NUTRITIVE VALUE OF THE PROTEIN IN VOLUNTARY MUSCLE, HEART, LIVER, AND KIDNEY, FROM CATTLE, SHEEP, AND HOGS[1]

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INTRODUCTION

The purpose of this investigation was to determine, as accurately as possible by the method employed, the relative nutritive values of voluntary muscle, liver, kidney, and heart, from cattle, sheep, and hogs, as sources of protein for maintenance and growth in albino rats.

The various edible organs and other by-products of cattle, sheep, and hogs represent a considerable proportion of the food value of each of these classes of animals. Lean meat is of value as a food chiefly as a source of protein, and to a lesser extent as a source of vitamins and mineral matter. The edible organs, also, are of value chiefly on account of their protein, although several of them are rich in vitamins, notably the liver and kidneys. In previous papers (*3, 4*)[2] the writers have reported the results of investigations concerning the vitamin content of the flesh and organs from cattle, sheep, and hogs, and in this paper they give the results of a study of the nutritive value of the protein from the same sources.

The total crude-protein content of an animal tissue ($N \times 6.25$) can be determined accurately, and by correcting for the presence of certain nonprotein nitrogenous constituents, the percentage of true protein can be estimated fairly well; but even such data do not show the true relative nutritive properties of the protein in different tissues from the same animal or in the same tissue from different animals. The determination of the percentage of each of the more important amino acids throws important light upon the nutritive value of the protein in a tissue, but even such information does not necessarily indicate the true food value of the product analyzed. In order to arrive at a fairly accurate estimate of the relative food values of protein from different sources it is necessary to use the so-called "biological method."

The biological method consists in feeding to man or animals the protein to be tested, or food containing the protein, as the sole source of protein in an otherwise adequate diet. The efficiency with which the different proteins are utilized under certain definite conditions, as measured by intake and outgo of nitrogen, or by maintenance of or by increase in weight, indicates the relative nutritive values of those proteins under those particular conditions. In principle, the biological method is relatively simple, but in practice it is beset with many difficulties, owing to numerous disturbing factors. A critical discussion of this field of research will be found in a recent article by Mitchell (*10*).

[1] Received for publication Sept. 17, 1925; issued June, 1926.
[2] Reference is made by number (italic) to "Literature cited," p. 1039.

In attempting to estimate the nutritive values of different proteins, one must consider the several functions which this class of food nutrients performs in the animal body, viz, (1) maintenance or repair of body tissue and as a constituent of internal secretions, (2) growth, (3) reproduction, (4) lactation. It does not necessarily follow that a single protein or the combined proteins in an individual food product will be equally efficient for each of the several purposes named, and for this reason most investigators have determined the biological value of a protein for a particular purpose. A few investigators, however, have attempted to determine the relative values of different proteins for all body functions by a series of feeding experiments with rats extending through several generations. In light of recent developments in this field of research, this method of investigation appears to be open to criticism.

Two general classes of biological methods are employed in studying the nutritive value of proteins—viz, one based on intake and outgo of nitrogen, and the other on nitrogen intake as related to maintenance in weight or to growth. For a discussion of the several methods in each class the reader is referred to the article by Mitchell (*10*). It may be said, however, that both classes of methods are capable of yielding very satisfactory results, although each has very definite limitations. The writers have chosen a method belonging to the second class, and have determined, under certain definite conditions the relation between nitrogen intake and growth in young albino rats. This method is based upon the work of Osborne, Mendel and Ferry (*12*).

PREVIOUS INVESTIGATIONS

This discussion will be confined to those investigations in which one or another of the tissues under examination by the writers constituted the sole source of nitrogen in the diet, since they are not concerned at this time with the supplementary value of the proteins of these tissues for each other or for proteins from other sources.

Thomas (*14*) studied the nutritive value of the nitrogenous compounds in a number of important foodstuffs by a series of nitrogen-balance experiments with himself as the subject. In each experiment the food product under examination constituted the only source of protein in the diet, the energy value being adjusted by means of sugar and fat. He calculated the "biological value" for each product tested, that term indicating the number of parts of body nitrogen replaceable by 100 parts of nitrogen in the food consumed. These data indicate the value of the digestible nitrogen from each source for maintenance purposes.

TABLE I.—*Biological value of nitrogenous compounds in different foods, according to Thomas*

Food product	Biological value	Food product	Biological value
Beef	104.7	Potatoes	78.9
Milk	99.7	Yeast	70.5
Casein	70.1	Spinach	63.8
Fish	94.5	Peas	55.7
Rice	88.3	Wheat flour	39.6
Cauliflower	83.9	Corn meal	29.5
Crabs	79.2		

Osborne and Mendel (*11*) found ox muscle and pig liver to be excellent sources of protein for growth in rats. A ration containing 2.4 per cent nitrogen from dried beef ($2.4 \times 6.25 = 15$ per cent protein), 15 per cent fat, and adequate for growth in other respects, induced normal growth in rats. Similar results were obtained with a ration containing 2.4 per cent nitrogen from pig liver, and 23 per cent fat.

