THE RELATIONSHIP OF THE NUTRITIVE RATIO OF THE RATION TO THE RATE OF GAIN IN PIGS

Thesis for the Degree of M. S.
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Willis H. Bash

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Preface

This thesis reports a study of the relationship of the nutritive ratio of the rations fed to various lots of swine and the rate of gain made by these lots.

During the study of nutrition relative to swine feeding, it has been assumed that there is a relationship between various nutritive ratios fed to swine and the rate these swine gained, particularly at different age and weight levels. However, in spite of this assumption, there is very little data available which would prove this relationship on the basis of a statistical analysis. The data taken from previous experiments performed at the Michigan Agricultural Experiment Station and at the Iowa Agricultural Experiment Station were used as a basis of making computations and conclusions contained in this paper.

The data selected was not originally designed for this study, but was such that it was readily adaptable for use in the study of this relationship. It was taken from nine experiments which included six hundred eighty-three pigs fed at the Michigan Station and one experiment performed at the Iowa Station which included fifty pigs, making a total of ten experiments and seven hundred thirty-three pigs fed in the experiments from which the data were used.

The author is very grateful for the constructive criticism and suggestions offered by Professor Brown, Professor Freeman, and Dr. W. D. Baten in the composition of this paper.

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THE RELATIONSHIP OF THE NUTRITIVE RATIO OF THE RATION TO THE RATE OF GAIN IN PIGS

Introduction

The nutritive ratio received by swine during the feeding period is of great economic importance. Protein is usually the most expensive nutrient fed in the ration. When ordinary grains, such as corn, make up the main part of the ration, the rate and economy of gains are materially increased by including protein-rich supplements. Because of its high cost, we wish to feed the least amount of protein that will give the most rapid and economical gains. Determining the most economical level of protein to feed pigs has been a major problem of swine nutrition and has resulted in rather definite feeding standards for pigs of different weights based on the ratio of protein to other nutrients included in the ration.

The nutritive ratio is the ratio of the digestible protein to the digestible carbohydrates, plus fat times 2.25 in the total feed consumed during the feeding period under consideration.

The term "rate of gain" as used in this paper refers to the average daily gain made by each pig for a certain period.

It is important to note that the kind of protein received by swine has a marked influence on the rate of gains. However, the data selected were obtained from experiments which contained a fairly

complete protein, except a few check lots which received cereal grains fed alone on pasture.

Considerable difficulty was experienced in selecting data which were adaptable for this study. Correlation coefficients of the nutritive ratio and the rate of gains for the pigs were computed using the entire feeding period involving various ages and weights of pigs fed from weaning to marketing time. The resulting correlation coefficients were not significant for any of the computations made.

The data were then divided according to the age of the pigs. Complete data were available for each twenty-eight days for the Michigan data and each thirty days for the Iowa data, the same as for the entire feeding period, giving the number of pigs, weights, daily gains made per pig in each lot, and the feeds consumed by each lot.

Correlation coefficients were then computed on the basis of the shorter feeding periods, using the twenty-eight-day period for the Michigan data and the thirty-day period for the Iowa data. The resulting correlation coefficients were significant only when the groups included pigs of comparable weights. When further studied, it was learned that there was a wide variation in the rate of gains made by various lots, particularly at different age and weight levels.

Another set of computations was made using the shorter periods, but grouped according to weights. The weight data for the short periods were arbitrarily divided into groups ranging from forty to forty-eight pounds, forty-nine to eighty pounds, eighty-one to one

hundred twenty pounds, and upward from one hundred twenty pounds, at the beginning of the respective periods. No group of pigs exceeded a final weight for the last period of one hundred eighty pounds for the Michigan data or two hundred forty pounds for the Iowa data. The procedure followed on the basis of the weight groupings is shown by the following example: A lot of pigs averaging forty-two pounds at the time they started the experiment would be in the first-weight group, ranging from forty to forty-eight pounds. If they started the next twenty-eight-day period with an average weight of fifty-five pounds, they would be in the second-weight group, which ranges from forty-nine to eighty pounds. Now suppose during this twenty-eight days they gained an average of only twenty-three pounds, allowing them to start the third period at an average weight of seventy-eight pounds, they would still come within the weight group of forty-nine to eighty pounds even though they were in the third feeding period. On the other hand, the majority of pigs passed from one weight group to the next in each feeding period.

The method of grouping will be easily understood as one studies the data.

The formula used in computing the correlation coefficient is the ordinary linear Pearson formula and is as follows:

$$r_{xy} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{N}}{\sqrt{\left[\Sigma x^2 - \frac{(\Sigma x)^2}{N}\right]\left[\Sigma y^2 - \frac{(\Sigma y)^2}{N}\right]}}$$

"r_{xy}" is the symbol for the correlation coefficient, "Σ" the symbol for summations, "x" the symbol for the average daily gain made by each pig in each lot by weight groups, and "y" the symbol for the nutritive ratio consumed by each corresponding lot of pigs.

The nutritive ratios of the feeds used in these experiments were computed on the basis of the analyses shown in Table 1.

Table 1 - Analysis of Feeds

Michigan State College Data*

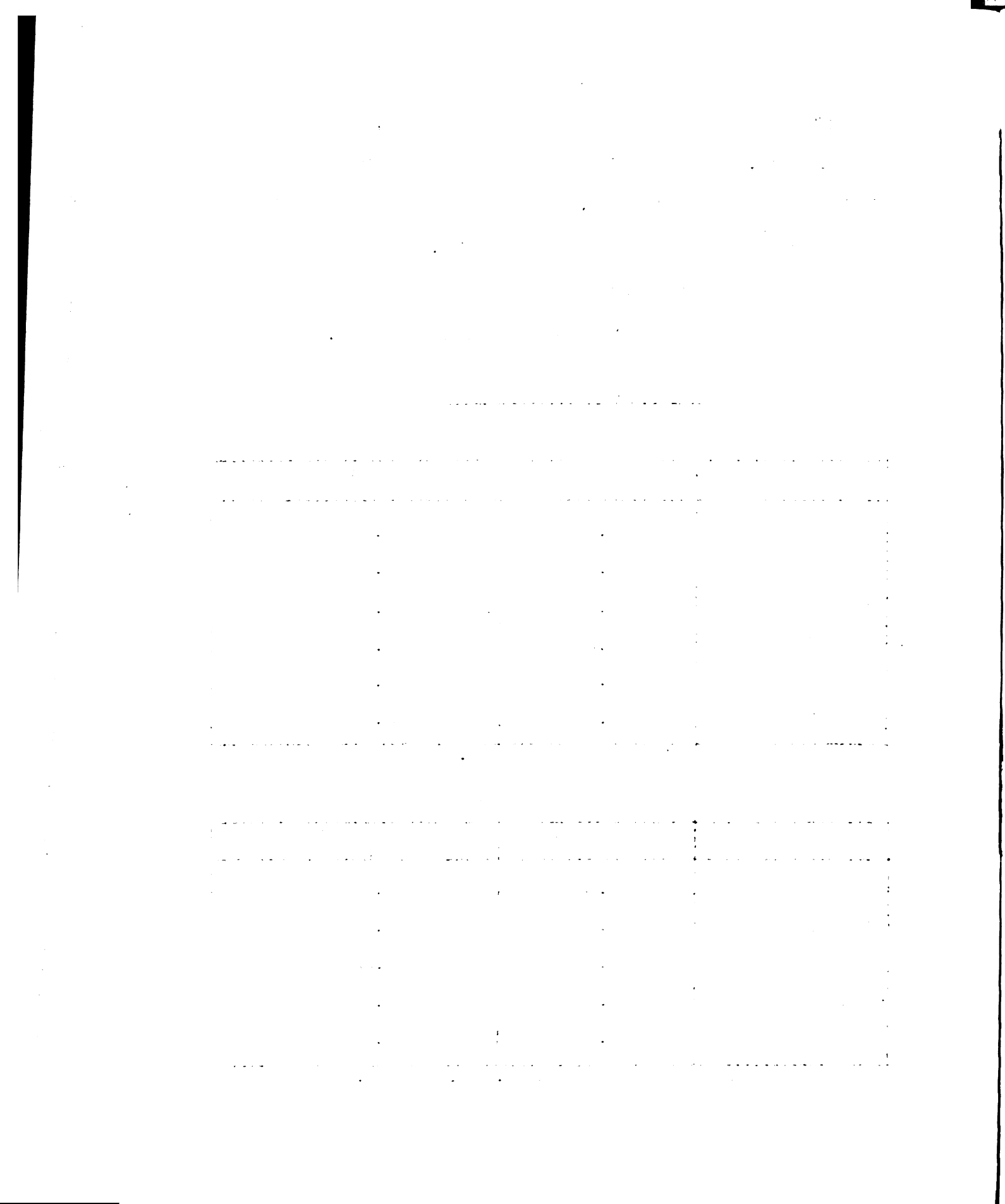
Feed	Digestible Protein	Digestible Carbohydrates and Fats Combined
Corn	7.0%	72.0%
Barley	9.3	69.4
Tankage	56.4	21.6
Skimmilk	3.5	5.1
Buttermilk	3.3	5.8
Alfalfa	10.6	39.7

