December 1, 1965

To the Graduate Council:

I am submitting herewith a thesis written by Yelloji Gnanoji Rao entitled "Performance of Self-fed and Limited-fed Pigs on Pasture and in Confinement." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

O C Chamberlain
Major Professor

We have read this thesis and recommend its acceptance:

Harold J. Smith

Robert L. Potter

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

PERFORMANCE OF SELF-FED AND LIMITED-FED PIGS ON PASTURE AND IN CONFINEMENT

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Yelloji Gnanoji Rao

December 1965

ACKNOWLEDGMENT

The author wishes to express his most sincere appreciation to the following persons who assisted in the preparation of this thesis:

To Dr. C. C. Chamberlain, major professor, for his critical reading of the manuscript for this thesis.

To Professor E. R. Lidvall for his valuable guidance in planning and conducting this study.

To Pat Moore and men at the farm for their assistance in the weighing of the pigs and collection of feed data for this thesis.

To Professor J. W. Cole, Dr. C. B. Ramsey, and Dr. Vernadine H. Meyer for providing slaughter, carcass, and cooking data.

To Dr. C. S. Hobbs, Head of the Animal Husbandry-Veterinary Science Department, for his encouragement.

To the secretaries of the department, the librarians, his fellow students, whose timely help has made graduate study a pleasant experience.

The computations in part of this research were done with the aid of the University Computing Center. This Computing Center was established with the aid of a National Science Foundation Grant (No. NSF-G13581).

635121

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION.	1
II.	REVIEW OF LITERATURE.	4
III.	EXPERIMENTAL PROCEDURE.	20
	Feedlot Procedure	20
	Slaughtering Procedure.	22
	Cooking Procedure	23
	Sensory Tests	24
	Shear Tests	24
IV.	RESULTS AND DISCUSSION.	26
V.	SUMMARY AND CONCLUSIONS	35
LITERATURE CITED.		37

LIST OF TABLES

TABLE		PAGE
I.	Summary of Wholesale Lard and Live Hog Prices (Chicago) and Per Capita Consumption of Lard in the U. S. A.	3
II.	Summary of Performance of Pigs Fed in Dry Lot and on Pasture.	5
III.	Results of Experiments from Hogs Receiving Various Levels of Feed	7
IV.	Composition of Ration.	21
V.	Average Weight, Age, Daily Gain, and Feed Efficiency of Pigs	27
VI.	Analysis of Variance with Mean Square Values	28
VII.	Carcass and Cooking Data from Pigs Fed in Confinement and on Pasture	30
VIII.	Simple Correlations of 25 Independent Variables.	31

CHAPTER I

INTRODUCTION

Improvement in the field of swine husbandry is needed both in the efficiency of production and the quality of product. While recent developments in this field have resulted in improvement in both the efficiency of production and carcass quality, further improvement is needed. The pork carcass being sold on the American market today still has too high a percentage of fat for maximum consumer's acceptability.

During the eighteenth and nineteenth centuries there was a world market for pork products of all types. Lard was the standard of excellence in edible fats. The average American swine breeder produced an animal in those days which did an excellent job of converting carbohydrates into edible fats and proteins. The consumer's preference has gradually changed due to a desire for lower caloric intake and the increasing availability of other meats such as beef and poultry. Recently, the repeated assertion of the relationship between animal fat and certain cardiovascular disorders have exerted considerable additional pressure upon the contemporary swine producers to produce pork with less fat.

Swine utilize concentrate feed more efficiently than other mammals. They readily convert feed into body tissue. Self-feeding high energy rations intensifies the deposition of fat. An average hog carcass contains approximately enough pork for two people for 1 year, whereas

the same carcass supplies enough lard for three people for the same period. This situation places lard in the category of a by-product. Since 1949 the wholesale price of lard has been less than the price paid for an equivalent weight of live animal as indicated in Table I.

A study of the table shows that, prior to the 1940-45 period, lard was worth more per pound than live hogs. Since that date live hogs were worth more per pound than lard, except during 1947-48. Since the 1940-46 period, there was a steady decline in the yearly per capita consumption of lard in the U. S. A.

Present thinking concerning the surplus lard problem is to reduce the amount of lard produced per animal. Scientists working on this problem have followed two general paths in their investigations. Through selection and other breeding programs, the animal breeder has strived to develop a leaner type hog which still retains rapidity of growth. Other scientists have studied the effects of regulating feed consumption and its relation to carcass quality. Research in swine nutrition has shown that the plane of nutrition exhibits an influence upon the physiological development. Concerning the latter school of thought, Morrison (1959) made the following statement:

> The net effect of limited feeding can be determined only by experiments in which pigs are fullfed in direct comparison with others that receive limited amount of the same feeds. It is important that such tests be continued until the limited fed pigs have reached market weights, which has not been done on some of the experiments on this problem.

It is the subject of this thesis to analyze the effects of regulating feed intake of the pigs under pasture and confinement systems on the rate of gain, economy of gain, carcass yield, and carcass quality.

TABLE I

SUMMARY OF WHOLESALE LARD AND LIVE HOG PRICES (CHICAGO) AND PER CAPITA CONSUMPTION OF LARD IN THE U. S. A.[a,b]

Period	Av. price of refined lard/ 100 lb. (dollars)	Av. price of hogs/100 lb. (dollars)	Per capita consumption of lard/year (pounds)
1910-19	15.10	10.69	11.46
1920-29	13.12	10.08	12.94
1930-39	8.65	7.19	12.20
1940-46	12.66	12.83	13.67
1947-48	24.10	23.80	13.30
1949-59	16.32	17.98	12.48
1960-63	14.33	15.77	10.75

[a]Livestock and Meat Statistics, 1962, U. S. Department of Agriculture, Bulletin Nos. 333, July, 1963, and August, 1964.

[b]Livestock Market News, 1955, U. S. Department of Agriculture.

CHAPTER II

REVIEW OF LITERATURE

Considerable work has been done with bacon type hogs by English investigators. Most English authors credit Americans for the initial step in studying the effects of restricted feed consumption. As early as 1926, Henry and Morrison reported on seventeen experiments conducted in Missouri, Ohio, Illinois, Kansas, and by the United States Department of Agriculture, in which hand feeding and full-feeding were compared. In their summary they concluded that full-feeding produced more rapid and efficient gains.