Drummond (*1*) determined the relative nutritive values of the coagulable protein from beef and from several kinds of fish by feeding tests with young rats. The percentage of protein in the rations ranged from 6 to 18, but the food intake of the rats is not reported. It was found that 10 per cent of either beef or fish protein in a ration was not quite sufficient to induce normal growth in rats, but that 15 per cent was ample. It was concluded that the coagulable protein from cod, herring, and salmon possessed nutritive value as high as that derived from beef.

McCollum, Simmonds, and Parsons (*6*) investigated the nutritive value of muscle (lean meat), liver, and kidney from the ox as sources of protein for growth and reproduction in rats. The rations were made up to contain 9 per cent of protein ($N \times 6.25$), adequate quantities of vitamins A and B, and mineral matter. A group of young rats was fed each ration, and in some instances the experiment was carried on with rats from the second and third generations. The food intake of the rats was not reported. The relative nutritive values assigned to muscle, liver, and kidney as sources of protein are based upon the growth, reproduction, and appearance of the rats. In concluding their article, they make the following statement (*6, p. 118*):

> The kidney, liver, and muscle of the ox contain proteins which, when they serve as the sole source of nitrogen, and are fed singly as the sole source of protein, but completely supplemented with respect to all necessary factors other than protein, are shown to possess about the same biological value as those of the wheat kernel.
>
> * * * Kidney proteins appear to have higher biological value than those of the other animal tissues yet studied.

In another publication McCollum (*7, pp. 108, 144*) makes the following statements concerning the nutritive value of certain animal proteins:

> *Proteins of extraordinary value.*—Kidney, liver, and milk proteins stand out as a group of foods containing proteins of unusual value. Among the cereal grains, wheat easily stands first in the quality of its proteins.
>
> As a source of protein for the support of growth the kidney is greatly superior to muscle tissue. Liver appears to fall between these in its value as a source of amino acids.

Mitchell (*8*) reports the results of a series of nitrogen-balance studies with rats to determine the biological value of the protein ($N \times 6.25$) in a number of food products. The term "biological value" is used to indicate the proportion of digestible nitrogen that is assimilated by the body, correction being made for metabolic nitrogen in the feces and for endogenous nitrogen in the urine. The biological values obtained by this method for a number of food products are reported as follows:

TABLE II.—*Biological value of proteins in foods, according to Mitchell*

Food product	Biological value when ration contained—		Food product	Biological value when ration contained—	
	5 per cent protein	8 to 10 per cent protein		5 per cent protein	8 to 10 per cent protein
Veal	97	84	Soybean	73	64
Milk	94	83	Casein	71	----
Beef	92	[1] 81	Potato	69	63
Do	----	[2] 68	Navy beans	29	38
Rice	88	----	Yeast	----	67
Oats	82	65	Alfalfa	----	62
Coconut	77	58	Tankage	----	33
Corn	73	58			

[1] 8 per cent protein. [2] 10 per cent protein.

In referring to the above data, Mitchell states that too much significance should not be attached to small differences in values, but that differences of 10 or more are probably significant.

In a later paper Mitchell and Carman (*9*) report the biological values obtained for the proteins in several other food products. The proteins in eggs, pork, and wheat were found to have values of 93, 74, and 67, respectively.

PRESENT INVESTIGATION

DESCRIPTION AND PREPARATION OF TISSUES

The beef consisted of round steak from fat steers, the pork of fresh hams from "butcher type" hogs, and the lamb of the fore quarters from heavy fat lambs. The livers, hearts, and kidneys were from the same grades of animals. All the above-named products were purchased in unfrozen condition on the local market. Each product was trimmed as free from fat and connective tissue as practicable, ground fine, mixed with water and toluol, and spread out in a thin layer in shallow pans. These were placed in an oven, where the material was dried in a current of air at a temperature not exceeding 60° C. The tissue became thoroughly air-dry in approximately 24 hours, when it was ground fine, transferred to glass jars, and placed in cold storage until needed. Each lot of dried tissue was analyzed for nitrogen and fat before use in a ration.

COMPOSITION OF RATIONS

With a few exceptions, each tissue was incorporated in each of three rations in such proportions that the rations contained 10, 12.5, and 15 per cent of protein ($N \times 6.25$), respectively, from this source. The only other source of protein in the ration was vitamin B, a commercial product prepared from yeast according to the method of Osborne and Wakeman (*13*). This product, which contained 54.7 per cent protein ($N \times 6.25$), was added to the rations in proportions ranging from 1 to 2 per cent. Vitamin A was supplied in cod-liver oil (1 to 2 per cent), or as an ether extract from egg yolk (5 per cent). The fat content of each ration was adjusted to 10

per cent by the addition of a sufficient quantity of hardened cottonseed oil. Mineral matter was supplied to the extent of 4 per cent as an ash mixture made up according to a formula by Drummond and Watson (*2, p. 237*). The rest of the ration consisted of cassava starch, which was found to be practically free from nitrogen. Each ration was made up in the quantity of 1,000 grams, when needed, and it was stored in covered glass jars.

