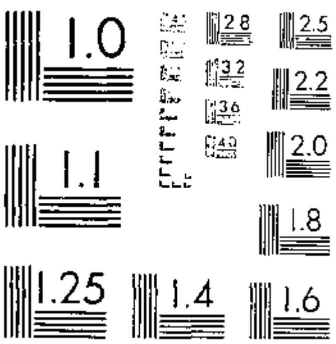
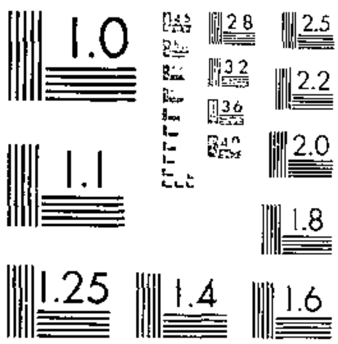
TB 413 (1934) USDA TECHNICAL BULLETINS UPDATA
EFFECT OF QUANTITY AND KINDS OF FEED ON ECONOMY OF GAINS AND BODY
ELLIS, N.R. ; ZELLER, J.H. 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 413 — MARCH 1934

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

EFFECT OF QUANTITY AND KINDS OF FEED ON ECONOMY OF GAINS AND BODY COMPOSITION OF HOGS[1]

By N. R. ELLIS, *chemist*, and J. H. ZELLER, *associate animal husbandman, Animal Husbandry Division, Bureau of Animal Industry*

CONTENTS

INTRODUCTION

Efficiency in the feeding of domestic animals involves not only the proper selection and combination of feeds and method of feeding, but also the proper daily allowance. In the case of dairy cattle, much attention has been given to the choice of feeding standards which provide the optimum level of protein, total energy, and other nutrient factors for efficient milk production. The profitable performance of animals raised for meat, such as hogs and cattle, depends in great measure on both the economy of live-weight increase and the quality of the meat.

In the case of hogs, the effect of variations in the level of feed intake on the efficiency of conversion of feed into body tissue and on the composition of the body has received little attention in comparison with that given to the many other feeding experiments, conducted during recent years, on the influence of the diet on rate of growth. Perhaps the main cause for this lack of attention has been the general

[1] This work was first undertaken as a part of the project, cooperative soft-pork investigations, which has been combined with the national project, cooperative meat investigations. The Bureaus of Animal Industry, Agricultural Economics, and Home Economics of the U.S. Department of Agriculture, and the agricultural experiment stations of 28 States have been or are now participating in the national project. The following representatives assisted in conducting the work: In firmness grading of carcasses, O. G. Hankins, Bureau of Animal Industry, and E. H. Hostetler, North Carolina Agricultural Experiment Station; in slaughtering and physical composition, K. F. Warner and R. L. Hiner, Bureau of Animal Industry; in chemical composition, H. E. McClure (resigned), W. O. Poole (resigned), R. W. Riemenschneider, J. M. Spadola, and W. R. Kauffman, Bureau of Animal Industry; in cooking tests, Lucy M. Alexander, Bureau of Home Economics; in statistical analyses and computations of carcass composition, Mrs. E. V. Steely, Bureau of Animal Industry, and a number of representatives of the Bureaus of Agricultural Economics, Home Economics, and Animal Industry for services on the palatability-of-meats committee. Acknowledgment is made to E. W. Sheets, Paul E. Howe, E. Z. Russell, S. S. Buckley (deceased), and O. G. Hankins for suggestions and advice.

27190°—34——1

assumption that a maximum rate of gain was of greatest importance. Economic reasons—for example, the desire to reduce the labor cost or to produce hogs for the early and top-price market—have governed feeding practices, in which rapidity of gains has been uppermost. In the study of the correction of nutritional deficiencies in hog rations, the increase in the growth rate along with greater feed utilization has been highly significant. It has been only natural to consider that there is a direct relationship between increase in growth and efficiency of feed utilization. Improvements in the nutritive values of feed combinations usually have been accompanied by increase in palatability and hence increased consumption.

The building of adipose tissue is a relatively more expensive process in terms of feed requirements than is the building of protein tissue. In addition, the changing market demands for meat have tended towards less fat in the pork cuts. Changes in hog types and the use of efficient protein, vitamin, and mineral supplements with corn in the hog ration have been an aid in meeting the demand for leaner meat. The readiness with which the hog stores fat mitigates against any pronounced decrease in fat storage as long as the hog remains on an ad libitum basis of feeding. Experiments [2] have shown that the nutritive ratio of a diet could be varied from 1:2 to 1:10 without effect on the fat content of hogs slaughtered at a weight of approximately 200 pounds. Restriction of the feed consumption offers a possible means of lessening the quantity of fat stored and thereby increasing the yield of lean meat in the carcass. Such a practice in feeding immediately raises the questions of economy of gains, rate of gain, and quality of meat as affected by age and fatness of hogs.

The purpose of these investigations was to determine the effect of different levels of feed intake by hogs (1) on the efficiency of converting feed into gain in weight, (2) on the physical and chemical composition of the meat and carcass, and (3) on the firmness, palatability, and other quality factors of the meat. Data are presented on three basal feeds, namely peanuts, corn, and wheat. Comparisons of feeding levels were made with the same diet in each experiment.

Among the questions involved in a study of this kind is that of experimental feeding methods. The usual feeding comparison, whether by the paired method or otherwise, does not take into account the possible differences in the response of hogs to different diets fed at equal and graduated levels or at free choice and variable levels. The question relative to the composition of the meat is largely one of fatness. The possible implications of control or limitation of the fat content of the carcass involve the changes in the yields of the lean and the fat cuts.

PREVIOUS INVESTIGATIONS

Interest in the effect of limited feeding was first aroused by the results from hog-feeding experiments [2] in which a study was made of the effect of retarded growth, through the lowering of the feed intake, on subsequent growth on full feed and on the firmness of the carcass. One lot of hogs was on a restricted ration during the first period and was self-fed during the second period. The other lot was full fed during the entire period. The former lot made so economical a utilization of feed during the second period that the cost of feeding

[2] Unpublished data.

and quantity of feed consumed were practically the same for the two lots during the entire experiment, even though an unbalanced ration of corn and mineral mixture was used during the restricted period. The results showed that limitation of feed did not produce any apparent permanent impairment to the well-being of the animal body as evidenced by the subsequent growth when the animals were changed to self-feeding.

Interest in the subject was further stimulated by observations on the growth of pigs on peanut rations (*7, 8, 9*).[3] Not only do hogs make greater gain in weight on a given quantity of a ration high in peanuts as compared with one high in corn, but they frequently show excessive fatness after periods of 2 months or more on a peanut ration, owing largely to the high oil content of peanuts. The suggestion was advanced that limitation of the feed intake might reduce the storage of oily fat without undue sacrifice in the rate of gain or the feed requirements per unit gain.

Comparisons of different levels of feeding have been conducted with hogs in connection with studies on the utilization of forage crops. In the usual case the animals have been given free access to a forage crop and have been hand fed at various levels ranging from approximately 4 pounds to 1 pound of feed per day per 100 pounds of live weight. Results of many feeding trials have shown a material saving of concentrate feeds at the lower feeding levels. However, it has been found that limited feeding of a concentrate ration with access to forage or hay may not lower the total feed consumption in all cases. Robison (*18*) compared the feed requirements of fall pigs on a full feed of corn and tankage with their requirements on a limited feed of corn and tankage, with access to alfalfa hay in both types of feeding. Although in the limited feeding the requirements for concentrates were reduced, the extra quantity of alfalfa hay consumed raised the total quantity of dry matter above that consumed by the full-fed groups.

The adoption of the self-feeder in place of hand feeding in swine-husbandry practice was due in great measure to the saving in labor and feed. The advantages of the self-feeder have been described by Henry and Morrison (*10*). Their summary of results of self-feeding in comparison with hand feeding pigs in dry lot (*10, p. 614*) shows a higher daily feed consumption for the self-fed pigs. Further, they state that this "is due to the fact that self-fed pigs help themselves many times a day and even during the night, thus being full fed at all times." At another point the same authors have expressed the prevailing opinion relative to full feeding in these words:

> When pigs are fed about all they will eat either by means of a self feeder or by hand feeding, they will consume less feed for each 100 pounds' gain up to market weights and therefore the gains will be cheaper than if they had been fed less grain.

Armsby (*1*), in discussing the production values of feedstuffs, states:

> It has been tacitly assumed that both the losses of chemical energy in the excreta and the increment of heat production consequent upon feed consumption are proportional to the quantity of feed ingested, that is, that the net energy values per unit of feed are substantially unaffected by the amount consumed or by the plane of nutrition of the animals.

Later in the discussion of this matter he mentions that heavy feeding may lower the digestibility of mixed rations, but that on the whole

[3] Italic numbers in parentheses refer to Literature Cited, p. 30.

"the net energy values may be regarded as being, if not strictly constant, at least nearly so over a wide range of feeding." It should be noted, however, that his statements relate in the main to Herbivora.

Benedict and Ritzman (*3*) state:

> It is reasonable to assume that the time-honored belief that domestic animals should be fed continually and fed to excess may be fairly challenged on two grounds: First, that the complete withdrawal of food for a few days is not injurious or distressing; second, that reasonably prolonged underfeeding is not distressing or permanently injurious.

At the Missouri station (*15, 16, 17*) beef animals were fed for extended periods at different levels of intake. One group was given all it would eat, another was fed at a level designed to obtain maximum growth without storage of surplus fat, and the third was distinctly retarded in growth by further limitation of feed. The decrease in feed level increased the quantity of feed required per unit of gain and produced carcasses containing decreased quantities of fat in the edible meat.

In a study of energy metabolism in relation to plane of nutrition in cattle, Forbes and associates (*5*) concluded that comparable determination of the specific dynamic effects of feedstuffs or nutrients can be determined only at the same plane of nutrition.

Mitchell and Hamilton (*14*) found that the percentage of available metabolizable energy of a 2-year-old steer at six levels of nutrition decreased with increase in the level of feeding. These workers also emphasized the fact that the net energy value of each ration must be expressed in relation to the dry-matter intake.

In studies on the growth of chickens, Jull and Titus (*11*) concluded that the relationship between growth and feed consumption is expressed by the law of diminishing increment. Subsequent work by Titus, Jull, and Hendricks [4] has led them to suggest underfeeding on an equal and uniform level in comparative feeding experiments. Such a procedure utilizes the paired-feeding method as applied by Mitchell and Beadles (*13*) but provides for a more uniform and graduated feeding schedule without greatly affecting the economy of gain.

The hog excels other farm animals in the economy of conversion of feed into edible body tissue. Henry and Morrison (*10*) point out that the hog not only has a low feed requirement per unit of gain but also yields a high percentage of dressed carcass. The edible portion of the carcass also has a high caloric value owing to the large quantity of fat stored during growth and fattening. Lusk (*12*) quotes Rubner as stating that growing hogs may store 40 percent of the caloric intake. Wilson, as reported by Lusk (*12*), found a 20-percent retention in young pigs on a milk diet. Armsby and Moulton (*2*) have calculated Swanson's data (*19*) in terms of gross efficiency and found the highest value to be about 39 percent. When corn was supplemented with protein and mineral elements, values of 30 percent or more were obtained in the usual case. Washburn and Jones (*20*) found a variation of from about 14 percent on skim milk to 44 percent on homogenized milk containing 8 percent of fat.

