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THE RELATION BETWEEN CHEMICAL COMPOSITION OF A RATION AND ITS FEEDING VALUE FOR BACON HOGS

by

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A THESIS

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The Relation Between Chemical Composition of a Ration and its Feeding Value for Bacon Hogs.

Abstract

This paper reports a study of the relation between the daily gain of bacon hogs from weaning to market weight, and the individual feed fractions of the standard chemical analysis (protein, ether extract, ash, crude fibre, and nitrogen-free extract) as compared to the fractions of the modified scheme proposed by Crampton and Maynard (protein, ether extract, ash, cellulose, lignin, and other carbohydrates).

The data was analyzed statistically by two methods, (1) partial regressions using the error variance, and (2) partial correlations using the between-lot variance.

The method of partial regression was found to be unsatisfactory for this type of data.

Partial correlations were calculated between gain and percent of the feed fractions, independent of level of food intake. Negative correlations existed with ether extract, ash, cellulose, and lignin, and positive correlations with protein, nitrogen-free extract and other carbohydrates.

INTRODUCTION

In view of the major importance of pasture lands in the Province of Quebec, Macdonald College has for the past ten years carried out a great deal of investigational work in connection with pasture improvement. Concurrent with this research in pasture improvement, the Department of Animal Nutrition has made a special study of variations in the nutritive value of pasture herbage.

The work had not progressed far when it was realized that the standard method of chemical analysis (i.e. protein, fat, ash, crude fibre, and nitrogen-free extract) was no guide to the nutritive value of forage grasses. Crampton and Finlayson (1935), working with young growing rabbits, noted a marked increase in their growth rate when fed fertilized as compared to unfertilized herbage. This improvement in nutritive value, they concluded, could not be satisfactorily accounted for on the basis of the higher protein level of the fertilized herbage alone. Cameron (1936) reports intra-seasonal changes in the nutritive value of pasture herbage when fed to growing rabbits; but again in this study, the standard chemical analyses bore no relationship to the gains observed.

Crampton and Forshaw (1940) made a study of the nutritive value of pasture grasses, using two systems of analyses, the standard method mentioned above and the modified scheme of analysis proposed by Crampton and Maynard (1938), which divides the carbohydrates into three fractions instead of just two, i.e., cellulose, lignin, and other carbohydrates versus crude fibre and nitrogen-free extract. Their results showed a definite negative correlation between live weight gain of rabbits and percent of lignin in the grasses fed.

All of this work, carried out at Macdonald College with forage grasses, has shown that the standard method of analysis does not afford a very precise index to the nutritive value of pasture herbage, and that the modified method is a definite improvement in predicting growth rates with this type of feed. With such results at hand, it was felt that this study of the two methods of analysis could, quite profitably, be extended to include concentrate feeds corresponding to those found in a typical swine ration. This thesis reports a study of the relation between the chemical composition of a ration and its feeding value for bacon hogs.

REVIEW OF LITERATURE

A review of the literature reveals that it is full of reports on differences in chemical composition of feeds of various types, For example, Morrison (1936) lists 25 analyses under the heading of alfalfa alone, which are gathered from a total of 2,422 samples. Somewhat fewer digestibility trials have been carried out on such feeds, but even here the numbers are relatively great. Some workers even record live weight gains without a knowledge of the quantity or quality of feed ingested. All in all, very little work has been reported which attempts to determine the effects of changes in chemical composition on nutritive value as measured by some physiological activity such as milk production, wool growth, or live weight gains.

The first report of importance on this subject was published in 1912 by Hall and Russell. They observed that the feeding value of pasture grass is determined in part by floral type and habit of growth. Habit of growth is governed essentially by soil fertility, and floral type by climatic factors. These workers found a leafy habit of growth in the fatting fields and a stemmy habit in the poorer fields. They also noted that, although the difference in feeding value was great, the differences revealed by the ordinary methods of chemical analysis was very small. They conclude that the ordinary methods are clearly inadequate for dealing with pasture grasses.

Fagan and Jones (1923) state that a determination of the chemical composition is but a small contribution to a knowledge of the nutritive value of grasses as pasture or hay. They observed that the leaf portion is distinctly richer than the stem, and that a knowledge of the proportion of leaf to stem would be a fair guide to the nutritive value of a pasture at any period of the year.

That quality of protein may be a factor in the nutritive value of pasture grass is reported by Crampton (1934), who found that by adding casein to a grass diet, the growth rate of rabbits was increased. However, later work by Crampton and Forshaw (1940) gave evidence that protein was not a limiting factor for growth, but rather that increases in protein probably represent merely increases in available energy. They also observed that herbage from different species of plants has an intrinsic nutritive value characteristic for each species. They found that the protein content of pasture grasses is highly correlated with gain in weight of animal.

Woodman, Norman, and French (1931) observed that not only does maturity or drought produce a lowering of protein, but the digestibility of protein is lowered likewise. Nutritive value and digestibility of the grasses were inversely related to the degree of lignification.

In feeding hay and mangels to steers, Watson et al. (1938) found that the level of the plane of nutrition had no significant effect on the digestibility coefficients of the different nutrients, although at a maxium level the digestibility of the protein was probably slightly depressed. In a later paper (1939) these same workers observed that when hay and corn silage were fed, differences in the digestibility of the protein at different planes of nutrition was not statistically significant.

Hayward, Steenbock, and Bohstedt (1936) observed that heating soybean meal to 150°C. for 2.5 minutes practically doubled the nutritive value of the protein. In this case they found that apparently the heating caused the cystine fraction of the protein to become available.

Morris, Wright, and Fowler (1936) report that blood meal proteins prepared by a high-temperature process have a lower nutritive value than those of blood meal prepared by a low-temperature process. They observed that the proteins of spring grass are markedly superior to those of autumn grass as regards their nutritive value for milk production. No significant differences were found between the nutritive values of the proteins of three types of grass silage.

Isaachsen, Ulvesli, and Husby (1935) report considerable differences between digestibility of protein in grass, hay, and straw as determined "in vitro" and "in vivo" with wethers. The higher the protein content, the closer were the two sets of results; and for protein feed of animal origin, the agreement was good.

Horwitt, Cowgill, and Mendel (1936), after a study of the known in vitro digestion techniques, failed to find a practical method that might be used to determine the utilizable nitrogen in the green leaf.

Wright (1938) found that when pigs were fed cafeteria style they consumed more tankage when fed light weight barley (27-29 lbs. per bus.) than when fed heavy weight barley (47-49 lbs. per bus.), even though the light barley had a higher percent of protein than the heavy. This would suggest that the protein of the low quality barley was very poorly utilized.

Adolph and Wu (1934) observed no effect on digestibility of food protein when cellulose (filter-paper) was fed to rats, showing that added fibre has no effect on digestibility.

Woodman, Evans, and Norman (1934) state that alfalfa resembles grass in displaying its highest digestibility at the earliest stage of growth, the main distinction between the two being the readiness with which the young alfalfa plant produces fibre, and the early stage of growth at which the fibre begins to display signs of lignification and diminished digestibility. Alfalfa in bud and in flower is comparable in nutritive properties to a superior coarse fodder rather than to the pasture cuts, the dry matter of which has the character of a concentrate. However, Woodman and Oosthuizen (1934) found that stage of growth is not the sole factor that determines composition and digestibility of pasture herbage; meteorological conditions, particularly in relation to their effect on the rate of growth must also be taken into account. They found that, if the growth rate has been checked by cold and frost, the digestibility and feeding value are lowered, despite the fact that the grasses have not progressed further than the leafy stage.

Woodman, Norman, and French (1931), working in England, report that, under a system of 1-, 2-, or 3-weekly cuts, pasture grass never reaches the stage of growth at which lignification sets in with consequent decline in the digestibility of not only the fibrous constituent, but also of the other organic ingredients. On the other hand, Crampton and Forshaw (1939) observed that marked differences in nutritive value may exist between herbage representing only ten days growth. No doubt, climatic factors produced this condition, in part at least, as it is mentioned that the herbage in certain clippings, even though only of ten days growth, was rapidly approaching maturity.