DESCRIPTION AND CARE OF RATS

The young albino rats used in these experiments were raised in the animal laboratory of the Bureau of Animal Industry, from healthy vigorous stock. Litters of more than 8 rats were reduced to that

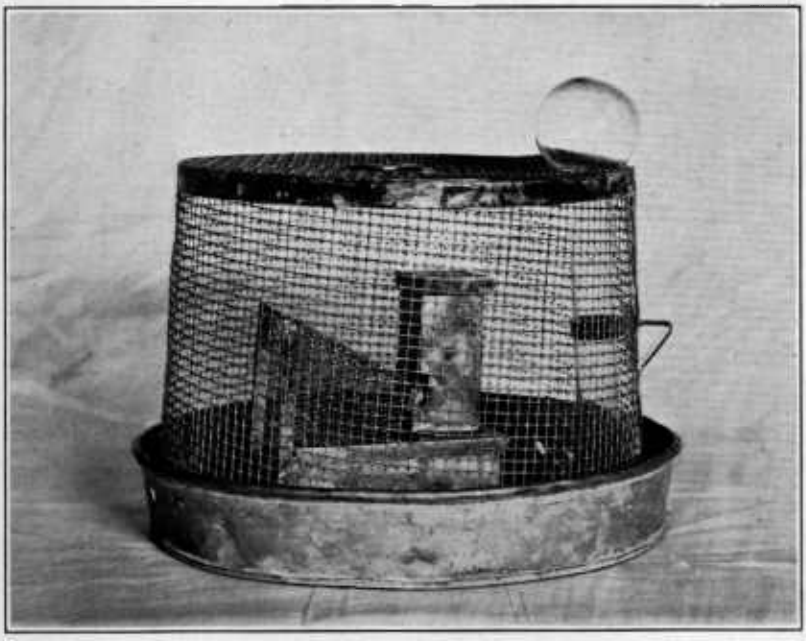

FIG. 1.—Rat cage, equipped with self-feeder and drinking fountain

number on the day of birth, and litters comprising fewer than 6 rats were discarded. Only young rats that weighed at least 40 grams each within 30 days from birth were used for experimental purposes. The breeding rats were fed a ration of uniform composition throughout these experiments.

Each experimental ration was fed to a group of 4 to 8 rats during a total period of 60 days, but the experimental data are tabulated for two periods, viz, (1) the first 30 days, and (2) for the entire 60 days. With few exceptions each ration was fed to a group composed of an equal number of male and female rats. Each rat was kept in an individual cage (fig. 1) and was supplied with water in a glass fountain and with its ration in a self-feeder (fig. 2). In the earlier experiments the rectangular type of feeder was used, but in the later tests an improved feeder of cylindrical shape was sub-

stituted (*5*). The rats were cared for daily, except Sunday, the blotting paper in the bottom of the cage being changed and any feed that had been pulled out of the feeders was replaced. The rats were weighed at the start of the test and regularly thereafter on Tuesday and Friday mornings. The self-feeder containing the ration was weighed when placed in the cage and again when nearly empty, the loss in weight indicating feed consumed. Cages, feeders, and drinking vessels were cleaned and sterilized at regular weekly intervals.

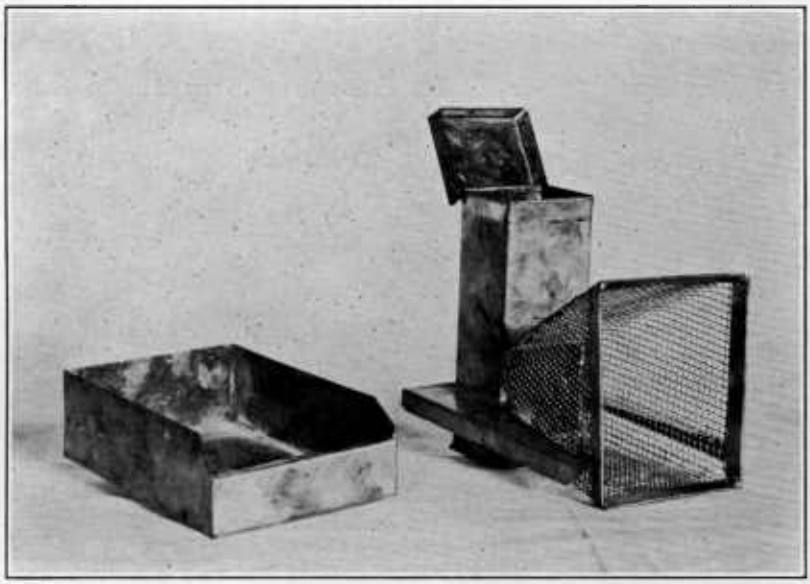

FIG. 2.—Self-feeder for rats

RELATIVE NUTRITIVE VALUE OF PROTEIN IN SEVERAL ANIMAL TISSUES

The results of the feeding experiments with the various animal tissues have been calculated and tabulated to show the result obtained with each rat, as well as the average result for the group of rats fed each ration, but it was found that the detailed results were so extensive as to make their publication undesirable. For this reason, only the average results will be presented.

THIRTY-DAY EXPERIMENTS

As regards the data presented in Table III, judgment of the relative nutritive values of the protein from the several tissues should be based chiefly upon the relation between feed and protein consumed, and the gain in weight of the rats, although the total gain in weight is of some importance also. The average data are given for each sex, but for the sake of brevity the discussion will be limited, for the most part, to the average data for both sexes. Although the results for the two sexes do not always run parallel, it is believed that the

average data for the male and female rats furnish the most satisfactory basis for comparison, on account of the larger number of rats involved.