*Analyses from Morrison's "Feeds and Feeding".

Iowa State College Data**

Feed	Digestible Protein	Digestible Carbohydrates and Fats Combined
Corn	6.63%	71.08%
Wheat Middlings	13.27	56.32
Buttermilk	3.32	5.57
Tankage	45.15	19.36
Alfalfa	6.59	28.27

**Analyses from Iowa Research Bulletin No. 118, page 226.



Experimental Data

Michigan Experiments

Experiment I - On buttermilk feeding in the winter of 1936-37.

This experiment was designed to study the effect of buttermilk fed in different daily allowances with corn and alfalfa self-fed to pigs in the dry lot.

Lots I, II, III, and IV were self-fed corn and alfalfa free-choice to all lots with tankage hand-fed at the rate of one-half pound per pig, for each day to Lot I and buttermilk hand-fed daily to lots II, III, and IV. Lots V, VI, and VII were self-fed a mixture of corn and ground alfalfa with a daily allowance of buttermilk hand-fed.

There were seven lots of pigs tested with nine pigs in each lot. All lots in the Michigan experiments were concluded when the pigs had acquired an average weight of one hundred eighty pounds.

The relationship of the nutritive ratio and the rate of gain showed a correlation coefficient of -.71 for the weight group ranging from forty-nine to eighty pounds, -.39 for the weight group from eighty to one hundred twenty pounds, and +.48 for the weight group upward from one hundred twenty pounds.

The data used in this experiment are summarized in Table 2.

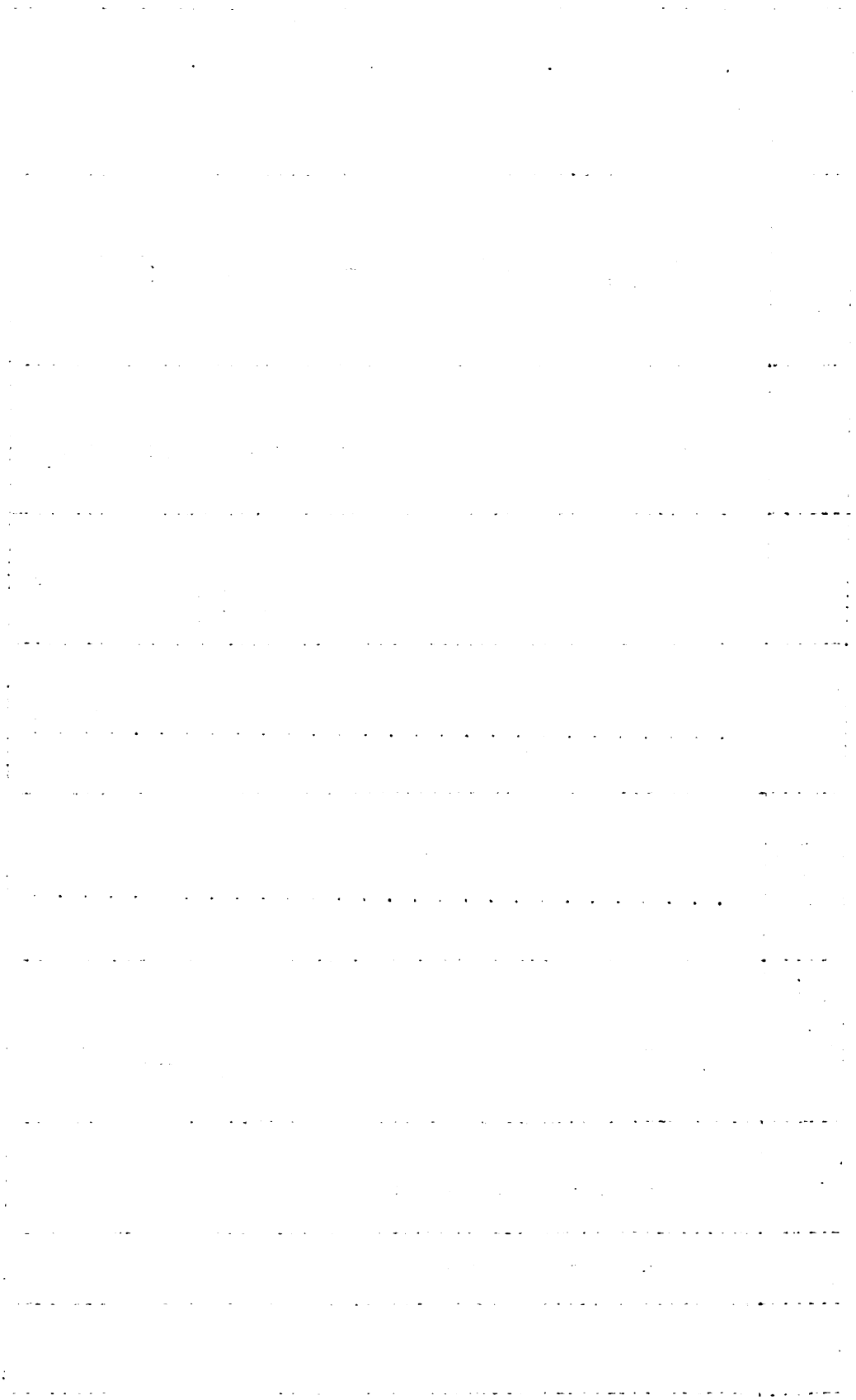
Experiment II - On skimmilk feeding in the winter of 1933-34.

This experiment was conducted for the purpose of studying the effect of skimmilk hand-fed in varying daily allowances, also with different proportions of corn and alfalfa for pigs in the dry lot.

The corn and alfalfa were each fed free-choice in Lots I, II, III, and IV, but mixed and self-fed in Lots V, VI, VII, and VIII. This

Table 2 - Buttermilk Feeding in the Winter of 1936-37

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Alfalfa (Pounds)	Buttermilk (Pounds)	Tankage (Pounds)
I	1	9	49	.78	3.93	550	68		121.5
	2	9	50	.56	6.60	535	71	729	
	3	9	49	.69	5.18	475	41	1445	
	4	9	49	.62	5.09	470	72	1459	
	5	9	49	.51	6.77	527	27	729	
	6	9	50	.63	6.56	508	56	729	
	7	9	50	.65	6.32	480	85	729	
II	1	9	71	.72	4.23	657	90		126.0
	2	9	65	.52	6.33	510	98	756	
	3	9	68	.60	4.85	420	46	1512	
	4	9	70	.61	4.34	480	59	2305	
	5	9	69	.38	6.99	614	32	756	
	6	9	69	.46	6.72	576	64	756	
	7	9	71	.66	6.48	548	97	756	
III	1	9	91	.89	4.98	910	89		126.0
	2	9	110	.59	6.99	662	85	714	
	3	9	95	.50	5.22	455	42	1356	
	4	9	98	1.00	4.32	564	44	2750	
	5	9	85	.40	6.76	508	27	714	
	6	9	106	.56	7.02	688	76	714	
	7	9	127	.91	6.79	774	136	714	
IV	1	9	130	.92	5.67	1152	69		120.0
	2	9	134	.98	8.13	792	46	465	
	3	9	151	.71	6.43	540	17	915	
	4	9	116	.96	4.32	671	52	3280	
	5	9	176	.73	6.23	436	23	426	
	6	9	116	1.05	7.42	654	73	549	
	7	9	160	1.24	7.18	694	122	594	



test includes eight lots with seven pigs in each lot. The data computed showed a correlation coefficient of -.70 for the weight group from forty-eight to eighty pounds, -.28 for the group from eighty-one to one hundred twenty pounds, and -.57 for the group upward from one hundred twenty pounds.