PLAN OF EXPERIMENTS

The hog-feeding experiments were conducted between 1924 and 1932, inclusive. Eighty-nine pigs were individually fed weighed

[4] TITUS, H. W., JULL, M. A., and HENDRICKS, W. A. GROWTH OF CHICKENS AS A FUNCTION OF FEED CONSUMPTION. Unpublished manuscript.

amounts of the rations twice daily. Six additional pigs were self-fed in a group. Most of the pigs weighed between 55 and 80 pounds when they were placed on experiment. In the usual case, purebred Poland China, Chester White, Duroc-Jersey, and Tamworth pigs were used and were weighed weekly. The initial and final weights were usually based on the average of three successive daily weighings. At the beginning of the experiments, the pigs were taken directly from self-feeder lots and received the weighed amounts of feed, according to the schedule of feed levels, without any intervening transition period. In those pigs on the low level of feed, the decrease in feed consumption tended to cause a marked drop in weight very soon after the beginning of the experiment. The feed consumption was recorded on a weekly basis.

The animals were confined in paddocks and segregated according to feed levels. No green vegetation was available at any time. Feeding crates were provided so that at feeding time each pig could be confined in a separate compartment and fed individually. The pigs were released from the crates when all the feed was consumed. When pigs failed to eat, as occasionally occurred, the feed was weighed back.

In three experiments designated as A, B, and C, the rations contained peanuts as the basal feed. The initial weights of all the pigs in the three experiments ranged from 56 to 82 pounds. Experiment A, begun in December 1927 with fall pigs, consisted of two lots. One lot containing 4 pigs received individually a full feed, whereas the second lot, of 8 pigs, was fed approximately half the amount, per pig, fed to the first lot. The feed allowance was adjusted at weekly intervals to quantities such that the pigs on full feed readily consumed their portion in a reasonable time and those on the low level received approximately half this allowance. An intermediate feed level was included in experiments B and C. Experiment B contained 4 pigs in the full-feed lot, 4 in the intermediate, and 8 in the low-level lot. Experiment C contained 8, 4, and 8 pigs, respectively, in these lots. Experiment B was begun in July 1928 with spring pigs. The 4 pigs on the full-feed level were given a somewhat smaller allowance of feed than those in experiment A owing to disinclination to consume readily the original level as planned. The intermediate and low-level groups of experiment B were also reduced accordingly. Fall pigs were also used in experiment C which was begun in December 1929.

The several lots of pigs in experiments A and B received the peanut rations until the average gains of each lot reached 50 pounds but did not greatly exceed 60. The three lots in experiment C were fed the peanut ration until the gains were approximately 40 pounds. Thereafter, those hogs not slaughtered for analysis were fed a hardening ration usually on a full-feed basis.

The pigs in two experiments, designated as D and E, received rations containing corn as the basal feed. Experiment D was conducted in 1924 and experiment E in 1930–31. In experiment D, 3 pigs in one group were individually fed 60 percent as much as 3 animals in another group on full feed. A complex mineral mixture was self-fed separately from the grain ration.

In experiment E, begun in August 1930, three groups of pigs were fed at three levels. These levels were based on live weight but were comparable to those for experiments B and C. One group of 6 pigs received 4 pounds of feed per 100 pounds of live weight, another group of 5 pigs 3 pounds, and the third group of 6 pigs 2 pounds. The quantity of feed was adjusted for each 20-pound increase in weight, based on group averages. Thus, on the 4-pound level of feeding the pigs weighing on the average between 60 and 79 pounds received 2.4 pounds of feed per day. When the average group weight was between 80 and 99 pounds, the feed allowance was raised to 3.2 pounds. Likewise, on the 3-pound level the feed allowances were 1.8 and 2.4 pounds, respectively, and on the 2-pound level the amounts of feed were 1.2 and 1.6 pounds, respectively. However, the method of feeding did not actually permit consumption of feed at the full levels of 4, 3, and 2 pounds per 100 pounds of live weight owing to the fact that the weight for calculation of the daily allowance was the lowest limit for the weight interval. All hogs in experiments D and E were fed to weights of approximately 200 pounds.

Finally a ration with wheat as the basal feed was used in experiment F. Three groups of six pigs, farrowed in the fall of 1931, were fed according to the same general plan followed in experiment E until their weights also approximated 200 pounds. In addition, six pigs were group fed with self-feeders until they weighed approximately the same as the other groups. The wheat ration just mentioned has been used with satisfactory results in other hog experiments at the United States Animal Husbandry Experiment Farm at Beltsville, Md. Adjustment of the daily feed allowances was made to permit the full intake of the 4-, 3-, and 2-percent levels by basing the calculation on the mid-point instead of the lowest point of the 20-pound weight interval.

The composition of the rations for the six experiments is given in table 1. The rations used in experiments A, B, and C were prepared with the view of providing for rapid growth on the full-feed levels. In this connection Hankins and Zeller (*9*) have shown that the efficiency of peanuts for growth of pigs is greatly increased by the addition of animal protein in the form of tankage. Halverson, Hostetler, and Sherwood (*6*) concluded that alfalfa meal and mineral mixture are effective as supplements to peanuts in producing satisfactory gains and that the further addition of animal protein supplements does not appear necessary. However, all these supplements and others were used in the present experiments.

TABLE 1.—*Percentage of different ingredients in rations used in experiments designated*

Experiment	Peanuts, shelled	Corn, yellow	Wheat	Wheat middlings	Alfalfa-leaf meal	Linseed meal	Skim-milk powder	Tankage	Mineral mixture
A	70	14	0	0	5	3	0	7	1
B	80	0	0	0	7	4	0	8	1
C [1]	82.7	0	0	5	5	0	0	5	2.3
D [2]	0	50	0	40	0	0	0	10	(3)
	0	75	0	19	0	0	0	6	
E	0	84	0	0	5	0	0	9	2
F	0	0	84	0	5	0	5	5	1

[1] This ration was suggested by E. H. Hostetler and H. O. Halverson of the North Carolina Agricultural Experiment Station. It has been used in a number of experiments by several of the cooperating stations.

[2] The first set of figures shows the percentage of the different ingredients fed when the pigs weighed less than 100 pounds; the second set, when they weighed 100 pounds or more.

[3] A complex mineral mixture was self-fed separately from the grain ration.

The average chemical composition of the rations is shown in table 2. The percentages of the feeds used in experiment D were changed when the pigs reached a weight of 100 pounds in order to reduce the protein content. The rations used in experiments A, B, C, E, and F were not altered during the course of the experiments. The rations used in experiments A, B, and C were high in ether extract, owing to the peanut oil, and in protein, also contained in large part in the peanuts. The average protein content of the corn ration was 14.3 percent and the nutritive ratio approximately 1:6; the corresponding figures for the wheat ration were 17.4 percent and 1:6, respectively. The peanut rations contained approximately twice as much protein as the corn ration and were much higher in caloric value than either the corn or wheat rations because of the differences in the fat content.

TABLE 2.—*Chemical composition (percent) of the rations used in experiments designated*

Experiment	Number of samples	Water	Protein	Ash	Ether extract	Fiber	Nitrogen-free extract
A	1	5.5	27.1	3.9	34.2	3.3	26.0
B	2	5.5	28.6	5.0	34.2	4.3	22.4
C	1	4.4	29.6	4.6	35.0	3.0	22.8
D [1]	1	10.8	16.9	[2] 4.5	4.3	4.3	59.2
	1	11.4	13.3	[2] 3.1	4.1	3.3	64.8
E	3	9.8	14.3	4.2	4.3	2.0	64.5
F	3	11.2	17.4	4.0	2.3	2.0	62.2

[1] The first set of figures shows the chemical composition of the ration fed while the pigs weighed less than 100 pounds; the second set, after they had attained this weight.
[2] Not including self-fed minerals.

Analyses were made of the carcasses of seven animals from experiments A and B, in which peanuts were fed, of 15 animals from experiment E, in which corn was fed, and of 18 individually fed animals from experiment F, in which wheat was fed. In addition, analyses of back fat were made on six self-fed animals in experiment F. The first-named lot of seven hogs consisted of selected animals which were slaughtered at weights ranging from 109 to 126 pounds immediately after the peanut-feeding period. From the full-fed groups, two hogs from experiment A and one from experiment B were used, and from the low-level groups two each were taken from experiments A and B. As each hog in experiments E and F attained a weight of approximately 200 pounds, it was removed from the feed lot. Feed was withheld for a day and the animal slaughtered.

At the time of slaughter the blood, hair, and all viscera from all hogs were saved, except those in experiment F. The stomachs and intestines were cleaned, and a composite sample of all visceral organs was prepared for each hog. Lot samples of blood and dried hair were also prepared. In the case of all the experimental hogs, after the warm dressed carcasses were weighed they were refrigerated for 3 days and then graded for firmness. Subsequently, fat samples were taken from all hogs after which the carcasses were separated into commercial cuts. The cuts were separated into lean, fat, bone, and skin fractions. The procedure throughout was essentially that usually followed in the cooperative investigations on quality of meats. The cutting methods have been described by Warner et al.[5] Analyti-

[5] WARNER, K. F., ELLIS, N. R., and HOWE, P. E. CUTTING YIELDS OF HOGS AN INDEX OF FATNESS. Jour. Agr. Research 48: 241-255, illus. 1934.

cal samples were prepared for certain cuts, including the lean and the fat of the ham, the loin, the back fat, and the remaining edible meat which was made into a composite sample. The total skin and the bone were also sampled for all the hogs except those in experiment F.

A number of hams from hogs on the 4- and 2-percent feed levels from experiments E and F were cooked, and palatability tests made in order to determine whether the low level of feeding had any pronounced effect on the quality of the meat.

EXPERIMENTAL RESULTS

EFFECTS OF FEEDING LEVEL ON ECONOMY OF GAINS

PEANUTS AS THE BASAL FEED

The feeding results obtained in experiments A, B, and C are shown in tables 3, 4, and 5. The daily feed consumption on the full-feed level of the peanut rations was lower for all the animals than is usually the case with pigs weighing not greatly more or less than 100 pounds and fed on cereal rations. As an example, compared with a daily intake of 4 pounds, the estimated consumption of feed per 100 pounds of live weight of the hogs in the full-fed lot in experiment B was 2.94 pounds. However, this quantity of feed had approximately the same caloric value as 4.4 pounds of the ration of corn and supplements used in experiment E. The small decrease in daily feed consumption in experiment B from that of the corresponding lots in experiment A was reflected to a slight extent in a decrease in the average daily gains of the animals. However, the feed required per 100 pounds of gain for comparable feed levels shows good agreement. The four pigs on the intermediate level in experiment B were exceptional in that they gained the most rapidly and required the least feed per 100 pounds' weight of any lot.

TABLE 3.—*Comparison of gains and feed consumption of pigs in experiment A on high and low levels of a peanut ration*

Feeding level	Hog no.	Breed [1]	Sex	Initial weight	Experimental period	Total gain	Average daily gain	Total feed	Feed consumption per 100 pounds' gain
				Lb.	*Days*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
High (full feed)	1	CW	Barrow	65	42	48	1.14	136.2	283.9
	2	CW	do	63	47	51	1.09	158.8	311.3
	3	PC	do	56	42	53	1.26	132.7	250.5
	4	PC	do	72	47	51	1.09	158.8	311.3
Average				64	44.5	50.8	1.15	146.6	289.2
Low (55 percent of full feed)	5	CW	Barrow	64	61	51	.84	112.5	220.6
	6	CW	Gilt	70	61	58	.95	109.0	187.9
	7	CW	Barrow	57	54	52	.96	80.8	172.6
	8	CW	do	57	61	58	.95	110.7	190.9
	9	PC	Gilt	65	68	45	.66	131.7	292.8
	10	PC	do	57	61	58	.95	110.7	190.9
	11	PC	do	71	61	57	.93	109.0	191.2
	12	PC	Barrow	63	61	55	.90	109.0	198.2
Average				63	61	54.3	.89	110.3	205.6

[1] CW=Chester White; PC=Poland China.