Enzymatic methods for determining nutritive value are theoretically more sound than straight chemical analysis, and several have been suggested, (Coleman '23; Woodman and Stewart '32; Williams and Olmstead '35; Horwitt, Cowgill, and Mendel '36a; Davis and Miller '39; and Olson and Palmer '40). However, the procedures are long and tedious, requiring one to two weeks or more for one analysis.

A true determination of the nutritive value of any feed or ration is no more accurate than the reliability of the methods of chemical analysis. Such is the situation with crude fibre. Norman (1935) states that, while crude fibre obtained by the Weende method may be taken as an indication of the amount of "bulk" or "roughage" in the material, it does not bear any relationship to any particular plant constituent or group of constituents; nor does crude fibre have a constant chemical composition. This fact, according to Williams and Olmstead (1935), was known even to the original investigators, Henneburg and Stohmann, and many reports since have shown this to be true.

Although the feed fraction termed "crude Fibre" is theoretically indigestible, Woodman, Blunt, and Stewart (1926) and (1927) have found that when pasture grass is fed to sheep the crude fibre is 80% digestible. On the other hand Mitchell and Hamilton (1933) claim that the crude fibre of oat hulls and of alfalfa meal, as well as pure cellulose, pass through the digestive tract of the pig almost, if not entirely, untouched by bacteria or other agencies of digestion.

Mangold (1934) states that in the pig, wide variations are found in the digestibility of fibre. The reason for these

Horwitt, Cowgill, and Mendel (1936a) state that progress in the chemistry of carbohydrates of feeds has advanced slowly, not for lack of efforts in this field, but rather because of the absence of relatively simple methods. Many investigators have carefully fractionated the carbohydrate portion of a few feeds into the various components, but each such attempt has constituted a complex problem in itself, and the technique used has been too involved to find favour in routine analyses of feeds. They state that enzymatic determination of crude fibre gives results three times as great as the official A.O.A.C. method.

There seems to be no doubt that the only reliable technique for evaluating the nutritive quality of a feed or ration is by a feeding test. Unfortunately, feeding trials are slow, requiring much labour and expensive equipment, and a very large sample for the trial, which seriously limits its usefulness. In an attempt at using the rabbit as a "pilot animal" for digestibility trials with steers, Crampton, Campbell, and Lange (1940) found that the digestibility of the carbohydrate fractions, isolated by the present feeding stuffs analysis, does not appear to be predictable for one species from the behaviour of the other. Since the rabbits and steers do react comparably with respect to gains in body weight, when fed spring grown as compared to mid-summer grown herbage, they conclude that a scheme of chemical analysis that isolated fractions of the carbohydrates which are more nearly biological units, would facilitate the usefulness of the rabbit as a "pilot animal". As proof of this theory, they point out that there are high correlations between the two species in the case of crude protein and lignin.

Manyard (1940) presents data to show that when rabbits, guinea pigs, and lambs were fed the same ration, the digestibility of cellulose and lignin was as follows:

	Digestibility	
	Cellulose	Lignin
Rabbit	28%	00%
Guinea Pig	41%	5%
Lamb	58%	28%

That lignin is absorbed from the alimentary canal in part, at least, is considered to be a fact by most workers. The process by which this is accomplished is not agreed upon by all. Cosonka, Phillips, and Jones (1929), and Phillips (1934) state that lignin is broken down in the stomach by an enzyme, probably in the gastric juice. Maynard (1937) points out that lignin is not attacked by bacteria, and in (1940) that there are no enzymes secreted by mammalian tissues that will digest lignin. Probably its solution is accomplished by the alkaline medium of the rumen or large intestines.

Woodman and Stewart (1932) observed that it is not necessarily the amount of ligno-cellulose which determines the running off in digestibility, but rather the intimacy of its association with the cellulose of the cell walls. In an experiment on sheep, they found that 19 gms. of ligno-cellulose in every 100 gms. of food-fibre rendered unavailable to the animal 39.7 gms. of digestible cellulose, each gram of which is equal to one gram of digestible starch for production in the ruminant. Also Maynard (1937) observed that a slight increase in lignin content may be responsible for a large decrease in nutritive value. Since lignin is apparently unattacked by alimentary bacteria, the higher its proportion in crude fibre, the lower the digestibility of this fraction. The diminution of cellulose breakdown in turn hinders the action of the digestive enzymes on the starch, protein, and fat contained in the plant cell.

Campbell and Booth (1930) and(1930a) report that when wood is oven-dried there is an increase of lignin and a slight amount of hydrolysis of the carbohydrate components. When wood is air-dried, lignin is enhanced at the expense of the furfuraldehyde yielding complexes, and cellulose is enhanced at the expense of the water soluble material of the green wood. Whether the drying of forage grasses under similar conditions would have similar effects is problematical.

Prjanischnikow and Tomme (1936) treated rye straw with chlorine dioxide (ClO_2) and got a marked increase in the digestibility of fibre and pentosans in rabbits, which was attributed to a definite lowering of its lignin content by the treatment.

In determining lignin in plant materials containing considerable amounts of protein, it has been found that the isolated lignin residue contains some nitrogen. Several workers calculated the crude protein in the sample (N x 6.25) and subtracted it from the lignin, thus assuming that all the nitrogen is present as protein. Norman and Jenkins (1934) believe that this correction is useless and likely to introduce in some cases an error greater than that caused by the presence of nitrogenous material.

In the method of Crampton and Maynard (1938), a pre-treatment with pepsin-HCl is used which removes, according to Crampton and Campbell (1938) 94.4% of the protein of forage grasses.

Many workers have criticized the use of nitrogen-free extract, chiefly because it does not represent a single constituent, but a residuum of numerous undetermined substances of variable nutritive value, the calculation of which by difference is rendered faulty because of the errors involved in the methods for determining the protein, fat, fibre, and ash. For instance, protein is generally calculated by multiplying the total nitrogen content by the factor 6.25, which assumes that the nitrogen makes up

16% of the protein and that all of the nitrogen is in the form of protein. Both assumptions are known to be erroneous, and in order to partially eliminate this error, Jones (1931) has presented a list of feeds with a factor for each, to be used in place of the 6.25. Just as crude fibre was considered to be indigestible, so the nitrogen-free extract was originally assumed to be completely digestible, but now it is known to contain, besides starch, such substances of low digestibility as hemicellulose, lignin, pectin, and inulin.

Maynard (1940) reports an experiment in which a fishmeal fed in a digestion trial was found to contain 0.9% nitrogen-free extract. This figure was not surprising, considering that it is determined by difference. But, when the feces obtained from the feeding of a given quantity of fishmeal was analyzed, the output was found to contain ten times as much nitrogen-free extract as was consumed. The author concludes that, although it is chemically correct by the difference method, it is physiologically impossible. For the sake of comparison, it might be noted that analytical work performed in connection with this thesis showed that the fishmeal used had 1.3% nitrogen-free extract.

Ether extract, commonly termed "crude fat", may include many substances other than true fats. Horwitt et al. (1936a) observed that in some green leaves the pigments alone may account for as much as 50% of the ether extract. This method of Horwitt's for the determination of true fats has been applied to digestibility trials at Macdonald College with interesting results. Lessard (1941) reports the following data:

	Ether Extract		Fatty Acids	
	% Comp.	App. Dig.	% Comp.	App. Dig.
Soybeans	23.19%	98.9%	16.65%	99.1%
Grass	3.78	54.	.938	62.

From the above data it may be seen that the ether extract of soybeans is practically as digestible as the fatty acids fraction, whereas in the case of grass there is a definite difference in favour of the fatty acids.

Watson et al. (1939) observed that when hay and corn silage were fed to steers, increasing the plane of nutrition had no statistically significant effect on the digestibility of the ether extract.

SOURCE OF DATA

The data used in this study were obtained from a feeding experiment carried on in the Department of Animal Nutrition at Macdonald College, the outline of which is given below:

Animals -- Sixty purebred Yorkshire pigs were put on test at an average age of 70 days and weighing at that time not less than 35 lbs. each. These pigs were all sired by the same boar and out of dams that are closely related, all of them being either full or half sisters.

Allotment -- The pigs were allotted at random to six groups of ten pigs each with the restriction that the sexes were equally divided within each group. All pigs were housed indoors in individual pens during the trial.