The data are summarized in Table 3.

Experiment III - On buttermilk feeding in the winter of 1935-36.

This experiment was set up to study the effect of feeding buttermilk in varying daily allowances, self-feeding a mixture of corn and ground alfalfa to lots I, II, and III, and self-feeding corn and alfalfa hay to lots IV, V, and VI.

There were six lots with nine pigs in each lot. The weight group ranging from forty-nine to eighty pounds showed a correlation coefficient of -.19, the next heavier group was -.59, and the last group was -.14.

The data of this experiment are shown in Table 4.

Because the three foregoing experiments were of a similar nature in the feeding methods and the feeds used, the data were combined and the correlation coefficient was computed for each weight group using the entire data of the three experiments combined.

The weight group from forty-nine to eighty pounds had a correlation coefficient of -.42, the next group, a correlation coefficient of -.16 and the last weight group, a correlation coefficient of -.17. The relationship between the nutritive ratio and rate of gain for the combined group from forty-nine to eighty pounds is shown graphically in Figure I.

Table 3 - Skimmilk Feeding in the Winter of 1933-34

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Alfalfa (Pounds)	Skimmilk (Pounds)	Tankage (Pounds)
I	1	7	63	1.10	4.38	580	44		106
	2	7	63	1.80	6.91	570	56	588	
	3	7	63	1.06	5.45	515	53	1176	
	4	7	64	1.26	4.30	565	57	2352	
	5	7	64	.65	6.43	459	76	588	
	6	7	64	.77	6.34	484	121	588	
	7	7	64	.93	4.77	380	95	1176	
	8	7	64	.55	5.69	344	114	588	
II	1	7	94	1.41	6.12	923	40		80
	2	7	86	.97	7.43	771	79	588	
	3	7	93	1.24	6.30	785	74	1176	
	4	7	99	1.34	5.17	865	25	2352	
	5	7	82	.72	6.78	570	95	588	
	6	7	82	.85	6.66	613	153	588	
	7	7	90	.98	5.40	544	136	1176	
	8	7	89	.85	6.22	496	165	588	
III	1	7	177	1.38	6.45	1070	49		80
	2	7	112	1.26	7.67	930	103	588	
	3	7	128	1.29	6.71	935	58	1176	
	4	7	137	1.85	5.59	868	7	1959	
	5	7	102	.85	7.13	722	120	588	
	6	7	109	.81	6.80	719	180	588	
	7	7	118	1.08	5.52	582	145	1176	
	8	7	103	.76	6.35	547	182	588	
IV	1	7	172	1.36	6.61	232			17
	2	7	148	1.30	8.40	977	13	504	
	3	7	167	1.23	6.98	421		504	
	5	7	126	1.29	7.41	1309	218	861	
	6	6	143	1.42	7.35	978	245	522	
	7	7	148	1.31	6.16	894	223	1218	
	8	7	124	1.31	6.79	1353	451	861	

Table 4 - Buttermilk Feeding in the Winter of 1935-36

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Alfalfa (Pounds)	Buttermilk (Pounds)	Tankage (Pounds)
I	1	9	60	1.04	4.82	845	44		127
	2	9	60	.67	7.30	732	38	756	
	3	9	61	.88	4.86	622	33	2268	
	4	9	62	1.12	4.77	698	37	2657	
	5	9	60	.89	7.12	770	103	756	
	6	9	60	1.27	7.26	817	98	1512	
II	1	9	90	1.07	5.23	982	52		124
	2	9	80	.76	7.60	879	46	756	
	3	9	80	1.02	4.90	689	36	2268	
	4	9	94	1.09	5.33	879	46	2518	
	5	9	85	.98	7.24	843	116	756	
	6	9	96	1.38	6.60	1069	113	1512	
III	1	9	148	1.29	5.74	1239	68		126
	2	9	101	.89	7.90	1026	54	729	
	3	9	101	1.10	5.60	874	46	2187	
	4	9	140	1.48	5.49	1039	55	2744	
	5	9	112	1.00	7.86	1159	107	739	
	6	9	135	1.38	6.08	1396	117		

Experiments on pasture: This group of data includes six experiments conducted on rape and on alfalfa pastures. Two of these experiments were conducted in the summer of 1933, two in 1934, and one in each 1935 and 1936.

The experiment of 1933, including seven lots of twelve pigs each, was conducted to study the effect of feeding corn and barley with varying quantities of tankage to pigs on rape pasture.

The data are shown in Table 5.

The other experiment of 1933, including nine lots of fourteen pigs each, was conducted to study the effect of feeding corn and barley with varying quantities of skimmilk and tankage to pigs on rape pasture.

The data are shown in Table 6.

The next experiment, including six lots of ten pigs each, was conducted in 1934 to study the effect of varying quantities of tankage with barley on rape or alfalfa pasture.

The data are shown in Table 7.

Another experiment, including four lots of twelve pigs each, was conducted in 1934 to study the effect of varying quantities of skimmilk fed with corn on rape pasture.

The data are shown in Table 8.

The next experiment, including eight lots of twelve pigs each, was conducted in 1935 to study the effect of varying proportions of tankage fed with corn on rape or alfalfa pasture.

The data are shown in Table 9.

The last experiment on rape pasture for which data was used in this study included eight lots of twelve pigs each and was conducted in 1936 to study the effect of feeding corn with varying proportions of

buttermilk and tankage on rape pasture.

The data are shown in Table 10.

The pasture experiments were all grouped and computations were made on the basis of weight groupings as in the winter feeding tests previously discussed.

The nutritive ratio was computed only for the concentrate feeds consumed. The amount of pasture consumed was not taken into consideration as it was impossible to measure or accurately estimate the amount consumed by any one lot of pigs.

The correlation coefficient was -.72 for the weight group ranging from forty to forty-eight pounds, -.75 for the group from forty-nine to eighty pounds, -.66 for the group from eighty-one to one hundred twenty pounds, and -.34 for the group upward from one hundred twenty pounds.

The data for these experiments are shown in Tables 5 to 10, inclusive.

The relationship between the nutritive ratio and rate of gain for the different weight groups is shown graphically in Figures II, III, IV, and V.