TABLE 4.—*Comparison of gains and feed consumption of pigs in experiment B on 3 levels of a peanut ration*

Feeding level	Hog no.	Breed[1]	Sex	Initial weight	Experimental period	Total gain	Average daily gain	Total feed	Feed per 100 pounds' gain
				Lb.	*Days*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
High (full feed)	13	CW	Gilt	73	63	69	1.10	181.5	263.0
	14	DJ	do	58	63	58	.92	181.5	312.9
	15	PC	do	67	63	69	1.10	181.5	263.0
	16	T	Barrow	72	70	50	.71	200.2	400.5
Average				67.5	64.8	61.5	.96	186.2	309.0
Medium (70 percent of full feed)	17	DJ	Barrow	79	48	59	1.23	107.8	182.6
	18	CW	Gilt	82	48	53	1.10	107.8	203.3
	19	CW	Barrow	80	48	60	1.25	107.8	179.6
	20	CW	Gilt	80	48	48	1.00	107.8	224.5
Average				80.3	48	55	1.15	107.8	197.5
Low (50 percent of full feed)	21	CW	Barrow	68	63	51	.81	85.2	167.2
	22	CW	Gilt	72	77	56	.73	108.0	192.9
	23	CW	Barrow	65	77	57	.74	106.2	186.4
	24	CW	do	67	70	51	.73	108.0	211.8
	25	CW	Gilt	72	77	58	.75	108.0	186.2
	26	DJ	Barrow	61	91	47	.52	133.8	284.6
	27	PC	Gilt	71	70	51	.73	95.7	187.6
	28	T	Barrow	64	84	57	.68	116.8	204.8
Average				67.5	76	53.5	.71	107.7	202.7

[1] CW=Chester White; DJ=Duroc-Jersey; PC=Poland China; T=Tamworth.

TABLE 5.—*Comparison of gains and feed consumption of pigs in experiment C on 3 levels of a peanut ration*

Feeding level	Hog no.	Breed [1]	Sex	Entire experimental period: Initial weight	Entire experimental period: Experimental period	Entire experimental period: Total gain	Entire experimental period: Average daily gain	Entire experimental period: Total feed	Entire experimental period: Feed per 100 pounds' gain	First 3 weeks of entire experimental period omitted: Experimental period	First 3 weeks omitted: Total gain	First 3 weeks omitted: Average daily gain	First 3 weeks omitted: Total feed	First 3 weeks omitted: Average feed per 100 pounds' gain
				Pounds	*Days*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Days*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
High (full feed)	29	CW	Barrow	67	56	40	0.72	170.5	426.3	35	32	0.91	113.5	354.7
	30	CW	Gilt	64	56	39	.70	167.0	428.1	35	32	.91	110.0	343.7
	31	CW	do	66	56	46	.82	170.5	370.7	35	37	1.06	113.5	306.8
	32	CW	do	60	70	40	.57	218.0	545.0	49	38	.78	161.0	423.7
	33	CW	Barrow	72	70	41	.59	219.5	535.4	49	43	.88	162.5	377.9
	34	DJ	do	67	56	43	.71	169.0	393.0	35	28	.80	112.0	400.0
	35	DJ	Gilt	64	63	39	.62	197.0	505.1	42	30	.72	140.0	466.7
	36	PC	do	60	70	37	.53	214.5	579.7	49	37	.76	157.5	425.7
Average				65	62	40.6	.66	190.8	472.9	41	34.4	.85	133.7	387.4
Medium (70 percent of full feed)	37	CW	Gilt	79	49	41	.84	98.0	239.0	28	28	1.00	45.5	162.5
	38	CW	Barrow	67	63	36	.57	143.7	399.3	42	37	.88	91.2	246.6
	39	CW	do	63	63	43	.68	143.7	334.4	42	42	1.00	91.2	217.3
	40	DJ	do	66	56	41	.73	113.8	277.4	35	33	.94	61.3	185.6
Average				68.8	58	40.2	.70	124.8	312.5	37	35	.95	72.3	203.0
Low (50 percent of full feed)	41	CW	Gilt	60	76	47	.62	111.0	236.2	55	45	.82	84.0	186.7
	42	CW	Barrow	67	76	50	.66	110.3	220.5	55	44	.80	83.2	189.2
	43	CW	Gilt	67	76	34	.45	111.0	326.5	55	28	.51	84.0	300.0
	44	CW	do	69	76	41	.54	111.0	270.7	55	42	.76	84.0	200.0
	45	CW	Barrow	64	76	41	.54	111.0	270.7	55	36	.66	84.0	233.3
	46	DJ	Gilt	61	76	44	.58	111.0	252.3	55	41	.75	84.0	204.9
	47	DJ	Barrow	68	76	37	.49	111.0	300.0	55	40	.73	84.0	210.0
	48	PC	do	62	76	31	.41	109.5	353.2	55	26	.47	82.5	317.3
Average				64.8	76	40.6	.54	110.8	278.8	55	37.8	.69	83.6	230.2

[1] CW=Chester White; DJ=Duroc-Jersey; PC=Poland China.

The performance of all the hogs for the entire period in experiment C was poor. This was especially marked in the group on full feed, not only in rate of gain but in feed required per 100 pounds of gain. It is noteworthy that the feed required per 100 pounds of gain was less on the limited feed levels, as occurred in experiments A and B.

During the first 3 weeks of experiment C, the full-fed hogs gained approximately 5 pounds and the medium and the low-level groups 3 pounds each. After this period of poor gains the growth rate improved. Insufficient evidence was available to indicate whether the failure of the hogs to gain during the early part of the experimental period was due to sickness incurred before the beginning of the experiment or to the abrupt change in ration and method of feeding. The results of the experiment, when the data for the first 3 weeks of all lots are excluded, as shown in table 5, indicate that the daily gains and the feed utilization were not greatly different for the remainder of the experiment from those of the earlier experiments.

The results obtained from this recalculation show the highest rate of gain and the best utilization of feed to be on the medium level of feed intake. The latter observation is not in harmony with the figures for the entire experimental period since the low-level group required only 278.8 pounds of feed per 100 pounds of gain compared with 312.5 pounds for the medium level. The significance of the difference between the means of (1) the average daily gains and (2) the feed consumed per unit gain, has been tested according to the method for t test given by Fisher (*4, p. 109*). Only the high and the low levels have been compared, but the t value has been calculated for the two sets of results for experiment C taken from table 5. The value of t for the two comparisons of average daily gains correspond, in terms of P, to 0.02, which means that the chances are 49 to 1 that the differences are significant. The comparisons of feed consumed per unit gain yield values for t which indicate that the chances are greater than 99 to 1 that the differences are significant. The order of significance was nearly identical for the two sets of data based either on inclusion or exclusion of the first 3 weeks of the feeding period. Since the differences due to level of feed intake in experiments A and B are in general accord with those in experiment C (table 5) both with and without the questionable 3-week period included, there appears little reason to doubt the significance of the differences produced by feed level.

The growth curves of the hogs, based on lot averages, are shown in figure 1 for each of the three experiments. It will be noted that in experiments B and C the curves for the medium-level lots closely follow those of the high-level lots. In both experiments the medium-level lots have increased rates of gain midway in the period and the gain curves remain above those of the high-level lots until the end of the periods.

Although growth was retarded on the low level of intake in all the experiments, the gains were made more efficiently in terms of feed consumption than on the high level and were not greatly different from those on the medium level. The feed requirements for unit gain on the high, or full-feed, level were generally lower than is found on peanut rations under the usual feeding conditions. As already indicated, this may be accounted for by the evidently high caloric value of peanuts, owing to oil content, and also to the high protein content.

Values such as were obtained on the high-level groups have been noted in other peanut-feeding experiments (*7*, *8*, *9*) in which the hogs were

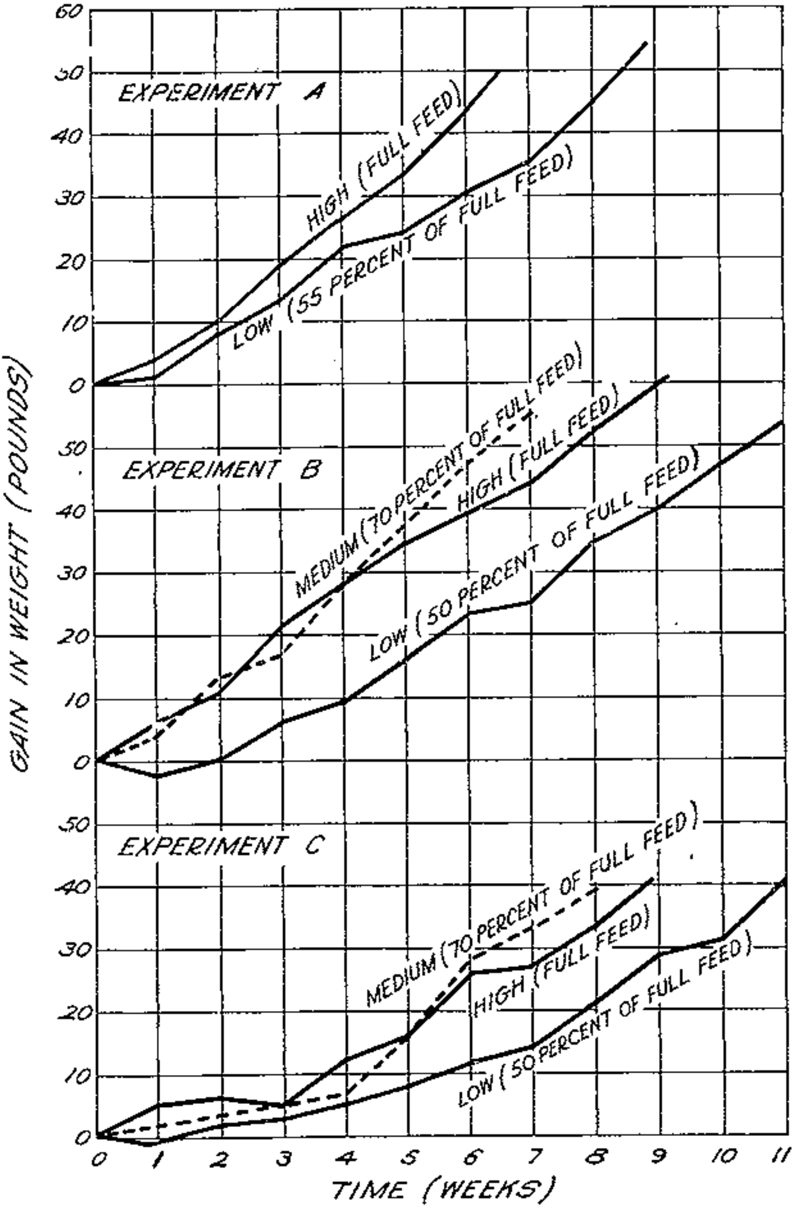


FIGURE 1.—Average gains, by weekly periods, of the lots of pigs fed peanut rations at high, medium, and low levels.

self-fed in groups. Results on 316 hogs (*7*) fed unshelled peanuts and a mineral mixture showed that the animals consumed, per 100 pounds of gain, 351.9 pounds of peanuts, the equivalent of approximately 275 pounds of shelled nuts. However, the shelled peanuts used in experiments A, B, and C, although representative of the product usually marketed for hog feeding, were not equal in feeding value, as judged by the chemical composition, to the usual quality and yield of nuts obtained by hand shelling whole nuts, which was done in order to obtain the above estimate of equivalent values of whole and shelled nuts.