Feeding Periods -- A growing ration was fed from the start of the test until a weight of 100 to 110 lbs. was reached by the pigs, afterwhich a fattening ration was used. This is the practice followed in the Feeding Stations for the Advanced Registry of Swine.

Rations -- The rations consisted of (1) a mixed protein-mineral supplement and (2) a basal ration. The supplement was of the same composition for all lots and constituted 15% by weight of the growing rations and 10% of the fattening rations.

The supplement consisted of the following:

50% Tankage

20% Linseed Oilmeal

15% Fishmeal (non-oily)

5% Fine Salt (iodized 1.6 oz. per 100 lbs.)

5% Ground Limestone

5% Feeding Bonemeal

The basal feeds for the six groups are described in Table I.

Feeding Practice -- All pigs were individually fed. During the growing period they were fed three times per day, and thereafter twice daily. At each feeding, the dry meal allowance was measured into the feed trough and about three pounds of water poured over it. The pigs were fed as much as they would readily consume. During the growing period, all pigs received 15 cc of "Alphadol" cod liver oil daily. This oil carried a guaranteed potency of 1800 I.U. of vitamin A and 400 I.U. of vitamin D.

Data recorded -- Records were kept for each pig, of feed consumed and live weight gains. The design of the experiment and individual records made possible an analysis of variance for each item listed in Table III, into the fractions indicated in Table II. The data for the third pig in Lot I (*) was deleted from the

Table I -- Description of Feeds in Basal Ration

Lot	Grain	Description as to Quality
I	No.1 Feed Barley	A typical sample of this grade as shipped from terminal elevator.
II	No.3 Feed Barley	A sample carrying the usual quantities of dockage, and with the barley itself of light weight per bushel.
III	No.1 Feed Barley + Dockage.	A quantity of the No.1 Feed Barley used in Lot I was recleaned to obtain a pure barley of standard weight per bushel. To this was added the amounts of wild oats (17%) and Weed Seeds (3%) found in No.3 Feed Barley. Thus the mixtures in Lots II and III differed only as to the quality of barley.
IV	No.2 C.W.Amber Durum Wheat	Typical sample.
V	Feed Wheat	Typical sample as sold from terminal elevators to grain trade.
VI	No.1 Recleaned Wheat Screenings	Typical sample, largely broken wheat kernels and wild buckwheat.

able II -- Analysis of Variance - Daily Gain to Market Weight

	Sex	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI	
	M	1.99	1.60	1.73	1.87	1.77	2.01	
	A	1.76	1.80	1.67	1.95	2.04	1.85	
	L	*1.73	1.87	1.45	1.79	1.68	1.76	
	E	1.59	1.83	1.65	2.01	1.73	1.86	
		1.76	1.67	1.83	1.83	1.55	1.88	
		8.83	8.37	8.33	9.45	8.77	9.38	
	F	1.61	1.49	1.55	1.79	1.85	1.57	
	E	1.63	1.75	1.76	1.79	1.69	1.90	
	M	1.75	1.29	1.86	1.71	1.68	1.81	
	A	1.66	1.07	1.68	1.68	1.81	1.71	
	L	1.91	1.66	1.37	1.79	1.70	1.65	
	E	8.56	7.26	8.22	8.76	8.73	8.64	
Σx		17.39	15.63	16.55	18.21	17.50	18.02	103.30
$\bar{x}$								1.72

Source of Variation	D/F	Mean Square (σ^2)	S.Dev. σ	F-values Obs.	F-values Nec.
Between 12 Sub-groups	11	.06			
Between 6 lots	5	.09		4.06	2.41
Between 2 sexes	1	.15		6.30	4.04
Interaction Sex x Lot	5	.02		--	2.41
Calculated value	1				
Remainder (Error)	47	.023	.152		
Total	59				

ecessary Difference between Lots $\frac{.152}{\sqrt{10}} \times \sqrt{2} \times 2.008 = .137$ lbs.

CHEMICAL ANALYSES

The chemical analysis of the rations is given in Table IV and V. The two schemes of analysis are presented in the table, (1) the standard analysis, comprising moisture, crude protein, ether extract, ash, crude fibre, and nitrogen-free extract, and (2) a modified scheme proposed by Crampton and Maynard (1938), consisting of moisture, crude protein, ether extract, ash, cellulose, lignin, and other carbohydrates. The "nitrogen-free extract" and the "other carbohydrates" are the residual fractions of the total feed, in their respective systems of analysis; that is, they are calculated by subtracting the other fractions from 100.

Chemical Procedures:

Moisture, ether extract, ash, and crude fibre were determined by the official A.O.A.C. methods.

For crude protein, the official A.O.A.C. method was used, except that 200 cc. (approx.) of 4% boric acid was used in the receiver when distilling instead of a standard hydrochloric acid solution. The indicator used was made up as follows: 100 mgms. of methyl red and 30 mgms. of methylene blue dissolved in 60 cc. of 95% ethanol, then made up to 100 cc. with distilled water. A .02/N sulphuric acid solution was used for titrating. The calculations are as follows:

$$\% \text{ crude protein} = \frac{\text{cc.acid x normality x 14 x 6.25}}{\text{wt. of sample}}$$

Cellulose was determined by the Crampton and Maynard (1938) method, except that a Gooch crucible was used for filtering instead of an alundum crucible, and a small quantity of acid-treated Gooch asbestos was mixed with the material to aid in filtering.

The procedure used for lignin was fundamentally the same as proposed by Crampton and Maynard (1938). However, slight modifications have been added from time to time, (Crampton and Campbell '38; and Crampton, Campbell, and Lange '39) such that, it seemed in order, to compile these modifications and rewrite the procedure for future reference. The procedure is as follows: Dry a 1 gram sample and extract with an ethanol-benzene solution (1:2). Transfer the dry sample to a 50 cc. Erlenmeyer flask. Moisten the material with water, stopper with a cotton plug and autoclave for 15 minutes at 15 lbs. pressure. Linseed meal, apparently because of its mucinous nature, persisted in boiling over when in the autoclave. This was avoided by autoclaving it, in a 250 cc. beaker covered with a watch-glass. Crampton and Campbell (1938) found that when grass samples were autoclaved some of the protein was rendered insoluble, and not removed by treatment with pepsin-HCl. In the case of cereal grains in this investigation, the starch was not completely dissolved by the acid unless the sample was autoclaved first.

Add 40 cc. of pepsin-HCl solution (0.2% pepsin in N/10 HCl), stopper and digest for 12 hours at 40°C., shaking hourly for the first four or five hours. Thoroughly mix a small quantity of acid-treated Gooch asbestos with the material in the Erlenmeyer flask, and place a small quantity of pre-ashed diatamaceous earth on an acid-hardened filter paper in a Buchner funnel, and wash around to form a thin layer. Filter the material with suction. Wash successively with 100 cc. portions of hot water, hot ethanol, hot benzene, hot ethanol, and ether. Transfer the dried residue to a 100 cc. beaker (the material is easily removed from the filter paper with a metal spatula, as the thin layer of diatamaceous earth prevents the sample from sticking to the filter paper) . Moisten this material with 6 cc. of 40% formaldehyde. Then add 6.cc. of 72% sulphuric acid, and allow it to penetrate the sample by slowly mixing with a stirring-rod. Add 9cc. of concentrated sulphuric acid, and stir vigorously to aid in solution of the sample. Do not let the temperature rise above 70°C. However, it was found desirable not to let the temperature get much below 70°C. For some feeds it was necessary to rewarm the mixture before solution of the sample could be accomplished. Because of the addition of asbestos and diatamaceous earth to the sample, it was found necessary to add slightly larger quantities of sulphuric acid and formaldehyde than recommended by Crampton and Maynard (1938).

When dissolved, stir in 35 cc. of a chloroform-glacial acetic acid granulating mixture (1:6 by volume). Then wash the mixture into an 800 cc. beaker and dilute with 500 cc. of distilled water. Boil gently until the chloroform has been driven off, or till the surface scum breaks. Filter on a Gooch with suction. Wash in not less than 200 cc. of 5% HCl. Dry at 110°C. and determine lignin by the loss on ignition.

Table IV -- Chemical Analysis of Growing Ration (Air-Dry Basis)
(Weaning to 110 Lbs.)

