RELATIONSHIPS BETWEEN GROWTH RATE, FEED EFFICIENCY, CARCASS QUALITY AND CERTAIN ORGAN WEIGHTS IN SWINE.

by

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THE SUPERINTENDENT

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EXPERIMENTAL FARM,

AGASSIZ, B.C.

15th August, 1957.

Librarian,
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Dear Sir,

In my M.S.A. thesis entitled "Relationships between growth rate, feed efficiency, carcass quality and certain organ weights in swine" I have discovered two errors. On Page 46 in Table 14 the correlation of "Feed/carcass and large intestine" for Group C should be -.21 rather than .21. Also on page 52 in Table 16 the regression of "Feed/carcass gain on large intestine" for Group C should be -5.52 rather than 5.52.

I am sorry that this has occurred. I hope that it can be corrected by use of an errata sheet. This thesis was submitted to you in April, 1957.

Yours very truly,

D.M. Bowden
Animal Husbandman.

DMB/EC

ABSTRACT

The object of this study was to consider effects of treatment on and relationships among, certain economic characteristics and organ weights in purebred Yorkshire market hogs.

Included are measurements on 132 pigs from three experimental groups. Economic characteristics measured were; rate of gain, dressing percentage, feed per unit gain, lean cuts, fat cuts and belly. Organs weighed were heart, liver, spleen, stomach, small intestine, large intestine and adrenals.

In the test of forage utilization pasture fed pigs grew slower, produced leaner carcasses and had heavier hearts, spleens and stomachs than those fed in drylot.

In the two tests of dried apple pomace utilization addition of 20% pomace had no significant effects on the characteristics or organs measured. Increasing the level to 40%, however, resulted in slower growth, greater feed consumption per unit gain, lower dressing percentage, leaner carcass, heavier liver and heavier large intestine.

Physiological aspects of correlations and regressions among the characteristics and organs are discussed as are the influences of treatments on these relationships.

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Department of Animal Husbandry

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INTRODUCTION

A greater understanding of functional relationships in the animal body would seem to be of value in developing animals for higher production. It is not well known what relationships are optimum under a given set of conditions for growth, fattening or reproduction. This information could be of great value to the animal nutritionist who has become conscious of the need for greater efficiency of feed utilization and higher production. More knowledge of relationships would aid the animal breeder to determine the limits of applying selection. It might help answer the question as to how many characteristics should be selected for at one time to give the greatest improvement.

In meat-producing animals the principal interest lies in the production of the greatest amount of lean meat per unit of feed consumed. Many factors can influence the amount and proportion of lean meat laid down on the animal carcass. Research work has shown that both breeding and feeding can influence the proportion of lean meat in the hog carcass.

The following study is designed to gain some further knowledge of the relationships existing between growth rate, feed consumption, carcass characteristics and organ size in the Yorkshire market hog.

The raw data used in this study are deposited at the Dominion Experimental Farm, Agassiz, B.C. Included in these are more than 2000 measurements.

I. LITERATURE REVIEW

A. Economic Characteristics

1. Growth rate

Rate of body weight gain has been used for many years as an important experimental criterion in assessing both genetic and nutritional differences in groups of meat-producing animals. The factors influencing growth rate are so numerous that a complete discussion will not be attempted here. We shall deal rather with those factors which are of greatest interest in swine production.

Breeding has been shown to influence growth rate. In a study involving 8 breeds of swine, Miranda et al (1946) found highly significant differences in rate of gain between breeds and between litters within breeds. Comstock et al (1944) observed growth rate differences between the Poland China and Minnesota No. 1 breeds. Stothart (1938) found differences between strains of Canadian Yorkshires. Johansson and Korkman, (cited by Blackmore, 1953), using data collected at Swedish swine testing stations revealed that Landrace pigs had a higher rate of gain than Large Whites. However, no significant differences between Landrace and Large Whites could be found in data from Danish testing stations as reported by Lush (1936). Blackmore (1953) found a tendency, though non-significant, for breed classes containing high perecntages of Landrace and / or Poland China to grow faster than those of mainly Duroc and /or Chester White breeding. Warren and Dickerson (1952), studying lines of Poland China, Hampshire, Yorkshire and Duroc Jersey swine, found significant differences in rate of gain between sire lines as well as dam lines.

Type of pig may also have some influence. Zeller (1944) found that intermediate pigs fed to approximately 225 lbs. gained about 0.17 lbs. more per day than small type pigs and 0.09 lbs. more than large-type pigs fed to the same weight.

Seasonal effects have also been noted. Dunlop and West (1942) showed that temperature can influence rate of gain. Cold weather reduced growth rate in a study by Crampton and Ashton (1946a). Temperatures above 75° F produced slower gains in pigs between 70 and 144 lbs. and temperatures above 60°F produced slower gains in pigs over 166 lbs. in a study by Heitman and Hughes (1949). Only temperatures above 40°F were studied. Blunn and Baker (1947) noted large seasonal differences in rate of gain also.