The hogs of experiments A, B, and C which were not slaughtered at the conclusion of the peanut-feeding period were individually fed a hardening ration of corn and supplements. Although the details of the hardening results are not given in this bulletin, it is of interest that the restriction of the peanut ration had little, if any, effect on the gains and feed utilization on the hardening ration. Twenty hogs from the lots on the low levels of the peanut rations gained an average of 1.61 pounds per day and consumed 424.4 pounds of feed per 100 pounds of gain, whereas 13 hogs from the high-level lots gained at the rate of 1.53 pounds and consumed 437.6 pounds of feed.

CORN AS THE BASAL FEED

The results on gains and feed consumption for experiment D are given in table 6. The daily feed of the full-fed lot on the corn ration, as calculated from the average weight, total feed consumption, and days on experiment, averaged 3.63 pounds and the 60-percent lot averaged 2.38 pounds per 100 pounds' live weight. On the basis of 4 percent of the live weight as approximately a full feed for hogs ranging from 50 to 200 pounds in weight, the consumption of these hogs was below the average. As indicated by the growth curves of the hogs, shown in figure 2, little difference in rate of growth existed between the two groups of hogs. The best gains were made after the hogs passed the 100-pound weight. The feed required per 100 pounds of gain was higher for hog 51 than is usually associated in practical feeding with thrifty, economical gains. The remaining two hogs on full feed showed satisfactory feed utilization according to the usual standards. The lowering of the daily feed allowance of three hogs to 60 percent of the full ration resulted in correspondingly lower feed requirement per unit gain.

TABLE 6.—*Comparison of gains and feed consumption of pigs in experiment D on 2 levels of a corn ration*

Feeding level	Hog no.	Breed [1]	Sex	Initial weight	Experimental period	Total gain	Average daily gain	Total feed	Average feed per 100 pounds' gain
				Lb	*Days*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
High (full feed)	49	T×gr. PC	Barrow	64	130	135	1.04	615.0	455.6
	50	PC	Gilt	64	130	146	1.12	615.0	421.2
	51	T	do	55	160	152	.95	804.0	528.9
Average				61	140	144	1.04	678.0	468.6
Low (60 percent of full feed).	52	CW	Gilt	57	130	139	1.07	382.0	274.8
	53	PC	Barrow	58	160	150	.94	498.3	332.2
	54	T	Gilt	54	160	144	.90	498.2	346.0
Average				56	150	144	.97	459.5	317.7

[1] CW=Chester White; PC=Poland China; T=Tamworth; T×gr.PC=Tamworth cross on grade Poland China.

The effect of feeding a corn ration at different feeding levels was further studied in experiment E. The results are given in table 7. The rate of growth as related to length of feeding period is shown in figure 2. The curves indicate that the rate of growth increased in

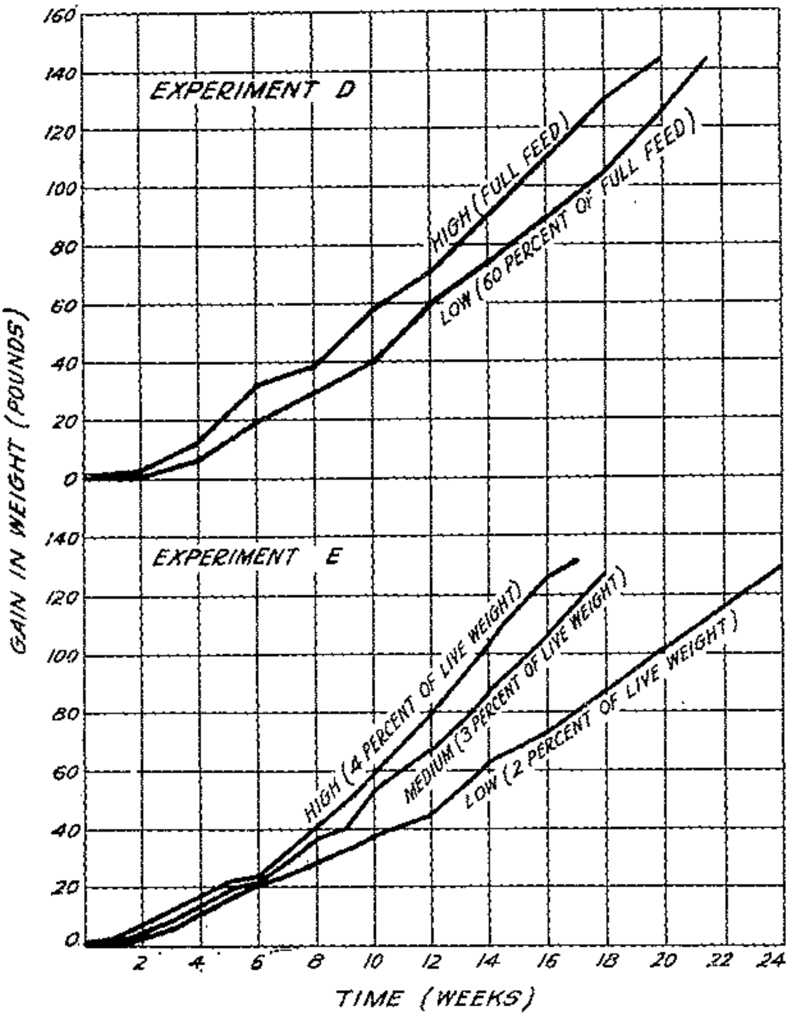


FIGURE 2.—Average gains, by weekly periods, of the lots of pigs fed corn rations at high and low levels in experiment D and high, medium, and low levels in experiment E.

all lots proportionally to the feeding level with increasing live weight. Thus, the curve for the lot on the low allowance of feed appears to deviate the least from a straight line and the curve for the lot on the full allowance the most.

TABLE 7.—*Comparison of gains and feed consumption of pigs in experiment E on 3 levels of a corn ration*

Feeding level	Hog no.	Breed [1]	Sex	Initial weight	Experimental period	Total gain	Average daily gain	Total feed	Average feed per 100 pounds' gain
				Lb.	*Days*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
High (4 percent of live weight).	55	CW	Gilt	73	115	124	1.08	529.6	427.1
	56	CW	Barrow	72	115	133	1.16	529.6	398.2
	57	CW	Gilt	67	115	132	1.15	522.4	395.7
	58	DJ	do	62	127	132	1.04	620.8	470.3
	59	PC	Barrow	74	115	155	1.35	528.2	340.8
	60	PC	do	62	127	136	1.07	620.8	456.5
Average				68.3	119	135.3	1.14	558.6	414.8
Medium (3 percent of live weight).	61	CW	Gilt	67	135	123	.91	503.0	408.9
	62	CW	Barrow	70	115	124	1.08	388.2	313.1
	63	DJ	Gilt	72	127	125	.98	449.8	359.8
	64	PC	do	62	135	141	1.05	502.0	356.0
	65	PC	Barrow	64	127	140	1.15	446.8	307.4
Average				68.2	127.8	131.8	1.03	458.4	349.0
Low (2 percent of live weight).	66	CW	Gilt	72	167	124	.74	395.5	318.9
	67	CW	do	72	167	132	.79	397.8	301.4
	68	CW	do	62	167	135	.81	397.8	294.7
	69	DJ	do	77	167	120	.72	397.8	331.5
	70	PC	Barrow	73	147	125	.85	326.9	261.5
	71	CW×Y	do	52	182	131	.72	454.8	347.2
Average				68	166	127.8	.77	395.1	309.2

[1] CW=Chester White; DJ=Duroc-Jersey; PC=Poland China; Y=Yorkshire.

Arrangement of the feeding and growth data in the form given in table 8 shows the average gains by successive 100-pound increments of feed intake. Adequate data on this phase of the study were obtained only in experiments E and F. Smoothed growth curves were first constructed from the running averages of three successive weekly weights of the individual pigs in order to remove occasional irregularities in weights. The gain in weight for each 100 pounds of feed intake was then obtained.

TABLE 8.—*Comparison of gains in weight (pounds) per successive 100 pounds of feed increment consumed at 3 levels of feeding in experiment E*

Feed increment	High level	Medium level	Low level
First 100 pounds	22.0	25.6	31.8
Second 100 pounds	24.0	31.8	36.0
Third 100 pounds	28.7	30.4	33.8
Fourth 100 pounds	26.3	29.2	28.2
Fifth 100 pounds	23.8		

It will be noted that the hogs on the high level made the greatest gain on the third 100-pound increment of feed, which occurred between weights of approximately 110 and 140 pounds. Greater gains on all corresponding feed increments occurred on the medium and low levels than on the high level. Apparently, the highest gains occurred in all lots during the second or third 100 pounds of feed intake and tended to decrease thereafter. The most pronounced decrease in efficiency of conversion of feed into body weight occurred in the high-level lot. The small decreases for the lots on the medium and low levels are undoubtedly indicative of increasing maintenance requirements resulting from increasing growth.

Table 7 shows that the total gains in weight of the 17 hogs ranged from 120 to 155 pounds with the lot averages within the range of 128 to 135 pounds. The time required to reach the desired gain increased from 119 to 166 days with the decrease in the feed level. Although the time required to reach a final weight of approximately 200 pounds was increased by limitation of the feed to 2 percent of the live weight of the animal, the total feed consumption was reduced fully 25 percent. The lot on the medium level of feeding gave results intermediate to the high- and low-level lots. In the experiments with the peanut rations the hogs on the medium levels tended to gain at rates slightly better than those on the full levels and at the same time utilized the peanut ration fully as well, if not better, than those on the low levels of feeding.

The differences in feed economy between lots are of such size as to indicate a significantly better utilization of feed with decreasing intake with the levels used. Although the numbers of hogs are small within any one group, there is a consistent trend from group to group. A study of the significance of the mean differences (*4, p. 109*) in the feed required per unit gain between the lots shows *P* values to be

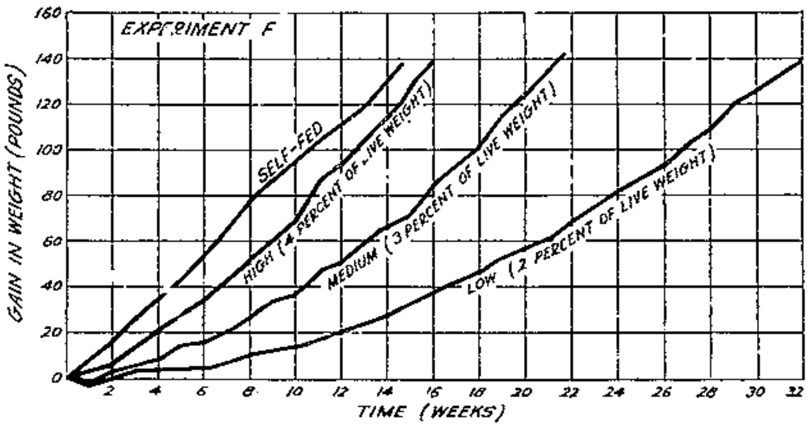


FIGURE 3.—Average gains, by weekly periods, of lots of pigs in experiment F fed a wheat ration at high, medium, and low levels, and of one lot self-fed the same ration.

less than 0.04 for lots on the high and medium levels and less than 0.01 for lots on the high and low levels. With odds greater than 24 to 1 and 99 to 1, as indicated by the values for *P*, the medium- and low-level lots appear to have made a significantly better utilization of the feed than the high-level lot, even though the hogs required a longer time to reach the same final weight. The data show a lack of significance in the feed requirements between the lots on the medium and low levels of feeding.

