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PRODUCTIVE ENERGY OF CORN MEAL, ALFALFA LEAF MEAL, DRIED BUTTERMILK, CASEIN, COTTONSEED MEAL, AND TANKAGE AS MEASURED BY PRODUCTION OF FAT AND FLESH BY GROWING CHICKENS

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This is a report of part of a comprehensive investigation of the value of feeds and foods for productive energy as measured by the production of fat and flesh in growing chickens. In 11 experiments with 256 chicks previously reported, it was found that the productive energy of a primary mixed ration for production of fat and flesh on growing chicks was 278 calories per 100 grams of effective digestible nutrients. The ration used was composed of 51 per cent yellow corn meal, 19 per cent wheat gray shorts, 10 cent dried buttermilk, 6 per cent cottonseed meal, 5 per cent alfalfa leaf meal, 4 per cent tankage, 2 per cent bone meal, 2 per cent oyster shell, and 1 per cent salt. The object of the work here reported was to ascertain the productive energy of the feeds named above and also of casein. A standard ration containing corn meal, or (in some cases corn meal and casein), was fed to one group of baby chicks. At the same time other groups were fed similar rations except that the feeds to be tested replaced part of the corn meal or corn meal and casein. At the end of 3 weeks, the chicks were analyzed and the gains in protein and fat determined. Analyses of the feeds and the rations were also made as well as digestion experiments on the rations. A preliminary comparison was made of the energy value of the corn meal with the other feeds in the primary mixed ration previously tested. From these data, the previous mixed ration was found to have 91 per cent of the productive energy of corn meal, thus making the productive energy of the corn meal 305 calories per 100 grams of effective digestible nutrients. The average productive energy per 100 grams of the effective digestible nutrients was found to be for alfalfa leaf meal (5 exp.) 241 Calories, dried buttermilk (4 exp.) 243 Calories, casein (5 exp.) 298 Calories, cottonseed meal (5 exp.) 280 Calories, tankage (7 exp.) 240 Calories, and wheat gray shorts (5 exp.) 270 Calories as compared with corn meal (standard) 305 Calories. When the productive energy of the ration and the corn meal were again calculated with these revised values, the productive energy of the corn meal was found to be 3.00 Calories per gram of effective digestible nutrients. The productive energy of the feed and the utilization of protein by the chicks and other matters pertaining to the productive energy are discussed.

CONTENTS

PRODUCTIVE ENERGY OF CORN MEAL, ALFALFA LEAF MEAL, DRIED BUTTERMILK, CASEIN, COTTONSEED MEAL, AND TANKAGE AS MEASURED BY PRODUCTION OF FAT AND FLESH BY GROWING CHICKENS

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The work here presented is a part of a comprehensive investigation of the value of the energy of different kinds of feeds as measured by the production of fat and flesh on growing chickens. Previous publications have discussed the digestibility of some chicken feeds (3), the utilization of energy of feeds by growing chickens (6), the utilization of the energy of wheat products by chickens (7), the energy values of corn bran, rice bran, and rye flour (8), the relation of gain in weight to gain in energy content of growing chickens (9), and the metabolizable energy of chicken feeds (10).

The object of the work is to measure the energy value of feeds in terms of the use made of the energy by chickens. Values of feeds have been compared in terms of digestible nutrients and of metabolizable energy on the assumption that these are measures of the utilization of the food by animals. Previous work (1, 2, 4, 7, 12) has shown that measured in terms of gains of fat and flesh by the animals, neither digestible nutrients or metabolizable energy are always correct measures for the energy value of feeds (7).

Extensive work has been done on the utilization of the energy of feed by ruminants by Kellner, Armsby, Forbes, and others. As the literature has already been summarized in previous publications (5, 6), it will not be again summarized here. A deficiency of protein (5) or of calcium (11) or vitamins of other elements or compounds necessary for growth may in some cases decrease the utilization of the energy of feed by animals. When productive energy is measured, the feed should be fed in a balanced ration which is not deficient in any substance needed for the assimilation or utilization of the digested feed or which contains any substance which interferes with the utilization of the energy.

A previous publication (Bulletin 571) reports measurements of the energy value of a mixed ration for production of flesh and fat on growing chickens which shall herein be termed the primary ration. In 11 experiments with 256 chicks, the mixture was fed at two levels, one of full feed and the other approximately half of full feed. Analyses of representative chickens at the beginning and of the experimental chickens at the end of the experiment permitted the determination of the gain in fat and flesh and the calculation of the Calories gained. Maintenance requirements of the chicks and productive energy of the primary ration were calculated

on the assumption that maintenance requirements vary directly with the weight. Calculations on this basis were found to be more in accordance with previous results of other workers than those calculated on the assumption that the maintenance requirements vary directly with the surface area of the chickens. The average productive energy of the effective digestible nutrients of the primary ration was found to be 278 Calories per 100 grams. The primary ration was composed of 51 per cent yellow corn meal, 19 per cent wheat gray shorts, 10 per cent dried buttermilk, 6 per cent cottonseed meal, 5 per cent alfalfa leaf meal, 4 per cent tankage, 2 per cent bone meal, 2 per cent oyster shell, and 1 per cent salt.

For preliminary comparisons of corn meal with other feeds, we assumed that the effective digestible nutrients of the corn meal had the same productive energy as the primary ration. However, comparisons of corn meal with wheat gray shorts (7) and some other constitutents of the primary ration showed that their digestible nutrients have lower productive energy values than those of corn meal, so that the productive energy of corn meal must be greater than that of the primary ration (2.78 Calories per gram). The next step, therefore, is to ascertain the productive energy of the constituents of the primary ration previously tested, as compared with corn meal, and from these data to calculate more closely the productive energy of corn meal. The corrected value of corn meal then can be used in the determination of the productive energy of other feeds which are compared with corn meal.

The objects of the work here presented are to determine the productive energy of the constituent feeds used in the primary ration previously studied, as compared with corn meal, in order to secure a more nearly correct productive energy value of the corn meal, and to calculate the productive energy of the other feeds relative to this new energy value for corn meal. Since casein was also used in comparing some of the feeds tested, determination of its productive energy compared with that of corn meal was also necessary. Some other feeds than those used in the primary ration were included in these experiments, and the data regarding them are given in order not to divide the experiments, but the values of these additional feeds will be discussed in more detail in connection with other work done in other experiments.

Method of Procedure

The method of procedure is similar to that used in the previous work already mentioned (7). The feeds to be tested were compared with corn meal or casein and corn meal as standards. Sixty or more baby chicks were placed upon the standard corn meal ration for a preliminary period of approximately one week. They were then weighed, and five groups of chicks were selected so as to have the same average weight and to be as nearly uniform as possible. The chickens left over after selecting the five groups were used for digestion experiments. One group was killed and analyzed. One of the four experimental groups received a standard

balanced ration containing 50 per cent or more of corn meal or corn meal and casein, while in the rations for the other three groups the corn meal or casein, or both, was partly replaced by the feed to be tested. The chickens were fed individually in battery brooders, each compartment being divided by a screen wire, so as to furnish two spaces, each to contain one chicken. The brooders were electrically heated and controlled by thermostats to a temperature of 92-94° F. The chickens were fed individually for 3 weeks and weighed at the end of each week. They were then killed, the intestinal contents removed, and the entire chick prepared for analysis. In experiments up to and including No. 8, boric acid and 3% ground filter paper were added before grinding. In the experiments after No. 8, ground filter paper alone was added. The filter paper absorbs the water which would otherwise separate, and gives a more uniform sample.

Beginning with experiment No. 26, the chickens were cooked before being ground for analysis. They are placed in fruit jars, heated in steam at 15 pounds pressure for 3 hr. in an autoclave, allowed to cool overnight, and then ground in a food chopper with 3% ground filter paper. The cooked chicks are more easily ground to a uniform mixture than the uncooked chicks. There is always some loss of water in cooking the chicks, which is ascertained by weighing the jars containing them before and after cooking. In tests with jars which contained water, only, the loss from 200 grams of water was about 4 per cent.

Protein (N x 6.25) was determined by the Kjeldahl-Gunning Method on 3.5 gram samples. Fat was determined on 4 gram portions by extraction with ether after drying under reduced pressure at 100° C. and grinding in a mortar. Three or more determinations were made on each chick. After correcting for the added quantities of filter paper and boric acid (when used) and the loss of water when the chicken was cooked, the energy content was calculated by the use of the factors 5.66 for protein and 9.35 for fat. This method was found in previous work (7) to give results agreeing with the heats of combustion of dried chicks as determined in a bomb calorimeter.

In Bulletin 589 (10) we showed that for chicken feeds or rations, the metabolizable energy for maintenance can be calculated with an excellent degree of accuracy from the digestible nutrients by means of the values of 4.4 Calories per gram of protein, 4.2 Calories per gram of nitrogen-free extract and of crude fiber, and 9.47 Calories per gram of ether extract. The digestible nutrients are reported in this publication in terms of effective digestible nutrients, which are the sum of the digestible protein, the digestible ether extract multiplied by 2.25, and the digestible nitrogen-free extract. For the purposes of this work, the grams of effective digestible nutrients have been multiplied by 4.2 calories to secure the metabolizable energy. The value so secured is probably a little low for feeds high in protein. Any correction for this lower value, if needed, can be made in subsequent publications.

Details and Data of the Work

The ingredients of the standard corn meal rations used in the various experiments are given in Tables 1, 2, and 3. In the other rations, the feed to be tested was substituted for part of the corn meal, and was usually 50 per cent of the total ration. In experiments with some of the high protein feeds, the standard ration was made up to be high in protein by use of casein and corn meal. The feed tested replaced part of the corn meal and part of the casein. Some of the feeds, such as alfalfa leaf meal, could not be fed in quantities as high as 50 per cent of the ration, as the ration killed some or all of the chicks, while others, such as dried buttermilk, caused illness, such as diarrhea. It was, therefore, necessary to use less than 50 per cent of such feeds in the rations fed. High protein feeds in some tests replaced corn meal to the extent of 50 per cent of the ration, resulting in a high protein content of the ration. In other experiments, the quantities were adjusted so that all the rations contained equal quantities of protein.

The quantities of feed which replaced the corn meal in the experimental rations, together with the identifying numbers of the feeds, are given in Table 4.

Chemical analyses were made of all the feeds and also of the mixed rations. The percentage composition of the feeds and their effective

Table 1. Names, registration numbers, and percentages of feeds used in standard rations Exp. 1-66, 8, 9, 11, 12, 21, 22, and 23

Lab. No.		Exp. 1–66	Exp. 8	Exp. 9	Exp. 11	Exp. 12	Exp. 21	Exp. 22	Exp. 23
53890	Corn meal	51.0							
48440	Corn meal		56.0	56.0					
48986	Corn meal				56.8				
49468	Corn meal					56.8			
48361	Casein		12.0	12.0	12.0				
49469	Casein					12.0			
54170	Casein						5.0	5.0	20.0
43898	Wheat gray shorts	19.0							
48265	Wheat gray shorts		20.0						
48740	Wheat gray shorts			20.0	20.0				
49467	Wheat gray shorts					20.0			
54168	Wheat gray shorts						16.3	16.3	16.3
43901	Dried buttermilk	10.0							
43903	Cottonseed meal	6.0							
43900	Tankage	4.0							
43902	Alfalfa leaf meal	5.0							
48263	Alfalfa leaf meal		6.0	6.0	6.0	6.0			
54172	Alfalfa leaf meal						4.0	4.0	4.0
48262	Yeast		2.0	2.0	2.0	2.0			
54171	Yeast						6.0	6.0	6.0
70402	Cod liver oil		1.0						
70632	Cod liver oil			1.0					
48426	Cod liver oil (fortified)				0.2	0.2			
71153	Cod liver oil						0.2	0.2	0.2
54169	Dried skim milk						10.0	10.0	
54330	Dried skim milk								10.0
33303	Bone meal	2.0							
	Oyster shell	2.0							
	Salt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Calcium carbonate		1.0	1.0	1.0	1.0	1.5	1.5	1.5
	Tri-calcium phosphate		1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 2. Names, registration numbers, and percentages of feeds used in standard rations for Experiments 24, 26, 27, 28, 30, and 31