Table 5 - Corn and Barley with Varying Proportions of Tankage on Rape Pasture - 1933

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn, Gr. (Pounds)	Shelled Corn (Pounds)	Ground Barley (Pounds)	Tankage (Pounds)
I	1	12	60	1.05	7.14	1056			61
	2	12	61	.89	6.80		876		59
	3	12	60	1.33	5.63	1270			140
	4	12	60	.96	7.46			1048	
	5	12	60	1.05	6.92			1119	61
	6	12	60	1.15	5.57			1489	89
	7	12	62	.95	6.38			1482	44
II	1	12	89	1.08	6.85	1295			86
	2	12	86	1.00	5.99		1105		105
	3	12	100	1.53	6.11	1853			167
	4	12	87	1.02	7.46			1400	
	5	12	90	1.12	5.64			1502	86
	6	12	100	1.37	6.08			2352	94
	7	12	98	1.24	6.69			2493	50
III	1	12	120	1.27	7.73	2994			129
	2	12	114	1.55	7.47		2719		134
	3	12	149	1.56	6.72	1345			94
	4	12	116	1.16	7.46			3825	
	5	12	122	1.37	6.47			3455	93
	6	12	151	1.23	6.70			1781	36
	7	12	146	1.16	7.05			1950	20

Table 6 - Corn and Barley with Varying Proportions of Skimmilk and Tankage on Rape Pasture - 1933

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Ground Barley (Pounds)	Skimmilk (Pounds)	Tankage (Pounds)
I	1	14	67	.96	7.73	1160			50
	2	14	67	1.34	5.63	1235			136
	3	14	67	.95	7.46		1293		
	4	14	66	.96	5.87		1190		57
	5	14	68	1.02	5.58		1490		89
	6	14	67	.99	6.37		1597		48
	7	14	67	1.05	5.87	1132		2268	
	8	14	67	1.07	7.50	1232		1134	
	9	14	66	1.28	3.87	1107		5884	
II	1	14	93	1.31	7.61	1525			70
	2	14	100	1.55	6.13	2182			196
	3	14	93	1.06	7.46		1860		
	4	14	93	1.38	6.31		1967		63
	5	14	100	1.46	6.08		2300		92
	6	14	100	1.23	6.69		2784		56
	7	14	97	1.44	6.47	1545		2352	
	8	14	97	1.34	7.84	1535		1176	
	9	14	102	1.48	4.47	1475		5684	
III	1	14	130	1.42	8.47	2325			65
	2	14	152	1.72	6.71	1383			97
	3	14	123	1.49	7.46		3267		
	4	14	132	1.41	6.51		2842		73
	5	14	149	1.60	6.70		1748		35
	6	14	148	1.46	7.06		1834		18
	7	14	137	1.62	7.08	1839		2100	
	8	14	134	1.42	8.18	2141		1344	
	9	14	144	1.63	4.54	1411		5278	

Table 7 - Barley with Varying Proportions of Tankage on Pasture - 1934*

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Shelled Corn (Pounds)	Ground Barley (Pounds)	Tankage (Pounds)
I	1	10	62	.84	5.91	711		70
	2	10	63	1.05	7.03		945	40
	3	10	63	.67	7.46		885	
	4	10	63	1.19	6.87		996	60
	5	10	63	1.02	6.37		926	28
	6	10	63	.93	7.46		1018	
II	1	10	86	1.45	5.96	1040		100
	2	10	92	1.49	6.28		1510	50
	3	10	82	1.21	7.46		1289	
	4	10	96	1.59	6.06		1712	70
	5	10	92	1.42	6.65		1456	31
	6	10	89	1.47	7.46		1745	
III	1	10	127	1.52	6.36	1593		130
	2	10	134	1.21	6.22		1845	65
	3	10	116	1.33	7.46		2008	
	4	10	141	1.65	6.53		1898	48
	5	10	132	1.57	6.92		2008	27
	6	10	130	1.45	7.46		2047	
IV	1	10	169	1.80	6.43	316		25
	2	10	168	1.46	7.30		506	7
	3	10	152	1.42	7.46		1557	
	5	10	175	1.25	7.05		309	3
	6	10	171	1.57	7.46		365	

*All lots were on rape pasture, except Lot 6, which was on alfalfa pasture.

Table 8 - Corn with Varying Proportions of Skimmilk on Rape Pasture - 1934

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Skimmilk (Pounds	Tankage (Pounds)
I	1	12	63	1.08	6.13	949		85
	2	12	65	1.00	6.94	835	1020	
	3	12	65	1.14	5.74	940	1992	
	4	12	64	1.36	3.92	899	4603	
II	1	12	93	1.24	5.96	1301		125
	2	12	93	1.14	7.64	1180	1008	
	3	12	97	1.23	6.18	1160	2016	
	4	12	103	1.46	4.17	1156	5208	
III	1	12	128	1.48	5.98	1625		155
	2	12	125	1.36	8.08	1515	1008	
	3	12	131	1.43	6.86	1590	2016	
	4	12	143	1.64	4.56	1196	4416	
IV	1	12	170	1.49	6.50	508		39
	2	12	163	1.44	8.29	863	504	
	3	12	171	1.55	7.07	377	432	

Table 9 - Corn with Varying Proportions of Tankage on Rape and Alfalfa Pastures - 1935

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Shelled Corn (Pounds)	Ground Corn (Pounds)	Tankage (Pounds)
I	1	12	58	.73	10.29	975		
	2	12	58	.92	7.93	1030		40
	3	12	58	1.12	5.63		1082	119
	4*	12	58	1.34	5.04		1164	163
	5*	12	58	.85	7.50	965		45
	6*	12	58	.88	10.29	1050		
	7*	12	58	1.04	8.03	1090		40
	8*	12	58	.82	10.29	990		
II	1	12	81	1.03	10.29	1226		
	2	12	87	.90	7.67	1124		50
	3	12	90	1.17	5.98		1370	131
	4	12	98	1.14	6.04		1343	125
	5	12	83	.93	7.03	1154		70
	6	12	82	.80	10.29	1160		
	7	12	87	.88	8.23	1232		40
	8	12	81	.85	10.29	1201		
III	1	12	111	1.13	10.29	1595		
	2	12	110	1.13	9.21	1645		25
	3	12	123	1.42	6.63		1669	138
	4	12	129	1.61	7.03		1973	121
	5	12	108	1.27	7.99	1603		60
	6	12	105	1.13	10.29	1590		
	7	12	112	1.35	7.44	1600		80
	8	12	105	.84	10.29	1340		
IV	1	12	143	.93	10.29	2226		69
	2	12	148	1.35	8.04	1894		
	3	11	150	2.03	6.68		536	38
	4	12	175	2.16	7.86		249	10
	5	11	135	1.49	8.96	1723		33
	6	12	137	1.26	10.29	2295		
	7	12	150	1.25	8.06	1777		67
	8	12	129	1.21	10.29	1712		

*Lots on alfalfa pasture instead of rape pasture.

Table 10 - Corn with Varying Proportions of Buttermilk and Tankage on Rape Pasture - 1936

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Buttermilk (Pounds)	Tankage (Pounds)
I	1	12	48	.83	6.09	800		70
	2	12	48	.70	10.29	770		
	3	12	48	.93	8.24	930		30
	4	12	48	1.07	5.62	923		102
	5	12	48	1.06	5.04	924		129
	6	12	48	.90	6.79	710	1044	
	7	12	48	1.01	5.45	710	1968	
	8	12	48	.92	4.29	610	3071	
II	1	12	71	.95	8.69	1055		25
	2	12	70	.64	10.29	830		
	3	12	74	.87	7.56	1060		50
	4	12	78	1.06	5.74	1178		124
	5	12	77	1.13	5.23	1066		137
	6	12	77	.78	7.25	873	1008	
	7	12	78	.96	5.99	910	1956	
	8	12	75	1.28	4.63	920	3840	
III	1	12	98	1.38	6.00	1375		130
	2	12	88	.74	10.29	1005		100
	3	12	98	1.40	6.91	1560		148
	4	12	108	1.51	6.13	1650		143
	5	12	109	1.59	6.28	1694		
	6	12	95	1.12	7.81	1160	1008	
	7	12	105	1.22	6.31	1122	2076	
	8	12	111	1.74	5.47	1425	3920	

Table 10 - Continued

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Buttermilk (Pounds)	Tankage (Pounds)
IV	1	12	137	1.54	7.80	2093		87
	2	12	109	.99	10.29	1205		
	3	12	137	1.71	8.39	1903		56
	4	12	150	1.72	6.73	1222		86
	5	12	154	1.69	7.89	1335		54
	6	12	126	1.22	8.29	1555	1008	
	7	12	141	1.65	7.26	1542	1800	
	8	12	160	1.76	6.08	763	1577	
V	1	12	137	1.37	10.29	2068		
	6	12	160	1.27	8.49	893	504	

Iowa Experiment[1]

This experiment was conducted at the Iowa Agricultural Experiment Station to study various feeding methods for pigs fed in the dry lot.