WHEAT AS A BASAL FEED

The feeding of a ration low in fat and normal in protein content, such as is found in the corn ration previously described, as distinguished from the high-fat and high-protein peanut ration, was continued in experiment F. Wheat replaced corn as the basal feed. As already noted, the plan of work for experiment F followed that of experiment E in most details. One additional lot on a self-fed basis was included for feed and growth comparisons with the feeding levels of 4, 3, and 2 percent of live weight. The results of this experiment are shown in table 9.

TABLE 9.—*Comparison of gains and feed consumption of the 4 lots of pigs in experiment F on a wheat ration*

Feeding level	Hog no.	Breed [1]	Sex	Initial weight	Experimental period	Total gain	Average daily gain	Total feed consumption	Average feed per 100 pounds' gain
				Lb.	*Days*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
High (4 percent of live weight)	72	CW	Barrow	57	111	141	1.27	524.0	371.0
	73	CW	Gilt	59	111	151	1.36	524.0	347.0
	74	DJ	do	69	111	144	1.30	524.0	363.9
	75	DJ	Barrow	67	111	135	1.22	524.0	388.2
	76	PC	do	64	125	142	1.14	636.0	447.9
	77	PC	do	62	111	143	1.29	524.0	366.4
Average				63	113	142.7	1.26	542.7	380.4
Medium (3 percent of live weight)	78	CW	Gilt	68	141	132	.94	450.5	341.3
	79	CW	do	52	153	157	1.03	517.3	329.5
	80	DJ	Barrow	71	153	137	.90	515.7	376.5
	81	DJ	Gilt	53	153	154	1.01	515.7	334.9
	82	PC	Barrow	71	153	130	.85	517.3	397.9
	83	PC	do	53	153	150	.98	517.3	344.8
Average				61.3	151	143.3	.95	505.6	354.2
Low (2 percent of live weight)	84	CW	Gilt	55	231	150	.65	510.0	340.0
	85	CW	do	57	231	142	.61	510.0	359.2
	86	DJ	Barrow	70	210	133	.63	435.9	327.7
	87	DJ	do	65	231	136	.59	510.0	375.0
	88	PC	do	78	231	126	.55	510.0	404.8
	89	PC	Gilt	55	210	146	.70	435.9	298.5
Average				63.3	224	138.8	.62	485.3	349.6
Self-fed	90	CW	Barrow	78	69	125	1.81		
	91	CW	Gilt	60	111	145	1.31		
	92	DJ	Barrow	56	111	154	1.39		
	93	DJ	do	70	97	130	1.34		
	94	PC	Gilt	61	125	146	1.17		
	95	PC	do	64	86	148	1.72		
Average				66.3	100	141.3	1.45	707.2	500.4

[1] CW = Chester White; DJ = Duroc-Jersey; PC = Poland-China.

The gains in weight as related to length of feeding period of the four lots of hogs are shown in figure 3. The most pronounced differences in rate of gain occurred during the early part of the experiment. Indeed, the low-level group failed to gain until the third week of the experiment, and it was not until after the seventh week that a reasonably rapid rate of gain was maintained. Several factors are possibly involved, namely, the "fill" at the beginning of the experiment, the disturbance to health and to normal body functions owing to decrease in feed, or other factors. A similar situation occurred in experiment C. In this case, however, all groups were affected, thus indicating with greater certainty that factors other than feed level were predominant. When once adjusted to these factors causing the early retardation, the lot on the low level of feeding in experiment F gained as well as the corresponding lot in experiment E. Indeed, the growth curve of the two experiments are much alike except for the early retardation as noted.

A tabulation of the data according to gain per 100 pounds of feed increments, as was presented for experiment E, yielded the results given in table 10. The high-level group showed the most efficient utilization of feed in the first 100 pounds consumed but was never greatly in excess and usually less than the two lower-level groups on all successive 100-pound increments.

TABLE 10.—*Comparison of gains in weight (pounds) for successive 100 pounds of feed consumed at 3 levels of feeding in experiment F (wheat ration)*

Feed increment	High level	Medium level	Low level
First 100 pounds	29.0	20.8	17.5
Second 100 pounds	29.3	32.5	28.5
Third 100 pounds	29.5	28.7	37.5
Fourth 100 pounds	22.8	30.8	30.5
Fifth 100 pounds	21.5	29.4	28.5

The slow gains during the early weeks on the low level of feeding were responsible for the low gain, 17.5 pounds, shown in table 10. On the other hand, the high gain attained on the second 100 pounds of feed increment on the low level was maintained until the end; on the medium level there was only a slight decrease; but on the high level a decided decrease occurred on the fourth and fifth 100-pound increments. The low-level group made a maximum gain per unit of feed intake between weights of approximately 115 and 150 pounds.

The growth and feed-consumption results for the entire experiment, as shown in table 9, indicate that the self-fed group made the highest average daily gain, but also consumed the largest quantity of feed per 100 pounds of gain. Although the requirement of 500.4 pounds of feed per 100 pounds of gain appears high, data from other experiments conducted at the same time showed equally high feed consumption when the animals were self-fed.[6]

The lots on the 4-, 3-, and 2-percent feed levels ranked in decreasing order not only for rate of growth but for feed requirement per 100 pounds of gain. The differences among the three groups in feed requirements were not so great as in experiment E. Statistical tests applied to the data in experiment F showed no significant differences between mean values of the groups. However, a study of the hogs from the same litter as distributed among the four lots indicated that litter mates on the lower feed level gained consistently more economically and thus supports the order of efficiency indicated by the group averages.

EFFECTS OF FEEDING LEVEL ON PHYSICAL AND CHEMICAL COMPOSITION OF THE HOGS

PEANUTS AS THE BASAL FEED

The composition of the entire bodies of three hogs from the high feeding levels and four hogs from the low levels on the peanut ration, the hogs being killed at approximately the same weights, is shown in table 11. The limitation of the daily ration to 50 or 55 percent of the full feed did not materially lower the fatness of the carcasses. The average percentage of fat differed by only 0.6 between the two groups. Furthermore, the average fat composition of these seven hogs was higher than that of hogs of similar weights taken from other experiments and self-fed on rations low in fat. Twelve such hogs showed an average fat content of 26.5 percent. However, results obtained on the hogs changed to hardening feed indicated a wider ratio of soft fat to hard fat in the carcasses of the hogs fed on the low level than in those on the full-feed level, thus showing a favorable effect on firmness through restriction of softening feed.

[6] Unpublished data.

TABLE 11.—*Comparison of the composition of the bodies of peanut-fed hogs fed at high and low levels*

Feeding level	Experiment	Hog no.	Live weight	Weights of parts analyzed	Composition of entire body			
					Water	Protein	Fat	Ash
			Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*
High (full feed)	A	1	113	97.9	55.1	13.9	27.7	3.0
	A	3	109	96.2	56.3	13.5	26.9	3.0
	B	16	126	111.3	51.8	13.2	31.5	2.9
Average			115	101.8	54.4	13.5	28.7	3.0
Low (50-55 percent of full feed)	A	5	112	102.9	54.3	14.2	25.3	2.8
	A	10	111	103.1	55.9	14.3	26.7	3.1
	B	24	122	107.2	55.3	14.1	27.2	2.9
	B	28	121	104.4	53.1	13.9	30.2	3.3
Average			116	104.4	54.6	14.1	28.1	3.0

CORN AS THE BASAL FEED

After the slaughter of the hogs in experiment E at weights of approximately 200 pounds, both physical and chemical analyses were made on the body parts of five hogs from each lot. The average percentage cutting yields for the principal cuts of the cold carcasses are given in table 12. A small but generally consistent difference was found between lots for the lean cuts (ham, shoulder, and loin) on the one hand, and for the fat cuts (belly, back fat, and cutting fat) on the other. Cutting fat, as here used, consists of the skinless back fat and fat trimmings and the leaf fat. The lean cuts increased with decrease in feed level and the fat cuts decreased with decrease in feed level. The ratio of belly and cutting fat to ham and loin as an index of fatness [7] also decreased with the lowering of feed level.

TABLE 12.—*Comparison of average percentage yield of cuts in carcasses of hogs fed at different levels on corn and on wheat*

Experiment and basal feed	Feeding level	Hogs	Cold carcass weight	Yield of—							Ratio of belly and cutting fat to ham and loin
				Shoulder	Ham	Trimmed loin	Back fat	Belly	Miscellaneous parts	Cutting fat	
		Number	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*1:*
E, corn	High	5	150.7	16.5	20.1	14.0	7.8	12.0	23.0	14.4	0.774
	Medium	5	150.4	16.4	20.7	14.5	7.1	11.6	22.9	13.9	.724
	Low	5	140.1	17.4	21.1	15.6	6.0	11.1	23.2	11.6	.620
F, wheat	High	6	152.2	17.5	19.4	14.4	8.4	11.4	20.3	16.7	.831
	Medium	6	148.8	18.2	20.3	14.3	8.2	12.0	19.5	15.7	.801
	Low	6	140.8	18.3	21.3	15.2	6.4	10.6	21.8	12.8	.641
	Self-fed	6	149.7	17.4	19.2	13.8	9.2	12.1	20.5	17.0	.882

An analysis of the variance (*4, p. 194*) within the lots in relation to that between lots for (1) the yield of the fat cuts and (2) the total yield of ham and loin showed that the feeding level had a significant effect on the yields of fat and lean cuts as judged by the odds of a chance observation. The value of *z* for the variance in the yield of fat falls (table 13) between the 5-percent and 1-percent values of the

[7] WARNER, K. F., ELLIS, N. R., and HOWE, P. E. See footnote 5.

z table and indicates odds of significance greater than 49 to 1. The z value for the yield of ham and loin is even higher than that for the 1-percent value with odds greater than 99 ot 1.

TABLE 13.—*Difference of variance in yield of (1) fat and of (2) ham and loin of percentage cutting yields in experiment E (corn ration)*

Item	Degrees of freedom	Sum of squares	Mean square	Standard deviation	Log standard deviation
		Percent	*Percent*	*Percent*	*Percent*
Yield of fat:					
Between lots	2	22.6295	11.3148	3.364	1.2131
Within lots	12	26.0000	2.1667	1.472	.3866
Total difference	14	48.6295			[1] (z=).8265
Yield of ham and loin:					
Between lots	2	17.5575	8.7787	2.963	1.086
Within lots	12	7.7600	.6467	.804	—.218
Total difference	14	25.3175			[1] (z=)1.304

[1] From Fisher's z table (4): For 5 percent (odds 1:19), z=0.6786, and for 1 percent (odds 1:99), z=0.9677.