Lab. No.		Exp. 24	Exp. 26	Exp. 27	Exp. 28	Exp. 30	Exp. 31
54347	Corn meal	40.0	.....	.....	.....	.....	.....
54984	Corn meal	.....	40.0	.....	.....	.....	.....
55087	Corn meal	.....	.....	40.0	.....	.....	.....
55225	Corn meal	.....	.....	.....	40.0	.....	.....
55463	Corn meal	.....	.....	.....	.....	40.0	.....
55588	Corn meal	.....	.....	.....	.....	.....	40.0
54371	Casein	20.0	20.0	20.0	20.0	20.0	20.0
54168	Wheat gray shorts	16.3	.....	.....	.....	.....	.....
54821	Wheat gray Shorts	.....	16.3	16.3	16.3	.....	.....
55462	Wheat gray shorts	.....	.....	.....	.....	16.3	16.3
54330	Dried skim milk	10.0	10.0	10.0	.....	.....	.....
55226	Dried skim milk	.....	.....	.....	10.0	10.0	.....
55587	Dried skim milk	.....	.....	.....	.....	.....	10.0
54171	Yeast	6.0	.....	.....	.....	.....	.....
54822	Yeast	.....	6.0	6.0	.....	.....	.....
55227	Yeast	.....	.....	.....	6.0	6.0	6.0
54172	Alfalfa leaf meal	4.0	.....	.....	.....	.....	.....
54985	Alfalfa leaf meal	.....	4.0	4.0	4.0	4.0	4.0
71153	Cod liver oil	0.2	.....	.....	.....	.....	.....
77434	Cod liver oil	.....	0.2	0.2	0.2	0.2	0.2
	Calcium carbonate	1.5	1.5	1.5	1.5	1.5	1.5
	Tri-calcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0
	Salt	1.0	1.0	1.0	1.0	1.0	1.0

Table 3. Names, registration numbers, and percentages of feeds used in standard rations Experiments 32, 33, 34, 35, and 36

Lab. No.		Exp. 32	Exp. 33	Exp. 34	Exp. 35	Exp. 36
55731	Corn meal	40.0	.....	.....	.....	.....
55840	Corn meal	.....	50.0	.....	.....	.....
56046	Corn meal	.....	.....	40.0	.....	.....
56076	Corn meal	.....	.....	.....	40.0	.....
56436	Corn meal	.....	.....	.....	.....	40.0
55732	Casein	20.0	.....	20.0	20.0	20.0
55462	Wheat gray shorts	16.3	16.3	16.3	.....	.....
56077	Wheat gray shorts	.....	.....	.....	16.3	16.3
55587	Dried skim milk	10.0	10.0	.....	.....	.....
56047	Dried skim milk	.....	.....	10.0	10.0	.....
56437	Dried skim milk	.....	.....	.....	.....	10.0
55733	Cottonseed meal	.....	10.0	.....	.....	.....
55227	Yeast	6.0	.....	.....	.....	.....
55841	Yeast	.....	6.0	6.0	6.0	6.0
54985	Alfalfa leaf meal	4.0	4.0	4.0	4.0	4.0
	Calcium carbonate	1.5	1.5	1.5	1.5	1.5
	Tri-calcium phosphate	1.0	1.0	1.0	1.0	1.0
	Salt	1.0	1.0	1.0	1.0	1.0
77762	Fish liver oil	0.2	0.2	0.2	0.2	0.2

organic constituents are given in Table 5. As stated in Bulletin 571, the percentage of effective organic constituents is the percentage of protein plus the percentage of fat multiplied by 2.25 plus the percentage of nitrogen-free extract. The water, the ash, and the crude fiber are not included for the reason that they have practically no energy value for the growing chickens. The chemical composition of the rations as found by analysis is given in Table 6.

Table 4. Percentages of feed which replaced corn meal or corn meal and casein, and identifying numbers

Experiment 66.
Oat meal 43891, 51; milo 43899, 51; wheat gray shorts 43898, 40.

Experiment 8.
Patent flour 48435, 50; low grade flour 48436, 50; wheat gray shorts 47764, 50.

Experiment 9.
Wheat gray shorts 47764, 50; wheat bran 48741, 50; corn bran 48706, 50.

Experiment 11.
Casein 48261, 38; starch 49094, 50.8; Wesson oil 49095, 15.

Experiment 12.
Casein 49469, 38; starch 49094, 50.8; Wesson oil 49095, 15.

Experiment 21.
Casein 54170, 50; cottonseed meal 54177, 50; tankage, 54178, 50.

Experiment 22.
Casein 54170, 50; dried buttermilk 49628, 50; alfalfa leaf meal 54172, 50.

Experiment 23.
Dried buttermilk 49648, 25% replacing 15% corn meal and 10% casein; cottonseed meal 54177, 43% replacing 23% corn meal and 20% casein; tankage 54178 28% replacing 20% casein and 8% corn meal.

Experiment 24.
Cottonseed meal 54177, 43% replacing 20% casein and 23% corn meal; dried buttermilk 49648, 25% replacing 10% casein and 15% corn meal; alfalfa leaf meal, 25% replacing 23% corn meal and 2% casein 54371.

Experiment 26.
Tankage 54178, 32% replacing 30% corn meal and 2% casein; alfalfa leaf meal 30% replacing 15% corn meal and 15% casein; meat meal 54664, 37%, replacing 20% casein and 17% corn meal.

Experiment 27.
50% protein meat and bone meal 54872, 35% replacing 20% casein and 15% corn meal; tankage 54873, 29% replacing 20% casein and 9% corn meal; cottonseed flour 54679, 30% replacing 20% casein and 10% corn meal.

Experiment 28.
Cottonseed meal 54903, 43% replacing 20% casein and 23% corn meal; meat scraps 54664, 37% replacing 20% casein and 17% corn meal; alfalfa leaf meal 54985, 30% replacing 20% casein and 10% corn meal.

Experiment 30.
Tankage 55081, 29% replacing 20% casein and 9% corn meal; 50% protein meat and bone meal 55082, 35% replacing 20% casein and 15% corn meal; corn gluten meal 55121, 38% replacing 20% casein and 18% corn meal.

Experiment 31.
Corn gluten feed, 55120, 39% replacing 9% casein and 30% corn meal; tankage 54873, 28% replacing 20% casein and 8% corn meal; soy bean oil meal 54665, 37% replacing 20% casein and 17% corn meal.

Experiment 32.
Cottonseed meal 55733, 43% replacing 20% casein and 23% corn meal; meat meal 54664, 37% replacing 20% casein and 17% corn meal; alfalfa leaf meal, 30% replacing 5% casein and 25% corn meal.

Experiment 33.
Wheat gray shorts 55840, 50; delinted cottonseed hulls 54860, 50; oat hulls 55505, 50.

Experiment 34.
Dried buttermilk 49648, 25% replacing 10% casein and 15% corn meal; dried skim milk 56047, 25% replacing 12% corn meal and 13% casein; cottonseed flour 54679, 30% replacing 20% casein and 10% corn meal.

Experiment 35.
Tankage 54873, 28% replacing 20% casein and 8% corn meal; 50% protein meat and bone meal 54872, 35% replacing 20% casein and 15% corn meal; peanut meal 54798, 40% replacing 20% casein and 20% corn meal.

Experiment 36.
Alfalfa leaf meal 56437, 30% replacing 5% casein and 25% corn meal; casein 55572, 30% replacing 30% corn meal; wheat gray shorts 56077, 50% replacing 30% corn meal and 20% casein.

Table 5. Percentage composition of feeds

Lab. No.		Used in Exp. No.	Protein	Ether Extract	Crude fiber	Nitrogen-free extract	Water	Ash	Effective organic constituents
43902	Alfalfa leaf meal	66	18.83	2.52	17.62	38.79	8.64	13.60	63.3
48263	Alfalfa leaf meal	8, 9, 11, 12	20.15	2.88	17.04	38.19	7.83	13.91	64.8
54172	Alfalfa leaf meal	21, 22, 23, 24	20.41	1.95	16.86	40.13	7.28	13.37	64.9
54985	Alfalfa leaf meal	26, 27, 28, 29, 30, 32, 33, 34, 35, 36	21.58	1.81	15.84	41.38	8.05	11.34	67.0
56438	Alfalfa leaf meal	36	23.27	3.77	11.27	41.17	8.00	12.52	72.9
33303	Bone meal	66	25.56	1.73	.....	4.51	6.37	61.83	34.0
43901	Buttermilk	66	34.64	.54	.42	49.92	6.70	7.78	85.8
49648	Buttermilk, dried	22, 24, 34	31.73	5.48	.12	46.55	6.83	9.29	90.6
48261	Casein	8, 9, 11	81.90	.27	.29	4.67	8.23	4.64	87.2
49469	Casein	12	81.93	.17	.16	5.39	8.51	3.84	87.7
54170	Casein	21, 22	81.65	1.74	.08	2.59	10.05	3.89	88.2
54371	Casein	24, 26, 28	81.10	1.79	.20	1.51	11.14	4.26	86.6
55732	Casein	32, 36	85.04	.18	.14	1.97	8.50	4.17	87.4
48706	Corn bran	9	8.83	7.00	13.01	60.19	8.82	2.15	84.8
55120	Corn gluten feed	31	26.09	1.24	8.54	47.60	10.11	6.42	76.5
55121	Corn gluten meal	30	47.40	1.22	4.83	34.69	8.30	3.56	84.8
43890	Corn meal	66	10.08	4.31	2.13	71.24	10.82	1.42	91.0
48440	Corn meal	8, 9	11.88	4.96	1.58	69.63	10.27	1.68	92.7
48986	Corn meal	11	11.98	4.84	1.45	69.74	10.31	1.68	92.6
49468	Corn meal	12	10.05	3.20	1.06	73.23	11.46	1.00	90.5
54173	Corn meal	21, 22, 23	10.76	2.59	1.08	74.35	9.91	1.31	90.9
54347	Corn meal	23, 24	10.34	2.59	1.27	73.93	10.58	1.29	90.1
54714	Corn meal	24	10.79	2.35	1.11	73.88	10.58	1.29	90.0
54984	Corn meal	26	10.22	2.51	1.24	74.26	10.52	1.25	90.1
55087	Corn meal	27	11.12	2.15	1.26	74.84	9.13	1.50	90.8
55225	Corn meal	28	10.31	3.04	1.32	74.77	9.56	1.00	91.9
55463	Corn meal	30	9.85	4.06	1.22	74.22	9.49	1.16	93.2
55588	Corn meal	31	10.31	3.04	1.00	74.85	9.79	1.01	92.0
55731	Corn meal	32	10.00	3.03	1.04	74.42	10.51	1.00	91.2
55840	Corn meal	33	10.25	2.94	1.01	73.75	10.95	1.10	90.6
56046	Corn meal	34	9.70	3.43	1.45	73.07	11.03	1.32	90.5
56076	Corn meal	35	9.95	2.98	.57	74.60	10.85	1.05	91.3
56436	Corn meal	36	9.66	2.48	.82	73.55	12.52	.97	88.8

Table 5. Percentage composition of feeds—Continued

Lab. No.		Used in Exp. No.	Protein	Ether Extract	Crude fiber	Nitrogen-free extract	Water	Ash	Effective organic constituents
54679	Cottonseed flour	27, 34	57.38	7.03	2.37	21.42	5.38	6.42	94.6
54860	Cottonseed hulls, delinted	33	3.01	.34	40.68	43.77	9.54	2.66	47.6
43903	Cottonseed meal	66	42.21	6.34	12.61	26.18	6.50	6.16	82.7
54177	Cottonseed meal	21, 23	44.45	7.17	8.82	26.80	6.28	6.48	87.4
54715	Cottonseed meal	24	44.59	7.38	9.11	25.33	7.22	6.37	86.5
54993	Cottonseed meal	28	41.81	6.39	12.86	26.97	6.36	5.61	83.2
55733	Cottonseed meal	32, 33	41.25	6.55	11.74	28.58	6.43	5.45	84.6
48435	Flour, patent	8	13.96	1.01	.40	70.88	13.22	.53	87.1
48436	Flour, low-grade	8	18.78	2.08	.50	64.89	12.74	1.01	88.4
54664	Meat scraps	26, 32	48.45	9.61	1.53	2.92	5.88	31.61	73.0
54872	50% meat and bone scraps	27, 35	50.69	8.51	1.76	1.68	6.59	30.77	71.5
55082	50% protein meat and bone scraps	30	51.30	9.60	2.31	.10	5.09	31.60	73.0
54169	Milk, dried skim	21, 22	35.47	.79	.08	50.97	5.00	7.69	88.2
54330	Milk, dried skim	23, 24, 26, 27	35.11	1.25	.16	50.13	5.72	7.63	88.1
55226	Milk, dried skim	28, 30	36.25	1.49	.14	50.19	4.03	7.90	89.8
55587	Milk, dried skim	31, 32, 33	36.68	1.30	.14	49.30	4.70	7.88	88.9
56047	Milk, dried skim	34, 35	34.56	1.19	.20	49.88	6.53	7.64	87.1
56437	Milk, dried skim	36	34.23	1.19	.13	50.36	6.45	7.64	87.3
43899	Milo, whole ground	66	11.75	2.95	2.16	71.02	10.30	1.82	89.4
55505	Oat hulls	33	3.51	.81	29.90	50.66	8.71	6.41	56.0
43895	Oatmeal	66	14.84	5.57	1.61	66.20	9.97	1.81	93.6
49095	Oil, cottonseed (Wesson)	11, 12	.....	100.00	.....	.....	.....	.....	225.0
54798	Peanut meal	35	44.23	6.74	8.89	25.54	7.12	7.48	84.9
54665	Soybean oil meal	31	47.34	.33	5.37	31.79	9.13	6.04	80.0
49094	Starch	11, 12	.62	.03	.13	87.02	12.13	.07	87.7