Each period of the experiment was thirty days in length and included ten lots of five pigs each.

Lot I was self-fed free-choice; Lot II was hand-fed three times each day; Lot III was hand-fed twice each day; Lot IV was hand-fed twice each day with the feed allowance based on digestible crude protein, digestible carbohydrates, and water per one hundred pounds of live weight at different age levels; Lot V was fed in the same manner as Lot IV; Lot VI was fed on the Kellner system based on digestible true protein and starch equivalent per one thousand pounds of live weight at different age levels; Lot VII was fed according to the Wolff-Lehmann standard based on the digestible crude protein and digestible carbohydrate equivalent as specified per one thousand pounds of live weight at different age levels; Lots VIII and IX were self-fed free-choice style; Lot X was self-fed the modified free-choice style which included three self-feeders containing various feeds, the mixture in the feeder depending upon the condition of the pigs.

The correlation coefficient for the group from forty to forty-eight pounds was -.54, for the group from forty-nine to eighty pounds, -.36, for the group from eighty-one to one hundred twenty pounds, -.02, and for the group upward from one hundred twenty pounds, +.10.

The data for this experiment are shown in Table 11.

1 "A New Feeding Method and Standards for Fattening Young Swine", by John Marcus Evvard. Research Bulletin 118. Iowa Agricultural Experiment Station. 1929.

Table 11 - Experiment on Methods of Feeding

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Alfalfa (Pounds)	Wheat (Pounds)	Buttermilk (Pounds)	Tankage (Pounds)
I	1	5	42	.64	4.20	232		106		59
	2	5	42	.64	4.06	266		116		73
	3	5	42	.47	4.44	234		108		52
	4	5	42	.49	4.40	239		53		55
	5	5	42	.47	4.36	234		49		55
	6	5	42	.61	3.49	220		53		80
	7	5	42	.41	4.30	226		40		54
	8	5	42	.41	7.22	275		16		19
	9	5	42	.77	4.08	243		112	220	55
	10	5	42	.49	4.69	227	21	6		44
II	1	5	62	1.01	4.40	416		104		94
	2	5	61	1.14	4.35	428		131		101
	3	5	56	.92	4.10	349		118		93
	4	5	56	.69	4.71	335		77		66
	5	5	56	.78	4.69	336		77		67
	6	5	60	.76	4.42	325		75		74
	7	5	52	.56	5.06	272		47		46
	8	5	54	.62	7.23	357		20		24
	9	5	65	1.28	4.91	490		65	300	74
	10	5	57	1.05	6.18	292	28	9		94
III	1	5	92	1.58	5.30	750		158		117
	2	5	95	1.47	5.05	728		95		126
	3	5	83	1.33	4.49	549		108		121
	4	5	77	1.05	4.79	508		100		97
	5	5	79	1.04	4.83	511		100		96
	6	5	83	.93	4.73	412		78		81
	7	5	71	.71	5.39	350		55		51
	8	5	72	.91	7.25	546		31		37

Table 11 - Continued

Period	Lot	No. of Pigs	Average Initial Wt. (Pounds)	Average Daily Gain (Pounds)	Nutritive Ratio 1:	Corn (Pounds)	Alfalfa (Pounds)	Wheat (Pounds)	Buttermilk (Pounds)	Tankage (Pounds)
III	9	5	103	1.44	6.18	753		34	300	66
	10	5	89	.96	4.58	518	43	9		109
IV	1	5	139	1.58	6.48	919		68		87
	2	5	139	1.59	6.44	922		72		88
	3	5	123	1.41	5.51	770		104		108
	4	5	109	1.63	5.16	755		122		123
	5	5	110	1.39	5.14	511		100		96
	6	5	110	1.05	5.08	522		87		88
	7	5	92	.91	5.72	448		58		57
	8	5	100	1.16	7.28	728		40		48
	9	5	147	1.41	7.25	907		16	300	47
	10	5	117	1.23	5.74	689	49	453		87
V	3	5	166	1.25	7.20	847		111		50
	4	5	158	1.29	8.01	942		40		43
	5	5	152	1.19	8.06	719		120		118
	6	5	142	1.10	5.46	644		93		92
	7	5	119	.85	6.01	534		62		60
	8	5	135	1.07	7.28	725		40		48
	10	5	154	1.06	6.54	713	36	24		65
VI	6	5	175	1.16	5.68	760		99		98
	7	5	145	1.00	6.16	642		70		67
VII	7	5	175	1.44	7.50	870		78		47
	8	5	166	1.36	6.59	762		42		50