Ferrin and McCarty (1928) fed groups of pigs both in dry lot and on pasture. One of the groups was self-fed and the other was restricted to 50 per cent feed based on the self-fed group. The ration consisted of shelled corn, straight midlings, tankage, and minerals. Table II briefly summarizes some of the results of their experiment.

Ellis and Zeller (1934) experimented by restricting the feed allowance of growing pigs in confinement. Ration composition was 84 per cent ground yellow corn, 5 per cent alfalfa meal, 9 per cent tankage, and 2 per cent minerals. The pigs were fed at 4, 3, and 2 per cent levels for each 100 lb. of live weight. The pigs receiving 2 per cent feed had 28.88 per cent fat in the total carcass, compared to 34.12 per cent for the 3 per cent pigs, and 35.16 per cent for the 4 per cent pigs. In the

TABLE II

SUMMARY OF PERFORMANCE OF PIGS FED IN DRY LOT AND ON PASTURE[a]

Item	Dry lot		Pasture	
	Self-fed	Limited 50%	Self-fed	Limited 50%
Pounds of feed per 100 lb. of gain	404.47	479.58	350.56	399.08

[a]From: E. F. Ferrin and M. A. McCarty, Minnesota Agricultural Experimental Station Bulletin No. 248 (1928).

edible meat fraction of the carcass the values were 23.56 per cent fat, 28.54 per cent, and 30.20 per cent, respectively.

Winters, Sierk, and Cummings (1949) reported on the effect of the plane of nutrition on the economy of production and carcass quality of the lard type hog. Four lots of pigs were fed from weaning to market weights at different levels of feed intake. Group 1 was full-fed the entire feeding period. Group 2 was full-fed to 125 lb. and then restricted to three-fourths full feed to 215 lb. Group 3 was fed a ration restricted to three-fourths of the full-fed group to 125 lb. and then full-fed to 215 lb. Group 4 was fed three-fourths of a full feed throughout the entire experiment. All groups were allowed pasture. Group 4, which was fed the restricted ration throughout the feeding period, required less feed per hundred pounds of gain and decidedly less nutrients per pound of gain when the estimated feed required for maintenance was subtracted. These pigs also produced the leanest carcasses. The authors concluded that less nutrients are required to produce a pound of lean meat; consequently, the selection of breeding stock on the basis of the economy of gain should be at least somewhat effective as a means of selecting animals that will yield a lean carcass. A summary of this work appears in Table III. These data indicate that the pigs fed a limited ration throughout the entire growing-fattening period on pasture required 18 lb. less of feed to produce 100 lb. of gain than did the full-fed group. However, this group required an additional 60 days to reach an average final weight of 216 lb.

TABLE III

RESULTS OF EXPERIMENTS FROM HOGS RECEIVING VARIOUS LEVELS OF FEED[a]

Item	Lots 1	2	3	4
Method of feeding, initial to 125 lb.	Full-fed	Full-fed	3/4 full-fed	3/4 full-fed
125 lb. to market	Full-fed	3/4 full-fed	Full-fed	3/4 full-fed
Av. initial weight in pounds	42	42	43	52
Av. daily gain (lb.)	1.40	1.19	1.11	0.92
Av. final weight	217	214	215	216
Av. final age (days)	206	219	230	266
Feed per cwt. gain	383	381	391	365

[a]Data from Winters, Sierk, and Cummings (1949).

Hutchinson, Terrill, Jensen, Becker, and Norton (1957) conducted experiments to compare complete and free-choice rations fed to pigs on pasture and dry lot. One hundred and twenty weanling pigs were employed in their tests. The free-choice ration consisted of supplement and shelled corn. The complete ration was the same except that the corn was ground and mixed with the protein supplement. Alfalfa pasture was used for pigs in the pasture phase and the pigs on dry lot were kept in pens provided with concrete platforms. In both experiments, a 14 per cent complete ration was fed to pigs until they reached 100 lb. and thereafter protein level was reduced to 12 per cent. The authors found that both on pasture and dry lot the pigs fed the free-choice ration gained less rapidly than pigs fed the complete ration ($P<.01$). Pigs fed on pasture required about 1/3 lb. less supplement per pig daily than did those fed on dry lot, resulting in a saving of about 45 per cent supplement per pound of gain. The carcasses from pigs fed free choice had a higher yield of the four lean cuts ($P<.01$).

On the contrary, Lassiter et al. (1955) reported superior performance of pigs fed free choice on pasture. Hutchinson and his co-workers have attributed this improvement to the protein level in the ration. The work of Warner and Meade (1954) quoted by Hutchinson et al. shows that pigs fed free choice on pasture gained less rapidly than those fed the complete ration, when the protein supplement contained about 38.5 per cent protein. However, when the protein level in the supplement was increased to 44.4 per cent, the difference in the growth rate between free-choice and complete ration groups disappeared.

Pasture studies with swine indicate that pigs utilize limited quantities of high quality forages. However, this may be important. Morrison (1959) has stated that there are some unidentified factors in the forage and young pigs may require these factors when they are kept continuously on a concrete floor. The need for such factors in baby pig rations has been indicated by the fact that it was difficult and sometimes impossible to secure maximum growth when baby pigs were fed a highly purified ration containing all the known vitamins and mineral supplements.

Smith, Cole, and McLaren (1957) conducted eight, different feeding experiments with growing, finishing swine at the University of Tennessee, to obtain information on the use of high quality pasture. A total of 365 pigs were used in these experiments. These experiments included the following treatments: full feed in dry lot; full feed on pasture; 80 per cent of the full feed on pasture; 60 per cent full feed on pasture. Rations of corn and protein supplement were fed to the pigs in six experiments and grain sorghum and protein supplement in two experiments. Three experiments included extra treatments of corn without protein supplement. Pastures of alfalfa, Ladino clover, Louisiana white clover, button clover and rye grass, crimson clover and oats, crimson clover and rye grass were used to assess the merit of each. The authors observed that pigs receiving a full feed of concentrates including protein supplement on pasture made faster gains, reached market weight sooner, and required less concentrates per 100 lb. of gain than pigs on full feed in dry lot. Carcasses of pigs on a full feed of

concentrates, whether in dry lot or on pasture, were about the same in desirability. Pigs on pasture receiving 80 per cent and 60 per cent of a full feed of concentrates made lower daily gains and required longer time to reach market weight than their counterparts. However, they required less concentrates for each 100 lb. of gain as compared to the pigs on full feed, either in dry lot or on pasture. Dressing percentages of pigs fed limited amounts of concentrates were lower than those on full feed. But limited-fed pigs produced leaner carcasses with less backfat, less fat trim, and a higher percentage of primal cuts. Growth rate, feed requirement, and carcass quality were similar for pigs fed either corn or grain sorghum with protein supplement. The six different pastures used in these experiments produced similar results in terms of growth rate, concentrate requirement for 100 lb. gain and carcass characteristics.