43900	Tankage	66	58.80	7.16	2.28	1.27	7.06	23.43	76.2
54178	Tankage	21, 23, 26	54.85	12.99	1.97	2.25	3.94	24.00	86.3
54873	60% digester tankage	27, 31, 35	61.48	6.65	1.30	.05	7.10	23.42	76.5
55081	60% digester tankage	30	59.75	8.63	2.65	1.96	8.23	18.78	81.1
48741	Wheat bran	9	19.62	4.06	9.05	50.52	10.71	6.04	79.3
43898	Wheat gray shorts	66	17.40	4.26	5.88	56.49	11.12	4.85	83.5
47764	Wheat gray shorts	8, 9	19.03	4.24	6.43	54.81	10.51	4.98	83.4
48265	Wheat gray shorts	8	19.50	4.62	6.47	54.94	9.57	4.90	84.8
48740	Wheat gray shorts	9, 11	20.96	4.46	5.78	51.49	12.76	4.55	82.5
49467	Wheat gray shorts	12	21.13	2.65	6.60	52.65	12.08	4.89	79.7
54168	Wheat gray shorts	21, 22, 23, 24	18.20	3.92	5.51	58.57	9.52	4.28	85.6
54821	Wheat gray shorts	26, 27, 28	19.17	4.60	6.00	53.64	12.39	4.20	83.2
55462	Wheat gray shorts	30, 31, 32, 33, 34	17.69	4.33	6.07	56.98	10.84	4.09	84.4
56077	Wheat gray shorts	35, 36	19.45	4.16	5.75	56.84	10.09	3.71	85.7
48262	Yeast	8, 9, 11, 12	45.42	.99	6.26	33.20	5.53	8.60	80.9
54171	Yeast	21, 22, 23, 24	48.32	4.31	.66	34.30	5.70	6.71	92.3
54822	Yeast, dried Brewer's	26, 27	48.67	4.58	3.77	31.30	5.13	6.55	90.3
55227	Yeast, dried Brewer's	28, 30, 31, 32	52.85	3.90	1.97	28.52	5.23	7.53	90.2
55841	Yeast	33, 34, 35, 36	44.60	1.52	1.17	41.89	3.49	7.33	89.9

Table 6. Percentage chemical composition of rations

Lab. No.	Name of ration	Protein	Fat	Crude fiber	Nitrogen-free extract	Water	Ash
43964	Corn meal Exp. 1–66	18.13	3.61	4.14	55.56	10.06	8.51
43965	Oat meal	21.12	4.39	3.80	54.08	8.54	8.07
43966	Wheat gray shorts	21.51	3.76	5.53	50.79	8.54	9.87
43967	Milo	19.21	2.96	3.86	56.33	9.34	8.30
48466	Corn meal Exp. 8	22.71	5.22	3.26	54.13	8.85	5.83
48467	Patent flour	24.01	2.92	2.76	56.17	8.75	5.39
48468	Low grade flour	25.75	3.48	3.04	52.02	10.29	5.42
48469	Wheat gray shorts	26.37	4.59	5.72	46.87	9.49	6.96
48791	Corn meal Exp. 9	22.81	5.06	3.18	53.80	9.38	5.77
48792	Corn bran	22.10	6.22	9.31	48.49	8.09	5.79
48793	Wheat gray shorts	26.60	4.89	5.48	47.08	8.84	7.11
48794	Wheat bran	26.75	4.51	7.00	44.64	9.09	8.01
49205	Corn meal Exp. 11	22.75	3.77	3.00	53.80	10.81	5.87
49206	Casein	49.23	2.11	2.63	30.35	9.70	5.98
49207	Starch	17.63	1.35	2.41	62.86	10.73	5.02
49208	Wesson oil	20.78	17.66	2.93	43.88	9.29	5.46
49478	Corn meal Exp. 12	22.08	2.84	3.03	55.90	10.53	5.62
49479	Casein	49.35	1.83	2.66	30.81	9.42	5.93
49480	Starch	16.90	1.05	2.32	63.79	10.95	4.99
49481	Wesson oil	20.50	16.87	2.94	46.39	8.07	5.23
54182	Corn meal Exp. 21	20.85	2.44	2.25	59.59	8.74	6.13
54179	Casein	56.38	1.35	1.61	24.52	8.94	7.20
54180	Cottonseed meal	37.33	5.00	6.20	35.81	7.13	8.53
54181	Tankage	43.14	7.56	2.69	24.24	5.46	16.91
54242	Corn meal Exp. 22	20.30	2.59	2.34	59.59	9.06	6.12
54243	Casein	56.02	1.26	1.70	24.02	9.34	7.66
54244	Dried buttermilk	31.01	4.16	1.77	45.31	7.78	9.97
54348	Corn meal Exp. 23	30.71	2.15	2.13	48.77	8.90	7.34
54349	Dried buttermilk	29.36	3.36	2.10	48.46	7.87	8.85
54350	Cottonseed meal	31.42	4.91	6.13	41.96	6.86	8.72
54351	Tankage	29.44	5.79	2.86	43.21	5.85	12.85
54716	Corn meal Exp. 24	30.26	2.14	2.11	48.95	9.28	7.26
54717	Cottonseed meal	31.09	4.77	5.95	41.85	7.61	8.73
54718	Dried buttermilk	28.98	3.27	2.00	48.66	8.11	8.98
54719	Alfalfa leaf meal	31.55	2.25	6.24	41.55	8.05	10.36
54989	Corn meal Exp. 26	31.61	2.15	2.20	48.66	9.15	6.23
54990	Tankage	31.53	5.95	2.89	40.89	6.09	12.65
54991	Meat meal	30.90	5.38	2.79	36.83	7.04	17.06
54992	Alfalfa leaf meal	31.51	2.11	7.11	42.79	7.29	9.19
55088	Corn meal Exp. 27	31.38	2.16	2.26	49.22	8.62	6.36
55089	50% meat and bone scrap	31.21	4.70	2.69	37.53	7.29	16.58
55090	60% tankage	31.84	3.83	2.47	42.25	7.53	12.08
55091	Cottonseed flour	30.79	4.00	2.84	47.36	7.73	7.28
55264	Corn meal Exp. 28	31.26	2.61	2.13	48.85	8.54	6.61
55265	Cottonseed meal	30.23	4.75	7.65	42.16	7.44	7.77
55266	Meat scrap	31.15	5.88	2.83	36.07	6.96	17.11
55267	Alfalfa leaf meal	31.19	2.40	6.58	42.47	7.98	9.38
55464	Corn meal Exp. 30	30.81	2.40	2.32	49.44	8.69	6.34
55465	60% tankage	30.89	4.63	3.08	42.83	7.93	10.64
55466	50% meat and bone	30.96	5.63	3.06	37.32	6.60	16.43
55467	Corn gluten meal	30.75	2.38	3.88	48.59	7.71	6.69
55589	Corn meal Exp. 31	30.74	2.45	2.19	49.55	8.55	6.52
55590	Corn gluten feed	30.22	2.20	4.87	45.88	8.35	8.48
55591	Tankage	30.60	3.96	2.10	44.23	7.69	11.42
55592	Soybean oil meal	29.59	2.20	4.27	48.17	8.15	7.62
55734	Corn meal Exp. 32	31.80	2.46	1.66	48.98	8.94	6.16
55735	Cottonseed meal	29.50	4.71	7.67	42.80	7.76	7.56
55736	Meat meal	31.01	5.48	2.34	34.91	7.67	18.59
55737	Alfalfa leaf meal	30.95	2.08	6.03	42.77	8.58	9.59
55842	Corn meal Exp. 33	19.36	3.25	3.34	58.37	9.44	6.24
55843	Wheat gray shorts	23.19	3.76	5.59	50.85	9.02	7.59
55844	Delinted cottonseed hulls	16.08	2.09	22.75	43.68	8.46	6.94
55845	Oat hulls	16.18	2.20	18.10	46.60	8.05	8.87
56048	Corn meal Exp. 34	30.15	2.37	1.61	50.05	9.33	6.49
56049	Dried buttermilk	28.63	3.09	1.87	49.51	8.81	8.09
56050	Dried skim milk	27.14	2.04	1.78	53.15	8.22	7.67
56051	Cottonseed flour	28.99	3.70	3.00	47.24	9.67	7.40
56078	Corn meal Exp. 35	31.24	2.24	1.77	49.13	9.36	6.26
56079	60% tankage	30.80	3.80	2.07	43.65	7.94	11.74
56080	50% meat and bone meal	30.35	4.81	2.81	37.93	7.71	16.39
56081	Peanut meal	29.80	4.22	5.44	44.07	8.13	8.34
56439	Corn meal Exp. 36	30.80	2.07	1.86	49.55	9.57	6.15
56440	Alfalfa leaf meal	31.18	2.65	4.85	43.10	8.73	9.49
56441	Wheat gray shorts	21.01	3.56	4.03	55.59	8.92	6.89
56442	Casein	54.61	1.38	1.37	25.87	9.36	7.41

Table 7. Average composition, weights and calories per 100 grams for chickens

Number of experiment and name of ration	No. averaged	Live weight at beginning, gm.	Live weight at end, gm.	Empty weight at end, gm.	Per cent empty wt. of live weight	Weight after preparation, gm.	Protein %	Fat %	Calories per 100 gm. empty weight
Experiment 1–66									
Preliminary chicks	4	.....	79.3	72.0	90.86	.....	18.32	3.70	138.2
Calories per 100 gms.	.....	.....	125.6	.....	.....	.....	.....	.....	.....
Corn meal ration, 28 days	3	76.4	217.0	211.7	97.55	206.2	20.69	7.75	189.6
Corn meal ration, 35 days	2	73.5	200.1	190.7	94.98	183.8	20.57	5.98	172.3
Oat meal ration, 28 days	3	76.4	216.3	206.6	95.65	201.5	20.79	4.37	158.5
Oat meal ration, 35 days	1	76.5	174.0	168.1	96.61	165.0	21.85	2.22	144.5
Wheat gray shorts ration, 28 days	3	74.6	178.1	170.4	95.76	164.7	21.41	2.93	148.6
Wheat gray shorts ration, 35 days	2	71.9	161.9	145.6	90.68	141.9	20.53	2.14	136.2
Milo ration, 28 days	3	76.0	208.4	196.0	94.18	190.7	20.77	5.50	169.0
Milo ration, 35 days	2	73.6	195.3	189.5	97.04	185.0	20.81	4.45	159.4
Experiment 8									
Preliminary chicks	4	.....	59.9	58.2	97.07	58.6	18.17	6.79	166.3
Calories per 100 gms.	.....	.....	161.4	.....	.....	.....	.....	.....	.....
Corn meal ration	6	60.5	209.7	203.2	96.91	203.4	20.34	8.04	190.3
Patent flour ration	6	59.6	194.7	189.7	97.46	189.7	20.93	7.04	184.3
Low grade flour ration	6	59.9	201.0	194.7	96.90	193.7	20.79	5.04	164.8
Wheat gray shorts ration	6	60.4	199.9	193.9	96.98	193.8	21.03	3.70	153.7
Experiment 9									
Preliminary chicks	4	.....	61.6	59.2	96.10	59.6	17.45	6.67	161.1
Calories per 100 gms.	.....	.....	154.8	.....	.....	.....	.....	.....	.....
Corn meal ration	5	59.4	216.5	208.8	96.38	209.4	21.45	6.66	183.7
Corn bran ration	6	60.2	215.2	205.9	95.82	200.9	23.04	3.13	159.6
Wheat gray shorts ration	6	60.6	209.1	201.8	96.53	200.7	22.94	2.97	157.6
Wheat bran ration	6	60.4	193.0	184.3	95.80	182.2	22.69	2.02	147.3
Experiment 11									
Preliminary chicks	4	.....	63.3	61.7	97.61	62.2	18.58	6.81	168.9
Calories per 100 gms.	.....	.....	164.8	.....	.....	.....	.....	.....	.....
Corn meal ration	6	62.5	212.6	207.3	97.49	203.8	20.97	7.38	187.7
Casein ration	6	62.9	156.9	152.4	97.16	150.1	21.62	2.62	146.8
Starch ration	6	63.3	161.3	157.7	97.77	155.0	19.96	9.58	202.6
Wesson oil ration	6	63.0	162.9	159.0	97.63	155.2	20.25	9.87	206.9

