graded as Good according to government standards. The amount of meat consumed by each subject was limited by the nitrogen content since a nitrogen balance study was to be made as a separate experiment. The protein was therefore calculated on the basis of 80 per cent of the 44.4 grams per 70 kilograms of body weight set by Sherman as the protein requirement. The meat supplied from 50 to 63 per cent of the phosphorus intake thus furnishing the major portion of that in the diet. This was believed to be sufficiently low in amount that differences in utilization, if present, could be observed and could be attributed to the meat.

It was necessary to use 10 beef hearts to supply the desired quantity of protein from this cut. They were freed of visible fat, weighed, coarsely ground, and thoroughly mixed. In order to eliminate differences in quality of meat as a possible factor, an equal weight of round was taken from each of the same 10 animals and prepared in the same way as the hearts. The daily allotment for each individual was divided into 2 portions of equal weight since meat was to be eaten for both lunch and dinner. These were

TABLE III

CALORIE INTAKE

Subject	Weight in kilograms	Total Calories[1]	Beef Round Experiment: Distribution of Calories: Beef round	Orange juice	Bread exclusive of lactose	Butter-fat exclusive of that in bread	Lactose[2]	Sucrose[2]	Beef Heart Experiment: Distribution of Calories: Beef heart	Orange juice	Bread exclusive of lactose	Butter-fat exclusive of that in bread	Lactose[2]	Sucrose[2]
A	47.7	2148	132	430	767	180	480	160	176	430	767	135	480	160
B	52.7	2372	146	430	767	329	480	160	194	430	767	342	480	160
C	53.6	2414	148	430	767	429	480	160	197	430	767	378	480	160
D	55.2	2485	153	430	767	496	480	160	203	430	767	444	480	160

1. Calculated on basis of 45 Calories per kilogram.

2. The Calories supplied by lactose varied from 22.3 to 19.7 per cent of the total. Lactose and sucrose combined supplied from 29.8 to 25.8 per cent.

wrapped separately in oiled paper and kept frozen to insure preservation until used. The meat was cooked in individual pans by first searing and then simmering in distilled water. To improve the flavor of the heart it was first seared at a very low temperature in a small amount of the individual's daily portion of butterfat. For both meats the liquid remaining in the frying pan at the end of the cooking process was served as soup.

Valencia oranges were purchased in crate lots as needed. The juice, prepared fresh each day, was extracted mechanically and strained to remove seeds and coarse pulp. Each subject consumed 1000 grams daily of the well-mixed juice to which 80 grams of lactose and 40 grams of sucrose had been added.

The special bread was made as follows:

	grams		grams
Cornstarch	120	Dextri-maltose	15
Lactose	40	Baking powder (tartrate)	3
Sodium chloride	3	Butterfat	32
Agar	5	Distilled water	180

The dry ingredients were mixed, then the melted butterfat and water were added to form a smooth paste. This paste was spread in an eighth-inch layer on a baking sheet oiled slightly with the fat remaining in the cup in which it was melted. The bread was baked for 1 hour at 325° F. In

order to facilitate its removal from the pans it was loosened with a spatula after baking 15 minutes. Each day 4 separate lots of bread were prepared. These were stored in individual containers and were eaten the day after baking.

Since the diet was lacking in feces-forming material, agar was added to supply bulk. Each subject consumed daily 4 grams of salt in addition to that in the bread. The diet was low in iron and calcium. Since these elements were not included in the study and are essential to an adequate diet, ferric citrate and calcium carbonate were added in amounts to meet Sherman's standard of 0.015 grams of iron and 0.68 gram of calcium per 70 kilograms of body weight per day.

In the first preliminary period each subject determined the quantity of distilled water she desired to drink each day. The amount varied with the individual from 850-900 cc. but remained approximately constant for each subject throughout the experiment.

The diet as calculated was strongly base-forming containing an approximate average excess of 35.5 cc. of 0.1 N base for the beef round experiments and 29.0 cc. for the beef heart experiments.

A special effort was made to maintain a pleasant environment at meal time and a regular schedule for eating.

The orange juice mixture, bread, and butterfat were consumed for breakfast, while these same foods were eaten with the meat for lunch and dinner. Occasionally the subjects experienced difficulty in consuming the daily amount of bread, but in general the diet was palatable and did not become monotonous.