The authors predicted that the superior performance of the full-fed pasture group over the full-fed dry lot may be due to some unidentified factors that may be present in the green forage.

Experiments of Mansfield and Trehane quoted by Sharrock (1940) were designed to compare full feeding with restricted feeding of swine. Restriction of feed intake was limited to 75 per cent of the full-fed group between 65 to 100 lb. of live weight and was further reduced to 66 per cent from 100 to 200 lb. live weight. The authors observed that both economy of feed conversion and grading results improved by lower level of feeding. In another comparison carried out by the same experimenters, the quantity of ration of the restricted group was not

based on the full-fed pigs but was increased daily in accordance with the schedule fixed by the authors, starting with 3 lb. per head per day at 60 lb. and ending with 5.3 lb. when the animals reached about 200 lb. live weight. Though the results of these experiments were inconclusive, 14 of the restricted pigs showed soft fat, which according to the authors was due "to the combination of slow fattening and very cold weather conditions."

The effects of plane of nutrition on the body development and carcass quality of pigs were studied by McMeekan (1940). Twenty, closely inbred pigs were allotted to five replications and four treatments viz., a high rate of feed intake throughout (H.H.); a high intake rate followed by a low intake rate (H.L.); a low followed by a high rate (L.H.); and low rate throughout the period (L.L.), so as to afford comparison between animals of same weight and age. The author noticed that H.H. and L.H. were similar with a greater proportionate development of the late developing parts of the body in comparison with H.L. and L.L., which showed proportionately greater development of the early developing parts. As growth proceeded, the competitive capacity of late developing tissues increased even under continued undernourishment. According to the author, this was due to the proportionately greater decline in the growth intensity with age of the earlier developing parts. All tissues showed recuperative capacity following undernourishment when ample nutritive supplies were provided. This response was relatively greater in respect to late developing tissues than early. There was a marked sex difference in that barrows had less bone and muscle and more

fat than gilts. According to the author, the extent of this difference could be modified by adjusting the plane of nutrition which influences the rate of growth, but alteration in the absolute rate of growth of any tissue by nutrition cannot exceed a maximum.

McMeekan's scheme of restricting feed to hogs for the latter part of the feeding period was studied by Crampton, Ashton, and Lloyd (1954). The results of a long term study of nutritional factors affecting bacon carcass characteristics have been reported by the authors. In their experiment 120 purebred Yorkshire pigs, weaned at 56 days of age and at initial weights of 35-40 lb. were used. During the growing period from 35 to 110 lb. live weight, all pigs were full-fed a 16 per cent ration consisting of barley and a protein-mineral supplement. During the finishing period, i.e., from 110 lb. to a market weight of 200 lb., the same ration was used with the exception that the protein was reduced to 13 per cent. Half the pigs were continued on full feed and the other half reduced to approximately 75 per cent of the intake of the full-fed group. The authors noted that the average daily feed intake and average daily gains of both groups of pigs, up to 110 lb., were approximately the same. After this period, an average reduction in growth rate of 0.45 lb. per day was noted. This caused an increase in the total feeding period of about 2 weeks. The most interesting observation was that feed efficiency was the same for the full-fed and restricted groups. Restriction in feeding increased the size of the loin muscle. Fifty-eight per cent of the pigs full-fed during the winter graded "A," whereas 70 per cent of the pigs on restricted feed intake attained

this grade. The authors concluded that a reduction of roughly 25 per cent in the growth rate during the latter phase of the growth period is essential for producing top quality carcasses. They advocated that the best way to achieve this objective is to restrict the feed intake during the finishing period.

Sharrock (1940) reported a summary of the results of twenty-two experiments involving four hundred pigs collected from experimental stations all over England and Ireland. In these experiments the same general plan was followed. The pigs were all full-fed to 100 lb. Afterwards, three levels of feeding were followed. One group was full-fed the entire feeding period. A second group received 80 per cent of the full feed. A third group received 70 per cent of the full feed. In general, restricted feeding led to a slower rate of growth and an increase in the fattening period of about 8 to 10 days. Furthermore, the restricted groups were more efficient in their feed utilization. However, the author concluded that the restriction of feed had little, if any, effect on carcass quality.

Crampton (1940) studied the relationship between rate of gain and carcass quality. He found no statistical evidence that the rate of gain in live weight affected either the length of bacon carcasses or their leanness. There was no evidence that the pigs that ate the least or gained the least during the growth period had carcasses any different from the average insofar as length or leanness was concerned. He concluded that differences in rate of gain of healthy young pigs in a given

herd or on a given feeding standard cannot be safely taken as an index to probable carcass quality.

Donald (1940) analyzed a series of carcass reports with the purpose of determining the relationship between variation in growth rate and carcass quality. In normally raised pigs, it appears that variations in growth rate are not reliable measures for predicting carcass quality. From his study, he concluded that after weaning, limited changes in growth affect carcass measurements and quality to a very limited extent. These effects are small and inconsistent.

Dickerson (1943) studied the relationship of rate of growth and feed utilization with carcass yields and measurements. The data were collected from 50 Poland China, 108 Danish Landrace, and 54 Poland-Landrace crossbred pigs. Dickerson reported a correlation of +0.60 or more between rate of gain and degree of fatness and a negative correlation of -0.60 to -0.70 between rapid fat deposition and feed requirements. He concluded that hogs which are selected for a fast rate of gain and for more economical gains will produce fatter carcasses. Dickerson and Gowen (1947) conducted an experiment with mice to study the relationship between carcass quality and efficiency of gain. They found a strain of mice that tended to be more obese and less active than other strains. This strain made greater gains on less feed. The authors suggested that possibly a genetic makeup such as this exists in fast gaining strains of hogs, sheep, and cattle. The study indicated that individuals that gain fast and utilize feed efficiently do not produce the best carcasses. In conclusion Dickerson makes this statement, "Rapid fat deposition

and low feed requirements tended to be caused by the same genes, ..."