Table 7. Average composition, weights and calories per 100 grams for chickens—Continued

Number of experiment and name of ration	No. averaged	Live weight at beginning, gm.	Live weight at end, gm.	Empty weight at end, gm.	Per cent empty wt. of live weight	Weight after preparation, gm.	Protein %	Fat %	Calories per 100 gm. empty weight
Experiment 12									
Preliminary chicks	4	.....	59.6	58.0	97.40	57.7	17.48	7.98	173.6
Calories per 100 gms.	.....	.....	169.1	.....	.....	.....	.....	.....	.....
Corn meal ration	6	60.0	190.5	185.8	97.56	182.0	21.04	7.55	189.6
Casein ration	6	60.6	162.8	157.0	96.39	154.2	21.39	2.84	147.6
Starch ration	6	60.1	137.8	134.4	97.53	133.3	19.59	9.31	197.9
Wesson oil ration	6	60.0	151.6	146.8	96.90	143.8	19.97	12.00	225.2
Experiment 21									
Preliminary chicks	6	.....	59.8	58.3	97.47	55.7	17.39	5.88	153.4
Calories per 100 gms.	.....	.....	149.5	.....	.....	.....	.....	.....	.....
Corn meal ration	6	60.9	209.7	205.5	98.01	204.4	20.79	8.71	199.1
Casein ration	5	61.9	166.9	162.4	97.11	162.9	22.44	2.97	154.8
Cottonseed meal ration	6	61.2	205.8	200.8	97.57	198.3	22.06	2.89	151.9
Tankage ration	5	61.7	177.9	170.3	95.69	168.5	21.38	3.47	154.0
Experiment 22									
Preliminary chicks	6	.....	49.9	47.9	95.92	47.6	17.70	3.97	137.3
Calories per 100 gms.	.....	.....	131.7	.....	.....	.....	.....	.....	.....
Corn meal ration	6	51.6	199.1	194.8	97.84	191.6	20.53	9.29	203.1
Casein ration	5	51.5	155.9	152.0	97.51	150.8	21.27	2.63	144.9
Dried buttermilk ration	5	52.4	141.7	136.9	96.36	135.0	21.50	2.36	143.7
Experiment 23									
Preliminary chicks	6	.....	57.0	54.4	95.46	54.7	17.97	3.61	135.4
Calories per 100 gms.	.....	.....	129.3	.....	.....	.....	.....	.....	.....
Corn meal ration	6	57.3	215.6	213.0	98.82	209.4	22.04	4.99	171.5
Dried buttermilk ration	6	57.9	214.6	211.2	98.42	207.8	22.29	3.43	158.2
Cottonseed meal ration	5	57.0	188.1	182.7	97.08	179.6	22.16	3.03	153.7
Tankage ration	6	57.5	168.5	162.7	96.48	159.6	21.78	4.56	165.9
Experiment 24									
Preliminary chicks	6	.....	45.6	43.8	96.09	42.7	17.49	6.98	164.3
Calories per 100 gms.	.....	.....	157.9	.....	.....	.....	.....	.....	.....
Corn meal ration	6	45.1	188.5	184.8	98.08	182.3	21.67	4.46	164.3
Cottonseed meal ration	4	45.8	187.1	182.3	97.48	181.7	21.60	3.71	156.9
Dried buttermilk ration	5	46.1	172.0	168.6	97.98	166.1	21.34	3.69	155.3
Alfalfa leaf meal ration	4	47.1	123.7	119.4	96.56	117.2	21.08	1.47	133.1

Experiment 26									
Preliminary chicks	6	.....	51.9	49.8	96.04	47.2	18.31	2.86	130.4
Calories per 100 gms.	.....	.....	125.2	.....	.....	.....	.....	.....	.....
Corn meal ration	6	52.5	210.6	206.6	98.06	196.7	20.51	5.35	116.1
Tankage ration	5	53.2	165.3	160.8	97.29	153.1	21.53	3.39	153.5
Meat meal ration	6	52.7	202.4	197.5	97.56	188.5	21.53	4.00	159.3
Alfalfa leaf meal ration	6	52.8	171.6	167.2	97.45	159.7	21.57	2.04	141.1
Experiment 27									
Preliminary chicks	6	.....	48.5	46.9	96.79	43.6	17.28	3.83	133.6
Calories per 100 gms.	.....	.....	129.3	.....	.....	.....	.....	.....	.....
Corn meal ration	6	47.9	181.6	177.0	97.47	166.8	21.38	4.25	160.7
Meat and bone meal ration	6	48.9	157.3	153.4	97.44	147.7	22.00	2.89	151.6
Tankage ration	6	48.3	156.8	153.1	97.47	147.9	22.11	3.74	160.1
Cottonseed flour ration	5	49.4	194.3	189.3	97.42	183.1	21.93	4.70	168.2
Experiment 28									
Preliminary chicks	6	.....	47.8	46.3	96.81	45.3	18.33	4.35	144.4
Calories per 100 gms.	.....	.....	139.8	.....	.....	.....	.....	.....	.....
Corn meal ration	6	48.1	213.9	207.9	97.12	196.4	21.65	4.68	166.3
Cottonseed meal ration	6	48.1	179.7	174.4	96.96	166.1	21.90	2.57	148.0
Meat meal ration	4	48.5	177.5	169.7	95.53	159.7	21.89	3.02	152.1
Alfalfa leaf meal ration	4	46.8	175.7	166.3	94.50	155.4	21.95	2.88	151.1
Experiment 30									
Preliminary chicks	6	.....	51.5	49.4	95.99	46.7	17.72	4.07	138.4
Calories per 100 gms.	.....	.....	132.8	.....	.....	.....	.....	.....	.....
Corn meal ration	6	51.5	171.8	167.0	97.06	156.8	21.39	3.67	155.4
Tankage ration	5	52.2	143.6	138.7	96.57	131.0	20.79	3.23	147.8
Meat and bone meal ration	4	52.3	154.4	150.7	97.75	141.5	22.64	3.11	158.3
Corn gluten meal ration	6	52.4	181.8	175.8	96.67	167.3	21.50	2.70	147.0
Experiment 31									
Preliminary chicks	6	.....	53.1	50.0	94.21	44.8	17.24	4.23	137.1
Calories per 100 gms.	.....	.....	129.2	.....	.....	.....	.....	.....	.....
Corn meal ration	6	53.1	207.7	202.0	97.22	196.8	22.17	4.83	170.6
Corn gluten feed ration	6	53.4	186.9	180.1	96.44	175.1	22.00	2.73	150.1
Tankage ration	6	53.5	191.5	185.4	96.83	178.1	21.82	3.88	159.8
Soybean oil meal ration	6	53.1	207.6	202.6	97.59	198.9	21.98	3.29	155.2
Experiment 32									
Preliminary chicks	6	.....	58.4	56.3	96.34	54.4	18.62	4.24	145.0
Calories per 100 gms.	.....	.....	139.7	.....	.....	.....	.....	.....	.....
Corn meal ration	6	58.4	236.5	230.7	97.50	211.9	21.54	4.91	167.8
Cottonseed meal ration	6	58.2	238.0	228.2	95.91	219.0	22.15	3.40	157.2
Meat meal ration	6	58.5	240.0	229.3	95.52	217.7	21.68	3.38	154.3
Alfalfa leaf meal ration	6	58.8	174.4	168.8	96.73	160.1	22.31	2.53	150.0

Table 7. Average composition, weights and calories per 100 grams for chickens—Continued

Number of experiment and name of ration	No. averaged	Live weight at beginning, gm.	Live weight at end, gm.	Empty weight at end, gm.	Per cent empty wt. of live weight	Weight after preparation, gm.	Protein %	Fat %	Calories per 100 gm. empty weight
Experiment 33									
Preliminary chicks	6	.....	56.8	54.7	96.33	53.0	18.81	5.02	153.3
Calories per 100 gms.	.....	.....	147.7	.....	.....	.....	.....	.....	.....
Corn meal ration	6	57.2	201.7	194.2	96.28	183.5	20.94	7.51	188.7
Wheat gray shorts ration	6	55.4	204.1	197.0	96.31	189.5	21.93	2.79	149.7
Cottonseed hulls ration	6	56.6	139.1	131.9	94.92	127.0	21.32	1.28	132.7
Oat hulls ration	4	54.6	115.0	109.5	95.24	104.7	22.51	1.29	139.5
Experiment 34									
Preliminary chicks	6	.....	55.9	53.7	96.10	40.0	19.18	3.66	142.8
Calories per 100 gms.	.....	.....	137.2	.....	.....	.....	.....	.....	.....
Corn meal ration	6	55.4	203.8	197.5	96.88	187.1	22.54	4.07	165.7
Dried buttermilk ration	6	55.8	184.2	177.1	96.17	169.2	22.07	3.42	156.9
Dried skim milk ration	6	56.1	174.1	166.7	96.03	160.6	22.55	2.63	152.2
Cottonseed flour ration	6	55.6	207.4	200.2	96.46	192.4	21.78	4.08	161.4
Experiment 35*									
Preliminary chicks	10	.....	58.2	55.0	94.39	46.0	19.45	3.93	146.9
Calories per 100 gms.	.....	.....	138.6	.....	.....	.....	.....	.....	.....
Corn meal ration	10	58.6	224.2	217.0	96.80	210.3	21.57	4.81	167.0
Tankage ration	10	58.6	205.1	195.8	95.48	191.1	22.03	3.36	156.1
Meat and bone meal ration	10	58.7	201.0	192.9	95.95	184.7	22.19	2.76	151.4
Peanut meal ration	10	59.0	224.0	217.1	96.88	211.4	22.03	4.10	163.1
Experiment 36									
Preliminary chicks	6	.....	53.7	51.2	95.20	47.9	18.06	3.60	135.9
Calories per 100 gms.	.....	.....	129.4	.....	.....	.....	.....	.....	.....
Corn meal ration	5	54.4	194.0	187.9	96.92	179.5	21.38	4.87	166.5
Alfalfa leaf meal ration	6	53.5	181.7	175.7	96.66	169.9	21.86	2.19	144.3
Wheat gray shorts ration	6	54.2	177.6	170.7	96.08	164.8	22.20	4.15	164.4
Casein ration	6	54.0	146.5	141.1	96.26	136.2	21.93	3.15	153.5

*Analyses made of composite sample of 10 chicks fed same ration.

Digestion experiments were made with all of the rations, usually two being made on each ration. The results will be presented in a subsequent publication. The digestion coefficients of the rations were averaged separately for each experiment on productive energy and, together with the analysis of each ration, were used to calculate the effective digestible nutrients of each ration. The effective digestible nutrients of each ration are given in Table 9. They were used to calculate the effective digestible nutrients of each feed, in comparison with those of the standard corn meal.

The average live weights, percentages of protein and fat, and Calories per 100 grams of chicken, as well as other data, are given in Table 7. The averages are made from the data of each individual chicken. Variations which may occur in the composition of individual chickens, with standard deviations, have already been discussed from other data in Bulletin 571, so that additional calculations were not made with the data in Table 7.