Referring to the average total gain in weight, it will be noted that the largest gain (86 grams) was made by the rats fed ox muscle and hog liver, respectively, and the smallest gain (61 grams) by those fed ox liver. The gain made by the rats fed ox muscle and hog liver, respectively, was 41 per cent greater than that made by those fed ox liver. The gains made by the other groups of rats ranged from 85 grams for those fed ox hearts to 73 grams for those fed hog hearts, or a difference of 16 per cent in favor of the former.

TABLE III.—*Average* [1] *growth values obtained with rats for muscle, heart, liver, and kidney from the ox, sheep, and hog, when the rations contained 10 per cent protein, and the duration of the test was 30 days*

Kind of tissue	Sex of rats	Number of rats	Gain in weight in 30 days	Total intake		Intake per gram gain in weight		Gain in weight		Average daily consumption per gram body weight	
				Feed	Protein	Feed	Protein	Per gram of feed	Per gram of protein	Feed	Protein
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Ox muscle	Male	4	95	302	30.2	3.2	0.32	0.31	3.15	0.1127	0.0113
Do	Female	4	76	252	25.2	3.4	.34	.30	3.00	.1059	.0106
Average			86	277	27.7	3.3	.33	.31	3.08	.1093	.0109
Hog muscle	Male	4	84	281	28.1	3.4	.34	.30	2.96	.1070	.0107
Do	Female	4	73	279	27.9	3.8	.38	.26	2.62	.1115	.0112
Average			79	280	28.0	3.6	.36	.28	2.79	.1093	.0109
Sheep muscle	Male	4	85	274	27.4	3.2	.32	.31	3.12	.1095	.0110
Do	Female	4	71	257	25.7	3.7	.37	.28	2.76	.1082	.0108
Average			78	266	26.6	3.5	.35	.30	2.94	.1089	.0109
Ox heart	Male	5	86	275	27.5	3.2	.32	.31	3.11	.1119	.0112
Do	Female	3	83	270	27.0	3.2	.32	.31	3.09	.1072	.0107
Average			85	273	27.3	3.2	.32	.31	3.10	.1096	.0110
Hog heart	Male	4	81	265	66.5	3.3	.33	.31	3.04	.1103	.0110
Do	Female	4	65	234	23.4	3.6	.36	.28	2.77	.1073	.0107
Average			73	250	25.0	3.5	.35	.30	2.91	.1088	.0109
Ox liver	Male	7	70	243	24.3	3.6	.36	.28	2.82	.1040	.0104
Do	Female	1	52	207	20.7	4.0	.40	.25	2.51	.1062	.0106
Average			61	225	22.5	3.8	.38	.27	2.67	.1050	.0105
Hog liver	Male	4	103	292	29.2	2.9	.29	.36	3.54	.1073	.0107
Do	Female	4	69	241	24.1	3.5	.35	.29	2.88	.1102	.0110
Average			86	267	26.7	3.2	.32	.33	3.21	.1088	.0109
Sheep liver	Male	4	82	257	25.7	3.2	.32	.32	3.18	.1016	.0102
Do	Female	4	78	277	27.7	3.6	.36	.29	2.82	.1108	.0111
Average			80	267	26.7	3.4	.34	.31	3.00	.1062	.0106
Ox kidney	Male	4	78	260	26.0	3.4	.34	.30	3.00	.1055	.0106
Do	Female	4	78	288	28.8	3.8	.38	.28	2.71	.1151	.0115
Average			78	274	27.4	3.6	.36	.29	2.86	.1103	.0110
Hog kidney	Male	5	88	281	28.1	3.2	.32	.32	3.18	.1089	.0109
Do	Female	3	64	220	22.0	3.5	.35	.29	2.90	.1020	.0102
Average			76	251	25.1	3.4	.34	.31	3.04	.1055	.0106

[1] In this and succeeding tables the average for the two sexes is the average of the averages for the males and females, respectively.

The feed intake per gram of gain in weight was largest for the rats fed ox liver (3.8 grams), and smallest for those fed ox heart and hog liver, respectively (3.2 grams).

The greatest gain in weight per gram of protein consumed was made by the rats fed hog liver (3.21 grams), and the smallest gain by those fed ox liver (2.67 grams), a difference of 20 per cent in favor of hog liver. If these two products are excepted, the values for the others range from 3.10 grams for ox hearts to 2.79 grams for hog muscle, or a difference of only 11 per cent in favor of ox hearts.