Blunn and Baker (1947) studied the relationship between rate of gain and depth of backfat. Blunn and Baker obtained a correlation value only about one-half that of Dickerson's and suggested that a breed difference may exist in the relationship between fatness and rate of gain.

Hammond and Murray (1937) stated that the live weight of the pig influenced carcass percentage more than breed or type. The authors suggested that an optumum carcass percentage of 79 per cent and an optimum yield of the English "Wiltshire side" of 58 per cent in bacon type hogs be established. They found that if percentages were higher than these figures, the carcasses would not be desirable because they would contain too high a percentage of fat, and if below these percentages, the bone content would be too high. By statistical analysis they demonstrated that as length of side increased, with weight held constant, the thickness of the backfat decreased. There was no similar effect on the thickness of the bacon side.

Bull and Olson (1935) stated that carcasses from barrows and gilts were about equal in the quality of pork produced. In percentage of fat and yield of the primal cuts, there was no significant difference between barrows and gilts.

Hammond and Murray (1937) studied the differences of carcasses from barrows and gilts. They found that gilts had thicker bellies and thinner back fat than barrows. When either sex were castrated, there

was an increase in backfat thickness and, in the females, a decrease in belly thickness.

Bennett and Coles (1946) reported that barrows produced carcasses with thicker backfat than gilts. They concluded from their study that gilts consistantly produce higher quality carcasses than barrows.

Brugman (1950) reported that the carcass qualities of swine can be changed by limiting the feed intake to 70 per cent of full feed up to 150 lb. After 150 lb., the hogs were full-fed to a market weight of 200 lb. He found that the pigs fed a limited ration to 150 lb. produced a significantly higher percentage of the five primal cuts and a lower percentage of total lard produced than the groups of pigs full-fed throughout the entire growing, fattening period.

Engelman, Dowell, Ferrin, and Anderson (1950) studied methods of marketing hogs by carcass weight and grade. For their evaluation the authors used several carcass measurements including average backfat thickness, length of the body, length of ham, thickness through shoulders, thickness through hams, and belly packet thickness. An "index of lean" was obtained by calculating the percentage of ham, loins, bellies, picnics, butts, and lean trimmings in the carcass. Statistical analysis revealed that average backfat thickness was the best single measure for explaining variations in the index of lean, body length was second, and other measurements were less important. The use of average backfat thickness and length gave little improvement in evaluation over backfat thickness alone.

Aunan and Winters (1949) studied the variations of muscle, fat, and bone of swine carcasses. The authors found that the area of the lean of the loin was associated with the lean content of the carcass. Uniformity of backfat did not have any significant relationship with the lean content of the carcass or the yield of the five primal cuts.

Aunan described a probing device which was designed for estimating the amount of fat and lean tissues and the percentage of five primal cuts in swine carcasses. He found that the fifth and sixth rib probe of the belly gave the highest degree of association with lean content of the carcass and the lean content of each of the five primal cuts. The author found a high degree of association between the ratio of fat to lean tissue of the probe and the ratio of fat to lean tissue of the carcass. The author suggested that the probing technique provides an excellent method for the evaluation of the proportion of fat and lean tissue in a swine carcass for breeding or nutritional experiments. However, the author stated that the time involved in weighing the samples from the probing technique may limit its use commercially.

Hazel and Kline (1951) reported that backfat thickness could be measured readily on live hogs by making a shallow transverse incision through the skin of the back. A blunt, narrow metal ruler was then placed through the soft backfat to the firm tissue underneath. Correlations between the averages of four carcass measurements of backfat and percentage of primal cuts, lean and loin area were -0.35, -0.23, and -0.14, respectively.

Robinson (1946) reported a study on the influence of the rate of fat deposition on the firmness of the fat of hogs. He stated that the pigs whose daily feed was limited to approximately 2.75 per cent of their weight made greater gains per unit of feed consumed than did the self-fed pigs. The carcasses of the limited-fed hogs contained a higher percentage of loin and of trimmed ham and a lower percentage of fat cuts than the carcasses of the full-fed hogs of similar weight. The fat of the rapid gaining hogs was slightly firmer than the fat of hogs which had gained more slowly measured by refractive index readings.

Clawson and Otto (1965) have reported the effect of feed processing for limited and full feeding of market hogs. Their experiment included two trials--winter 1963-64 and summer 1964--and six treatments: (1) free choice of shelled corn and supplement; (2) a ground and mixed ration; (3) a similar ration, pelleted; and (4, 5, 6) the same as 1, 2, and 3, respectively, except that they were limited-fed. Both the limited-fed and full-fed groups were full-fed the respective ration until about 120 lb. During the remainder of the test, the limited-fed group was given 5 lb. of feed per head per day and the free-choice pigs 4 lb. of corn and 1 lb. of protein supplement. Results showed that limited-fed pigs grew slower. There was a reduction in backfat thickness and an increase in the number of U. S. No. 1 carcasses. The limited-fed pigs grew slower, with daily gains ranging from 1.10 to 1.20. Full feeding not only minimized the time required to reach the market weight but also the amount of feed required to produce a pound of gain. In the first trial, daily gain figures showed an advantage for

the full-fed pelleted ration, i.e., 1.73 compared with 1.51 free choice and 1.65 for the mixed ration.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. FEEDLOT PROCEDURE

This study included 48 pigs from the 1963 spring farrowing season. The pigs used were purebred Duroc barrows and gilts from the Tennessee Agricultural Experiment Station, Blount Farm, Knoxville. One was lost during the study so the data from the remaining 47 were utilized. Both the female and male pigs were randomly selected for use and the barrows were castrated at about 3 weeks of age. The pigs were started on test at an average weight of 64 lb., at approximately 76 days of age, and fed to a live weight of about 210 lb.

Six pigs, three barrows, and three gilts were lotted per each one-half acre pasture lot. Pasture consisted of an excellent first-year stand of Ladino clover and orchard grass. The lots were equipped with automatic waterers and portable housing for shade. Pigs were fed on a 14 per cent protein ration until they reached a weight of about 100 lb., and then a 12 per cent protein ration was fed for the remainder of the experiment.