Organization.--The experiments with each cut of meat continued for at least 13 days. They consisted of a 4-day preliminary period and 2 periods of 4 days each, during which urine and feces were collected quantitatively. A 1-day lag period at the end of the experiment, during which the diet was continued, was usually sufficient to secure the marker in the feces.

A 250-cc. portion of each 24-hour collection of urine for each subject was preserved with an eighth-inch layer of toluol and 3 cc. of concentrated hydrochloric acid. As part of this problem, the results of the analyses for phosphorus in each day's urinary excretion were to be compared with the daily average obtained from analysis of a composite sample of the 4-day periods. Since it is customary to use composite samples it was desired to determine the agreement of the two methods. The composite sample was prepared by combining 1/10 of the total daily volume of urine for each subject during a given period and preserving each added

portion with toluol and concentrated hydrochloric acid (2 cc.) as were the daily samples.

Feces for each 4-day period were separated by carmine markers taken in capsules 30 minutes before breakfast at the beginning and end of a period. They were preserved by drying and by use of acidified alcohol (1 part concentrated hydrochloric acid to 9 parts alcohol by volume). Immediately after each collection the feces were mixed with the acidified alcohol and added to the drying composite. They were dried to practically constant weight in an oven held at approximately 60° C. They were then ground, run through a 1-mm. sieve, thoroughly mixed, and stored in glass-stoppered bottles.

Weighed samples of the meats were preserved by addition of 2 drops of formaldehyde. They were then dried and otherwise treated in the same manner as the feces.

A composite sample of orange juice for each period was made by combining 200-gram portions of that prepared each day. This was preserved for analysis by canning in half-pint jars by means of the cold-pack method using a water bath.

Methods of Analysis.--Phosphorus determinations of food and excreta were made volumetrically by the A. O. A. C. method. A known sample was first analyzed to prove accuracy

of technic. Analyses were made in triplicate.

The collagen and elastin content of the meats was determined by a revised method from the Illinois Agricultural Experiment Station (13).

RESULTS AND DISCUSSION

The subjects maintained their weights throughout the experiment which indicated an adequate Calorie intake. Subject C suffered from constipation thus making the separation of the feces somewhat difficult. Subject B was nauseated during the first day of her menstrual period and was unable to retain food. Since this occurred on the first day of the first collection period for the heart experiment, the results for her for this particular period are computed on a 3-day basis. In this instance the feces marking the beginning of the period were separated with charcoal since she had already taken the carmine marker. Subject D normally took psyllium seed to promote excretion and continued to do so during the experiment. This laxative is not digested so appears quantitatively in the feces. Upon analysis, the approximate daily dosage of 18 grams (1 tablespoon) was found to contain 0.0662 grams of phosphorus. This amount of phosphorus was therefore added to the daily intake in computing balances since the seed was included in the output and analyzed as a constituent of the feces.

The findings for phosphorus are shown in Tables IV and V. The results indicated for urine are those obtained by analysis of daily samples. Analyses of the composite samples agreed with these results within the limits of experimental error ranging from 0.8 per cent to 1.7 per cent as indicated by Table VI.

The actual phosphorus content of the meats and orange juice used in this experiment varied from the calculated values more than was expected. The orange juice contained an average of 0.00021 grams of phosphorus per gram of juice whereas Rose (15) suggests a value of 0.00016 gram and Long (10) obtained 0.00019 gram. The heart was found to contain 1.281 grams of phosphorus per 100 grams of protein for this experiment as compared with the calculated value of 1.078 grams (17). The round actually contained 0.0018 gram of phosphorus per gram of meat agreeing exactly with the results of Long but containing less than the 0.0023 gram suggested by Rose and used in the calculations.