Calculation of Maintenance Requirements and Productive Energy of Rations

The maintenance requirements are calculated from the data secured with the standard corn meal ration, and these are used to calculate the productive energy of the other rations used at the same time in the experiment. Average data for the calculations of the maintenance requirements are given in Table 8. The productive energy of the effective digestible nutrients of the corn meal ration was taken to be 2.78 Calories per gram as was found to be the average of previous results (Bulletin 571). For each experiment the productive energy of the corn meal used was ascertained by multiplying the effective digestible nutrients of the corn meal ration, as found in the digestion experiments, by 2.78. The maintenance requirements are calculated with use of the average weights by periods. This has been shown (6) to give more consistent results than the use of the average of the first and last weights and better in accord with the previous work of others than the use of the surface area (6).

Since corn meal is used as the standard, the Calories of productive energy used for maintenance under the conditions of each experiment are calculated from the data from the corn meal ration, as given in Table 8. The initial energy content of the chicks is calculated from the initial live weight and the initial energy per gram, as found by analysis (Table 7). The final energy content is calculated from the final empty weight and final energy content of the chicks. The productive energy of the ration eaten is the grams eaten multiplied by the productive energy per gram of ration as given in Table 8 (1.98 in case of experiment No. 8). The productive energy used for maintenance is the productive energy of the ration eaten less the gain of energy in calories of the chicks, since, by definition, the productive energy is measured by the gain in energy. The maintenance requirements are calculated as Calories of productive energy required to maintain 100 gm. of chicken for the period of each experiment.

Table 8. Average data and calculation of maintenance requirements for chickens fed on the standard corn meal ration

Experiment number	Number averaged	Average wt. by periods gm.	Initial energy content Cal.	Final energy content Cal.	Gain of energy Cal.	Prod. energy of ration Cal. per gm.	Ration eaten gm.	Prod. energy of feed eaten Cal.	For Maintenance		
									Total prod. energy Cal.	Prod. energy per period per 100 gm. Cal.	Prod. energy per day per 100 gm. Cal.
	(28 days)										
1–66.....	3	132.4	95.9	402.5	306.5	1.672	503.3	841.5	535.0	404.2	14.43
	(35 days)										
1–66.....	2	119.1	92.3	333.3	241.0	1.672	546.9	914.4	673.4	565.1	16.15
8.....	6	131.9	97.6	386.8	289.2	1.980	288.6	571.4	282.2	214.2	10.20
9.....	5	131.5	91.9	383.2	291.3	1.979	322.8	638.8	347.5	264.5	12.60
11.....	6	140.4	103.9	389.0	286.1	1.876	315.9	592.6	306.5	220.0	10.50
12.....	6	124.0	101.4	352.8	251.3	1.899	280.0	531.7	280.4	226.4	10.79
21.....	6	138.7	91.0	409.1	318.1	1.923	363.1	698.3	380.2	275.8	13.13
22.....	6	133.2	68.0	396.3	328.3	1.933	354.7	685.6	357.3	268.3	12.78
23.....	6	138.1	74.1	365.3	291.2	1.878	354.6	665.9	374.7	271.5	12.93
24.....	6	118.6	71.3	304.1	232.9	1.798	301.5	542.2	309.3	261.5	12.45
26.....	6	131.4	65.8	342.6	276.8	1.871	335.2	627.2	350.4	268.0	12.76
27.....	6	117.7	62.0	284.8	222.9	1.911	293.4	560.6	337.8	288.3	13.73
28.....	6	129.4	67.3	347.3	280.0	1.926	313.4	603.5	323.5	249.8	11.89
30.....	6	116.4	68.4	261.2	192.8	1.896	269.4	510.8	318.0	274.2	13.06
31.....	6	131.3	68.6	346.1	277.5	1.884	318.5	600.1	322.7	246.8	11.75
32.....	5	160.1	82.0	403.1	321.1	1.892	377.9	715.0	393.8	246.2	11.73
33.....	6	136.8	84.5	367.3	282.9	1.800	373.4	671.9	389.0	285.2	13.58
34.....	6	140.0	76.0	326.4	250.4	1.825	340.4	621.2	370.8	265.1	12.62
35.....	10	144.0	81.2	362.5	281.3	1.816	335.9	610.0	328.7	228.3	10.87
36.....	5	124.3	70.4	312.7	242.2	1.885	291.6	549.6	307.4	247.1	11.46
Average (20)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.49

Table 9. Data and calculation for average productive energy of rations and their effective digestible nutrients

Experiment number and name of ration	Number averaged	Average wt. by periods gm.	Initial energy content Cal.	Final energy content Cal.	Gain of energy Cal.	Ration eaten gm.	Used for maintenance Cal.	For gain and maintenance Cal.	Prod. energy of ration Cal. per gm.	Effective digestible nutrients of ration per 100 gm.
Experiment 1–66										
Oatmeal	(28 days) 3	131.5	96.0	328.6	232.7	503.3	531.1	763.8	1.51	64.7
Oatmeal	(35 days) 1	113.9	96.1	242.8	146.7	521.9	643.5	790.2	1.51	
Wheat gray shorts	(28 days) 3	113.5	94.2	251.9	157.7	503.3	458.5	616.3	1.22	54.2
Wheat gray shorts	(35 days) 2	98.4	90.3	198.5	108.2	546.9	555.7	663.9	1.21	
Milo	(28 days) 3	125.5	95.4	332.0	236.6	503.3	506.9	743.5	1.48	62.0
Milo	(35 days) 2	114.8	92.4	308.8	216.4	546.9	648.4	864.7	1.58	
Experiment 8										
Patent flour	6	128.4	96.1	351.8	255.0	299.8	274.8	529.8	1.76	69.9
Low grade flour	6	127.7	96.7	321.6	224.9	289.2	273.3	498.2	1.72	65.2
Wheat gray shorts	6	124.1	97.5	297.9	200.4	376.1	265.7	466.1	1.25	53.5
Experiment 9										
Corn bran	6	135.7	93.1	329.7	236.6	442.2	358.4	594.9	1.35	48.4
Wheat gray shorts	6	132.1	93.9	320.4	226.5	362.2	348.7	575.1	1.58	54.7
Wheat bran	6	126.2	93.4	271.4	178.0	423.3	333.3	511.3	1.21	49.0
Experiment 11										
Casein	6	112.8	103.6	224.0	120.3	220.0	248.1	368.4	1.67	66.2
Starch	6	113.2	104.3	321.6	217.3	270.1	249.1	466.4	1.72	70.4
Wesson oil	6	116.7	103.9	330.9	227.0	237.0	256.7	483.7	2.05	83.3
Experiment 12										
Casein	6	111.1	102.4	232.3	129.9	213.1	251.1	381.0	1.80	69.7
Starch	6	100.9	101.7	268.2	166.5	238.7	228.0	394.5	1.65	69.5
Wesson oil	6	108.5	101.5	333.4	231.9	217.4	245.2	477.1	2.19	87.9
Experiment 21										
Casein	5	117.1	92.5	251.7	159.3	252.6	323.2	482.4	1.90	64.1
Cottonseed meal	6	139.9	91.5	306.6	215.1	408.7	386.2	601.3	1.47	54.8
Tankage	5	125.3	92.3	264.2	171.9	375.5	345.9	517.9	1.39	48.7

Table 9. Data and calculation for average productive energy of rations and their effective digestible nutrients—Continued

Experiment number and name of ration	Number averaged	Average wt. by periods gm.	Initial energy content Cal.	Final energy content Cal.	Gain of energy Cal.	Ration eaten gm.	Used for maintenance Cal.	For gain and maintenance Cal.	Prod. energy of ration Cal. per gm.	Effective digestible nutrients of ration per 100 gm.
Experiment 22										
Casein	5	108.8	67.9	220.4	152.6	243.9	291.5	444.0	1.82	61.5
Dried buttermilk	5	108.3	69.1	198.3	129.2	300.7	290.3	419.5	1.39	56.0
Experiment 23										
Dried buttermilk	6	143.3	74.9	334.4	259.5	377.8	388.3	647.9	1.73	63.2
Cottonseed meal	5	125.8	73.7	281.8	208.1	372.5	341.0	549.0	1.47	55.9
Tankage	6	120.8	74.4	270.3	195.9	364.8	327.3	523.2	1.43	58.3
Experiment 24										
Cottonseed meal	4	122.8	72.4	286.3	213.9	377.8	320.4	534.3	1.42	54.6
Dried buttermilk	5	112.2	72.8	262.1	189.4	321.0	292.9	482.3	1.51	61.9
Alfalfa leaf meal	4	87.2	74.4	159.1	84.8	252.1	227.6	312.3	1.25	49.5
Experiment 26										
Tankage	5	116.7	66.7	247.5	180.8	333.8	312.7	493.5	1.48	57.4
Meat meal	6	134.4	66.0	315.2	249.2	365.4	360.1	609.3	1.67	56.9
Alfalfa leaf meal	6	120.3	66.1	236.2	170.2	355.3	322.5	492.6	1.39	51.1
Experiment 27										
Meat and bone scraps	6	112.7	63.2	232.7	169.5	310.1	324.6	494.1	1.60	56.9
Tankage	6	109.4	62.4	247.8	185.3	295.9	314.9	500.3	1.69	61.0
Cottonseed flour	5	127.0	63.9	319.4	255.5	316.2	365.8	621.3	1.98	63.0
Experiment 28										
Cottonseed meal	6	118.1	67.2	262.0	194.8	351.9	295.2	490.0	1.38	54.3
Meat scraps	4	114.6	67.8	259.0	191.1	317.8	286.4	477.5	1.50	57.5
Alfalfa leaf meal	4	113.8	65.4	254.0	188.7	348.5	284.5	473.2	1.34	50.1
Experiment 30										
Tankage	5	107.5	69.3	206.3	137.0	283.6	294.5	431.5	1.52	58.4
Meat and bone meal	4	117.5	69.4	238.9	169.5	306.0	321.8	491.3	1.60	58.0
Corn gluten meal	6	122.0	68.9	259.1	190.1	315.5	334.2	524.3	1.66	60.1
Experiment 31										
Corn gluten feed	6	120.2	69.0	271.0	202.1	377.0	296.9	498.9	1.32	49.9
Tankage	6	128.6	69.1	296.6	227.6	349.9	317.7	545.3	1.56	60.9
Soybean oil meal	6	136.6	68.6	311.1	245.9	395.4	337.4	583.3	1.48	54.8

Experiment 32										
Cottonseed meal	6	155.8	81.3	358.9	277.5	465.6	383.2	660.7	1.42	52.9
Meat meal	6	156.2	81.6	353.1	271.4	486.3	384.3	655.8	1.36	53.1
Alfalfa leaf meal	6	124.6	82.2	253.2	171.0	359.6	306.6	477.6	1.32	48.8
Experiment 33										
Wheat gray shorts	6	140.3	81.8	295.0	213.2	451.0	399.9	613.1	1.36	49.3
Cottonseed hulls	6	106.6	83.6	175.4	91.8	672.8	303.8	395.6	.59	23.0
Oat hulls	4	99.2	80.6	152.7	72.2	538.8	282.6	354.6	.66	24.0
Experiment 34										
Dried buttermilk	6	127.3	76.6	278.9	202.3	340.0	337.4	539.7	1.58	60.1
Dried skim milk	6	127.6	77.0	254.4	177.4	343.4	338.1	515.5	1.49	59.2
Cottonseed flour	6	142.4	76.3	323.8	247.6	373.7	377.4	625.0	1.67	58.7
Experiment 35										
Tankage	10	136.9	81.3	305.7	224.5	387.8	312.2	536.6	1.38	57.9
Meat and bone meal	10	136.1	81.4	292.0	210.6	400.2	310.3	520.9	1.30	50.5
Peanut meal	10	149.4	81.8	353.9	272.1	435.9	340.6	612.8	1.41	55.9
Experiment 36										
Alfalfa leaf meal	6	121.1	69.3	255.0	185.7	380.9	299.2	484.9	1.27	51.0
Wheat gray shorts	6	123.5	70.1	280.8	210.7	370.7	305.0	515.7	1.40	54.7
Casein	6	103.3	69.8	218.1	148.3	234.1	255.1	403.4	1.72	63.8

Table 10. Variations in average productive energy of rations as calculated from data from individual chickens