TABLE IV.—*Average growth values obtained with rats for muscle, heart, liver, and kidney from the ox, sheep, and hog, when the rations contained 10 per cent protein, and the duration of the test was 60 days*

Kind of tissue	Sex of rats	Number of rats	Gain in weight in 60 days	Total intake		Intake per gram gain in weight		Gain in weight	
				Feed	Protein	Feed	Protein	Per gram of feed	Per gram of protein
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Ox muscle	Male	4	170	667	66.7	3.9	0.39	0.25	2.55
Do	Female	4	114	523	52.3	4.6	.46	.22	2.18
Average			142	595	59.5	4.3	.43	.24	2.37
Hog muscle	Male	4	137	554	55.4	4.1	.41	.25	2.46
Do	Female	4	106	531	53.1	5.0	.50	.20	2.02
Average			122	543	54.3	4.6	.46	.23	2.24
Sheep muscle	Male	4	152	611	61.1	4.1	.41	.25	2.48
Do	Female	4	103	534	53.4	5.2	.52	.19	1.94
Average			128	573	57.3	4.7	.47	.22	2.21
Ox heart	Male	5	168	639	63.9	3.8	.38	.26	2.64
Do	Female	3	117	520	52.0	4.5	.45	.22	2.24
Average			143	580	58.0	4.2	.42	.24	2.44
Hog heart	Male	4	149	596	59.6	4.0	.40	.25	2.49
Do	Female	4	98	481	48.1	4.9	.49	.21	2.06
Average			124	539	53.9	4.5	.45	.23	2.28
Ox liver	Male	7	126	543	54.3	4.3	.43	.23	2.31
Do	Female	1	91	488	48.8	5.4	.54	.19	1.86
Average			109	516	51.6	4.9	.49	.21	2.09
Hog liver	Male	4	171	673	67.3	4.0	.40	.25	2.53
Do	Female	4	102	497	49.7	5.0	.50	.20	2.02
Average			137	585	58.5	4.5	.45	.23	2.28
Sheep liver	Male	4	156	598	59.8	3.8	.38	.26	2.61
Do	Female	4	119	564	56.4	4.8	.48	.21	2.10
Average			138	581	58.1	4.3	.43	.24	2.36
Ox kidney	Male	4	135	557	55.7	4.2	.42	.24	2.42
Do	Female	4	110	539	53.9	5.0	.50	.20	2.02
Average			123	548	54.8	4.6	.46	.22	2.22
Hog kidney	Male	5	159	622	62.2	3.9	.39	.26	2.56
Do	Female	3	86	471	47.1	5.6	.56	.18	1.18
Average			123	547	54.7	4.8	.48	.22	2.19

Sixty-Day Experiments

From Table IV it will be noted that the greatest average gain in weight was made by the rats fed ox hearts (143 grams), and the smallest gain by those fed ox liver (109 grams), a difference of 31 per cent in favor of the former. The gains made by the other groups of rats ranged from 142 grams for those fed ox muscle to 122 grams for those fed hog muscle, or a difference of 16 per cent in favor of ox muscle.

The feed intake for each gram of gain in weight made by the rats ranged from 4.2 grams for ox hearts, to 4.9 grams for ox liver.

The gain in weight per gram of protein consumed was greatest for the rats fed ox heart (2.44 grams), and smallest for those fed ox liver (2.09 grams), a difference of 17 per cent in favor of the ox heart. The values for the other tissues range from 2.19 grams for hog kidneys, to 2.37 for ox muscle, or a difference of only 8 per cent.

The variations in the results obtained during the 60-day test are smaller than those in the results obtained during the 30-day test. This was to have been expected, of course, on account of the decreasing requirement of the rat for protein as it increases in weight.

RELATIVE NUTRITIVE VALUES OF ANIMAL TISSUES WHEN RATIONS CONTAINED 12.5 PER CENT PROTEIN

Thirty-Day Experiments

From Table V it will be noted that the average gain in weight made by each of the several groups of rats ranged from 87 grams for those fed ox kidney to 101 grams for those fed sheep liver, or a difference of 16 per cent in favor of the sheep liver. This is to be contrasted with a difference of 41 per cent in the gains made by the rats fed the rations containing 10 per cent protein for a period of 30 days.

The feed intake for each gram of gain in weight ranged from 2.7 grams for the rats fed hog kidney to 3.4 grams for those fed hog liver.

The greatest gain in weight per gram of protein consumed was made by the rats fed hog kidney (3.01 grams), and the smallest gain by those fed hog liver (2.46 grams), a difference of 22 per cent in favor of hog kidney.

Taking into consideration the several factors involved, it appears that hog kidney and hog heart had somewhat higher values as sources of protein for growth than did the other tissues, when the rations contained 12.5 per cent protein and the duration of the test was 30 days. The differences in the values obtained for the products other than hog heart and hog kidney are so small as to have no significance.

TABLE V.—*Average growth values obtained with rats for muscle, heart, liver, and kidney from the ox, sheep, and hog, when the rations contained 12.5 per cent protein, and the duration of the test was 30 days*