Slightly better phosphorus balances were observed with beef heart than with beef round as indicated by the average balances for all subjects of +0.0039 and -0.0536 gram respectively. As the diet was calculated it was anticipated that the 2 cuts of meat would supply equal amounts of phosphorus. However, actual analysis showed that 1/3 more phos-

TABLE IV

PHOSPHORUS FINDINGS FOR BEEF ROUND EXPERIMENT

Subject	Period	Day	Daily Intake of Phosphorus: Meat	Orange Juice	Total	Daily Output of Phosphorus: Urine	Feces	Total	Balance
			gm.	gm.	gm.	gm.	gm.	gm.	gm.
A	I	1	0.2032	0.2058	0.4090	0.3485	0.1529	0.5014	-0.0924
		2	"	"	"	0.3555	"	0.5084	-0.0994
		3	"	"	"	0.3304	"	0.4833	-0.0743
		4	"	"	"	0.3007	"	0.4536	-0.0446
		Av.	"	"	"	0.3338	"	0.4867	-0.0777
	II	1	0.2032	0.2058	0.4090	0.3630	0.1768	0.5398	-0.1308
		2	"	0.2035	0.4067	0.2239	"	0.4007	+0.0060
		3	"	0.2035	"	0.3333	"	0.5101	-0.1034
		4	"	"	"	0.2806	"	0.4574	-0.0507
		Av.	"	0.2047	0.4079	0.3002	"	0.4770	-0.0691
	Average		0.2032	0.2053	0.4085	0.3170	0.1649	0.4819	-0.0734
B	I	1	0.2247	0.2058	0.4305	0.3986	0.2354	0.6340	-0.2035
		2	"	"	"	0.3380	"	0.5734	-0.1429
		3	"	"	"	0.3059	"	0.5413	-0.1108
		4	"	"	"	0.2904	"	0.5258	-0.0953
		Av.	"	"	"	0.3332	"	0.5686	-0.1381
	II	1	0.2247	0.2058	0.4305	0.1641	0.1835	0.3476	+0.0829
		2	"	0.2035	0.4282	0.3985	"	0.5820	-0.1538
		3	"	"	"	0.1643	"	0.3478	+0.0804
		4	"	"	"	0.3745	"	0.5580	-0.1298
		Av.	"	0.2047	0.4294	0.2754	"	0.4589	-0.0295
	Average		0.2247	0.2053	0.4300	0.3043	0.2095	0.5138	-0.0838
C	I	1	0.2284	0.2058	0.4342	0.2420	0.1612	0.4032	+0.0310
		2	"	"	"	0.3003	"	0.4615	-0.0273
		3	"	"	"	0.3089	"	0.4701	-0.0359
		4	"	"	"	0.2876	"	0.4488	-0.0146
		Av.	"	"	"	0.2847	"	0.4459	-0.0117
	II	1	0.2284	0.2058	0.4342	0.2872	0.1706	0.4578	-0.0236
		2	"	0.2035	0.4319	0.2559	"	0.4265	+0.0054
		3	"	"	"	0.3044	"	0.4750	-0.0431
		4	"	"	"	0.3553	"	0.5259	-0.0940
		Av.	"	0.2047	0.4331	0.3007	"	0.4713	-0.0382
	Average		0.2284	0.2053	0.4337	0.2927	0.1659	0.4586	-0.0249
D[1]	I	1	0.2359	0.2058	0.4417	0.2518	0.1633	0.4151	+0.0266
		2	"	"	"	0.3011	"	0.4644	-0.0227
		3	"	"	"	0.3546	"	0.5179	-0.0762
		4	"	"	"	0.3198	"	0.4831	-0.0414
		Av.	"	"	"	0.3068	"	0.4701	-0.0284
	II	1	0.2359	0.2058	0.4417	0.3351	0.2083	0.4772	-0.0355
		2	"	0.2035	0.4394	0.2853	"	0.4274	+0.0120
		3	"	"	"	0.2405	"	0.3826	+0.0568
		4	"	"	"	0.4776	"	0.6197	-0.1803
		Av.	"	0.2047	0.4406	0.3346	"	0.4767	-0.0361
	Average		0.2359	0.2053	0.4412	0.3272	0.2189	0.4799	-0.0323
All	Average								-0.0536