Pigs fed on concrete platforms were provided housing similar to that used in the pasture lots. These pigs also had free access to automatic waterers. They were started on a 16 per cent protein ration and changed to a 14 per cent ration when the pigs averaged 100 lb. in weight. The composition of ration is shown in Table IV.

TABLE IV

COMPOSITION OF RATION

Ingredient	Ration (lb.) 16% protein	14% protein	12% protein
No. 2 yellow corn	751	811	861
Soybean oil meal (44%)	150	100	70
Tankage (55%)	50	40	25
Dehydrated alfalfa meal (17%)	30	30	25
Dicalcium phosphate	10	10	10
Salt	5	5	5
Tracemineral premix[a]	1	1	1
Antibiotics[b]	1	1	1
Vitamin premix[c]	2	2	2
	1000	1000	1000

[a]Provides an addition to the ration of 100 p.p.m. of Mn, 1 p.p.m. Co, 100 p.p.m. Fe, 10 p.p.m. Cu, and 100 p.p.m. Zn.

[b]Contains 10 gm. chlorotetracycline per pound.

[c]Provides an addition to the ration of 2 gm. of riboflavin, 4 gm. pantothenic acid, 9 gm. niacin, 10 gm. choline, 10 mg. B_{12}, 500,000 I.U. Vitamin A, and 250,000 I.U. Vitamin D.

Limited-feeding was started when the pigs reached an average weight of 135 lb. At the start of limited-feeding, they were fed at the rate of 5 lb. per head per day for the first 2 weeks, and the quantity was raised to 5.5 lb. during the subsequent 2 weeks. From this period, till the pigs reached market weight, they were fed at the rate of 6 lb. per head per day. This feeding program provided a feed intake of about 80 per cent that of the full-fed pigs.

All pigs were wormed with Piperazine at the start of the experiment and again 25 days later. No cooling system was provided for either the pasture or concrete pens.

II. SLAUGHTERING PROCEDURE

Procedure accepted by the Reciprocal Meat Conference (1952) was followed for the evaluation of carcass traits. As the pigs reached an off-feed weight of approximately 210 lb., they were trucked eight miles from Blount Farm to The University of Tennessee Meat Laboratory, at weekly intervals, for slaughter. They were allowed a 24-hour shrinkage period without feed but had free access to water. A shrunk slaughter weight was taken just prior to slaughter.

The warm carcasses were sawed down the center of the back and allowed to hang in a thermostatically controlled, 38°F. cooler for 48 hours before cutting. After chilling, carcass length was measured from the anterior end of the first rib to the anterior edge of the aitch bone. Backfat thickness, including skin, was measured to the nearest millimeter over the vertebral column at the first rib, last rib, and last

lumbar vertebra. The first rib, last rib, and last lumbar measurements were averaged to obtain the average backfat thickness. Backfat thickness was adjusted to a standard weight of 200 lb. according to the method described in the University of Tennessee Special Circular 498.

Weights of both sides of the carcass were recorded to the nearest 0.1 lb. Weights of cuts were recorded to the nearest 0.1 lb. A tracing was made of the cross section of the l. dorsi muscle between the tenth and eleventh ribs and measured to the nearest 0.01 sq. in. with a compensating planimeter.

Dressing per cent was calculated on a chilled carcass and shrunk slaughter weight basis. The weights of the skinned ham, trimmed loin, ham and loin combined, skinned "New York" shoulder, and lean cuts were doubled and expressed as a per cent of the total chilled carcass weight. Marbling was subjectively evaluated in the cut surface of the l. dorsi muscle at the tenth rib and given a numerical score.

III. COOKING PROCEDURE

The thawed loin and rib chops were placed on wire racks in shallow pans after applying salt. As soon as the holding period was complete, the meat was broiled in electric ovens of 30-inch household electric ranges. The ovens were preheated for 20 minutes at 425°F. with doors closed. Just prior to putting the meat into the ovens, the controls were turned to the "Broil" position. All chops were broiled simultaneously. The doors were left ajar in the broiling position while the meat was cooking.

Meat thermometers were used to determine the internal temperature of the chops. The chops were cooked on one side to an internal temperature of 183°F., approximately the "well done" stage usually recommended for pork. The chops were weighed 10 minutes after removal from the oven to determine cooking losses.

IV. SENSORY TESTS

During the test a panel of six judges, five of whom were experienced in scoring pork, scored the meat for flavor, juiciness, and tenderness.

Scoring was done on a 9-point scale, with the points defined as follows:

9 - Excellent

8 - Very good

7 - Good

6 - Fair plus

5 - Fair

4 - Fair minus

3 - Poor

2 - Very poor

1 - Extremely poor.

V. SHEAR TESTS

Shear values for all chops were measured by the Warner-Bratzler mechanical shear, using cores one-half inch in diameter, cut parallel to

the muscle fibers. Two cores were obtained from each chop, one from the medial half and one from the lateral half. Each core was sheared once and the two values were averaged.

CHAPTER IV

RESULTS AND DISCUSSION

The data in Table V shows no differences in the average weight nor in the age in days at the start of the limited-feeding period. This indicates that all the pigs had performed similarly up until the beginning of the limited-feeding phase. Thus, any differences that might develop would be due to the limited-feeding phase of the experiment. The only difference up to the limited-feeding phase was a significant reduction in the feed consumed per cwt. of gain in favor of the pigs on pasture. The pasture forage consumed by the pigs apparently caused a reduction in the amount of concentrate consumed

The analysis of variance is shown in Table VI. Data as presented in this table indicates a highly significant difference in average daily gain between those pigs on full-feed and those on limited-feed during the limited-feeding period. This was as expected. However, when the average daily gain over the entire period is considered, the differences were not significant. Thus any differences in production or in carcass traits would be due to the difference obtained in the average daily gain during the limited-feeding period.