Lot	Moist-ure	Crude Protein	Ether Extract	Crude Fibre	Ash	*N-Free Extract	Lignin	Cell-ulose	**Other Carbo.
	%	%	%	%	%	%	%	%	%
I	11.86	17.21	1.97	4.99	6.26	57.71	2.82	4.87	54.98
II	11.42	17.40	2.41	5.60	6.35	56.82	2.93	5.22	54.24
III	11.47	16.26	2.82	6.57	6.57	56.31	3.26	5.94	53.65
IV	11.00	20.56	1.46	2.67	5.69	58.62	1.00	2.39	57.88
V	11.47	20.28	2.68	5.55	5.82	54.20	3.53	4.62	51.58
VI	11.57	18.76	3.18	4.97	5.85	55.67	4.95	4.10	51.57

* Nitrogen-free extract = 100-(moisture+protein(Nx6.25)+ether extract+ash+crude fibre).

** Other carbohydrates = 100-(moisture+protein(Nx6.25)+ether extract+ash+cellulose+lignin).

Table V -- Chemical Analysis of Fattening Ration (Air-Dry Basis)
(110 lbs. to Market Weight of 200 lbs.)

Lot	Moist-ure	Crude Protein	Ether Extract	Crude Fibre	Ash	*N-Free Extract	Lignin	Cell-ulose	**Other Carbo.
	%	%	%	%	%	%	%	%	%
I	12.05	15.43	1.78	5.15	5.01	60.58	2.87	5.04	57.82
II	11.58	15.64	2.24	5.79	5.10	59.65	2.99	5.42	57.03
III	11.85	14.43	2.47	6.82	5.34	59.09	3.33	6.17	56.40
IV	11.13	18.98	1.24	2.70	4.40	61.55	0.94	2.41	60.89
V	11.64	18.68	2.53	5.74	4.54	56.87	3.62	4.77	54.22
VI	11.74	17.07	3.06	5.13	4.57	58.43	5.12	4.23	54.20

* Nitrogen-free extract = 100-(moisture+protein(Nx6.25)+ether extract+ash+crude fibre).

**Other carbohydrates = 100-(moisture+protein(Nx6.25)+ether extract+ash+cellulose+lignin).

STATISTICAL ANALYSIS OF THE DATA

Two systems of statistical analysis were applied in this investigation, (1) Standard partial regressions as described by Snedecor (1937). These coefficients were calculated for the daily intake of each of the feed fractions on the daily gain in order to evaluate the relative weight of each of the feed fractions in causing daily gains. (2) Partial correlations (Snedecor '37). These were calculated between gains and the several feed fractions.

RESULTS AND DISCUSSION

The individual data for feed intake and gains by the pigs are given in Appendix Tables I to X. From this data, the means and standard deviations were calculated (Table III). As might be expected, the coefficients of variability for daily feed intake and for each of the eight feed fractions were almost identical (6%).

Partial Regression:

In computing the standard partial regressions of the daily intake of each feed fraction on daily gain, the error variance was used as a means of evaluating individual pigs after removal of sex differences and differences in chemical make-up of the rations. The simple correlation coefficients obtained are shown in Table VI. As in the case of the coefficients of variability, the relationship existing between the feed fractions is again evident. The simple correlation coefficients of daily gain with daily feed intake and with daily intake of each feed fraction all approximate +.4000; while the correlations of the daily consumption of one feed fraction and another give coefficients very close to perfect.

Multiple correlations were calculated for the two systems of analysis (Table VII).

Table VI -- Simple Correlation Coefficients*

	Protein	Fat	Ash	Fibre	N.F.E.	Cellulose	Lignin	Other Carbo.
Gain	.3879	.4006	.4233	.4062	.3970	.4117	.3868	.3954
Protein		.9785	.9789	.9723	.9899	.9664	.9672	.9893
Fat			.9753	.9897	.9775	.9821	.9936	.9755
Ash				.9754	.9799	.9787	.9571	.9795
Fibre					.9851			
N.F.E.								
Cellulose							.9740	.9843
Lignin								.9673

* All correlations are positive.

Table VII. Multiple Correlations.

Method of Analysis	R*	R^2
Standard Analysis	.4432	.1964
Modified Scheme**	.4439	.1970

* To be significant at P.05, R = .509
**Crampton and Maynard (1938).

The multiple correlations in neither case were significant. The values of R^2 indicate that only about 20% of the variability found between the gains of pigs after sex and lot differences are removed can be traced to differences in daily intake of the feed fractions.

From the simple correlations, the beta (β) values and partial regression coefficients were calculated as shown in Tables VIII and IX. Since the rations were considered to be nutritionally satisfactory, it is doubtful that any one feed fraction would be a limiting factor for growth. Such a condition, however, if present, would no doubt enhance the value of the limiting fraction. When due account is taken of the fact that the rations were nutritionally balanced, it is impossible to justify such values as are found in the column headed "Relative Weight." Although it is quite feasible that protein should account for 35% of the 20% variation in gains (Table VIII), it is not reasonable that ash, an inert material, should account

Table VIII -- Standard Partial and Net Partial Regression Coefficients (Standard Method of Chemical Analysis)

Feed Fraction	Standard Partial Reg. Coeff. (beta-value)	Relative Weight %	Net Partial Reg. Coeff. (b - value)
Protein	.6465	35	1.6803
Ash	.9845	53	8.2420
Ether Extract	.0351	2	.6504
Crude Fibre	.1477	8	1.1386
Nitrogen-Free Extract	.0390	2	.0296

Table IX -- Standard Partial and Net Partial Regression Coefficients (Modified Scheme - Crampton and Maynard '38)

Feed Fraction	Standard Partial Reg. Coeff. (beta-value)	Relative Weight %	Net Partial Reg. Coeff. (b-value)
Protein	.6316	27	1.6416
Ash	.8971	39	7.5103
Ether Extract	.3657	16	6.7761
Cellulose	.0922	4	.7916
Lignin	.2801	12	3.7338
Other Carbohydrates	.0351	2	.0277

for 53% of the variability. Since similar relationships exist in both systems of analysis, it may be concluded that, although such beta-values are statistically correct, they are physiologically impossible, and that the method of partial regressions is unsatisfactory for this type of data.

The reason for the incongruous nature of the results probably lies in the fact that the various feed fractions are not independent of each other, since each fraction is a definite portion of the total daily feed consumption.

Partial Correlations:

The partial correlations were derived from simple correlations calculated between percentage composition of the rations, daily gain, and daily feed intake. A simple correlation between two variables measures the total extent to which one responds to a known change in the other; but in this investigation, there was also a third variable, level of feed intake, to be considered. Hence it would not be correct to base conclusions on the separate simple correlation coefficients, calculated independently. In order to ascertain the effect of each feed fraction on daily gain, independent of daily feed intake, partial correlations (Snedecor '37) were computed. Since percentage composition was to be studied, the between-lot variance was used rather than the between-pig (error) variance.

The simple and partial correlations are shown

Table X -- Simple and Partial Correlations using Between Lot Variance

	Simple Correlations		Partial Correlations -Intake held constant*
	Daily Feed Intake	Daily Gain	
Protein	+.5184	+.8233	+.8194
Ether Extract	+.1519	-.0669	-.3450
Ash	+.0152	-.4432	-.8083
Fibre	-.1806	-.5708	-.7602
N.F.E.	+.7430	+.6752	+.1632
Cellulose	-.2312	-.6731	-.8788
Lignin	+.3248	+.0068	-.4901
Other Carbo.	+.4985	+.6019	+.3890
Gain	+.8258		

*Necessary Partial Correlation to be significant P = .05 is .878.