1. Corrected for psyllium seed.

TABLE V

PHOSPHORUS FINDINGS FOR BEEF HEART EXPERIMENT

Subject	Period	Day	Daily Intake of Phosphorus: Meat	Orange Juice	Total	Daily Output of Phosphorus: Urine	Feces	Total	Balance
			gm.	gm.	gm.	gm.	gm.	gm.	gm.
A	I	1	0.3194	0.2169	0.5363	0.2574	0.2045	0.4619	+0.0744
		2	"	"	"	0.4968	"	0.7013	-0.1650
		3	"	"	"	0.3067	"	0.5112	+0.0251
		4	"	"	"	0.3493	"	0.5538	-0.0175
		Av.	"	"	"	0.3526	"	0.5571	-0.0208
	II	1	0.3194	0.2132	0.5326	0.3713	0.2045	0.5758	-0.0432
		2	"	"	"	0.2550	"	0.4595	+0.0731
		3	"	"	"	0.3693	"	0.5736	-0.0410
		4	"	"	"	0.3057	"	0.5102	+0.0224
		Av.	"	"	"	0.3253	"	0.5298	+0.0028
	Average		0.3194	0.2151	0.5345	0.3389	0.2045	0.5434	-0.0089
B[1]	I	1	0.3527	0.2169	0.5696	0.1759	0.1406	0.3195	+0.2501
		2	"	"	"	0.3574	"	0.4980	+0.0716
		3	"	"	"	0.3577	"	0.4983	+0.0713
		Av.	"	"	"	0.2990	"	0.4386	+0.1310
	II	1	0.3527	0.2132	0.5659	0.4076	0.2051	0.6127	-0.0468
		2	"	"	"	0.4172	"	0.6223	-0.0564
		3	"	"	"	0.4931	"	0.6982	-0.1323
		4	"	"	"	0.4211	"	0.6262	-0.0603
		Av.	"	"	"	0.4348	"	0.6399	-0.0740
	Average		0.3527	0.2151	0.5678	0.3664	0.1728	0.5392	+0.0139
C	I	1	0.3588	0.2169	0.5757	0.4188	0.2303	0.6491	-0.0734
		2	"	"	"	0.4089	"	0.6392	-0.0635
		3	"	"	"	0.4315	"	0.6618	-0.0861
		4	"	"	"	0.4316	"	0.6619	-0.0862
		Av.	"	"	"	0.4227	"	0.6530	-0.0773
	II	1	0.3588	0.2132	0.5720	0.3271	0.1902	0.5173	+0.0547
		2	"	"	"	0.3375	"	0.5277	+0.0443
		3	"	"	"	0.3313	"	0.5215	+0.0505
		4	"	"	"	0.3467	"	0.5369	+0.0351
		Av.	"	"	"	0.3357	"	0.5259	+0.0461
	Average		0.3588	0.2151	0.5739	0.3792	0.2103	0.5895	-0.0156
D[2]	I	1	0.3689	0.2169	0.5858	0.4146	0.1764	0.5910	-0.0052
		2	"	"	"	0.3879	"	0.5643	+0.0215
		3	"	"	"	0.3607	"	0.5371	+0.0487
		4	"	"	"	0.4292	"	0.6056	-0.0198
		Av.	"	"	"	0.3981	"	0.5745	+0.0113
	II	1	0.3689	0.2132	0.5821	0.3855	0.1429	0.5284	+0.0537
		2	"	"	"	0.3729	"	0.5158	+0.0663
		3	"	"	"	0.4851	"	0.6280	-0.0459
		4	"	"	"	0.3810	"	0.5239	+0.0582
		Av.	"	"	"	0.4061	"	0.5490	+0.0331
	Average		0.3689	0.2151	0.5840	0.4021	0.1597	0.5618	+0.0222
All	Average								+0.0039

1. Period of 3 days.

2. Corrected for psyllium seed.

TABLE VI

COMPARISON OF RESULTS OF PHOSPHORUS ANALYSES OF DAILY AND COMPOSITE SAMPLES OF URINE

Subject	Period	Beef Round Experiment					Beef Heart Experiment				
		Daily		Composite			Daily		Composite		
		Total period	Av./day	Total period	Av./day	Difference	Total period	Av./day	Total period	Av./day	Difference
		gm.	gm.	gm.	gm.	per cent	gm.	gm.	gm.	gm.	per cent
A	I[1]	0.9866	0.3289	0.9883	0.3294	0.2	1.4102	0.3526	1.4318	0.3580	1.6
	II	1.2008	0.3002	1.2103	0.3026	0.8	1.3011	0.3253	1.3129	0.3282	0.9
B[2]	I[1]	0.9343	0.3114	0.9418	0.3139	0.8	0.8940	0.2980	0.9094	0.3031	1.7
	II	1.1014	0.2754	1.0824	0.2706	1.8	1.7390	0.4348	1.7168	0.4292	1.3
C	I[1]	0.8968	0.2989	0.8823	0.2941	1.6	1.6908	0.4227	1.6751	0.4188	0.9
	II	1.2028	0.3007	1.1944	0.2986	0.7	1.3426	0.3357	1.3532	0.3383	0.8
D	I[1]	0.9755	0.3252	0.9957	0.3313	1.8	1.5924	0.3981	1.5689	0.3922	1.5
	II	1.3385	0.3346	1.3635	0.3409	1.9	1.6245	0.4061	1.6443	0.4111	1.3