The comparison between the pigs on pasture and those in confinement indicates that pigs on pasture required significantly less feed per cwt. of gain during both phases of the experiment. The improvement in

TABLE V

AVERAGE WEIGHT, AGE, DAILY GAIN, AND
FEED EFFICIENCY OF PIGS

Item	Confinement		Pasture	
Start to L.F.	Full-fed	Full-fed	Full-fed	Full-fed
L.F. to market	Full-fed	Limited-fed	Full-fed*	Limited-fed
No. of lots	2	2	2	2
No. of pigs/lot	6	6	6	6
Av. weight in lb.				
Initial	56.6	55.5	55.7	55.5
Start to limited feed	137.5	135.0	131.1	133.6
Final	206.6	209.2	210.7	209.8
Av. age in days				
Initial	75.7	75.1	75.7	75.6
Start to limited feed	122.1	122.1	122.7	122.6
Final	159.0	173.3	162.8	167.4
Av. daily gain (lb.)				
Start to limited feed	1.75	1.70	1.63	1.68
Limited feed to market	2.04	1.45	1.99	1.71
Start to market	1.87	1.57	1.80	1.69
Feed/cwt. gain (lb.)				
Start to limited feed	290.00	290.00	282.00	273.00
Limited feed to market	359.00	386.00	335.00	326.00
Start to market	323.00	336.00	309.00	299.00

*One pig was removed from this group for reasons other than treatment.

TABLE VI

ANALYSIS OF VARIANCE WITH MEAN SQUARE VALUES

		Average daily gain			Feed efficiency			Average daily feed consumption			Backfat	
	d.f.	Lot-L.F.[a] M.S.	L.F.-Mkt.[b] M.S.	Lot-Mkt.[c] M.S.	Lot-L.F.[a] M.S.	L.F.-Mkt.[b] M.S.	Lot-Mkt.[c] M.S.	Lot-L.F.[a] M.S.	L.F.-Mkt.[b] M.S.	Lot-Mkt.[c] M.S.	Unadjusted backfat M.S.	Backfat adjusted to 200 lb. M.S.
Total	46											
Between lots	7	0.048	0.449	0.120	0.494	0.494	0.163	0.498	4.124	1.144	0.633	0.419
Location	1	0.063	0.167	0.014	0.180*	2.076*	0.781	2.076	1.336	1.524	0.651	0.175
Level	1	0.000	2.339**	0.454	0.028	0.104	0.002	0.059	23.410**	4.738*	2.413	1.131
L x L	1	0.028	0.221	0.121	0.020	0.377	0.161	0.059	0.903	0.185	0.004	0.012
L/L x L	4	0.061	0.101	0.064	0.021	0.212	0.045	0.327	0.921	0.434	0.326	1.599
Within	39	0.024	0.032	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.162	0.123

[a]Lotting to limited-feeding.

[b]Limited-feeding to market.

[c]Lotting to market weight.

*Significant at ($P<0.05$).

**Significant at ($P<0.01$).

feed efficiency over the entire experiment, from beginning of the test to market weights, was significant.

None of the other differences in production traits as shown in Table V, page 27, nor the differences in carcass or cooking traits as shown in Table VII were significantly different.

Simple correlations, using the entire sample of 47 pigs, were run on 25 traits. The data is presented in Table VIII. In these data a correlation value of 0.288 was significant ($P<0.05$), and a value of 0.372 was highly significant ($P<0.01$).

This experiment indicated that there was a highly significant positive correlation between off-test weight and carcass length (0.378). The same was true with the unadjusted backfat value (0.443). However, when the backfat was adjusted to 200 lb. live weight, there was a decrease in the correlation from the unadjusted weight (0.443 to 0.294). The latter was significant. The correlation between loin eye area and off-test weight (0.102) was nonsignificant. Thus two of the three carcass measurements used in certification procedures for swine (length and backfat) showed significant correlation with weight at slaughter.

In this study, there was a negative correlation (-0.239) between off-test weight and age in days when removed from test. With pigs on limited-feeding to market, there was a highly significant correlation (0.560) between the average backfat and the average daily gain. This coupled with a significant negative correlation (-0.309) between average backfat and market age indicated that the younger, faster growing pigs had a tendency to deposit more external fat.

TABLE VII

CARCASS AND COOKING DATA FROM PIGS FED IN CONFINEMENT AND ON PASTURE

Item	Pasture		Confinement	
	Self-fed	Limited-fed	Self-fed[a]	Limited-fed
Carcass Data				
Av. final live wt. in lb.	210.7	209.8	211.8	209.2
Av. total carcass wt. (lb.)[b]	146.5	144.5	146.1	145.7
Dressing percentage	74.2	72.4	72.8	73.4
Carcass length (cm.)	75.7	76.0	76.2	77.4
Av. backfat (cm.)	4.00	3.53	3.74	3.30
Av. backfat adjusted to 200 lb. (cm.)	3.62	3.34	3.53	3.19
Av. loin eye area (sq. in.)	3.86	3.67	3.60	3.68
Av. marbling score	8.00	6.80	7.75	6.50
Av. grade	1.16	1.30	1.20	1.00
Av. ham+loin (%)	35.00	35.50	34.20	35.70
Av. ham+loin+shoulder (%)	52.70	53.10	51.30	53.40
Cooking Data				
Av. shear score	11.3	10.2	11.4	12.7
Av. tenderness	7.7	7.9	7.4	7.0
Av. juiciness	6.5	6.2	6.6	6.5
Av. flavor	7.6	7.6	7.4	7.6
Av. cooking loss	28.5	30.0	28.6	29.0
Av. evaporation loss	21.2	22.6	20.4	21.3
Av. drip loss	7.3	7.4	8.2	7.7

[a]One pig was removed from this group for causes not related to treatment.

[b]All pigs were held off feed for 24 hours before slaughter.