Kind of tissue	Sex of rats	Number of rats	Gain in weight in 30 days	Total intake		Intake per gram gain in weight		Gain in weight		Average daily consumption per gram body weight	
				Feed	Protein	Feed	Protein	Per gram of feed	Per gram of protein	Feed	Protein
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Ox muscle	Male	3	107	313	39.1	2.9	0.37	0.34	2.73	0.1035	0.0129
Do	Female	5	69	242	30.5	3.6	.45	.28	2.27	.0985	.0123
Average			88	278	34.8	3.3	.41	.31	2.50	.1010	.0126
Hog muscle	Male	2	108	308	38.5	2.9	.36	.35	2.82	.1072	.0134
Do	Female	2	80	274	34.3	3.5	.43	.29	2.32	.0990	.0124
Average			94	291	36.4	3.2	.40	.32	2.57	.1031	.0129
Sheep muscle	Female	4	78	274	34.3	3.5	.44	.29	2.27	.1113	.0139
Ox heart	Male	1	114	307	38.4	2.7	.34	.37	2.97	.1089	.0136
Do	Female	3	77	267	33.3	3.5	.44	.29	2.31	.1090	.0136
Average			96	287	35.9	3.1	.39	.33	2.64	.1080	.0136
Hog heart	Male	3	114	286	35.8	2.5	.32	.40	3.21	.1023	.0128
Do	Female	1	73	217	27.1	3.0	.37	.34	2.69	.0924	.0116
Average			94	252	31.5	2.8	.35	.37	2.95	.0974	.0122
Ox liver	Male	2	121	325	40.7	2.7	.34	.37	2.97	.0972	.0122
Do	Female	2	65	253	31.7	3.9	.49	.26	2.05	.0985	.0123
Average			93	289	36.2	3.3	.42	.32	2.51	.0976	.0123
Hog liver	Male	3	111	304	38.0	2.8	.35	36	2.91	.0983	.0123
Do	Female	1	64	254	31.8	4.0	.50	.25	2.01	.1052	.0132
Average			88	279	34.9	3.4	.43	.31	2.46	.1018	.0128
Sheep liver	Male	2	117	335	41.9	2.9	.36	.35	2.78	.1155	.0144
Do	Female	2	85	275	34.4	3.3	.41	.31	2.46	.1086	.0136
Average			101	305	38.2	3.1	.39	.33	2.62	.1121	.0140
Ox kidney	Male	2	84	256	32.1	3.2	.39	.33	2.58	.0977	.0122
Do	Female	2	89	274	34.2	3.1	.39	.33	2.59	.1081	.0135
Average			87	265	33.2	3.2	.39	.33	2.59	.1029	.0129
Hog kidney	Male	2	109	270	33.7	2.5	.31	.40	3.22	.0968	.0121
Do	Female	2	86	244	30.6	2.9	.36	.35	2.79	.0988	.0124
Average			98	257	32.2	2.7	.34	.38	3.01	.0978	.0123

SIXTY-DAY TESTS

In Table VI are summarized the results of the 60-day feeding experiments with rations containing 12.5 per cent protein. The average total gain in weight made by each of the groups of rats varied within comparatively narrow limits, ranging from 158 grams for those fed ox heart to 139 grams for those fed ox liver, or a difference of only 13.7 per cent in favor of the ox heart.

The feed intake per gram of gain in weight ranged from 3.8 grams for the rats fed hog kidneys to 4.5 grams for those fed ox muscle and hog liver, respectively.

The gain in weight per gram of protein consumed ranged from 2.18 grams for the rats fed hog heart to 1.84 grams for those fed hog liver, or a difference of 18 per cent in favor of the hog heart.

The results of this series of experiments are very similar to those obtained with the same rations during the 30-day test, as regards relative nutritive values of the proteins from the several tissues. Hog heart and hog kidney seemed to have somewhat higher values than the other tissues.

TABLE VI.—*Average growth values obtained with rats for muscle, heart, liver, and kidney from the ox, sheep, and hog, when the rations contained 12.5 per cent protein, and the duration of the test was 60 days*

Kind of tissue	Sex of rats	Number of rats	Gain in weight in 60 days	Total intake		Intake per gram gain in weight		Gain in weight	
				Feed	Protein	Feed	Protein	Per gram of feed	Per gram of protein
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Ox muscle	Male	3	194	718	89.8	3.8	0.47	0.26	2.14
Do	Female	5	101	509	63.6	5.1	.64	.20	1.58
Average			148	614	76.7	4.5	.56	.23	1.86
Hog muscle	Male	2	174	668	83.5	3.9	.49	.26	2.08
Do	Female	2	117	555	69.4	4.8	.60	.21	1.69
Average			146	612	76.5	4.4	.55	.24	1.89
Sheep muscle	Female	4	113	556	69.4	4.9	.62	.20	1.63
Ox heart	Male	1	201	681	85.1	3.4	.42	.30	2.36
Do	Female	3	114	519	64.9	4.5	.57	.22	1.76
Average			158	600	75.0	4.0	.50	.26	2.06
Hog heart	Male	3	190	651	81.4	3.8	.43	.29	2.33
Do	Female	1	121	478	59.8	4.0	.49	.25	2.02
Average			156	565	70.6	3.9	.46	.27	2.18
Ox liver	Male	2	179	656	82.0	3.7	.46	.27	2.18
Do	Female	2	98	499	62.4	5.1	.64	.20	1.57
Average			139	578	72.2	4.4	.55	.24	1.88
Hog liver	Male	3	186	679	84.9	3.7	.46	.27	2.18
Do	Female	1	95	508	63.5	5.3	.67	.19	1.50
Average			141	594	74.2	4.5	.57	.23	1.84
Sheep liver	Male	2	185	735	91.9	3.8	.50	.26	2.01
Do	Female	2	120	553	69.2	4.7	.58	.22	1.73
Average			153	644	80.6	4.3	.54	.24	1.87
Ox kidney	Male	2	161	590	73.8	3.8	.47	.27	2.18
Do	Female	2	126	596	70.3	4.5	.56	.22	1.79
Average			144	576	72.1	4.2	.52	.25	1.98
Hog kidney	Male	2	183	607	75.9	3.4	.42	.31	2.41
Do	Female	2	120	502	62.7	4.2	.53	.24	1.90
Average			152	555	69.3	3.8	.48	.28	2.16