1. Day I not included in composite for beef round. Daily figures are computed on the same basis.

2. A 3-day period for Period I in beef heart experiment.

phorus was obtained from beef heart than from beef round. Had the round supplied as much of this element it is probable no such difference would have been observed.

In neither experiment did the phosphorus intake reach the minimum requirement suggested by Sherman (17) of 0.88 gram per 70 kilograms of body weight per day. In the case of the heart the subjects ranged from 0.06 to 0.11 gram below the minimum requirement and from 0.36 to 0.46 gram less than the optimum standard (17) of 1.32 grams per 70 kilograms of body weight per day. The difference was even greater when round was consumed ranging from 0.19 gram to 0.25 gram below the minimum requirement and from 0.49 to 0.60 gram below the optimum. (Table VII).

TABLE VII

COMPARISON OF PHOSPHORUS INTAKE WITH ACCEPTED STANDARDS

Subject	Daily Intake[1]		Accepted Daily Standards	
	Round	Heart	Minimum Requirement	Optimum Requirement
	grams	grams	grams	grams
A	0.41	0.54	0.60	0.90
B	0.43	0.57	0.66	1.00
C	0.43	0.57	0.67	1.02
D	0.44	0.58	0.69	1.04

1. Obtained by analysis.

At this low level of phosphorus intake the ability of the subjects to reach approximate equilibrium during the heart experiment and to maintain only slightly negative balances with the round indicates a good source of phosphorus, or conditions unusually favorable to its utilization, or both. As has been suggested by Chaney and Blunt (3), the large amounts of orange juice consumed may have produced more favorable conditions for absorption. This probably provided a more acid condition in the alimentary tract thus rendering the phosphorus more soluble and making it more readily available for absorption. Due to the orange juice (Tables I and II), the diet was strongly base-forming which is believed to increase the utilization of phosphorus. A more neutral diet might have shown even better utilization according to the work of Shohl, Bennett, and Weed (21).

Lactose in the amount of 25 per cent of the diet was found by Bergeim (1) to increase to a marked extent the utilization of phosphorus. Since lactose supplied from 19 to 23 per cent of the Calorie intake in this experiment, it may have been a factor in the favorable results obtained. On the other hand, a high connective tissue content, particularly elastin, has been thought to inhibit the utilization of meats. Since analysis of the heart and round showed the elastin content to be almost identical in these cuts

(Table VIII) it can scarcely have been a factor. The collagen content was almost twice as great in the heart but apparently did not affect the phosphorus utilization of this cut.

TABLE VIII

ELASTIN AND COLLAGEN CONTENT OF MEATS USED

Meat	Elastin per cent		Collagen per cent	
	Nitrogen	Protein (N x 6.25)	Nitrogen	Protein (N x 6.25)
Round	0.0111	0.0694	0.265	1.656
Heart	0.0102	0.0638	0.497	3.106

Wide fluctuations in total urinary phosphorus occurred from day to day. In one instance a difference of as much as +0.2394 gram was observed for one subject on successive days. These fluctuations occurred to some extent with all subjects. The individual differences from day to day appeared to be as great as the average variation between subjects. The volume of urine seemed to bear little relation to the amount of phosphorus excreted daily. Although the intake of liquid was controlled great variations in volume of urine were observed from day to day.