TABLE VIII

SIMPLE CORRELATIONS OF 25 INDEPENDENT VARIABLES

Traits	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
(1) Off-test weight	0.38	0.44	0.29	0.82	-.19	0.10	-.18	0.02	-.30	-.36	0.11	-.28	-.24	0.33	0.41	0.40	0.32	0.47	-.03	-.15	-.08	0.14	0.08	0.15
(2) Carcass length		-.12	0.22	0.44	-.08	0.18	-.16	0.16	0.05	-.34	-.02	-.19	0.08	0.28	0.20	0.22	-.29	-.11	0.08	0.14	0.18	0.21	-.29	-.10
(3) Av. backfat			0.82	0.42	0.14	0.08	0.13	0.18	-.36	0.07	0.03	-.06	-.31	0.04	0.25	0.20	0.56	0.54	-.04	-.35	-.30	-.07	0.41	0.26
(4) Backfat adjusted				0.28	-.03	0.04	0.26	0.22	-.54	0.16	-.07	0.02	-.40	0.10	0.30	0.36	0.49	0.56	-.02	-.27	-.22	0.09	0.44	0.34
(5) Total carcass wt.					-.18	0.36	-.23	0.40	0.14	-.28	-.06	-.26	-.07	0.19	0.33	0.28	0.12	0.26	0.07	0.01	0.07	0.03	0.05	0.07
(6) Marbling score						-.19	-.30	-.03	-.08	0.19	0.27	0.14	0.05	-.18	-.06	0.25	0.18	0.00	0.29	0.15	0.16	-.07	0.36	0.25
(7) Loin eye area							-.04	0.48	0.58	0.07	-.55	-.03	-.12	0.05	0.02	0.14	0.02	0.13	-.08	-.10	-.07	-.03	0.04	0.04
(8) Grade								-.16	-.25	0.35	-.11	-.01	-.21	0.03	-.09	0.01	0.22	0.17	-.17	-.27	-.28	0.13	0.15	0.13
(9) Dressing %									0.10	-.04	-.26	-.10	-.06	-.02	0.10	0.08	0.03	0.09	0.15	0.12	0.16	-.07	0.13	0.09
(10) Ham+loin+shoulder %										-.04	-.29	0.08	0.22	-.06	-.24	-.19	-.36	-.37	-.15	0.01	-.02	-.16	-.34	-.32
(11) Tenderness											-.10	0.52	0.03	-.28	-.07	-.12	0.06	0.03	-.25	-.24	-.31	-.34	0.03	-.14
(12) Juiciness												0.13	0.16	-.13	-.12	-.22	0.12	-.08	0.25	0.15	0.17	0.03	0.13	0.10
(13) Flavor													0.33	-.34	-.21	-.21	-.20	-.26	-.03	0.05	0.01	-.31	-.24	-.32
(14) Market age														-.72	-.38	-.60	-.72	-.84	0.14	0.42	0.29	-.46	-.51	-.63
(15) Wt. when lotted															0.23	0.45	0.22	0.39	-.22	-.28	-.15	0.53	0.08	0.37
(16) At start of L.F.																0.81	0.13	0.49	0.15	0.10	0.09	0.22	0.10	0.12
(17) A.D.G. lot to L.F.																	0.18	0.63	0.03	-.04	0.01	0.45	0.10	0.26
(18) A.D.G. L.F.-mkt.																		0.86	-.04	-.44	-.35	0.12	0.73	0.62
(19) A.D.G. lot-mkt.																			-.08	-.40	-.31	0.26	0.59	0.59
(20) F.E. lot-L.F.																				0.82	0.88	0.51	0.44	0.50
(21) F.E. L.F.-mkt.																					0.97	0.31	-.01	0.09
(22) F.E. lot-mkt.																						0.43	0.10	0.24
(23) Av. D.F.C. lot-L.F.																							0.36	0.68
(24) Av. D.F.C. L.F.-mkt.																								0.91
(25) Av. D.F.C. lot-mkt.																								

A significant negative correlation (-0.350) between average backfat and feed efficiency, coupled with a highly significant positive correlation (0.406) of average backfat to average daily feed consumption indicated that pigs which consumed more feed per day had higher backfat value and required less feed per unit of gain.

There was a negatively significant correlation in the limited-fed pigs during the limited-feeding phase of average carcass length of the pigs to both average daily gain (-0.294) and average feed consumption (-0.293).

Neither average daily gain nor feed efficiency showed any significant correlation to loin eye area. Though there was no significant correlation between loin eye area and off-test weight, there was a significant correlation (0.364) between loin eye area and total carcass weight, and a highly significant correlation between loin eye area and per cent of ham + loin + shoulder (0.578). The influence of rapid growth and high rate of feed consumption on the reduction of the per cent yield of ham + loin + shoulder is indicated by the negatively significant correlations of it to the average daily gain (-0.356) and average feed consumption (0.344) during the limited-feeding phase of the experiment.

Correlation between the weight of the pigs when lotted and average daily gains from lotting to limited-feeding (0.454) and also from lotting to off-test period (0.390) were highly significant. This indicated that the initial weight of the pigs at the start of the experiment influenced average daily gain. Average daily gain was highly correlated (0.452)

with both average feed consumption from lotting to limited-feeding and also from limited-feeding to market weight (0.862).

There was a highly significant reduction in average daily gain when pigs were placed on limited-feeding as indicated by a negative correlation (-0.402) from limited-feeding to market weight. Average daily gain showed a highly significant correlation (0.593) with feed consumption. This showed that pigs gained less rapidly during their limited-feeding regime. This resulted in an increase of the amount of feed required per unit of gain (decline in feed efficiency) as the average daily gain declined. This was due to an increasing percentage of the ration, consumed by the pigs during the limited-feeding phase, being required for maintenance with less feed being available for production. There was a highly significant correlation (0.509) between feed efficiency and feed consumption, indicating that the amount of feed required per unit of gain decreased (increase in feed efficiency) when daily feed consumption increased. This was because the additional quantity of feed, over and above the maintenance requirement, was utilized by the pigs for production, as was evident from their rapid gains.

There was no significant difference in the average daily gains from start to limited-feeding as all the animals were under the same treatment during this period. However, there was a highly significant difference in the average daily gains between full-fed and limited-fed groups from the time the level of feed intake was changed till the pigs attained final weight. When the entire feeding period, lotting to

market, is taken into consideration, the difference approached significance ($P<0.10$).

The pigs on pasture ate significantly less concentrates than those in confinement per 100 lb. of gain during the entire experimental period. Thus, the total feed efficiency for the entire feeding period was significantly improved (less feed per hundred weight of gain) for the pasture group as compared to the confined groups of pigs.

CHAPTER V

SUMMARY AND CONCLUSIONS

An experiment was conducted using 48 Duroc pigs, 24 barrows and 24 gilts, to determine whether limiting the feed intake of the pigs during the latter part of the feeding trial would have any effect on production traits, on carcass traits, or on the meat when it was prepared for human consumption. Data were compiled and then analyzed by analysis of variance and correlation methods.