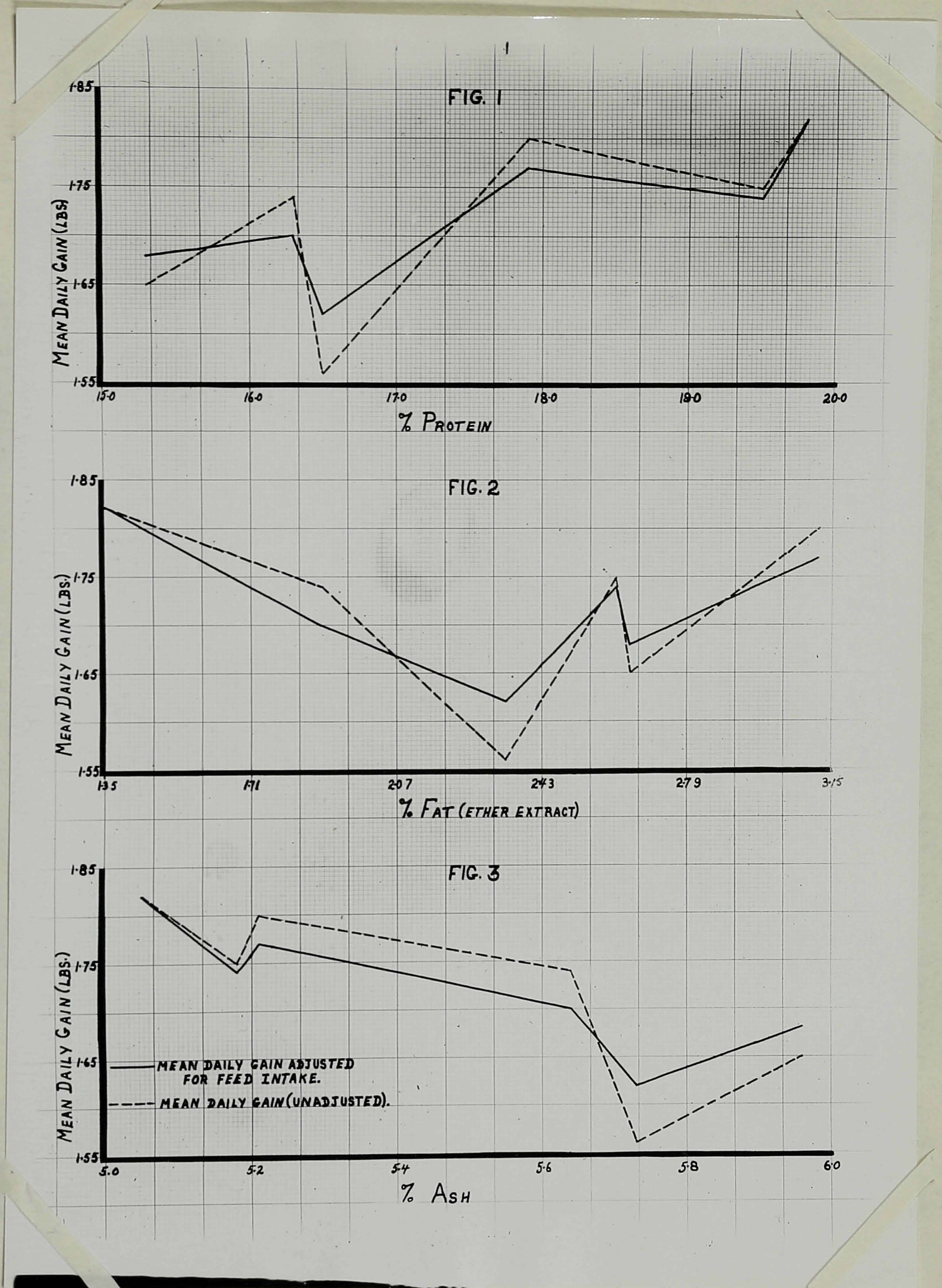
in Table X. Correlations of daily gain and percentage composition of the rations are plotted graphically in Figures 1 to 8. The mean daily gain for each lot and the mean daily gain, adjusted by simple regression, for feed intake is shown in Table XI. The percent of the feed fraction, shown in each curve, is the mean of the two analyses in Tables II and III. The curve of the non-adjusted gains is comparable to the simple correlation in Table X, and the curve of the adjusted gains is comparable to the partial correlation.

Table XI. Mean Daily Gains and Gains Adjusted for Feed Intake for the Six Lots

Lot	I lbs.	II lbs.	III lbs.	IV lbs.	V lbs.	VI lbs.
Mean Daily Gain	1.74	1.56	1.65	1.82	1.75	1.80
Mean Gain Adjusted for Feed Intake	1.70	1.62	1.68	1.82	1.74	1.77

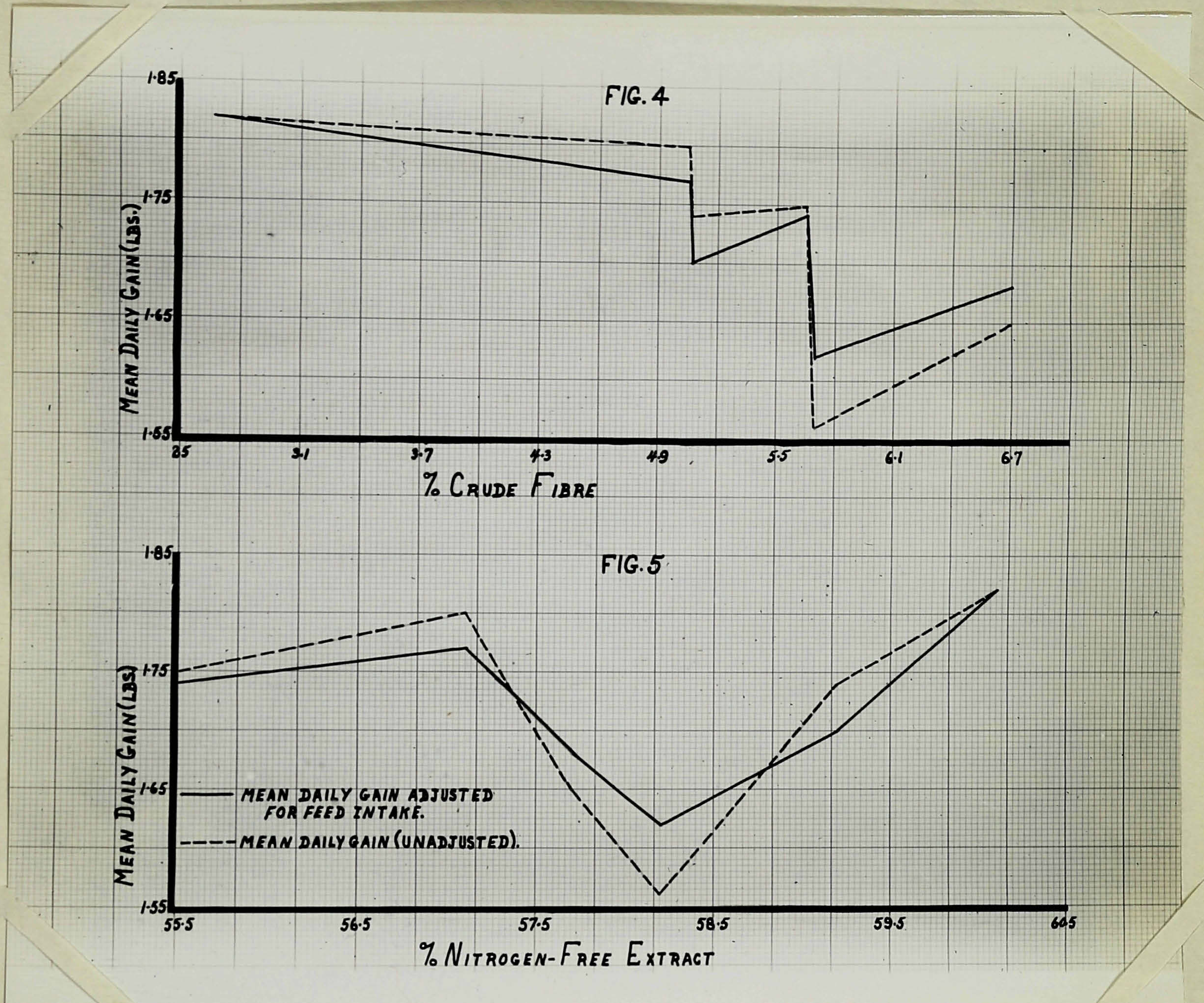
The necessary partial correlation to be significant, at P.05, is .878, which means that of all the fractions, cellulose is the only one that has a statistically significant effect on the daily gain in live weight of bacon hogs. Due to the small number of degrees of freedom (3) available for the test of significance, the partial correlation needed for statistical significance is abnormally high. This does not mean that the other fractions are of no importance. On the contrary, most of the fractions are essential for growth, even bulk in the form of cellulose and lignin is necessary for proper alimentation and well being of the animal. If the number of degrees of freedom were increased by the addition of more lots to the experiment, all fractions might fall into the category of statistical significance.