Table 14 shows the percentage of water, protein, fat, and ash in the edible and inedible parts of the bodies of the animals. The ham was separated into lean and fat and these parts analyzed separately. The composition of the total edible ham meat was then calculated. An additional series of calculated results was obtained by the combination of all the edible-meat fractions as the total edible portion of the carcass.

TABLE 14.—*Comparison of the average percentage chemical composition of body parts of the hogs in experiment E (corn ration) on 3 levels of feed*

Body part	High level				Medium level				Low level			
	Water	Protein	Fat	Ash	Water	Protein	Fat	Ash	Water	Protein	Fat	Ash
Edible parts:												
Ham, lean	72.32	20.35	6.22	1.08	72.50	20.29	5.97	1.02	73.76	21.09	4.64	1.11
Ham, edible	55.53	15.76	27.90	.79	56.30	15.84	27.01	.76	60.57	17.40	21.78	.90
Loin	55.52	16.46	27.37	.83	56.62	16.81	25.85	.89	56.27	17.88	24.69	.83
Back fat	7.64	1.93	90.44	.12	8.60	2.06	89.01	.13	10.03	3.06	87.4'	.14
Remaining edible	39.86	11.06	48.65	.48	39.90	11.13	48.42	.63	45.56	12.82	41.39	.51
Total edible	42.31	11.91	45.46	.56	43.54	12.30	43.60	.67	48.45	14.04	37.15	.77
Inedible parts:												
Skin	40.30	25.81	34.40	.72	40.02	24.82	35.39	.59	45.17	26.80	28.76	.55
Bone	43.20	18.99	13.87	22.38	41.33	18.91	14.99	23.51	41.17	20.10	14.68	22.88
Viscera	60.92	14.74	21.86	1.00	60.10	14.70	23.13	1.02	71.12	12.16	14.62	.89
Blood	79.16	20.25	.09	1.02	79.30	20.12	.08	.94	79.21	20.20	.07	.96

The protein content (nitrogen times 6.25) of the meat samples, both fat and lean, showed a generally consistent increase from the high level of feeding to the low level, just as there was an increasing yield of lean cuts. On the other hand, the fat content of the meat cuts decreased as the protein content increased. The total edible meat from the high-level and low-level lots differed in fat content by 8.31 percent and from the medium-level and low-level lots by 6.45 percent. A statistical analysis of the differences between the mean of the high- and low-level lots and of the medium- and low-level lots gave P values of less than 0.01, which indicates significantly less fat in the low-level lot than in either of the other two lots. However, there is no significant difference between the lots on the high and medium levels of feeding. The composition of the skin, bone, blood, and viscera appears to bear no relation to the feed level since no consistent differences between lots were observed.

The total percentage yields of mechanically separable fractions of the carcass, together with the average chemical composition of the entire bodies, are given in table 15. There were only small differences between lots in the average quantity of bone and skin. Hog 69 in the low-level lot yielded more bone than any other hog, and chemical analyses later showed that this hog had the highest ash content of all 15 hogs.

TABLE 15.—*Comparison of the physical and chemical composition of the entire bodies of hogs in experiment E (corn ration) on the 3 levels of feed*

Feeding level	Hog no.	Weight of hog: Close of experiment	Weight of hog: Parts analyzed	Physical composition of parts analyzed [1]: Blood	Viscera	Skin	Bone	Edible meat: Lean	Edible meat: Fat	Chemical composition: Water	Protein	Fat	Ash
		Lb.	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
High (4 percent of live weight)	55	198	174.2	4.3	12.4	6.0	14.4	34.0	26.7	49.45	15.15	31.25	3.61
	56	205	190.2	3.4	10.8	4.6	12.3	34.1	30.7	49.68	14.62	33.25	3.26
	57	199	183.5	3.5	12.0	5.8	13.1	33.2	28.7	48.26	15.53	32.00	3.65
	58	194	177.7	3.1	10.1	5.9	13.6	35.0	29.6	45.75	14.68	36.52	3.04
	60	198	185.3	3.2	9.4	5.7	12.0	32.0	35.3	41.23	13.37	42.77	3.25
Average		198.8	182.2	3.5	10.94	5.78	13.08	33.66	30.20	46.87	14.67	35.16	3.48
Medium (3 percent of live weight)	61	190	173.2	3.7	11.2	6.8	13.4	38.0	24.4	49.38	15.78	31.12	3.80
	62	200	182.0	3.9	11.5	4.6	12.3	31.8	32.3	46.27	13.85	35.94	3.46
	63	197	178.1	3.5	11.8	6.0	14.8	34.1	26.7	46.25	14.05	34.28	4.20
	64	203	190.0	3.3	10.5	5.7	12.7	35.6	29.4	48.04	14.97	33.52	3.70
	65	210	192.1	3.6	11.4	5.5	13.6	33.2	29.0	46.34	14.27	35.75	3.70
Average		200.0	183.1	3.65	11.28	5.72	13.36	34.54	28.54	47.20	14.70	34.12	3.78
Low (2 percent of live weight)	66	196	176.4	3.7	10.7	4.8	12.5	40.0	24.7	50.60	15.82	30.30	3.39
	67	204	185.3	3.2	11.1	5.2	13.0	40.4	24.7	51.82	15.78	28.87	3.63
	68	197	177.7	3.7	10.7	5.7	13.4	37.6	26.3	50.83	15.52	29.73	3.68
	69	197	173.0	3.9	10.7	6.5	16.5	41.6	17.5	53.35	17.17	25.43	4.02
	70	198	187.9	3.6	11.4	5.7	12.4	39.8	24.6	51.66	15.05	29.03	3.55
Average		198.5	180.1	3.62	10.92	5.60	13.56	40.06	23.56	51.65	15.87	28.88	3.77

[1] The hair and hoofs included in parts analyzed, but not listed, varied from 0.5 to 0.75 percent and averaged for lot 1, 0.63 percent; for lot 2, 0.05 percent; and for lot 3, 0.7 percent. The evaporation from the carcasses during chilling constitutes the remaining difference between 100 percent and the sum of parts listed including hair and hoofs.

The lots on the high and medium levels of feeding differed very little in yields of lean and of fat. However, the low-level lot yielded approximately 16 percent more lean meat and 17 percent less fat than the medium-level lot. In only one case the percentage of lean meat in the medium-level lot exceeded the lowest percentage among the hogs in the low-level lot, whereas the lowest percentage of fat in the medium-level lot was exceeded once in the low-level lot.

Just as in comparisons of physical and chemical analyses, there were no pronounced differences in chemical composition between the high- and medium-level lots. The hogs in the former lot, however, had relatively wide extremes in percentages of fat, which ranged from 31.25 to 42.77.

The hogs on the lowest feed level contained less fat and more lean than either of the other two lots. The t test of Fisher for significance of differences between the lots on the highest and the lowest levels of feeding, as well as between the lots on the medium and lowest levels, again showed P values of 0.01 or less. It appears reasonably certain that the limitation of the ration to 2 pounds for each 100 pounds of live weight produced significantly less fat in the body as a whole than either the 3-pound or 4-pound ration.

WHEAT AS THE BASAL FEED

The physical and chemical analyses of the hogs on the wheat ration (experiment F) yielded results generally comparable to those of the preceding experiment. The comparisons of the yields of cuts are included in table 12. The group of hogs which were self-fed had the lowest percentage of lean cuts and the highest percentage of fat cuts of the four lots. The data show the same order of increase in lean and decrease in fat with change in feed level found on the corn ration. The differences between lots are also of a comparable order of significance to those already described.

The chemical analyses of the edible meat of each carcass from the hogs on the 4-, 3-, and 2-percent feeding levels are given in table 16. Analyses are given on 2 lean cuts, the ham and loin, and on 2 fat cuts, the belly and back fat. The lean meat of the ham was the only sample which did not show a marked change in fat content as the feed level decreased. The lot on the medium level of feeding yielded results midway to those of the other 2 lots and indicated that the reduction in feed level from 4 to 3 percent of the live weight of the animal had a greater effect on composition of the meat than a similar reduction on the corn ration. The differences in fat content of the total edible meat was 10.83 percent between the high- and low-level lots and 7 percent between the medium- and low-level lots. The fat content of the meat of the low-level lot was reduced to approximately 76 percent of that of the lot on the high level of feeding. A statistical examination of the differences of the means for fat and for protein content showed that a significant difference existed between the lots on the high and medium levels of feeding, on the medium and low levels, and on the high and low levels. The essential point of difference from experiment E was in the more pronounced reduction in fat content in the medium-level lot.

TABLE 16.—*Comparison of the average chemical composition (percent) of edible portions of pork cuts of the hogs in experiment F on 3 levels of the wheat ration*

Pork cut	High level				Medium level				Low level			
	Water	Protein	Fat	Ash	Water	Protein	Fat	Ash	Water	Protein	Fat	Ash
Ham, lean	73.60	19.55	5.85	1.06	72.84	20.32	5.90	1.02	73.30	20.48	5.47	1.04
Ham, edible	55.89	14.98	28.33	.80	58.01	16.27	24.83	.81	61.78	17.73	20.24	.87
Loin	56.38	15.21	27.40	.79	58.94	16.67	23.77	.80	61.64	17.93	19.66	.87
Back fat	8.53	2.46	88.36	.18	10.44	2.82	85.98	.16	11.31	3.08	85.10	.25
Belly	35.58	9.57	54.44	.61	38.27	10.37	50.02	.53	41.77	11.12	46.57	.56
Remaining edible	41.62	10.60	47.00	.61	44.61	11.44	43.03	.59	46.10	12.90	37.08	.69
Total edible	42.00	11.22	45.49	.63	45.28	12.23	41.66	.61	50.73	13.88	34.66	.72

EFFECTS OF FEEDING LEVEL ON FIRMNESS OF FAT, PALATABILITY, AND OTHER QUALITY FACTORS

One of the factors which contribute to the quality of pork is the firmness of the fat tissues. Peanuts generally produce a soft or oily fat when they are fed to hogs for extended periods. The seven hogs killed at the conclusion of the peanut-feeding period in experiments A and B graded soft, and analyses of the fat showed the usual fat constant values found under such conditions. No marked differences were noted between the three hogs on full feed and the four hogs on the low feeding levels.

The firmness gradings of the six hogs in experiment D fed a corn ration and slaughtered at weights of 185 to 200 pounds were hard for two hogs and medium hard for one hog in the full-fed group, and hard for one hog and medium hard for two hogs in the group fed at the 60-percent level. The average refractive-index readings on the back fat were 1.4593 and 1.4595 respectively for the two groups.

A ration of corn with nonsoftening supplements fed to hogs until their weights approximate 200 pounds usually produces firm carcasses when the hogs are full fed or self-fed. The results given in table 17 indicate that the carcasses in experiment E were less firm than the usual average. Two of the carcasses of the lot on the 4-percent feed level were medium soft. Decreases in fed allowance were associated with increased softness in the carcasses. Those carcasses with the thickest back-fat layer were usually the firmest.