The experimental design was a two by two factorial. Half of the pigs were fed in confinement on concrete platforms and the other half were fed on pasture. Within each of these groups half of the pigs were full-fed to market weights, while the other half were full-fed to approximately 135 lb. and then limited in their feed to approximately 80 per cent of that consumed by the full-fed group.

Up to the beginning of limited-feeding phase the average daily gain, average weight, and average age in days were not different. The pigs on pasture consumed significantly less feed per cwt. of gain than did those in confinement. Thus, the difference obtained should be due to the limited-feeding phase.

The average daily gain of the limited-fed pigs during the period of feed restriction was significantly less than those full-fed during this period. The feed required per cwt. of gain was significantly less during both the full-fed and the limited-fed periods for the pigs on

pasture than for those in confinement.

There was a positive, significant correlation between off-test weight and both carcass length and backfat. In the latter case, there was significance for both the unadjusted backfat and the backfat adjusted to a 200 lb. weight. The correlation between off-test weight and loin eye area was not significant.

The younger, faster growing pigs had a tendency to deposit more fat as indicated by a significant negative correlation between off-test weight and age in days at the end of the test; and a significant negative correlation between backfat and market age in days.

With a higher average daily feed consumption, pigs gained at a more rapid rate, deposited a thicker covering of backfat and required less feed per unit of gain. This was indicated by a significant correlation between backfat and average daily feed consumption and a significant negative correlation between backfat and feed efficiency.

Limiting the feed to 80 per cent of that of the full-fed pigs resulted in a significant decrease in average daily gain and average daily feed consumption.

Loin eye area was significantly correlated with total carcass weight and the per cent of ham, loin, and shoulder in the carcass. However, there was a reduction in the percentage of ham, loin, and shoulder with an increase in average daily gain as indicated by a significant negative correlation between average daily gain and per cent of ham, loin, and shoulder.

LITERATURE CITED

LITERATURE CITED

Aunan, W. J. and L. M. Winters. 1949. A study of the variations of muscle, fat and bone of swine carcasses. J. Animal Sci. 8:182.

Bennett, J. A. and J. H. Coles. 1946. A comparative study of certain performance and carcass characteristics of Yorkshire barrows and gilts. Scientific Agr. 26:265.

Brugman, H. H. 1950. The effect of the plane of nutrition on the carcass quality of a line of swine based on a Chester White and Danish Landrace cross. J. Animal Sci. 9:602.

Blunn, Cecil T. and M. L. Baker. 1947. The relation between average daily gain and some carcass measurements. J. Animal Sci. 6:524.

Bull, S., F. C. Olson, G. E. Hunt and W. E. Carroll. 1935. Value of present day swine types in meeting changed consumer demand. Illinois Agr. Exp. Sta. Res. Bul. 415:259.

Clawson, A. J. and C. H. Otto. 1965. Effect of feed processing for limited and full-feeding of market hogs. Feed Stuffs F.6.65.37:49+.

Crampton, E. W. 1940. Effect of early rate of growth on leanness of carcass. Scientific Agr. 20:592.

Crampton, E. W., G. E. Ashton and L. E. Lloyd. 1954. The effect of restricting feed intake on market hogs. J. Animal Sci. 13:321.

Dickerson, G. E. 1943. Changes in hog carcasses associated with genetic superiority in economy of gain. J. Animal Sci. 2:357.

Donald, H. P. 1940. Growth rate and carcass quality in bacon pigs. A study of polynomial coefficients fitted to growth rate data. J. Agr. Sci. 30:382.

Ellis, N. R. and J. H. Zeller. 1934. Effects of quantity and kinds of feed on economy of gain and body composition of hogs. U.S.D.A. Tech. Bul. 413:1.

Engelman, G., A. A. Dowell, E. F. Ferrin and P. A. Anderson. 1950. Marketing slaughter hogs by carcass weight and grade. Minnesota Agr. Exp. Sta. Res. Bul. 187.

Ferrin, E. F. and M. A. McCarty. 1928. Shall growing pigs be full fed? Minnesota Agr. Exp. Sta. Res. Bul. 248:10.

Hammond, John and G. N. Murray. 1937. The body proportions of different breeds of bacon hogs. J. Agr. Sci. 27:394.

Hazel, L. N. and E. A. Kline. 1951. Mechanical measurement of backfat thickness on the live hog. J. Animal Sci. 10:1025.

Hutchinson, H. D., S. W. Terrill, A. H. Jensen, D. E. Becker and H. W. Norton. 1957. Comparison of free-choice and complete rations for growing, finishing pigs on pasture and dry lot. J. Animal Sci. 16:562.

Lassiter, J. W., S. W. Terrill, D. E. Becker and H. W. Norton. 1955. Protein levels for pigs as studied by growth and self-selection. J. Animal Sci. 14:482.

Livestock and Meat Statistics. 1963. U.S.D.A. Bul. 333.

Livestock and Meat Statistics. 1964. U.S.D.A. Bul. 333.

Livestock Market News. 1955. U.S.D.A.

McMeekan, C. P. 1938. Shape of the growth curve as a controlling factor in conformation and anatomical composition of the animal body-swine. Am. Soc. Animal Prod. Proc. 31:337.

Morrison, Frank B. 1959. Feeds and Feeding, 22nd ed., The Morrison Publishing Company, Ithaca, N. Y., p. 874.

Report of the Pork Carcass Evaluation Committee. 1952. Cutting procedure. Fifth Am. Recip. Meat Conf. 5:120.

Robinson, W. L. 1946. The influence of rate of fat deposition on the firmness of the fat on hogs. Ohio Agr. Exp. Res. Sta. Bul. 664.

Sharrock, R. W. 1940. The restricted feeding of bacon pigs. J. Agr. Sci. 30:598.

Smith, H. J., J. W. Cole and J. B. McLaren. 1957. Pasture studies with swine. Unv. Tenn. Agr. Exp. Sta. Res. Bul. 264.

Snedecor, G. W. 1956. Statistical Methods, 5th ed., Collegiate Press, Inc., Ames, Iowa.

University of Tennessee Agricultural Experiment Station. Probe for profit. Sp. Cir. 498.

Winters, L. M., C. F. Sierk and J. N. Cummings. 1949. The effect of plane of nutrition on the economy of production and carcass quality of swine. J. Animal Sci. 8:132.