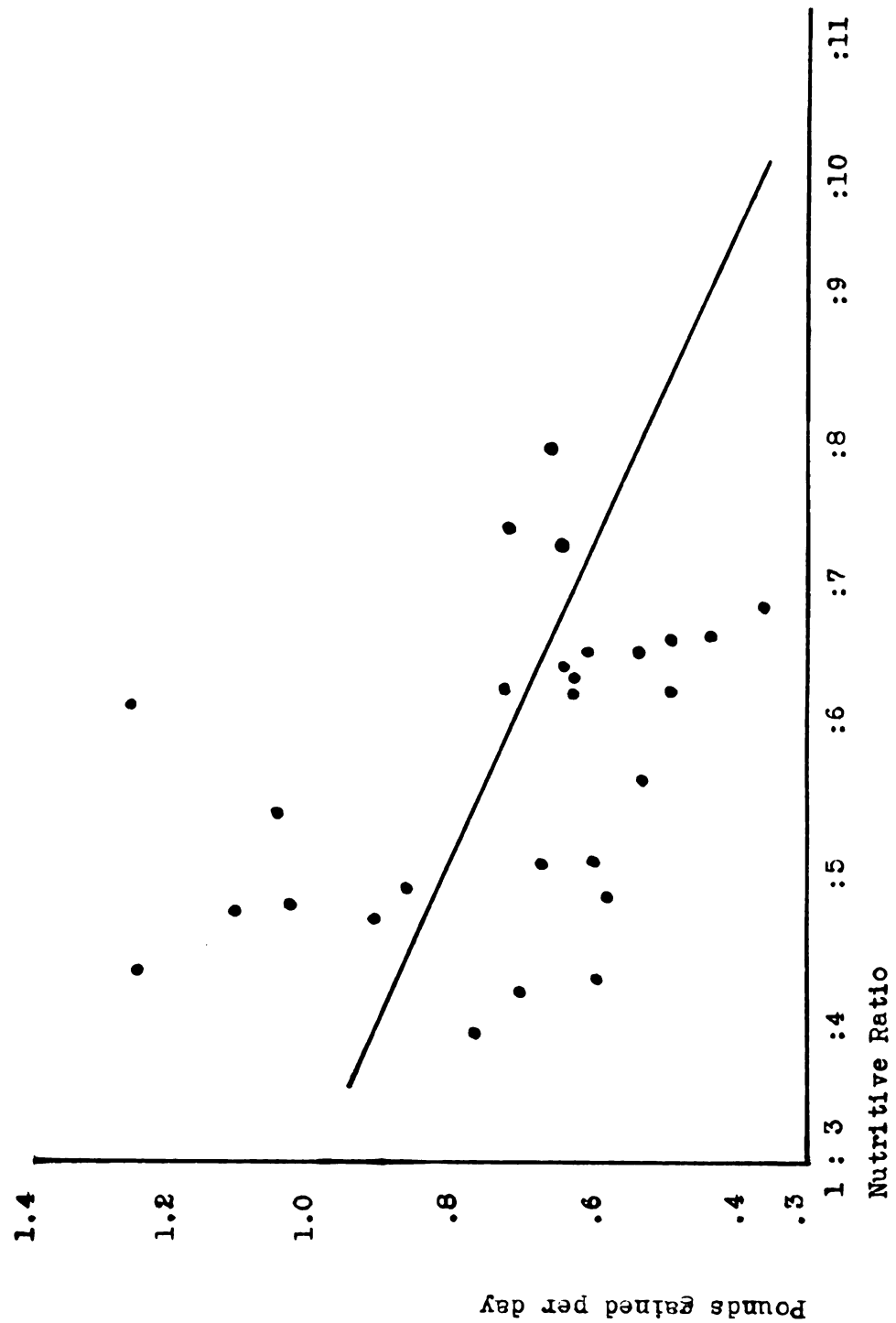
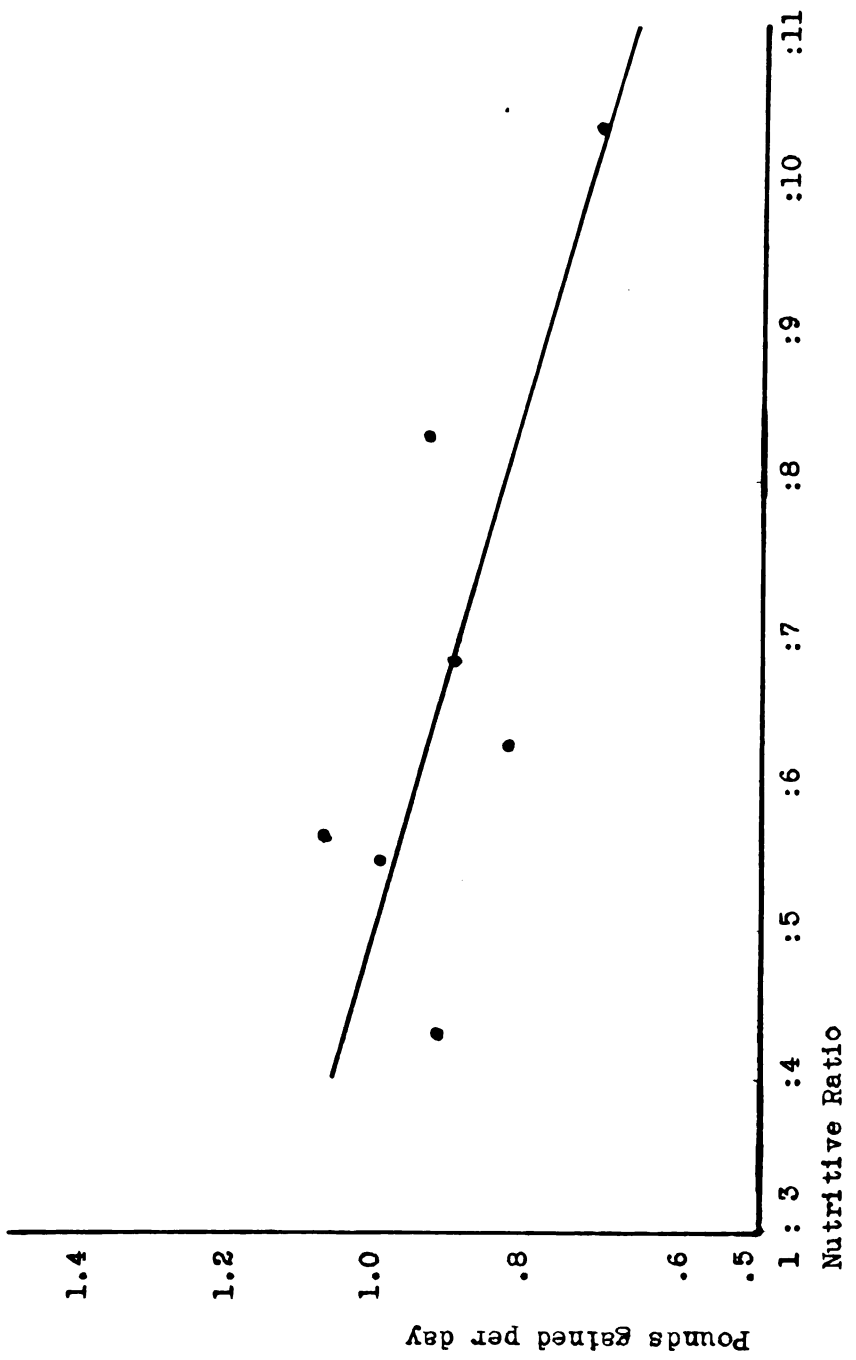


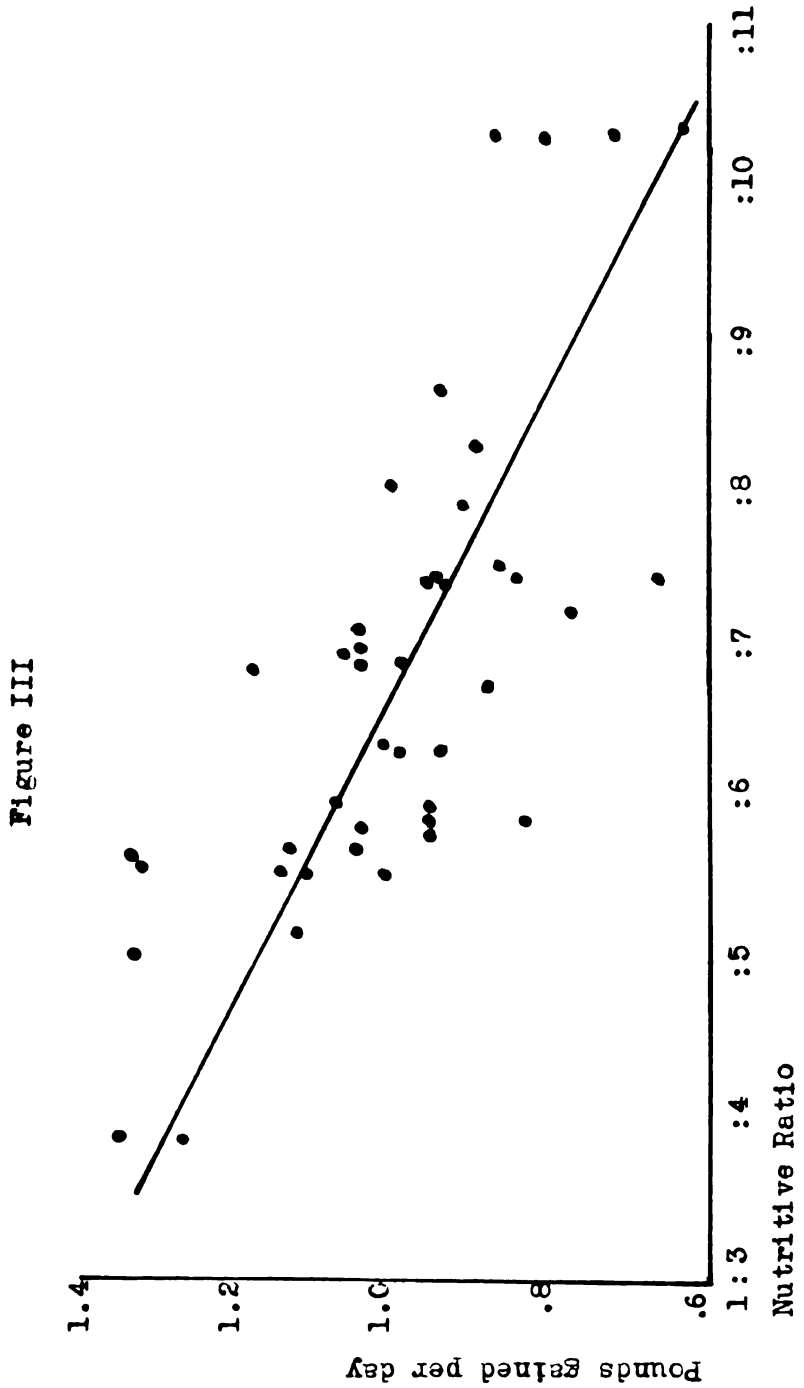
Figure I

Rate of Gain and Nutritive Ratio
Weight Group from 49 to 80 Pounds (Combined Milk Experiments).

Figure II



Rate of Gain and Nutritive Ratio
Weight Group from 40 to 48 Pounds, (Pasture Experiments).