TABLE 17.—*Comparison of the firmness, fat analyses, and fat-layer measurements of the carcasses of the hogs in experiment E (corn rations)*

Feeding level	Hog no.	Slaughter weight	Firmness of carcass	Back fat		
				Refractive index 40° C.	Iodine no.	Thickness
		Pounds				*Millimeters*
High	55	188	Medium soft	1.4599	68.6	25
	56	195	Medium hard	1.4597	65.8	36
	57	190	Medium soft	1.4598	68.2	26
	58	190	Medium hard	1.4594	64.2	35
	59	220	do	1.4594	65.4	32
	60	193	Hard	1.4593	64.3	42
	Average	196		1.4596	66.1	32
Medium	61	190	Medium soft	1.4600	70.3	29
	62	191	Medium hard	1.4596	65.2	32
	63	193	Medium soft	1.4598	67.6	30
	64	203	Medium hard	1.4598	69.7	38
	65	204	do	1.4594	65.4	31
	Average	196		1.4597	67.6	32
Low	66	190	Medium soft	1.4602	73.3	26
	67	200	do	1.4601	70.1	32
	68	187	do	1.4600	69.9	28
	69	190	Soft	1.4605	75.9	24
	70	203	Medium soft	1.4600	69.8	29
	71	195	do	1.4601	70.8	31
	Average	194		1.4602	71.6	29

Both the refractive-index and the iodine-number values showed a definite increase in unsaturation of the body fat with decrease in feed level. The changes in saturation of the fat indicated that the decrease in total fat stored was largely at the expense of the saturated acids such as palmitic and stearic. These acids generally occur in relatively small proportions in the oils contained in the usual hog feeds and when built into body fat in the hog are largely the product of synthesis. Although the intake of the unsaturated acids was greatly reduced by the restriction in feed intake of this experiment, the proportion of these acids in the total fat actually stored was increased. Of the two possible sources available, namely, synthesis or use of ingested fatty acids, the greater reduction apparently occurred in the former source.

A marked difference in finish occurred in the three lots in experiment E as judged by yields of lean and fat meat, fat content of the carcasses, and thickness of the back fat. Increasing firmness of hogs fed on rations of corn with nonsoftening supplements has been found to be related to weight, which in turn is generally associated with the finish or fatness (*7*). With weight held constant in experiment E, the firmness was related to the finish.

The results relating to the firmness of the hogs receiving wheat as the basal feed (experiment F) are given in table 18. All hogs on the 4-percent feed level were graded hard, whereas in the self-fed lot only three out of six were graded hard. The differences in the fat constants between lots were small. Apparently, the feed level had little if any effect on the firmness of the carcass. The relationship noted in experiment E between the thickness of the back-fat layer as an expression of finish and the firmness was also negligible.

TABLE 18.—*Comparison of the firmness, fat analyses, and fat-layer measurements of the carcasses of hogs in experiment F (wheat rations)*

Feeding level	Hog no.	Slaughter weight	Firmness of carcass	Back fat: Refractive index 40° C.	Back fat: Iodine no.	Back fat: Thickness
		Pounds				*Millimeters*
High	72	187	Hard	1.4584	56.6	31
	73	203	do	1.4580	58.4	39
	74	203	do	1.4584	55.2	44
	75	193	do	1.4584	50.9	35
	76	200	do	1.4587	58.4	35
	77	190	do	1.4584	57.7	36
	Average	196		1.4585	57.2	36.6
Medium	78	190	Hard	1.4588	58.4	32
	79	199	Medium hard	1.4588	60.1	36
	80	195	Hard	1.4584	54.2	37
	81	191	do	1.4585	57.5	36
	82	188	do	1.4586	58.6	36
	83	189	Medium hard	1.4587	57.5	33
	Average	192.5		1.4586	57.7	35.1
Low	84	196	Hard	1.4587	57.9	25
	85	190	do	1.4588	57.9	30
	86	190	do	1.4584	54.9	32
	87	191	Medium hard	1.4588	58.2	26
	88	190	Hard	1.4586	56.3	28
	89	196	Medium hard	1.4592	60.4	27
	Average	192		1.4588	57.6	27.9
Self-fed	90	191	Hard	1.4587	58.7	48
	91	194	Medium hard	1.4591	59.5	37
	92	193	Hard	1.4585	55.1	38
	93	192	do	1.4587	57.8	42
	94	201	Medium hard	1.4590	59.4	41
	95	190	Medium soft	1.4592	62.5	30
	Average	193.5		1.4589	58.5	39.5

The cooking and palatability tests carried out according to the procedure used in cooperative meat investigations [8] were made on uncured hams from hogs on the high and low levels of feeding in experiments E and F. The average results are given in table 19. Comparison of the two lots in each experiment shows that the feed level failed to produce any marked differences in the factors of quality.

TABLE 19.—*Comparison of the total cooking loss and palatability* [1] *of half-ham samples from experiments E and F*

Feeding level	Hogs studied	Cooking loss		Aroma		Texture	Flavor of fat		Flavor of lean		Tenderness	Juice	
		Evaporation	Drippings	Intensity	Desirability		Intensity	Desirability	Intensity	Desirability		Quality	Quantity
EXPERIMENT E (CORN AS BASAL FEED)													
	No.	*Percent*	*Percent*										
High	5	18.1	10.8	[2] 5.1	[3] 4.9	[4] 4.6	[2] 4.6	[3] 5.4	[2] 5.0	[3] 5.0	[5] 4.0	[6] 4.2	[7] 4.2
Low	4	18.0	9.5	[2] 5.4	[3] 4.7	[4] 4.8	[2] 4.5	[3] 5.0	[2] 4.6	[3] 4.9	[5] 4.4	[6] 3.9	[7] 3.7
EXPERIMENT F (WHEAT AS BASAL FEED)													
High	6	19.7	10.6	[2] 4.7	[3] 5.2	[4] 5.3	[9] 3.7	[3] 4.7	[2] 4.2	[3] 4.0	[5] 4.7	[6] 3.9	[7] 4.1
Low	6	21.0	11.1	[2] 5.1	[3] 4.9	[4] 4.9	[9] 3.6	[3] 5.1	[2] 4.5	[3] 5.1	[5] 4.6	[6] 3.8	[7] 3.5

[1] Palatability as determined by cooked-meat grading committee. Maximum score for each item is 7.
[2] Moderately pronounced.
[3] Moderately desirable.
[4] Moderately fine.
[5] Moderately tender.
[6] Slightly rich.
[7] Slightly dry.
[8] Slightly tough.
[9] Slightly pronounced.

Only a slight decrease occurred in the lots on the low-feeding level in both experiments in desirability of aroma, in intensity of flavor of fat, in tenderness, and in quality or richness of juice. In texture and in desirability of flavor of fat and lean, the differences between lots in one experiment were at variance with those of the other. The greatest difference between lots was observed in the quantity of juice; the low-feeding level apparently produced the drier meat when cooked.

With respect to cooking losses, the differences between lots both in evaporation and drippings (table 19) were neither consistent between experiments nor of sufficient size to offer an explanation for the differences in quantity of juice. The slightly higher percentage of drippings in the low level as compared with the high-level lot of experiment F was contrary to normal expectation, on the basis of fat content by analysis, and also contrary to results obtained for drippings in experiment E.

The fat content of the lean meat of the hams (tables 14 and 16) was not greatly affected by feeding level and may have been responsible in part for the slight differences in palatability and cooking losses.

[8] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF HOME ECONOMICS AND ANIMAL INDUSTRY. METHODS OF COOKING AND TESTING MEAT FOR PALATABILITY. 30 pp. Revised, February 1933. [Mimeographed.]

DISCUSSION

The feeding results obtained with peanuts, corn, and wheat as the basal feeds have generally agreed in the increased economy of gain resulting from reductions in feed allowance to the hogs. The feeding levels used in the different rations varied somewhat, owing chiefly to the nature of the ration. Thus, the peanut rations, with their high oil content, were not consumed at the same weight level on a full-feed basis although they were usually consumed at a higher caloric level than the corn and wheat rations. The results of experiments A, B, and C with the peanut rations suggested that the medium level afforded the most economical utilization of feed. Although further reduction of feed to approximately one half of a full feed caused a slight increase in feed requirements, it was not sufficient to be judged significant.

Experiment D, with the corn ration, showed increased economy when the feed level was reduced 40 percent from that of the full-fed lot. The average results of experiment E, also with the corn ration, showed that the saving in feed by reduction from the 4 to 3-percent level was not greatly different from the saving obtained by further reduction from 3 to 2 percent. On the other hand, no further saving was effected on the wheat ration (experiment F) by the reduction in feed level from 3 to 2 percent. The poor gains of the lot on the lowest level during the early part of the experiment and the consequent lengthening in the time required to reach a final weight of 200 pounds are the main points of difference in the reaction of the lot to the wheat ration and the reaction of the corresponding lot in experiment E to the corn ration.

Most of the initial weights in all the experiments were within the range of 55 to 80 pounds. The work with peanuts did not permit the continuation of the restricted feeding much beyond a weight of 135 pounds. Since the feeding level on a full or limited basis of the growing animal during the early period of growth is generally higher than during the later period as maturity approaches, the more severe effects of feed restriction are likely to be felt during the early growth period.

It is apparent that further decreases in the feed allowance below the quantities given in these experiments would eventually lead to increasing requirements for unit gains. That a 50-percent reduction in the feed allowance below the full level should result in better utilization and lowered feed requirements per unit of gain even when the rate of gain is reduced is undoubtedly a contradiction of the general opinion as shown in the references previously quoted.

The rations were not unusual in composition. The peanut rations contained more protein than the corn or wheat rations. In experiment E with the corn ration, the daily protein intake of the six hogs on the low level of feeding at 100-pound weights was approximately 0.3 pound. This quantity is little more than half that given in feeding standards. Whether the protein, the total energy derived from the feed, or other dietary constituents limited the development of the animal remains for future experiments to determine.

The vigor and thriftiness of the pigs were undoubtedly factors in the efficient utilization of feed on the limited feed levels, not that the pigs were exceptional in this respect but rather that unthrifty pigs could not be expected to respond efficiently at reduced feed levels.

One example of such abnormality was furnished in experiment C when pigs at the three levels under test failed to gain at a reasonable rate during the first 3 weeks of the experiment. Information from group-feeding experiments had indicated that individual feeding was not an important factor but it served to insure a definite quantity of feed to each pig at each feeding and thus prevented wide variations in feed consumption and rate of growth likely to occur in group feeding.

The pronounced saving in feed effected by restriction of the feed level on the peanut and corn rations and also the small saving on the wheat ration can be explained only by a more efficient utilization of the feed constituents and a decrease in the quantity of fat stored in the body tissues. The data suggest that the initial increases in economy of gains, particularly on the medium level, on the various rations were due to increased efficiency in utilization. Undoubtedly a lower percentage of the nutrients in mixed rations may be assimilated by heavily fed animals than by moderately fed animals. Other workers (*1, 5, 14*) have recognized that plane of nutrition is a factor in the evaluation of the efficiency of utilization.

Because of their high oil content, the peanut rations are particularly susceptible to a relatively low efficiency in digestion and assimilation of the food constituents on a high feeding level. The overtaxing of the digestive and assimilative processes of the body may have been sufficiently relieved by the lowered intake to permit of more efficient utilization. Although a peanut ration has approximately a 50-percent higher caloric value than that of a corn ration, the intake in calories in the five lots in experiments A, B, and C on low and medium levels was below the estimates for a normal intake of a corn ration. This would indicate that more efficient conversion of food constituents into body constituents occurred rather than a difference in the proportions of fat and protein storage.