RELATIVE NUTRITIVE VALUES OF ANIMAL PROTEINS WHEN RATIONS CONTAINED 15 PER CENT PROTEIN

THIRTY-DAY EXPERIMENTS

Only 7 of the 10 animal tissues previously examined were tested in this experiment, and one was fed to female rats only. In Table VII it will be noted that the average total gain in weight for the

rats of both sexes ranged from 104 grams for the rats fed ox liver to 82 grams for those fed sheep muscle, or a difference of 27 per cent in favor of the ox liver. The gains made by the other groups of rats ranged from 101 grams for those fed ox heart to 89 grams for those fed hog muscle, or a difference of 13 per cent in favor of the former.

The feed intake per gram gain in weight ranged from 2.8 grams for the rats fed ox liver to 3.3 grams for those fed sheep muscle.

The gain in weight per gram of protein consumed varied from 2.40 grams for the rats fed ox liver to 2.06 grams for those fed sheep muscle, or a difference of 16.5 per cent in favor of the ox liver. If sheep muscle is excepted, the variation in the values of the other tissues amounts to only 9 per cent.

The results of this series of tests appear to indicate that sheep muscle had a somewhat lower nutritive value than the other tissues in this group, but, considering the limited number of rats used to test each tissue, it is doubtful whether the difference is great enough to be significant.

Sixty-Day Experiments

In Table VIII it will be noted that the greatest average gain in weight was made by the rats fed the ration containing ox heart (165 grams), and the smallest gain by those fed sheep muscle (142 grams), or a difference of 16 per cent in favor of the ox heart.

Table VII.—*Average growth values obtained with rats for muscle, heart, and liver from the ox, sheep, and hog, when the rations contained 15 per cent protein, and the duration of the test was 30 days*

Kind of tissue	Sex of rats	Number of rats	Gain in weight in 30 days	Total intake		Intake per gram gain in weight		Gain in weight		Average daily consumption per gram body weight	
				Feed	Protein	Feed	Protein	Per gram of feed	Per gram of protein	Feed	Protein
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Grn.*	*Gm.*
Ox muscle	Male	2	107	300	45.0	2.8	0.42	0.36	2.38	0.0977	0.0147
Do	Female	2	84	254	38.1	3.1	.46	.33	2.20	.0981	.0147
Average			96	277	41.6	3.0	.44	.35	2.29	.0979	.0147
Hog muscle	Male	2	99	277	41.5	2.8	.42	.36	2.39	.0954	.0143
Do	Female	2	78	242	36.3	3.1	.47	.32	2.14	.0959	.0144
Average			89	260	38.9	3.0	.45	.34	2.27	.0957	.0144
Sheep muscle	Male	1	85	271	40.7	3.2	.48	.31	2.09	.1013	.0152
Do	Female	3	79	259	38.9	3.3	.49	.30	2.02	.1009	.0151
Average			82	265	39.8	3.3	.49	.31	2.06	.1011	.0152
Ox heart	Male	2	125	326	48.9	2.6	.39	.38	2.56	.1047	.0157
Do	Female	2	77	245	37.7	3.2	.49	.32	2.04	.1017	.0153
Average			101	286	43.3	2.9	.44	.35	2.30	.1032	.0155
Ox liver	Male	3	120	310	46.6	2.6	.39	.38	2.57	.0940	.0141
Do	Female	1	88	264	39.6	3.0	.45	.33	2.22	.0943	.0141
Average			104	287	43.1	2.8	.42	.36	2.40	.0942	.0141
Hog liver	Male	2	114	305	45.7	2.7	.41	.37	2.48	.0950	.0143
Do	Female	2	66	227	34.1	3.4	.52	.29	1.94	.0933	.0140
Average			90	266	39.9	3.1	.47	.33	2.21	.0942	.0142
Sheep liver	Female	4	90	289	43.4	3.3	.49	.31	2.07	.1074	.0161

TABLE VIII.—*Average growth values obtained with rats for muscle, heart, and liver from the ox, sheep, and hog, when the rations contained 15 per cent protein, and the duration of the test was 60 days*

Kind of tissue	Sex of rats	Number of rats	Gain in weight in 60 days	Total intake		Intake per gram gain in weight		Gain in weight	
				Feed	Protein	Feed	Protein	Per gram of feed	Per gram of protein
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Ox muscle	Male	2	170	669	100.2	3.9	0.60	0.26	1.7
Do	Female	2	125	545	81.8	4.4	.66	.23	1.53
Average			148	607	91.0	4.2	.63	.25	1.62
Hog muscle	Male	2	175	624	93.6	3.6	.54	.28	1.87
Do	Female	2	118	577	86.6	4.9	.74	.21	1.37
Average			147	601	90.1	4.3	.64	.25	1.62
Sheep muscle	Male	1	164	590	88.5	3.6	.54	.28	1.85
Do	Female	3	120	534	80.1	4.5	.68	.22	1.47
Average			142	562	84.3	4.1	.61	.25	1.66
Ox heart	Male	2	205	719	107.9	3.6	.53	.29	1.90
Do	Female	2	124	518	77.7	4.2	.63	.24	1.59
Average			165	619	92.8	3.9	.58	.27	1.75
Ox liver	Male	3	195	638	95.7	3.3	.49	.31	2.04
Do	Female	1	115	455	68.3	4.0	.59	.25	1.68
Average			155	547	82.0	3.7	.54	.28	1.86
Hog liver	Male	2	187	683	102.4	3.7	.55	.28	1.83
Do	Female	2	98	481	72.1	5.0	.76	.21	1.35
Average			143	582	87.3	4.4	.66	.25	1.59
Sheep liver	Female	4	122	582	87.3	4.8	.72	.21	1.40