Experiment number and name of ration	Number averaged	Productive energy of rations, Calories per gram			Average difference	Standard deviation
		Average	Maximum	Minimum		
Experiment 1–66						
Oat meal ration	4	1.51	1.65	1.44	.07	.10
Wheat gray shorts ration	5	1.22	1.33	1.16	.05	.07
Milo ration	5	1.52	1.72	1.43	.10	.13
Experiment 8						
Patent flour ration	6	1.76	1.88	1.57	.11	.13
Low grade flour ration	6	1.72	1.84	1.63	.06	.08
Wheat gray shorts ration	6	1.25	1.45	1.09	.13	.16
Experiment 9						
Corn bran ration	6	1.35	1.48	1.18	.10	.12
Wheat gray shorts ration	6	1.58	1.81	1.33	.13	.17
Wheat bran ration	6	1.21	1.26	1.16	.03	.04
Experiment 11						
Casein ration	6	1.67	1.80	1.56	.07	.09
Starch ration	6	1.72	1.80	1.48	.08	.12
Wesson oil ration	6	2.05	2.32	1.75	.19	.23
Experiment 12						
Casein ration	6	1.80	1.97	1.64	.08	.11
Starch ration	6	1.65	1.82	1.35	.14	.18
Wesson oil ration	6	2.19	2.47	1.69	.25	.31
Experiment 21						
Casein ration	5	1.90	2.04	1.60	.15	.19
Cottonseed meal ration	6	1.47	1.55	1.39	.06	.07
Tankage ration	5	1.39	1.54	1.29	.09	.11
Experiment 22						
Casein ration	5	1.82	1.93	1.68	.08	.10
Dried buttermilk ration	5	1.39	1.58	1.20	.12	.15
Experiment 23						
Dried buttermilk ration	6	1.73	2.21	1.42	.16	.26
Cottonseed meal ration	5	1.47	1.56	1.30	.08	.11
Tankage ration	6	1.43	1.57	1.33	.05	.08

Experiment 24						
Cottonseed meal ration	4	1.42	1.44	1.36	.03	.04
Dried buttermilk ration	5	1.51	1.54	1.41	.04	.06
Alfalfa leaf meal ration	4	1.25	1.37	1.13	.08	.10
Experiment 26						
Tankage ration	5	1.48	1.63	1.38	.07	.10
Meat meal ration	6	1.67	1.81	1.54	.06	.09
Alfalfa leaf meal ration	6	1.39	1.47	1.26	.05	.07
Experiment 27						
Meat and bone scraps ration	6	1.60	1.74	1.45	.09	.11
Tankage ration	6	1.69	1.83	1.53	.10	.12
Cottonseed flour ration	5	1.98	2.21	1.85	.11	.14
Experiment 28						
Cottonseed meal ration	6	1.38	1.56	1.22	.09	.12
Meat scraps ration	4	1.50	1.55	1.41	.05	.06
Alfalfa leaf meal ration	4	1.34	1.44	1.16	.09	.12
Experiment 30						
Tankage ration	5	1.52	1.61	1.32	.08	.12
Meat and bone meal ration	4	1.60	1.75	1.50	.10	.12
Corn gluten meal ration	6	1.66	1.80	1.52	.10	.11
Experiment 31						
Corn gluten feed ration	6	1.32	1.49	1.21	.07	.10
Tankage ration	6	1.56	1.61	1.44	.04	.06
Soybean oil meal ration	6	1.48	1.54	1.39	.04	.05
Experiment 32						
Cottonseed meal ration	6	1.42	1.51	1.33	.05	.06
Meat meal ration	6	1.36	1.47	1.23	.09	.10
Alfalfa leaf meal ration	6	1.32	1.41	1.18	.05	.08
Experiment 33						
Wheat gray shorts ration	6	1.36	1.45	1.25	.08	.09
Cottonseed hulls ration	6	.59	.65	.56	.02	.03
Oat hulls ration	4	.66	.68	.63	.02	.02
Experiment 34						
Dried buttermilk ration	6	1.58	1.64	1.53	.03	.04
Dried skim milk ration	6	1.49	1.66	1.30	.11	.13
Cottonseed flour ration	6	1.67	1.84	1.51	.09	.11
Experiment 36						
Alfalfa leaf meal ration	6	1.27	1.37	1.16	.06	.07
Wheat gray shorts ration	6	1.40	1.53	1.16	.11	.14
Casein ration	6	1.72	1.83	1.54	.10	.12

The average maintenance requirement per day per 100 grams, as shown in Table 8, is 12.49 Calories of productive energy. The maximum average of an experiment is 16.15, and the minimum average of an experiment is 10.20 calories per day per 100 grams. It is pointed out in Bulletin 571 that these variations from one experiment to another appear not to affect the productive energy, which is compared with the use of the maintenance value obtained in the same experiment.

The maintenance requirements calculated in Table 8 are used in Table 9 to calculate the productive energy of the rations containing the feeds compared with corn meal. The method of procedure in each case is indicated in the headings of the table. The energy used for maintenance is calculated by multiplying the average weight by periods by the Calories required to maintain 1 gram of chicken as found by the use of the corn meal ration for the same experiment, and is given in Table 8. The sum of the Calories used for gain and for maintenance divided by the quantity of feed eaten gives the Calories of productive energy of one gram of the ration. These are given in the next to last column of Table 9.

The values given in Tables 8 and 9 are averages of those calculated from the data for individual chickens. The results would be slightly different had average data been used in the calculating of the maintenance requirements or of the productive energy. The standard difference from the mean, the standard deviation, and the standard error of the mean are given in Table 10.

Tentative Productive Energy of Certain Feeds

The method used for calculating the productive energy of the individual feeds from that of the ration when corn meal alone is replaced is shown in Table 11. (Test 7-6-8-7-6-36). The difference between the assumed productive energy value of 1 gm. of the corn meal ration (1.980 Cal.) and of the patent flour ration (1.764) gives the effect (— .216) of substitution of 0.5 gm. of patent flour for 0.5 gm. of corn meal. This difference added to the productive energy of 0.5 gm. of the corn meal (1.130) makes the productive energy of 0.5 gm. of the patent flour to be 0.914 Cal. or 1.828 for one gram. The preliminary value for the productive energy values of the other feeds used to replace corn meal alone were calculated in a similar way.

In some of the experiments, however, the calculation was slightly different, since both corn meal and casein were used in the standard ration, and the feed tested (usually high in protein) was substituted partly for corn meal and partly for casein. The method for calculating the data for such feeds is illustrated in Table 12. The productive energy used for casein, 1.97 Calories per gram, is the average of 4 of the 5 experiments shown in Table 13.

These preliminary calculations are based upon the assumption that corn meal has the average productive energy of 2.78 Calories per gram of effective digestible nutrients found for the primary ration used in previous work (6). The effective digestible nutrients of the feeds com-

Table 11. Calculation of productive energy of feed substituted for corn meal Experiment 8

Line No.		Corn meal	Patent flour	Low grade flour	Wheat gray shorts
A	Productive energy, calories per gram.	2.260	.....	.....	.....
B	Productive energy of mixture, Tables 8 and 9.....	1.980	1.764	1.723	1.250
C	Effect of substitution, Line B minus 1.980.....	.....	—.216	—.257	—.730
D	Productive energy (.5 gm.) corn meal substituted.....	.....	1.130	1.130	1.130
E	Productive energy 0.5 gm. feed substituted (Line C plus line D).....	.....	.914	.873	.400
F	Productive energy of 1 gram feed substituted (Line E divided by 0.5).	2.260	1.828	1.746	.800
G	Effective digestible nutrients of 1 gm. feed (Table 13).....	.813	.787	.692	.459
H	Productive energy of effect. digest. nut. (Line F divided by line G)...	2.780	2.323	2.523	1.743
I	Relative productive energy of effect. digest. nut. with corn meal as 100 (Line H divided by 2.780 and multiplied by 100).....	100	84	91	63

Table 12. Calculation of productive energy of feed substituted for corn meal and casein, Experiment 36

Line No.		Corn meal	Alfalfa leaf meal	Wheat gray shorts	Casein
A	Productive energy, calories per gram.	2.174	.....	.....	.....
B	Productive energy of mixture, Tables 8 and 9.....	1.885	1.270	1.395	1.721
C	Effect of substitution, line B minus 1.885.....	.....	—.615	—.490	—.164
D	Casein substituted, gm.....	.....	.05 gm.	.20 gm.	.....
E	Prod. energy of quantity of casein substituted (1.97 cal. per gm.)....	.....	.099	.394	.....
F	Corn meal substituted, gm.....	.....	.25 gm.	.30 gm.	.30 gm.
G	Prod. energy of quantity of corn meal substituted.....	.....	.544	.652	.652
H	Prod. energy of casein and corn meal substituted (Line E plus line G)...	.....	.643	1.046	.....
I	Quantity of feed substituted (grams).	.....	.30 gm.	.50 gm.	.30 gm.
J	Prod. energy of quantity of feed substituted (Line C plus line H).....	.....	.028	.556	.488
K	Prod. energy of 1 gram feed substituted (Line J divided by line I)..	.....	.093	1.112	1.626
L	Effective digestible nutrients of 1 gm. feed (Table 13).....	.782	.214	.499	.681
M	Prod. energy of effect. digest. nut. (Line K divided by line L).....	2.780	.435	2.228	2.390
	Relative prod. energy of effect. digest. nut. with those of corn meal as 100 (Line L divided by 2.780 and multiplied by 100).....	100	16	80	86

pared with corn meal were calculated from the digestion experiments by methods similar to those used for calculating the productive energy, as described above.

The tentative productive energy of certain feeds, their effective digestible nutrients, the productive energy per gram of effective digestible nutrients of each feed, and the relative value of the productive energy of the effective digestible nutrients as compared with that of corn meal as 100, are given in Table 13.

Table 13. Tentative productive energy of certain feeds

Exp. No.		Productive energy of feed, calories per gram	Effective digestible nutrients		
			In feed, per cent	Productive energy calories per gram	Productive energy compared with those of corn meal as 100
	Alfalfa leaf meal				
24	54172	0	17.4	0	0
26	54985	.547	23.5	2.328	84
28	54985	.243	15.0	1.620	58
32	54985	.293	14.8	1.980	71
36	56438	.093	21.4	.435	16
	Average (5)	.235	18.4	1.273	46
	Average (4) (24 excluded)	.294	.....	.....	57
	Wheat gray shorts				
8	47764	.800	45.9	1.744	63
9	47764	1.468	48.5	3.037	109
1–66	43898 (Brown)	1.093	65.4	1.671	60
33	55462	1.326	48.8	2.717	98
36	56077	1.112	49.9	2.228	80
	Average (5)	1.160	51.7	2.279	82
	Dried buttermilk				
22	49648	1.138	52.9	2.152	77
23	49648	1.516	58.5	2.591	93
24	49648	.940	64.0	1.469	53
34	49648	1.148	54.7	2.099	76
	Average (4)	1.186	57.5	2.078	75
	Cottonseed meal				
21	54177	1.312	51.1	2.567	92
23	54177	1.142	48.1	2.374	85
24	54715	1.200	51.1	2.348	84
28	54993	.856	40.5	2.114	76
32	55733	1.014	41.7	2.432	88
	Average (5)	1.105	46.5	2.367	85
	Tankage				
21	54178	1.156	39.0	2.966	107
23	54178	.432	40.1	1.077	39
26	54178	.822	41.8	1.967	71
27	54873	1.279	45.6	2.805	101
31	54873	.889	48.1	1.848	66
30	55081	.779	39.4	1.977	71
35	54873	.504	48.4	1.041	37
	Average (7)	.837	43.2	1.954	70
	Casein				
11	48261	1.724	77.9	2.213	80
12	49469	1.950	83.4	2.338	84
21	54170	2.178	69.7	3.123	112
22	54170	2.004	64.0	3.132	113
36	55732	1.626	68.1	2.390	86
	Average (5)	1.896	72.6	2.639	95

The differences in the values of the same feed compared with corn meal are greater than are desirable, especially with alfalfa leaf meal. The errors of the work on the digestion experiments as well as those in determining the productive energy are all assigned to the productive energy. It is considered, however, that the average values are approximately correct. Additional determinations are needed and will be furnished later.

Calculation of Revised Productive Energy of Corn Meal

The relative productive energy of the feeds compared with corn meal listed in Table 13 were used to calculate a more nearly correct value of the productive energy of corn meal. The productive energy of the effective digestible nutrients of each primary ration for which the productive energy was ascertained in Bulletin 571 was calculated by the procedure outlined in Table 14. The percentage each ingredient contributed to the total of 70.45 per cent of effective digestible nutrients in the primary ration was calculated. Each of these percentages was multiplied by its average relative productive energy (Table 13) as compared with corn meal, and the total gives the productive energy of the effective digestible nutrients of the primary ration Mixture 14 to be 90.9% of that of corn meal (Table 14). Similar calculations were made for other primary rations, Mixtures 18, 22, 23, 24, and 25. The average productive energy of all the primary rations is 91.0% of that of corn meal. Since the average productive energy per gram of the effective digestible nutrients of the primary ration was 2.78 Calories, the effective digestible nutrients of corn meal have a productive energy of 2.78 divided by 0.91, which is 3.05 calories per gram.