The building of fatty tissue requires a greater expenditure of food constituents (fat excepted) than the building of lean tissue. The limitation of the peanut rations to approximately a half feed did not materially decrease the storage of fat in the bodies of the hogs analyzed. If the energy required had been the limiting factor the ingested fat would have been used for this purpose and a greatly decreased rate of fat storage should have resulted. Apparently this did not occur, judging by the results given in table 11.

Although the hogs on the reduced feed levels in experiments E and F apparently utilized their feed somewhat more efficiently than those on the high level, much of the saving in feed was made at the expense of the fat storage. From table 15 it can be determined that the hogs on the 2-percent level of experiment E stored approximately 12 pounds less fat than those on the 4-percent level. A similar difference between the lots on the corresponding feed levels is indicated in experiment F. The longer period of growth on the reduced feed levels, with the consequent greater quantity of feed used for maintenance, makes difficult even an approximation of the saving in feed due to decreased fat storage and to greater efficiency in utilization. The feed expended for maintenance by the lot of hogs on the 2-percent level in experiment F due to their slow rate of growth (table 9) undoubtedly dissipated much of the possible saving of feed otherwise effected by decrease in fat storage and by other increases in efficiency of utilization.

Recent experimental work on paired feeding has shown the importance of controlled feeding. The present work has gone one step beyond the paired method in that different levels of feeding have been employed. The hogs within a given group were usually fed the same daily allowance. In experiments E and F this allowance was based on a certain percentage of the weights of the hogs, namely 4, 3, and 2 percent. The high level represented a full feed in the usual case. This method furnished a convenient way for describing the exact allowance to be used. If differences in feed allowance result in marked differences in the relationship between feed consumption and gain in weight, as occurred in these experiments, then comparisons of feeds and of rations need to be made at definite and stated levels of feed intake.

Thus one ration may be markedly superior to others but may not show its value because it is consumed in larger quantities with consequent decrease in efficiency of utilization. It must not be overlooked that in many experiments reported in the literature the hogs have actually made improved rates of gain along with increased savings in feed requirements per unit gain when an improvement in the palatability of the ration has resulted in increased consumption. Frequently this improvement has been brought about by incorporation of a supplement supplying a certain substance or group of substances lacking in the ration in question. Improvement in the health and vigor of the animal brings with it increased appetite. The wide variation among growing animals of a given species, even though of the same age and sex and under the same environment, in their ability to consume feed and to convert feed into body constituents, has been a primary factor contributing toward the observed differences in the feed lot.

It must be recognized that the restriction of the feed allowance in the present experiments is not entirely comparable to the self-imposed restriction of one self-fed hog of small appetite, as compared with the greater consumption by a second hog similarly fed but with a better appetite and greater ability to assimilate the feed constituents. The combination of factors responsible for the association of increased efficiency of feed utilization and increased rate of growth in the latter case of unrestricted feeding may be different and less involved than the combination of factors in the limitation of the daily feed allowance. One distinction, at least, concerns the individual ability of the animals regardless of the quantity of feed consumed as contrasted with the general relationship between quantity of feed and efficiency of assimilation.

The effect of restriction of feed on the decreased proportion of fat in the carcass observed in experiments E and F is an important factor in the field of meat production. Present-day demands of the meat-consuming public are for lean cuts rather than for fat cuts. Because degree of finish or fatness of the hog carcass in the usual case is largely a question of weight, the 175- to 200-pound hog usually sells for a higher price per pound than the 250- to 300-pound hog. The fact that the rate of fattening was checked by limitation of the feed appears worthy of consideration in the development of feeding methods to meet the market demands for meat. Cooking and palatability tests on hams from these lots did not reveal any noteworthy differences. However, the carcasses of the hogs fed corn had a somewhat less desirable degree of firmness in the lot on the low feeding level than in the other lots. The use of wheat apparently eliminated the possible softening effect of the feed level.

The differences observed in the response to reduction in feed level of peanuts, corn, and wheat suggest that the composition of the ration is a factor. The need is at once apparent for an adequate supply of the essential mineral elements, proper proteins, vitamins, and other factors essential to the well-being of the animal. Other properties more particularly concerned with the digestibility of the feed constituents may play a part.

The application of reduced feed levels to practical feed-lot and market conditions remains to be determined. Necessarily, the savings in feed will vary with the kind and choice of feeds in the ration, the thriftiness of the hogs, and how well the feeder can control the feed allowance under group-feeding conditions. It is altogether possible that the increased labor charge and other undesirable factors associated with the lengthened feeding period more than offset the saving in feed shown in the present experiments.

SUMMARY

Restriction of the feed allowance of growing pigs to approximately three fourths and one half of a full feed generally decreased the quantity of feed required to produce a unit of gain.

On peanut rations the best gains were produced on a three-fourths allowance. Although the feed requirements for a unit of gain were the lowest on this level, the differences between these requirements and those on the low level were not significant.

Hogs fed a ration of corn with supplements, at levels of 4, 3, and 2 pounds of feed per 100 pounds of live weight, gained from an initial weight of approximately 65 pounds to 200 pounds at rates of 1.14, 1.03, and 0.77 pounds per day, respectively. However, the feed consumption per unit gain showed a significant decrease with the decrease in feed level, and the group on the high-feed level required 34 percent more feed than the group on the low-feed level.

Results with a wheat ration fed under conditions comparable to those for the above-mentioned corn ration showed average daily gains of 1.26, 0.95, and 0.62 pounds with decrease in feed level. The feed consumption per unit gain was not decreased to the extent of that of the corn ration.

The carcasses of hogs on the most restricted feeding level of corn and of wheat contained a significantly greater proportion of lean meat and yielded a higher percentage of lean cuts. The fat content of the entire body was decreased as a result of the restriction of feed. No marked effect on the fatness of the body resulted from the restriction of the peanut rations to 50 percent of a full feed in the case of pigs fed for gains of from 50 to 60 pounds. Although the restricted feeding apparently resulted in a slight decrease in the firmness of the carcasses in the corn-fed lots, no significant differences in the palatability factors of the cooked meat were found in comparisons of the high and low feeding levels on both the corn and the wheat rations.

These results also indicate the influence of controlled feeding levels in comparative feeding experiments with hogs with respect to the effect of differences in intake of hogs on the efficiency of utilization of the ration.

LITERATURE CITED

(1) Armsby, H. P.
1917. THE NUTRITION OF FARM ANIMALS. 743 pp., illus. New York.

(2) ——— and Moulton, C. R.
1925. THE ANIMAL AS A CONVERTER OF MATTER AND ENERGY. 236 pp., illus. New York.

(3) Benedict, F. G., and Ritzman, E. G.
1923. UNDERNUTRITION IN STEERS. 333 pp., illus. Washington, D.C. (Carnegie Inst. Wash. Pub. 324).

(4) Fisher, R. A.
1930. STATISTICAL METHODS FOR RESEARCH WORKERS. Ed. 3, 283 pp., illus. Edinburgh and London.

(5) Forbes, E. B., Braman, W. W., Kriss, M., and others.
1928. THE ENERGY METABOLISM OF CATTLE IN RELATION TO THE PLANE OF NUTRITION. Jour. Agr. Research 37: 253–300, illus.

(6) Halverson, J. O., Hostetler, E. H., and Sherwood, F. W.
1931. THE VALUE OF PEANUTS FOR GROWING PIGS. N.C. Agr. Expt. Sta. Tech. Bull. 41, 27 pp.

(7) Hankins, O. G., and Ellis, N. R.
1926. SOME RESULTS OF SOFT-PORK INVESTIGATIONS. U. S. Dept. Agr. Bull. 1407, 68 pp., illus.

(8) ——— Ellis, N. R., and Zeller, J. H.
1928. SOME RESULTS OF SOFT-PORK INVESTIGATIONS. II. U. S. Dept. Agr. Bull. 1492, 50 pp., illus.

(9) ——— and Zeller, J. H.
1929. CORRECTING THE INEFFICIENCY OF PEANUTS FOR GROWTH IN PIGS. U. S. Dept. Agr. Tech. Bull. 110, 12 pp., illus.

(10) Henry, W. A., and Morrison, F. B.
1928. FEEDS AND FEEDING. Ed. 19, 770 pp., illus. Ithaca, N.Y.

(11) Jull, M. A., and Titus, H. W.
1928. GROWTH OF CHICKENS IN RELATION TO FEED CONSUMPTION. Jour. Agr. Research 36: 541–550, illus.

(12) Lusk, G.
1928. THE ELEMENTS OF THE SCIENCE OF NUTRITION. Ed. 4, reset, 844 pp., illus. Philadelphia and London.

(13) Mitchell, H. H., and Beadles, J. R.
1930. THE PAIRED-FEEDING METHOD IN NUTRITION EXPERIMENTS AND ITS APPLICATION TO THE PROBLEM OF CYSTINE DEFICIENCIES IN FOOD PROTEINS. Jour. Nutrition 2: 225–243.

(14) ——— and Hamilton, T. S.
1932. THE EFFECT OF THE AMOUNT OF FEED CONSUMED BY CATTLE ON THE UTILIZATION OF ITS ENERGY CONTENT. Jour. Agr. Research 45: 163–191, illus.

(15) Moulton, C. R., Trowbridge, P. F., and Haigh, L. D.
1921. STUDIES IN ANIMAL NUTRITION. I. CHANGES IN FORM AND WEIGHT ON DIFFERENT PLANES OF NUTRITION. Mo. Agr. Expt. Sta. Research Bull. 43, 111 pp., illus.

(16) ——— Trowbridge, P. F., and Haigh, L. D.
1922. STUDIES IN ANIMAL NUTRITION. II. CHANGES IN PROPORTIONS OF CARCASS AND OFFAL ON DIFFERENT PLANES OF NUTRITION. Mo. Agr. Expt. Sta. Research Bull. 54, 76 pp., illus.

(17) ——— Trowbridge, P. F., and Haigh, L. D.
1922. STUDIES IN ANIMAL NUTRITION. III. CHANGES IN CHEMICAL COMPOSITION ON DIFFERENT PLANES OF NUTRITION. Mo. Agr. Expt. Sta. Research Bull. 55, [88] pp., illus.

(18) Robison, W. L.
1920. THE USE OF FORAGE CROPS IN THE FATTENING OF PIGS. Ohio Agr. Expt. Sta. Bull. 343: 169–222, illus.

(19) Swanson, C. O.
1921. EFFECT OF RATION ON THE DEVELOPMENT OF PIGS. Jour. Agr. Research 21: 279–341, illus.

(20) Washburn, R. M., and Jones, C. H.
1916. STUDIES OF THE VALUES OF DIFFERENT GRADES OF MILK IN INFANT FEEDING. Vt. Agr. Expt. Sta. Bull. 195, [144] pp., illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Assistant Secretary	REXFORD G. TUGWELL.
Director of Scientific Work	A. F. WOODS.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	SETH THOMAS.
Agricultural Adjustment Administration	CHESTER C. DAVIS, *Administrator.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	JAY N. DARLING, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	KNOWLES A. RYERSON, *Chief.*
Bureau of Plant Quarantine	A. S. HOYT, *Acting Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Weather Bureau	WILLIS R. GREGG, *Chief.*

This bulletin is a contribution from

Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Animal Husbandry Division	E. W. SHEETS, *Chief.*

U.S. GOVERNMENT PRINTING OFFICE 1934

For sale by the Superintendent of Documents, Washington, D.C. - - - - - - - - Price 5 cents

END