Rate of Gain and Nutritive Ratio
Weight Group from 49 to 80 Pounds (Pasture Experiments).

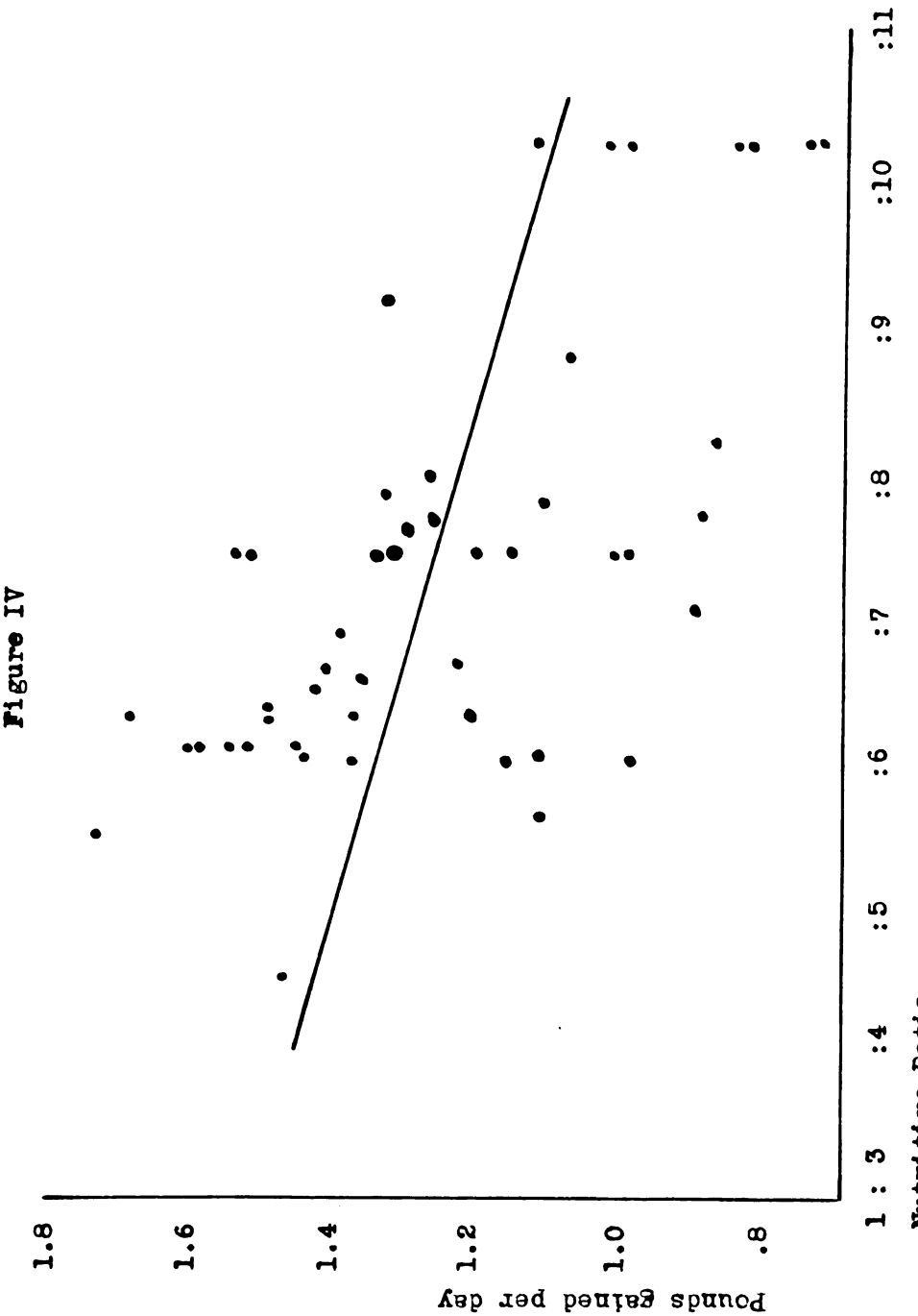


Figure IV

Rate of Gain and Nutritive Ratio
Weight Group from 81 to 120 Pounds (Pasture Experiments).

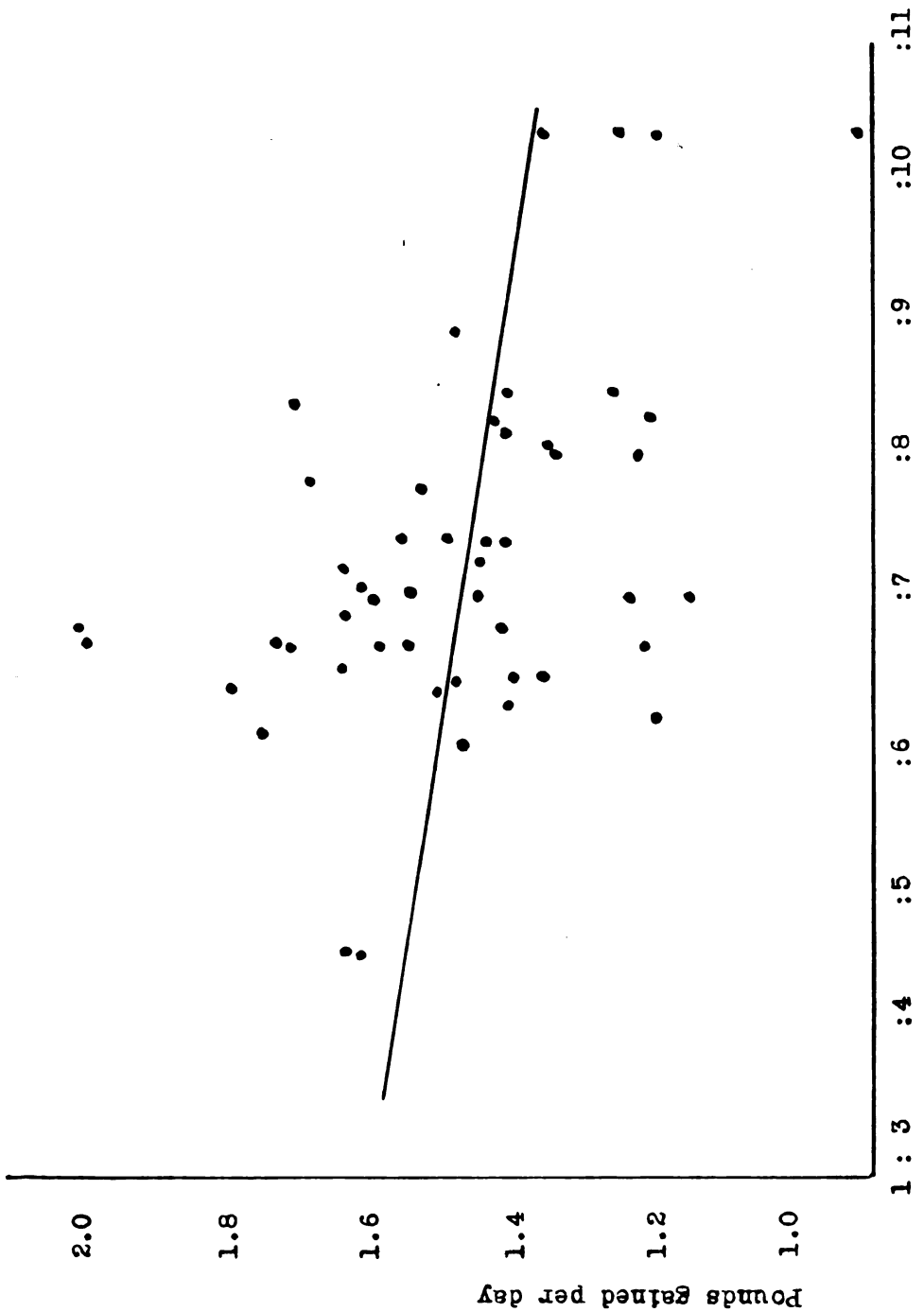


Figure V

Rate of Gain and Nutritive Ratio
Weight Group Upward from 120 Pounds (Pasture Experiments).