The corrected productive energy of the effective digestible nutrients of corn meal, therefore, becomes 3.05 calories per gram, instead of the 2.78 calories previously used. (This value was subsequently found to be a little high as will be seen on a later page.) Since the other feeds are compared with corn meal as a standard, the use of this revised productive energy for corn meal makes necessary the revision of the productive energy values obtained for the other feeds.

Revised Productive Energy Values of Certain Feeds

The productive energy values of all the feeds compared with corn meal in the work reported in this publication were calculated with use of the value of 3.05 calories per gram for the effective digestible nutrients for corn meal and the revised value of 2.14 calories per gram for the casein. The results for those feeds used in the primary ration are summarized in Table 15.

A comparison of the revised values in Table 15 with the tentative values in Table 13 is given in Table 16 and shows that the revised values are higher for the effective digestible nutrients of the various feeds compared with those of corn meal. This is particularly noticeable with

Table 14. Calculated productive energy of primary ration No. 14 as compared with corn meal

Lab. No.	Name of feed	Ingredients	Effective digestible nutrients in feed	Effective digestible nutrients in mixture	Per cent effective digestible nutrients	Relative value to corn meal dig.	Relative contribution of each ingredient to productive energy
33918	Yellow corn meal	51.0	82.62	42.14	59.8	1.00	59.80
35673	Wheat gray shorts	19.0	60.66	11.53	16.4	.82	13.45
33972	Dried buttermilk	10.0	79.42	7.94	11.3	.75	8.48
35675	Cottonseed meal	6.0	70.29	4.22	6.0	.85	5.10
33973	Alfalfa leaf meal	5.0	28.90	1.45	2.0	.46	.92
32790	Tankage	4.0	65.48	2.62	3.7	.70	2.59
33303	Bone meal	2.0	27.31	.55	.8	.70	.56
33304	Oyster shell	2.0	.....	.....	.....	0	0
	Salt	1.0	.....	.....	.....	0	0
	Total	.....	.....	70.45	100.0	.....	90.90

Table 15. Productive energy in terms of feed, effective organic constituents, effective digestible nutrients, and metabolizable energy

Name and laboratory number of feed	Exp. No.	Per cent of ration	Effective organic constituents per cent	Effective digestible nutrients per cent	Metabolizable energy Cal. per 100 gm.	Productive energy				
						Total feed Cal. per 100 gm.	Effective organic constituents Cal. per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy
Alfalfa leaf meal										
54172	24	25	64.9	17.4	73	18	28	106	35	25
54985	26	30	67.0	23.5	99	75	112	320	105	76
54985	28	30	67.0	15.0	63	45	67	302	99	71
54985	32	30	67.0	14.8	62	50	75	338	111	81
56438	36	30	72.9	21.4	90	29	40	137	45	32
Average (5)			67.8	18.4	77	43	64	241	79	57
Buttermilk, dried										
49648	22	50	90.6	52.9	222	135	149	256	84	61
49648	23	25	90.6	58.5	246	171	189	293	96	70
49648	24	25	90.6	64.0	269	114	126	178	58	42
49648	34	25	90.6	54.7	230	135	149	246	81	59
Average (4)			90.6	57.5	242	139	153	243	80	58
Casein										
48261	11	38	87.2	77.9	327	195	224	250	82	60
49469	12	38	87.7	83.4	350	216	246	259	85	62
54170	21	50	88.2	69.7	293	239	271	344	113	82
54170	22	50	88.2	64.0	269	222	252	347	114	83
55732	36	30	87.4	68.1	286	196	224	288	94	69
Average (5)			87.7	72.6	305	214	243	298	98	71
Corn meal (standard)										
43890	1–66		91.0	80.1	336	244	268	305	100	73
48440	8		92.7	81.3	341	248	268	305	100	73
48440	9		92.7	81.3	341	248	268	305	100	73
48986	11		92.6	81.3	341	248	268	305	100	73
49468	12		90.5	79.7	335	243	269	305	100	73
54173	21		90.9	79.9	336	244	268	305	100	73
54173	22		90.9	79.9	336	244	268	305	100	73
54347	23		90.1	79.3	333	242	269	305	100	73
54714	24		90.0	79.0	332	241	268	305	100	73
54984	26		90.1	79.3	333	242	268	305	100	73
55087	27		90.8	79.7	335	243	268	305	100	73
55225	28		91.9	80.9	340	247	269	305	100	73

Table 15. Productive energy in terms of feed, effective organic constituents, effective digestible nutrients, and metabolizable energy—Continued

Name and laboratory number of feed	Exp. No.	Per cent of ration	Effective organic constituents per cent	Effective digestible nutrients per cent	Metabolizable energy Cal. per 100 gm.	Productive energy				
						Total feed Cal. per 100 gm.	Effective organic constituents Cal. per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy
Corn meal—Cont.										
55463	30	.....	93.2	82.2	345	251	269	305	100	73
55588	31	.....	92.0	81.0	340	247	268	305	100	73
55731	32	.....	91.2	80.4	338	245	269	305	100	72
55840	33	.....	90.6	79.8	335	243	268	305	100	73
56046	34	.....	90.5	79.7	335	243	269	305	100	73
56076	35	.....	91.3	80.4	338	245	268	305	100	73
56436	36	.....	88.8	78.2	328	239	269	305	100	73
Average (19)	.....	.....	91.1	80.2	337	245	268	305	100	73
Cottonseed meal										
54177	21	50	87.4	51.1	215	153	175	299	98	71
54177	23	43	87.4	48.1	202	134	153	278	91	66
54715	24	43	86.5	51.1	215	139	161	273	89	65
54993	28	43	83.2	40.5	170	105	126	260	85	62
55733	32	43	84.6	41.7	175	121	143	290	95	69
Average (5)	.....	.....	85.8	46.5	195	130	152	280	92	67
Tankage										
54178	21	50	86.3	39.0	164	137	159	352	115	84
54178	23	28	86.3	40.1	168	61	71	153	50	36
54178	26	32	86.3	41.8	176	101	117	241	79	57
54873	27	29	76.5	45.6	192	146	191	321	105	76
55081	30	29	81.1	39.4	165	97	120	245	80	59
54873	31	28	76.5	48.1	202	108	141	224	73	53
54873	35	28	76.5	48.4	203	69	90	142	46	34
Average (7)	.....	.....	81.4	43.2	181	103	127	240	78	57
Wheat gray shorts										
43898	1–66	40	83.5	65.4	275	131	157	200	66	48
47764	8	50	83.4	45.9	193	102	122	222	73	53
47764	9	50	83.4	48.3	203	169	203	350	115	83
55462	33	50	84.4	48.8	205	154	182	316	104	75
56077	36	50	85.7	49.9	210	131	153	262	86	62
Average (5)	.....	.....	84.1	51.7	217	137	163	270	89	64

alfalfa leaf meal, with which, for example, in Experiment 24 the preliminary relative value of 0 was changed to 35, and in Experiment 36, the preliminary value of 16 is changed to 45. The explanation for the increase is that when the feed is substituted for corn meal, the higher revised productive energy of the corn meal gives a higher revised value to the same quantity of feed substituted. Since the percentage of effective

Table 16. Average tentative and corrected productive energy of digestible nutrients and their standard deviations, standard errors, and percentile errors

	Number of tests	Prod. energy per 100 gm. Cal.	Standard deviation Cal.	Standard error Cal.	Standard error per cent
Alfalfa leaf meal.					
Tentative	5	127	101	45	35
Corrected	5	241	110	49	21
Buttermilk, dried.					
Tentative	4	208	46	23	11
Corrected	4	243	48	24	10
Casein.					
Tentative	5	264	43	19	7
Corrected	5	298	46	20	7
Cottonseed meal.					
Tentative	5	236	17	7	3
Corrected	5	280	15	6	3
Tankage.					
Tentative	7	195	75	28	14
Corrected	7	240	78	29	11
Wheat gray shorts.					
Tentative	5	228	60	26	11
Corrected	5	270	63	28	10

Table 17. Average constituents and productive energy of certain feeds

	Alfalfa leaf meal	Buttermilk, dried	Casein	Corn meal (standard)	Cottonseed meal	Tankage	Wheat gray shorts
Number of tests	5	4	5	.....	5	7	5
Effective organic constituents, per cent	61.8	90.6	87.7	91.1	85.8	81.4	84.1
Effective digestible nutrients, per cent	18.4	57.5	72.6	80.2	46.5	43.2	51.7
Metabolizable energy, cal. per 100 gm.	77	242	305	337	195	181	217
Productive energy							
Total feed, cal. per 100 gm.	43	139	214	245	130	103	137
Effective organic constituents, cal. per 100 gm.	64	153	243	268	152	127	163
Effective digestible nutrients, cal. per 100 gm.	241	243	298	305	280	240	270
Rank with effective digestible nutrients of corn meal as 100	79	80	98	100	92	78	89
In percentage of metabolizable energy	57	58	71	73	67	57	64

digestible nutrients of the feed substituted remains the same, and is lower than those for corn meal, the productive energy of the effective digestible nutrients becomes proportionately larger compared with that of corn meal. Greater increases in relative value thus occur with feed of low digestibility, namely, the alfalfa leaf meal, while the increase is not great with feeds whose effective digestible nutrients are not widely different from those of corn meal. There is little difference in the standard deviation and standard error of the tentative and of the revised values for productive energy of any of the feeds except alfalfa leaf meal. On account of the higher revised productive energy, the percentage of error is lower.

When the productive energy of the primary ration is recalculated with the new values compared to corn meal given in Table 16, but otherwise using the same procedure, the value relative to corn meal is 90 instead of 91. Use of this new figure would give a revised productive energy of corn meal of 3.01 instead of 3.05 calories per gram of effective digestible nutrients. The value rounded off to 3.00 will be used in subsequent work. The corresponding productive energy per gram of corn meal would be 2.40 and for the effective organic constituents it would be 2.63.

The productive energy values are summarized in Table 17 for the feed, the effective organic constituents, the effective digestible nutrients, and the metabolizable energy. The standard deviation and error are also given in Table 18.

Table 18. Standard deviation and standard error of productive energy of the feed, the effective organic constituents, and the metabolizable energy

	Alfalfa leaf meal	Butter-milk, dried	Casein	Cotton-seed meal	Tankage	Wheat gray shorts
Number of tests	5	4	5	5	7	5
Total feed						
Prod. energy per 100 gm., Cal.	43	139	214	130	103	137
Standard deviation, Cal.	22	24	19	18	32	26
Standard error, Cal.	10	12	8	8	12	12
Standard error, per cent	21	8	4	6	12	8
Effective organic constituents						
Prod. energy per 100 gm., Cal.	64	153	243	152	127	163
Standard deviation, Cal.	33	26	20	19	41	31
Standard error, Cal.	15	13	9	8	15	14
Standard error, per cent	24	9	4	5	12	8
In percentage of metabolizable energy						
Prod. energy per 100 gm., Cal.	57	58	71	67	57	64
Standard deviation, Cal.	26	12	11	4	19	15
Standard error, Cal.	12	6	5	2	7	6
Standard error, per cent	21	10	7	3	11	10

Effect of High Protein Content

In some of the experiments, a high protein feed replaced corn meal, with a resulting high protein content of the ration. In most of the experiments in which high protein feeds were used, these feeds replaced corn meal and casein in such a way that the protein content of the rations remained around 30 per cent. A high protein content of the rations did not, however, appear to decrease the utilization of the energy of the ration. When casein replaced 50% corn meal (Table 16) it had a higher productive energy than when only 30 to 38% of corn meal was replaced. Cottonseed meal and tankage replacing 50% corn meal had higher productive energy values than when the protein was lower. The evidence indicates that a high protein content of the ration does not interfere with the utilization of the energy of the ration. It has other effects, however, since high protein in the ration produces chickens with a low fat content, as can be seen from the data in Table 7.

Productive Energy of Other Feeds

The productive energy of some other feeds was determined in the experiments here reported, in addition to those discussed in the preceding pages, and the results are given in Table 19. The data for corn meal are based on the value of 3.05 calories per gram of effective digestible constituents and not on the comparisons, since corn meal is itself the standard.