The phosphorus excreted in the urine ranged from 72.0 to 59.0 per cent and averaged 65.4 per cent (Table IX) com-

TABLE IX

AVERAGE DAILY EXCRETION OF PHOSPHORUS

Subject	Period	Beef Round Experiment					Beef Heart Experiment				
		Urine		Feces		Total	Urine		Feces		Total
		gm.	per cent	gm.	per cent	gm.	gm.	per cent	gm.	per cent	gm.
A	I	0.3338	68.6	0.1529	31.4	0.4867	0.3526	63.3	0.2045	36.7	0.5571
	II	0.3002	62.9	0.1768	37.1	0.4770	0.3253	61.4	0.2045	38.6	0.5298
	Average	0.3170	65.8	0.1649	34.2	0.4819	0.3390	62.4	0.2045	37.6	0.5435
B	I	0.3332	58.6	0.2354	41.4	0.5686	0.2980	67.9	0.1406	32.1	0.4386
	II	0.2754	60.0	0.1835	40.0	0.4589	0.4348	68.0	0.2051	32.0	0.6399
	Average	0.3043	59.3	0.2095	40.7	0.5138	0.3664	67.9	0.1729	32.1	0.5393
C	I	0.2847	63.9	0.1612	36.1	0.4459	0.4227	64.7	0.2303	35.3	0.6530
	II	0.3007	63.8	0.1706	36.2	0.4713	0.3357	63.8	0.1902	36.2	0.5259
	Average	0.2927	63.8	0.1659	36.2	0.4586	0.3792	64.3	0.2103	35.7	0.5895
D[1]	I	0.3198	66.2	0.1633	33.8	0.4831	0.3981	69.3	0.1764	30.7	0.5745
	II	0.3346	70.2	0.1421	29.8	0.4767	0.4061	72.2	0.1429	27.8	0.5490
	Average	0.3272	68.2	0.1527	31.8	0.4799	0.4021	71.6	0.1597	28.4	0.5618
All	Average	0.3103	64.2	0.1733	35.8	0.4836	0.3717	66.6	0.1869	33.4	0.5585

1. Corrected for psyllium seed.

pared with 68.5 to 65.0 per cent suggested by Shohl and Sato (19, 20) and 80.0 to 70.0 per cent observed by Hawk and Bergeim (8). According to Shohl and Sato the basicity of the diet or, possibly, the calcium-phosphorus ratio as advanced by Orr et al (14) may have been factors affecting the channel of excretion. The loss of phosphorus through the skin is believed to be negligible (23) and was therefore ignored in this experiment.

The weight of the wet feces for the different subjects ranged from an average of 50.6 grams to 132.4 grams daily. Subject D, taking psyllium seed, consistently excreted a larger bulk of feces than the other subjects. Deducting the weight of the seed taken by Subject D during a given period from the dry weight of the feces for that period, the weight of total feces is slightly lower than for the other subjects (Table X). This may be expected of a person who is normally constipated. The average weight of dry feces for all subjects including the corrected values for Subject D was lower even with the addition of agar than is normally found for persons consuming an ordinary mixed diet (11). The average weights of dry feces eliminated by the subjects daily were 14.5 and 14.0 grams for the beef round and beef heart experiments respectively. Omitting Subject D the average was 15.5 and 16.1 grams for each experiment.

TABLE X

AVERAGE DAILY ELIMINATION OF FECES
(DRY WEIGHT)

Subject	Period	Beef Round Experiment	Beef Heart Experiment
		grams	grams
A	I	14.6	18.4
	II	15.8	18.1
	Average	15.2	18.3
B	I	19.1	11.6 [1]
	II	14.7	15.4
	Average	16.9	13.5
C	I	13.5	18.0
	II	15.2	14.7
	Average	14.4	16.4
D[2]	I	14.4	10.2
	II	8.8	4.9
	Average	11.6	7.6
All	Average	14.5	14.0

1. Period of 3 days.

2. Corrected for psyllium seed.

The menstrual period of 3 of the subjects occurred during the heart experiment. A balance of +0.2501 grams of phosphorus was observed the second day for Subject B which is possibly accounted for by her inability to retain food the previous day. Sherman, Gillette, and Pope (18) have found the loss of phosphorus in the menstrual flow to be too small to affect the results appreciably.

CONCLUSIONS

1. The phosphorus of beef heart and beef round appears to be well utilized by human subjects under the conditions of this experiment as indicated by approximate phosphorus equilibrium with beef heart and but slightly negative balances with beef round. The results suggest that the phosphorus from the heart is at least as well used as that from the round.

2. The usual method of analyzing composite samples of the urine of a given period appears to be satisfactory from the results obtained in this experiment unless daily fluctuations are to be observed.

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