Crampton and Forshaw (1939) and Woodman et al. (1931), who worked with forage crops, found a high negative

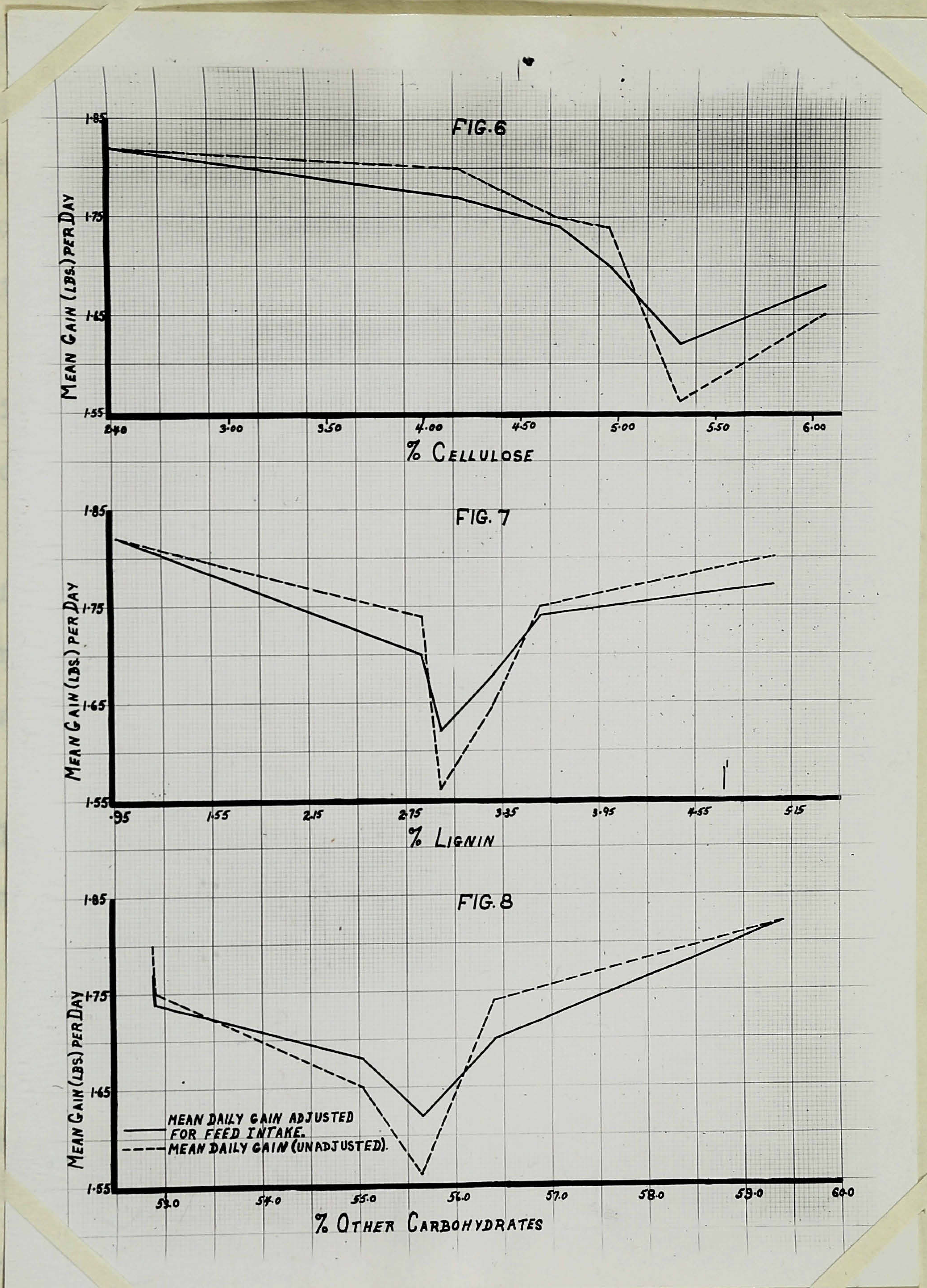


Correlation Graphs for Gain with

% Protein, Ether Extract, and Ash.



Correlation Graphs for Gain with % Crude Fibre and % N.F.E.



Correlation Graphs for Gain with

% Cellulose, % Lignin, and % Other Carbohydrates correlation between the percent of lignin in grass and live weight gains of herbivorous animals. The theory for this, suggested by Woodman and Stewart (1932), is that the lignin, which inhibits bacterial action, is intimately associated with the cellulose of the cell wall, thus preventing cellulosic digestion of the wall and utilization of the food nutrients inside. But, since Mitchell and Hamilton (1933) have shown that cellulose is not digested by swine, and since cellulose makes up a greater percent of the ration than lignin, the anti-bacterial property of lignin is not apparent, and as a result the partial correlation of lignin would be expected to be lower than for cellulose.

As is shown in Figure 6, the only lot that did not follow the trend of inverse relationship between gain and percent of cellulose in the ration was Lot III on the extreme left of the graph. This ration was a mechanical mixture of high grade recleaned barley with 17% wild oats, and 3% of weed seeds added. The wild oats were responsible for the high cellulose content, while the plump, high quality barley, no doubt, had a favourable influence on the observed daily gains. What might be concluded from the papers of Adolph and Wu (1934) and Wright (1938), who worked with omnivora, has been confirmed; that is, when cellulose is an innate part of the grain, a slight increase will lower the nutritive value of all the feed fractions; but when the cellulose is added from an extraneous source this inhibiting effect is not prevalent.

It seems apparent, therefore, that for the general run of rations or for individual feeds, the percent of cellulose might be a good index to the nutritive value. However, the fact that the specially prepared ration of Lot III does not follow this trend, shows that cellulose as determined chemically cannot be considered an infallible guide to nutritive value in the feeding of bacon hogs This would hold, particularly in the case of commercially mixed rations, where the origin of the various feed fractions is not known.

Although cellulose was the only statistically significant partial correlation, protein undoubtedly plays a very important part in determining live weight gains of pigs; but, since the rations were all adequately supplied with protein, a rise or fall of 2% would not affect the growth of the pigs, and hence would not affect the partial correlation coefficient to any great extent. The regression curve for percent protein in the ration on gain is shown in Figure 1.

A high negative partial correlation is noted for ash, which was the case in the experiments of Crampton and Forshaw (1940). They concluded that it was due to the diluent effect of this inorganic material, since it made up from 10 to 17% of the total dry matter. Although the ash content of the swine rations in this study was only 5 to 6%, there is the possibility that its diluent effect may account for the high negative correlation in this case also. The more likely explanation, however, is that it is associated with one of the fractions of low digestibility such as cellulose or crude fibre. Ether extract too shows a negative partial correlation as was observed in the rabbit trials of Crampton and Forshaw (1940). The partial correlation for crude fibre was higher for swine than with forage grasses in the case of rabbits. This may be accounted for by the fact that, according to the work of Crampton and Forshaw, crude fibre is about 20% digestible, while Mitchell and Hamilton (1933) found it to be only 2% digestible with swine. Since it is known that most of the lignin is found in the nitrogen-free extract fraction of the standard chemical analysis, by separating lignin from the digestible carbohydrates, the partial correlation was raised from +.1632 (nitrogen-free extract) to +.3890 (other carbohydrates), leaving lignin with a partial correlation of -.4901.

SUMMARY AND CONCLUSIONS

Swine feeds were analyzed chemically for the various feed fractions in the standard method of analysis and for the fractions in the modified scheme proposed by Crampton and Maynard (1938) as follows:

Standard Analysis	Modified Scheme
Protein	Protein
Ether Extract	Ether Extract
Ash	Ash
Crude Fibre	Cellulose
Nitrogen-free Extract	Lignin
	Other Carbohydrates

The daily intake of each feed fraction, which makes up the whole of each system, and the observed daily gain in live weight of each pig was analyzed statistically by two methods, partial regression, and partial correlation.