Additional experiments are being made on other samples of the same kinds of feeds as are listed in Table 19 and their productive energy will be discussed more fully when the additional data are reported.

Delinted cottonseed hulls and oat hulls had no productive energy. The productive energy of cottonseed oil was lower than could be expected. The digestible constituents of corn bran, corn gluten meal, and cottonseed flour had a productive energy equal to that of corn meal.

Utilization of Protein in the Rations

Analyses of the chicks, of the rations, and the digestion experiments furnished data as to the retention of digestible protein by the chicks. These data are summarized in Table 20.

The highest retention of the digestible protein is usually with the corn meal ration containing about 20 per cent protein, in which retention was 50 to 56 per cent. With corn meal rations containing above 30 per cent protein, the retention was about 40 per cent. The lowest retention of digestible protein was with the high-protein rations containing casein, in Exp. 11, 12, 21, 22, and 36, in which the retention was 21 to 26 per cent. In spite of this low retention of protein, however, the casein had a high productive energy, as shown in Table 15. The next lowest retention,

Table 19. Productive energy as determined for certain feeds

Laboratory number of feed	Name of ration	Exp. No.	Effective organic constituents per cent	Effective digestible nutrients per cent	Metabolizable energy Cal. per 100 gm.	Productive energy				
						Total feed Cal. per 100 gm.	Effective organic constituents Cal. per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy
48706	Corn bran	9	84.8	35.7	150	121	143	340	111	81
55120	Corn gluten feed	31	76.5	32.4	136	94	123	291	96	69
55121	Corn gluten meal	30	84.8	53.9	226	170	200	315	103	75
54679	Cottonseed flour	27	94.6	53.7	226	247	261	459	151	109
54679	Cottonseed flour	34	94.6	52.1	219	172	182	330	108	79
54860	Delinted cottonseed hulls	33	47.6	—3.8	—16	1	2	0	0	0
48436	Flour, low grade	8	88.4	69.2	291	197	223	284	93	68
48435	Flour, patent	8	87.1	78.7	331	205	235	260	85	62
54872	Meat and bone scraps	27	71.5	39.8	167	136	190	343	112	81
55082	Meat and bone scraps	30	73.0	45.6	192	146	200	320	105	76
54872	Meat and bone scraps	35	71.5	33.7	142	81	113	239	78	57
54664	Meat meal	26	73.0	45.8	192	171	234	374	123	89
54664	Meat meal	28	73.0	42.6	179	114	156	267	88	64
54664	Meat meal	32	73.0	35.8	150	84	115	235	77	56
56047	Milk, dried skim	34	87.1	50.4	212	95	109	188	62	45
43899	Milo	1–66	89.4	83.8	352	219	241	258	84	62
55505	Oat hulls	33	56.0	—1.8	—8	15	27	0	0	0
43895	Oat meal	1–66	93.6	89.0	374	213	228	240	79	57
49095	Cottonseed oil, Wesson	11	225.0	186.5	783	367	163	197	65	47
49095	Cottonseed oil, Wesson	12	225.0	210.3	883	438	195	208	68	50
54798	Peanut meal	35	84.9	52.9	222	127	150	240	79	57
54665	Soybean oil meal	31	80.0	39.5	166	119	149	302	99	72
49094	Starch	11	87.7	86.7	364	217	247	251	82	60
49094	Starch	12	87.7	81.9	344	194	222	237	78	56
48741	Wheat bran	9	79.3	36.8	155	94	119	254	83	61

Table 20. Protein gained by chicks and eaten in rations

Number of experiment and name of ration	Number averaged	In chicks			In rations		Digestible retained by chicks, per cent
		At beginning gm.	At end gm.	Gain gm.	Total gm.	Digestible gm.	
Experiment 1–66							
Corn meal ration, 28 days	3	12.72	43.82	31.10	91.26	60.72	51
Corn meal ration, 35 days	2	12.24	38.90	26.66	99.15	65.97	40
Oat meal ration, 28 days	3	12.72	42.88	30.16	106.31	68.87	44
Oat meal ration, 35 days	1	12.74	36.73	23.99	110.23	71.41	34
Wheat gray shorts ration, 28 days	3	12.48	36.43	23.95	108.27	69.35	35
Wheat gray shorts ration, 35 days	2	11.96	29.87	17.91	112.63	72.14	25
Milo ration, 28 days	3	12.65	40.71	28.06	96.69	63.43	44
Milo ration, 35 days	2	12.26	39.51	27.26	105.05	68.92	40
Experiment 8							
Corn meal ration	6	10.67	41.32	30.66	65.58	52.36	59
Patent flour ration	6	10.51	39.67	29.15	71.66	57.08	51
Low grade flour ration	6	10.56	40.46	29.91	74.47	58.22	51
Wheat gray shorts ration	6	10.65	40.79	30.14	99.33	74.45	40
Experiment 9							
Corn meal ration	5	9.95	44.78	34.83	73.62	61.56	57
Corn bran ration	6	10.08	47.41	37.33	97.72	72.50	51
Wheat gray shorts ration	6	10.16	46.33	36.17	96.35	73.23	49
Wheat bran ration	6	10.12	41.76	31.64	113.23	82.15	39
Experiment 11							
Corn meal ration	6	11.33	43.33	31.99	71.87	56.96	56
Casein ration	6	11.41	32.97	21.56	108.31	90.28	24
Starch ration	6	11.48	31.45	19.97	47.62	38.26	52
Wesson oil ration	6	11.43	32.17	20.74	49.08	38.67	54
Experiment 12							
Corn meal ration	6	10.22	39.11	28.89	61.82	49.63	58
Casein ration	6	10.31	33.60	23.28	105.16	90.99	26
Starch ration	6	10.24	26.29	16.05	40.35	31.58	51
Wesson oil ration	6	10.22	29.23	19.01	44.57	36.54	52
Experiment 21							
Corn meal ration	6	10.32	42.73	32.41	75.71	59.68	54
Casein ration	5	10.49	36.33	25.83	142.40	115.79	22
Cottonseed meal ration	6	10.38	44.22	33.84	152.58	115.71	29
Tankage ration	5	10.47	36.74	26.85	162.01	75.35	36

Table 20. Protein gained by chicks and eaten in rations—Continued

Number of experiment and name of ration	Number averaged	In chicks			In rations		Digestible retained by chicks, per cent
		At beginning gm.	At end gm.	Gain gm.	Total gm.	Digestible gm.	
Experiment 22							
Corn meal ration	6	8.77	39.81	31.04	72.00	54.94	56
Casein ration	5	8.75	32.33	23.58	136.64	109.00	22
Dried buttermilk ration	5	8.91	29.47	20.56	93.24	62.95	33
Experiment 23							
Corn meal ration	6	9.83	46.82	36.99	108.89	86.42	43
Dried buttermilk ration	6	9.94	46.99	37.05	110.91	80.79	46
Cottonseed meal ration	5	9.79	40.54	30.75	117.04	85.99	36
Tankage ration	6	9.87	35.35	25.48	107.40	58.82	43
Experiment 24							
Corn meal ration	6	7.59	40.03	32.43	91.25	71.06	46
Cottonseed meal ration	4	7.71	39.35	31.64	114.95	84.16	38
Dried buttermilk ration	5	7.75	36.08	28.33	93.03	69.06	41
Alfalfa leaf meal ration	4	7.92	25.20	17.27	79.55	57.78	30
Experiment 26							
Corn meal ration	6	9.24	42.50	33.26	105.97	86.47	38
Tankage ration	5	9.37	34.68	25.31	105.24	56.66	45
Meat meal ration	6	9.28	42.51	33.24	112.90	73.88	45
Alfalfa leaf meal ration	6	9.28	36.08	26.80	111.96	79.98	34
Experiment 27							
Corn meal ration	6	8.01	37.86	29.85	92.06	75.72	39
Meat and bone meal ration	6	8.17	33.74	25.57	96.77	63.77	40
Tankage ration	6	8.08	33.87	25.79	94.21	64.94	40
Cottonseed flour ration	5	8.27	41.52	33.25	97.36	72.95	46
Experiment 28							
Corn meal ration	6	8.54	44.97	36.44	97.95	81.35	45
Cottonseed meal ration	6	8.53	38.21	29.69	106.37	80.19	37
Meat meal ration	4	8.61	37.16	28.56	99.01	66.31	43
Alfalfa leaf meal ration	4	8.29	36.47	28.17	108.69	77.78	36
Experiment 30							
Corn meal ration	6	8.76	35.78	27.02	83.01	67.83	40
Tankage ration	5	8.88	28.89	20.01	87.60	54.08	37
Meat and bone meal ration	4	8.90	33.90	25.01	94.75	62.39	40
Corn gluten meal ration	6	8.92	37.80	28.88	97.01	75.69	38

Experiment 31							
Corn meal ration	6	11.57	44.71	36.08	97.92	78.11	46
Corn gluten feed ration	6	8.67	39.61	30.95	113.91	81.18	38
Tankage ration	6	8.68	49.46	31.78	107.05	71.53	44
Soybean oil meal ration	6	8.62	44.52	35.90	117.01	86.09	42
Experiment 32							
Corn meal ration	6	10.48	49.65	39.17	120.16	98.46	40
Cottonseed meal ration	6	10.45	50.49	40.04	137.34	95.63	42
Meat meal ration	6	10.49	49.67	39.19	150.81	98.15	40
Alfalfa leaf meal ration	6	10.55	37.60	27.05	111.29	80.46	34
Experiment 33							
Corn meal ration	6	10.39	40.64	30.28	72.27	55.23	55
Wheat gray shorts ration	6	10.03	43.05	33.02	104.58	74.13	45
Cottonseed hulls ration	6	10.26	28.15	17.89	108.18	63.46	28
Oat hulls ration	4	9.89	24.58	14.69	87.17	49.40	30
Experiment 34							
Corn meal ration	6	10.20	44.39	34.18	102.62	80.34	43
Dried buttermilk ration	6	10.29	39.03	28.74	97.35	72.11	40
Dried skim milk ration	6	10.34	37.57	27.23	93.19	68.58	40
Cottonseed flour ration	6	10.25	43.63	33.35	108.34	77.32	43
Experiment 35							
Corn meal ration	10	10.75	46.80	36.05	104.93	83.78	43
Tankage ration	10	10.76	43.14	32.38	119.45	75.31	43
Meat and bone meal ration	10	10.78	42.79	32.01	121.45	72.74	44
Peanut meal ration	10	10.83	47.82	36.99	129.91	92.50	40
Experiment 36							
Corn meal ration	5	9.36	40.17	30.81	89.81	74.10	42
Alfalfa leaf meal ration	6	9.20	38.41	29.47	102.09	87.58	34
Wheat gray shorts ration	6	9.31	37.81	28.50	77.88	54.84	52
Casein ration	6	9.28	31.02	21.74	127.81	104.65	21

28 to 30 per cent, was with the rations containing cottonseed hulls and oat hulls, rations of low energy value. Low retention of protein also occurred with the alfalfa leaf meal rations.

The utilization of protein will be discussed more fully in a subsequent publication.

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Summary

The gains of fat and flesh by young growing chickens during a period of 3 weeks on a standard ration containing corn meal were compared with the gains made by similar chickens at the same time and under the same conditions fed on similar rations in which other feeds were substituted for corn meal or corn meal and casein.

The gains were ascertained by chemical analyses of representative chickens at the beginning of the experiment, and of those on experiment at the end. The values of the feeds tested for producing gains of flesh and fat were expressed in Calories and termed the productive energy. A preliminary calculation of the productive energy of the feeds tested relative to that of corn meal enabled the productive energy of the corn meal to be calculated from the results of a preceding set of experiments in which the productive energy of a mixed ration was determined.

The productive energy of corn meal finally decided upon was 3.00 Calories per gram of effective digestible constituents, 2.40 Calories per gram of corn meal and 2.63 Calories per gram of effective organic constituents.

The average productive energy of the feeds studied was alfalfa leaf meal 241 Calories per 100 grams of effective digestible nutrients, dried buttermilk 243 Calories, casein 298 Calories, corn meal 300 Calories, cottonseed meal 280 Calories, tankage 240 Calories and wheat gray shorts 270 Calories.

The productive energy of the effective organic constituents and of the metabolizable energy are also given.

The productive energy values of a few other feeds are given.

A high protein content of the ration does not seem to affect the utilization of the energy of the ration by the chick.

The utilization of protein in the ration by chicks is discussed briefly.

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