Discussion

When data for the entire feeding period, from weaning to market weights were computed, practically no correlation between nutritive ratio and rate of gain was found. An analysis of the factors affecting these figures shows why it was necessary to sub-divide the data into shorter feeding periods.

Under average feeding conditions, younger pigs consume a narrower nutritive ratio than older pigs, because the younger pigs require a larger proportion of protein for body development than the older, fattening pigs. As market weight is approached, there is less growth of body tissues and more fat is deposited. Therefore, as the pigs grow older and become of a heavier weight, they will require a smaller proportion of protein. Pigs fed at self-feeders, free-choice between grains and protein-rich supplements, consume wider nutritive ratios as they approach market weight.

While the young pig gains very rapidly on the basis of percentage of his weight, his feed capacity grows with him so that his daily rate of gain increases materially with age. Market-weight pigs frequently gain two pounds daily, while weanling pigs seldom average one pound of gain daily.

When the entire feeding period, from weaning to market weight, is considered, the natural change in nutritive requirement is a constantly reduced proportion of protein and the normal rate of gain shows a gradual increase. If we assume from feeding standards that high rates of gain should correlate with a narrow nutritive ratio, these two factors tend to reverse or off-set the normal relationship between rate of gain and nutritive ratio when considered over any considerable

period.

When the data was divided according to time periods, the first period showed a much better correlation than later periods. It was believed that this was due to the fact that some lots of pigs gained more rapidly than others so that grouping according to comparable time periods made each group include pigs with rather wide differences in their weights. To overcome this, the data for the time periods were grouped together according to each lot's initial weight for the period. It was necessary to make the weight group large enough to include the weight gained by the more rapid-gaining lots. Narrower weight groups would leave too many lots out of certain groups and reduce the accuracy of the computations. If complete data were available for shorter periods so that narrower weight groupings could be made, it is believed by the author that more perfect correlations would be found.

In order to visualize the results of the foregoing computations, a summary of the r_{xy} is presented by weight groups for each experiment in Table 12.

The group with an initial weight from forty to forty-eight pounds in each experiment had a correlation coefficient which was very significant, meaning that there was a very close relationship between the nutritive ratio and the rate of gain. It is a negative correlation because the rate of gain decreases as the nutritive ratio widens or becomes larger.

The correlation coefficient for the second group with an initial weight ranging from forty-nine to eighty pounds was very significant in three experiments, was less significant in the Iowa experiment, and was not significant in the Michigan experiment with buttermilk in the winter of 1935-36.

Table 12 - Summary of Correlation Coefficients

	Number of Pig-Feeding Periods	Correlation Coefficient
Michigan Pasture Experiments:		
Group I (40-48 lbs.)	96	-.72
Group II (49-80 lbs.)	510	-.75
Group III (81-120 lbs.)	640	-.66
Group IV (121-180 lbs.)	581	-.34
Iowa Experiment:		
Group I	50	-.54
Group II	65	-.36
Group III	70	-.02*
Group IV (121-240 lbs.)	70	+.10*
Buttermilk 1936-37:		
Group II	126	-.71
Group III	63	-.39
Group IV	36	+.48**
Skimmilk 1933-34:		
Group II	54	-.70
Group III	81	-.28
Group IV	27	-.57
Buttermilk 1935-36:		
Group II	56	-.19*
Group III	91	-.59
Group IV	69	-.14*
Combined Milk Experiments:		
Group II	236	-.42
Group III	225	-.16*
Group IV	132	-.17*

*Not significant.

**Significant, but reversed.

The correlation coefficient for the third group of pigs with an initial weight from eighty-one to one hundred twenty pounds showed less relationship between the nutritive ratio and the rate of gains than the preceding weight group.

The correlation coefficients were significant for four of the five experiments, but were not for the combined data of the three Michigan milk experiments and the data from the Iowa experiment.

The correlation coefficient computed for the fourth group, with initial weights upward from one hundred twenty pounds, showed less correlation. It was significant in two experiments, not significant in two, and a significant positive correlation in one experiment.

The two groups of pigs with initial weights ranging from forty to forty-eight pounds and from forty-nine to eighty pounds showed a higher correlation between the nutritive ratio and the rate of gain than the heavier-weight pigs. This should be expected because the protein supply is more likely to be a limiting factor with young pigs than with older, heavier pigs.

The four weight groups of pasture-fed pigs all showed a highly significant correlation coefficient between rate of gain and nutritive ratio. The highest coefficients were for the two lighter-weight groups, -.72 and -.75 respectively, slightly lower for the third group, -.66, and only about half as high for the heaviest-weight group, or -.34. This lowering of the coefficient may be accounted for either by the lowered need for protein, making other factors such as disease or individuality of relatively more importance than the nutritive ratio, or by the wider weight differences of this group extending over a range of 60 pounds from 120 to 180 pounds. The pigs are reported to have been especially thrifty throughout these pasture experiments.

The first weight group of the Iowa experiment had a significant correlation coefficient of -.54 and the second weight group had a significant correlation of -.36. The correlation coefficient decreased rather rapidly for the third group. It was only -.02 which was not significant. The correlation coefficient for the last group was positive, but not significant. The lack of a significant correlation coefficient for the last two groups can probably be explained by the fact that there was an abnormal decrease in the rate of gains as the pigs became heavier in seven of the ten lots. Also, the last group included lots of pigs with a wider variation in average weight, ranging from one hundred twenty to two hundred forty pounds. These pigs were on a prolonged dry-lot feeding experiment. Their ration did not include a satisfactory vitamin supplement. It appears that after having been in the experiment several periods, other factors became more important in affecting the rate of gain than the nutritive ratio.

The buttermilk and skimmilk experiments gave highly significant correlation coefficients in two cases out of three for the lighter-weight groups and for the corresponding group when the data from the three experiments were combined. The correlation coefficient for the eighty-one to one-hundred-twenty-pound group, while significant for each experiment, was not so when the data were combined from the three experiments. For the heaviest group, the coefficients were badly scattered showing a significant negative correlation as expected in one experiment, not significant in one experiment, and a reversal for the other experiment in that it had a high enough positive correlation to be considered significant.

Part of the failure of these experiments to show the expected correlation may be explained by unthrifty pigs. The pigs were winter-fed

and several became unthrifty. Several pigs were substituted. It appears that after several weeks in the dry-lot, the pigs were affected by other factors that influenced their rate of gain and interferred with the normal correlation between rate of gain and nutritive ratio.

This study would have been more comprehensive and accurate if each experiment used herein would have been especially designed for this study. Such experiments should be set up with each lot of pigs fed the same kind of feeds in varying proportions through the various feeding periods at different definite nutritive ratios.

There would probably be a higher correlation coefficient if the data had been available in shorter feeding periods so that it could have been logically divided into narrower weight groups. With fourteen-day periods, instead of twenty-eight, the number of samples would have been the same with twice as many weight groups. However, to do this with the data used in this paper would reduce the number of samples in each group below the number needed for accurate computations.

Conclusions

The study shows there was a definite relationship between the nutritive ratio of a ration and the rate of gains made by the lighter-weight pigs of this study. As the pigs are fed a narrower nutritive ratio, they tend to make more rapid gains. As the ratio widens, the gains are slower. With the exception of the pasture-fed pigs, the heavier-weight pigs of this study seemed to be affected by other factors influencing the rate of gain fully as much as the nutritive ratio.

Because of the influence of increased rate of daily gain as the pigs grow toward market weight, the relationship of nutritive ratio to rate of gain must be studied over relatively short periods to show its influence clearly.

The pasture-fed pigs gave more uniformly significant correlation coefficients between nutritive ratio and rate of gain than the dry-lot-fed pigs studied, even though no estimate of the nutrient intake from pasture was included in figuring the nutritive ratio. This may have been due to more uniform thriftiness and normal development among the pasture-fed pigs.