In an attempt to evaluate the importance of the daily intake of each dietary fraction in producing gains, independent of the other fractions, the method of partial regression was applied and found to be unsatisfactory for the data used, presumably because the variates were not entirely independent.

The procedure of partial correlations between percent of each feed fraction in the ration, daily gain, and feed intake, indicated negative correlations between gain and ether extract, ash, cellulose, and lignin.

Positive correlations existed between gain and protein, nitrogen-free extract, and other carbohydrates. The only statistically signigicant correlation was between gain and percent of cellulose. This negative trend did not hold, however, when the cellulose was added to an otherwise highly digestible ration in the form of wild oats and weed seeds. It might be concluded that when cellulose is an innate part of the grain a slight increase will lower the nutritive value of all the feed fractions, but, when the cellulose is added from an extraneous source, this inhibiting effect is not prevalent.

Similar partial correlations of the other feed fractions were found to those observed by Crampton and Forshaw (1940); namely, negative correlations for ash and ether extract, and a high positive correlation for crude protein.

In order to gain more reliable knowledge of the problem, it is suggested that further work be performed, that would include a greater number of different rations, thus increasing the number of degrees of freedom for lots, which in turn will reduce the estimate for significance.

LITERATURE CITED

Adolph, W.H., and Wu, M.

1934 The influence of roughage on protein digestibility.
J. Nut. 7:381-393.

Cameron, T.

1936 The nutritive value of pasture grasses.
Thesis, Faculty of Graduate Studies and Research. McGill University, Montreal.

Campbell, W.G., and J. Booth

1930 The chemical aspect of the drying timber.
Biochem. J. 24:641-648.

-----, -----.

1930a The chemical aspect of the drying timber.
Biochem. J. 24:756-762.

Coleman, D.A.

1928 Report of the committee on methods of analysis.
Cereal Chem. 5:268-276.

Cosonka, A.F., M. Phillips, and D.B. Jones

1929 Studies on lignin metabolism.
J. Biol. Chem. 85:65-75.

Crampton, E.W.

1934 Pasture studies. IV. The nutritive value of pasture herbage---quality of protein.
Emp. J. Exp. Agr. 2:337-348.

Crampton, E.W.

1939 Pasture studies. XIV. The nutritive value of pasture herbage. Some problems in its estimation and some results thus far obtained at Macdonald College.
Sci. Agr. 19:345-357.

-----, and J.A. Campbell

1938 The relative ability of steers and rabbits to digest pasture herbage.
Unpublished data, Macdonald College.(Thesis)

-----, -----, and E.H. Lange

1940 Pasture studies. XVII. The relative ability of steers and rabbits to digest pasture herbage.
Sci. Agr. 20:504-509.

-----, and R.P. Forshaw

1939 Pasture studies. XV. The intra-seasonal changes in the nutritive value of pasture herbage.
Sci. Agr. 19:701-711.

-----, -----.

1940 Pasture studies. XVI. The nutritive values of Kentucky blue grass, red top, and brome grass, with particular reference to the relation between the chemical composition of the herbages and the live weight gains made by the animals subsisting thereon.
J. Nut. 19:161-172.

Crampton, E.W., and D.A. Finlayson

1935 The effect of fertilization on the nutritive value of pasture grass.
Emp. J. Exp. Agr. 3:331-345.

-----, and L.A. Maynard

1938 The relation of cellulose and lignin content to the nutritive value of animal feeds.
J. Nut. 15:383-395.

Cunningham, I.J.

1940 Feed requirements of stock. How to assess the nutritive value of foodstuffs.
N. Zealand J. Agr. 60:81-86.

Davis, R.E., and C.O. Miller

1939 Partition of the less easily digested carbohydrate complex of forages.
An. Ed. Ind. and Eng. Chem. 11:651-652.

Fagan, T.W., and H.T. Jones

1920-23 The nutritive value of grasses as shown by their chemical composition.
Welsh Plant Breeding Station Series H.
No. 3:85-130.

Hall, A.D., and E.J. Russell

1912 On the causes of high nutritive value and fertility of the fatting pastures of Romney Marsh and other marshes in the S.E. of England.
J. Agr. Sci. 4:339-370.

Hayward, J.W., H. Steenbock, and G. Bohstedt

1936 The effect of cystine and casein supplements upon the nutritive value of the protein of raw and heated soybeans.
J. Nut. 12:275-283.

Horwitt, M.K., G.R. Cowgill, and L.B. Mendel

1936 The availability of the proteins and inorganic salts of the green leaf.
J. Nut. 12:237-254.

-----, -----, -----.

1936a Availability of carbohydrate and fats of green leaf together with some observations on crude fibre.
J. Nut. 12:255-273.

Isaachsen, H., O. Ulvesli, and M. Husby

1935 Comparison of the digestibility of protein found in experiments with animals and in digestion trials with pepsin-HCl.
41st report Inst. An. Nut. Roy. Agr. Col. Norway.
Nut. Abs. Rev. 5:35-36.

Jones, D.B.

1931 Factors for converting percentages of nitrogen in foods and feeds into percentage of protein.
U.S.D.A. Circ. 183:1-21.

Lessard, H.L.

1941 Comparative digestibility by rabbits of ether extract and true fats of feeds.
Thesis, Faculty of Graduate Studies and Research. McGill University, Montreal.

Mangold, E.

1934 The digestion and utilization of crude fibre.
Nut. Abs. Rev. 3:647-656.

Maynard, L.A.

1937 Interpretation of variations in plant composition in relation to feeding value.
J. Am. Soc. Agron. 29:504-511.

-----.

1940 Symposium on the nitrogen-free extract of foods and feeding stuffs. Nitrogen-free extract in animal nutrition.
J. Ass. Off. Agr. Chem. 23:156-161.

Mitchell, H.H., and T.S. Hamilton

1933 True and apparent digestibility of oat hulls and alfalfa meal by swine, with special reference to the ability of swine to digest cellulose and crude fibre.
J. Agr. Res. 47:425-435.

Morris, S., N.C. Wright, and A.B. Fowler

1936 The nutritive value of proteins for milk production.

J. Dairy Res. 7:97-121.

Morrison, F.B.

1936 Feeds and Feeding. pp. 954, and 966.

Morrison Publishing Co., Ithaca, N.Y.

Norman, A.G.

1935 The composition of crude fibre.

J. Agr. Sci. 25:529-540.

-----, and S.H. Jenkins

1934 The determination of lignin. II. Errors introduced by the presence of proteins.

Biochem. J. 28:2160-2168.

Olson, F.C., and L.S. Palmer

1940 Comparison of a chemical and a biochemical method for determining the biological value of proteins and an evaluation of the endogenous nitrogen.

J. Agr. Res. 60:331-342.

Phillips, M.

1934 The chemistry of lignin.

Chem. Rev. 14:103-170.

Prjanischnikow, J.E., and M.F. Tomme

1936 Effect of lignin on digestibility of rye straw.

Biedermann's Zentr. B. Tierernahr. 8:104.

Nut. Abs. Rev. 6:231.

Watson, C.J., J.C. Woodward, W.M. Davidson, C.H. Robinson, and G.W. Muir

1938 Digestibility studies with ruminants. III. Plane of nutrition and digestibility of mangels. Sci. Agr. 18:586-605.

-----, -----, -----, -----, -----.

1939 Digestibility studies with ruminants. IV. Plane of nutrition and digestibility of corn silage. Sci. Agr. 19:622-651.

Williams, R.D., and W.H. Olmstead

1935 A biochemical method for determining undigested residue in feces. J. Biol. Chem. 108:653-666.

Woodman, H.E., D.L. Blunt, and J. Stewart

1926 Nutritive value of pasture. I. Seasonal variations in the productivity, botanical and chemical composition, and nutritive value of medium pasture on a light sandy soil. J. Agr. Sci. 16:205-274.

-----, -----, -----.

1927 Nutritive value of pasture. II. Seasonal variations in the productivity, botanical and chemical composition, and nutritive value of pasturage on a heavy clay soil. J. Agr. Sci. 17:209-263.