The feed consumption per gram of gain in weight ranges from 3.7 grams for the rats fed ox liver to 4.4 for those fed hog liver.

The greatest gain in weight per gram of protein consumed was made by the rats fed ox liver (1.86 grams), and the smallest gain by those fed hog liver (1.59 grams), a difference of 17 per cent in favor of the ox liver.

The results of the 60-day feeding test with rations containing 15 per cent of protein from each of 6 animal tissues, respectively, seem to indicate that ox liver had a somewhat higher value as a source of protein for maintenance and growth than the other tissues, but, considering the fact that each ration was tested with only 4 rats, it is possible that this difference is within the limit of experimental error.

RELATIVE NUTRITIVE REQUIREMENTS OF MALE AND FEMALE RATS

In Tables III to VIII, inclusive, it will be noted that, with relatively few exceptions, very different results were obtained from the male rats than from the female. With two exceptions, the male rats made a greater gain in weight per gram of protein consumed, and required less feed for each gram of gain in weight, than did the female rats getting the same ration. The two exceptions are: (1) The

rats fed the ration containing 10 per cent of ox heart protein for a period of 30 days (Table III), and (2) those fed the ration containing 12.5 per cent of ox kidney protein for a like period (Table V). In both of these instances, practically the same results were obtained from the male rats as from the female.

An explanation for the difference in the results obtained from the two sexes is not hard to find. In Tables III to VIII, inclusive, it will be observed that, with only a few exceptions, the male rats made considerably greater gains in weight than did the females getting the same ration, the differences being greater for the 60-day than for the 30-day tests. This indicates that the feed was utilized more efficiently for growth by the faster-growing rats, the males, than by the slower-growing rats, the females. This is in accordance with the well-known fact that the faster-growing animal utilizes its feed more efficiently for growth than does the slower-growing one, chiefly for the reason that the latter requires a larger proportion of its feed for maintenance than does the former.

This explanation is supported by the fact that in two instances where the male rats made approximately the same gain in weight as did the female, both sexes utilized the ration with practically equal efficiency for growth (rats fed ox heart, Table III, and those fed ox kidney, Table V). Thus, rate of growth, rather than sex, seems to determine the efficiency with which the rat utilizes its feed for growth.

In another instance, however (ox kidney ration, Table III), the male and female rats made the same gain in weight, but the latter consumed appreciably more feed and consequently utilized their ration less efficiently for growth.

However, the preponderance of evidence supports the view that the female rats utilized their feed less efficiently for growth than did the male rats, because of the difference in the rate of growth of the two sexes.

The practical significance of these observations, as related to the use of male and female rats for the determination of the relative nutritive values of proteins, is apparent.

The fact that in every instance the rats of both sexes utilized their feed much more efficiently for growth during the 30-day test than during the entire period of 60 days is in harmony with the experience of practical feeders and students of nutrition, that the larger animals require less feed per pound of gain early in the growing period than later.

SUMMARY OF RESULTS

In this paper are reported the results of a series of feeding experiments with young albino rats to determine the relative values for maintenance and growth of the protein in voluntary muscle, heart, liver, and kidney from cattle, sheep, and hogs.

Protein was fed at three levels of intake, viz, 10, 12.5, and 15 per cent, and the rations were prepared so as to have practically the same energy value.

When protein was fed at the 10 per cent level for a period of 30 days, hog liver had a somewhat higher value and ox liver a slightly lower value than any of the other tissues; but the differences in the

values obtained for the several tissues were less marked when the duration of the experiment was 60 days.

When protein was fed at the 12.5 per cent level, hog heart and hog kidney seemed to have somewhat higher values than the other tissues, for both the 30 and the 60 day experiments.

Only ox, hog, and sheep muscle, ox heart, and ox, hog, and sheep liver were fed in rations containing 15 per cent protein, and the differences in the values obtained do not seem large enough to be significant.

The male rats were found to utilize protein much more efficiently for growth than the female rats. This is explained by the more rapid growth of the male rats, resulting in a smaller proportionate requirement of protein for maintenance as compared with that needed for growth than was the case with the slower-growing female rats.

Each ration was utilized much more efficiently for growth during the 30-day than during the 60-day experiment. This is due to the increasing requirement of the rat for feed for maintenance, as compared with that required for growth, as it increases in weight.

As regards the probable relative nutritive values of voluntary muscle, heart, liver, and kidney from the ox, sheep, and hog, as sources of protein in the human dietary, it seems likely that when the diet contains an adequate amount of protein these tissues will have approximately the same value for maintenance and growth.

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