Woodman, H.E., R.E. Evans, and D.B. Norman

1934 Nutritive value of lucerne. II. Investigations into the influence of systematic cutting at three different stages of growth on the yield, composition and nutritive value of lucerne. J. Agr. Sci. 24:283-311.

-----, D.B. Norman, and M.H. French

1931 Nutritive value of pasture. VII. The influence of the intensity of grazing on the yield, composition and nutritive value of pasture herbage. J. Agr. Sci. 21:267-323.

-----, and P.M. Oosthuizen

1934 Nutritive value of pasture. XI. The composition and nutritive value of winter pasturage. J. Agr. Sci. 24:575-597.

-----, and J. Stewart

1932 The mechanism of cellulose digestion in the ruminant organism. III. The action of cellulose-splitting bacteria on the fibre of certain typical feeding stuffs. J. Agr. Sci. 22:527-547.

-----, and E.J. Underwood

1932 Nutritive value of pasture. VIII. The influence of intensive fertilizing on the yield and composition of good permanent pasture. J. Agr. Sci. 22:26-71.

Wright, T.

1938 Comparative value of barley of different test weights for feeding hogs.
Proc. Am. Soc. An. Prod. 31:138-140.

Yates, F.

1933 The analysis of replicated experiments when the field results are incomplete.
Emp. J. Exp. Agr. 1:129-142.

APPENDIX

Table I

Daily Gain To Market Weight (Lbs.)

Lot	I	II	III	IV	V	VI
M	1.99	1.60	1.73	1.87	1.77	2.01
A	1.76	1.80	1.67	1.95	2.04	1.85
L	*1.73	1.87	1.45	1.79	1.68	1.76
E	1.59	1.43	1.65	2.01	1.73	1.88
	1.76	1.67	1.83	1.83	1.55	1.88
F						
E	1.61	1.49	1.55	1.79	1.85	1.57
M	1.63	1.75	1.76	1.79	1.69	1.90
A	1.75	1.29	1.86	1.71	1.68	1.81
L	1.66	1.07	1.68	1.68	1.81	1.71
E	1.91	1.66	1.37	1.79	1.70	1.65

Table II

Daily Feed Consumption (Lbs.)

Lot	I	II	III	IV	V	VI
M	6.51	5.70	5.52	5.99	5.95	6.61
A	5.80	5.65	5.87	6.01	6.74	6.25
L	*5.96	6.01	5.07	5.82	5.59	6.12
E	5.77	5.77	6.27	6.08	5.56	6.06
	6.50	5.75	5.89	5.85	6.14	6.25
F						
E	6.53	5.95	6.00	5.92	5.98	6.24
M	5.99	5.47	6.00	5.58	6.57	5.91
A	5.82	5.75	5.64	6.07	5.49	5.91
L	5.92	4.63	6.32	6.23	5.61	5.95
E	6.47	5.58	5.46	5.79	6.03	5.76

* Calculated value.

Table III

Daily Crude Protein Consumption(Lbs.)

Lot	I	II	III	IV	V	VI
M	1.05	.92	.84	1.17	1.14	1.17
A	.93	.92	.88	1.17	1.29	1.11
L	* .95	.98	.76	1.14	1.08	1.09
E	.93	.93	.94	1.18	1.07	1.07
	1.04	.93	.89	1.14	1.18	1.11
F						
E	1.04	.96	.91	1.16	1.15	1.10
M	.96	.89	.90	1.08	1.26	1.05
A	.93	.94	.85	1.19	1.06	1.04
L	.95	.75	.95	1.22	1.08	1.05
E	1.03	.90	.82	1.13	1.17	1.01

Table IV

Daily Crude Fat Consumption (Lbs.)

Lot	I	II	III	IV	V	VI
M	.121	.131	.144	.079	.153	.205
A	.107	.130	.152	.079	.174	.194
L	*.109	.138	.131	.077	.144	.190
E	.107	.132	.162	.079	.144	.188
	.120	.132	.152	.077	.158	.194
F						
E	.120	.136	.156	.079	.154	.194
M	.110	.126	.156	.074	.169	.184
A	.107	.133	.147	.080	.142	.183
L	.109	.107	.164	.082	.145	.185
E	.119	.128	.141	.076	.156	.178

* Calculated value.

Table V

Daily Ash Consumption(Lbs.)

Lot	I	II	III	IV	V	VI
M	.361	.313	.322	.290	.296	.331
A	.317	.313	.337	.291	.334	.317
L	*.324	.331	.292	.283	.278	.310
E	.314	.314	.360	.292	.280	.305
	.353	.318	.339	.286	.304	.317
F						
E	.350	.325	.350	.293	.295	.315
M	.323	.303	.346	.271	.324	.304
A	.314	.323	.328	.295	.274	.291
L	.323	.257	.364	.302	.281	.301
E	.348	.307	.313	.282	.306	.286

Table VI

Daily Crude Fibre Consumption (Lbs.)

Lot	I	II	III	IV	V	VI
M	.331	.327	.371	.161	.337	.336
A	.295	.323	.395	.162	.383	.317
L	*.300	.344	.342	.157	.317	.310
E	.294	.331	.422	.164	.315	.307
	.331	.329	.397	.157	.349	.317
F						
E	.333	.341	.403	.159	.340	.316
M	.306	.313	.404	.150	.373	.299
A	.297	.328	.379	.163	.312	.300
L	.302	.265	.425	.168	.318	.302
E	.330	.320	.368	.156	.341	.292

* Calculated Value.

Table VII

Daily N.F.E. Consumption (Lbs.)

Lot	I	II	III	IV	V	VI
M	3.87	3.35	3.20	3.63	3.33	3.80
A	3.45	3.31	3.41	3.64	3.77	3.59
L	*3.56	3.53	2.95	3.52	3.13	3.51
E	3.44	3.39	3.64	3.69	3.10	3.48
	3.87	3.37	3.43	3.53	3.44	3.59
F						
E	3.90	3.50	3.48	3.57	3.35	3.58
M	3.58	3.21	3.49	3.38	3.68	3.38
A	3.47	3.36	3.27	3.67	3.07	3.41
L	3.53	2.72	3.67	3.77	3.13	3.41
E	3.87	3.28	3.18	3.50	3.36	3.31

Table VIII

Daily Cellulose Consumption (Lbs.)

Lot	I	II	III	IV	V	VI
M	.324	.306	.335	.144	.281	.277
A	.289	.302	.358	.145	.318	.261
L	*.297	.322	.309	.140	.264	.256
E	.287	.309	.382	.146	.262	.254
	.324	.308	.359	.140	.290	.261
F						
E	.326	.319	.365	.142	.282	.261
M	.399	.293	.365	.134	.311	.247
A	.290	.307	.343	.146	.259	.248
L	.295	.248	.385	.159	.264	.249
E	.323	.299	.333	.139	.284	.241

* Calculated value.

Table IX

Daily Lignin Consumption (Lbs.)

Lot	I	II	III	IV	V	VI
M	.186	.170	.182	.058	.213	.335
A	.165	.168	.194	.058	.242	.316
L	*.170	.179	.168	.056	.201	.309
E	.165	.171	.207	.058	.199	.307
	.186	.171	.195	.056	.221	.316
F						
E	.187	.177	.198	.057	.215	.315
M	.171	.163	.198	.054	.236	.298
A	.166	.171	.186	.058	.197	.300
L	.169	.138	.209	.060	.201	.301
E	.185	.166	.180	.056	.216	.292

Table X

Daily Consumption - Other Carbo. (Lbs.)

Lot	I	II	III	IV	V	VI
M	3.69	3.20	3.05	3.58	3.17	3.52
A	3.29	3.17	3.26	3.60	3.60	3.32
L	*3.39	3.37	2.81	3.48	2.98	3.25
E	3.28	3.24	3.48	3.65	2.96	3.23
	3.70	3.22	3.27	3.49	3.28	3.32
F						
E	3.73	3.34	3.32	3.53	3.19	3.32
M	3.41	3.07	3.33	3.34	3.51	3.13
A	3.31	3.21	3.12	3.63	2.93	3.16
L	3.37	2.60	3.50	3.73	2.99	3.17
E	3.69	3.13	3.03	3.46	3.20	3.07

* Calculated value.