Growth rate apparently differs between sexes. Lacy (1932) and Donald (1940) report faster growth in male pigs. Sex differences in rate of growth from weaning to slaughter were .039 lbs. per day for the Poland China breed and .089 lbs. per day for the Minnesota No. 1 in work by Comstock et al (1944). Yorkshire barrows gained significantly faster than gilts in work by Crampton and Ashton (1946a) and Bennett and Coles (1946). However, no mention is made in the latter work of corrections for season, year or ration differences which are contained in their data. Fredeen (1953) found that females took 5.4 days longer to reach market weight than males. Ten to fifteen percent faster gains in males were obtained by Crampton and Ashton (1945) with the greatest difference between sexes occurring in the fattening period from 110 lbs. to 200 lbs.

Despite finding a highly significant difference in rate of gain between sexes, Miranda et al (1946) felt that the effects of sex were hardly worth considering when alloting to feeding trials. Danish workers have not found large enough differences to consider correcting gain for sex effect under their pig testing program (cited by Blackmore, 1953).

Growth rate may be influenced by weight and age at the beginning of the recording period. These factors are discussed fully by Brody (1945). Miranda et al (1946) concluded that initial weights on experimental trials were worthwhile considering only when they varied widely. They found that the correlation between initial weight and future gains varied with length of the feeding period and initial age of pigs when recording period started.

Protein has been a nutritional factor quite widely studied as to its effect on rate of gain. Ellis and Hankins (1935) demonstrated that a ration containing 18.9% protein gave faster gain than rations containing 15.4% and 12.4% protein. In a study of rations containing protein levels of 10, 12, 14, 16, 18 and 20% Jensen et al (1955) found that average daily gains reached a maximum between 16 and 18% protein without antibiotics and at 14% with either terramycin or aureomycin fed as an antibiotic. In further work on protein levels Speer et al (1956) observed that a maximum rate of gain was reached at 16% up to

75 lbs. and 14% if fed at one level throughout the test period from weaning until 200 lbs.

Crampton and Ashton (1946a) found that reducing protein from animal source down to 1.4% of the total ration did not affect rate of gain in swine. This finding is supported by a second study, Crampton and Ashton (1946b) in which no difference in rate of gain occurred when animal protein was fed at levels of 0.5, 10, and 20% of the total protein in the ration.

Influence of high fiber feeds on gains in swine has received some attention in recent years. In a study of crude fiber levels Axelsson and Eriksson (1953) used wheat straw in rations balanced in all other respects to give crude fiber levels from 4.8 to 9.3% of the ration dry matter. Crude fiber content of 6.57% was found to be optimum for weight gain with higher levels giving decreased gain. Teague and Hanson (1954) obtained decreased rate of gain at high levels of crude fiber. Pigs receiving 10 to 30% of alfalfa in their rations differed little in rate of gain in tests by Bohman _et al_ (1953). Alfalfa levels above 30% however tended to reduce gains. A later study by Bohman _et al_ (1955) using alfalfa levels of 0, 10, 30 and 50% showed reduced rate of gain with each increase in alfalfa.

A number of antibiotics have received a great deal of attention in recent years due to their ability to stimulate growth under certain circumstances. Braude, Wallace and Cunha (1953) have reviewed extensively the large number of papers published on antibiotics in swine nutrition. The influence of antibiotics on rate of gain is apparently determined by the clinical or subclinical infections present in the pigs to which they are fed. This would account for the great variability in results obtained by different workers and by the same workers with different groups of pigs.

Synthetic hormone preparations are at present being widely tested for their influence on growth rate. A highly significant growth depression in pigs fed from 51 lbs. to 220 lbs. and receiving 27 mg. or more of methyl testosterone per day was reported by Perry et al (1956).

2. Feed efficiency

There is a positive relationship between rate of gain and feed efficiency. Thus, the fastest gaining pig in most instances has the lowest feed consumption per unit of body gain Evvard et al (1927) obtained a correlation of -.59 between daily gain and feed requirements with data from the Iowa State College herd. Rapid growth, low feed requirements and rapid fat deposition were found to be positively associated by Dickerson (1947). All the following workers, who have been mentioned previously in this study, have also demonstrated this point; Ellis and Hankins (1935), Stothart (1938), Dunlop and West (1942), Zeller (1944), Fredeen (1953), Teague and Hanson (1954), Bohman et al (1955) and Speer et al (1956). The strong relationship between gain and feed requirement is attributed by most workers to the lower feed requirement for maintenance of the faster growing animal.

Evvard et al (1927) found that spring pigs required less feed /100 lbs. body gain than fall pigs. These workers also noted that an increase in initial weight resulted in an increase in feed required per 100 lbs. gain. The latter point is supported in work noted by Zeller (1947) where rate of gain and feed efficiency were studied at 50 lb. intervals from 75 lbs. up to 374 lbs. live weight. These results given in Table 1, show that feed required per unit gain increased rapidly in pigs as body weight increased.

TABLE 1

Gain and Feed Utilization of Pigs at Various Body Weights

Weight Interval	No. of pigs on test	Average daily gain	Feed per 50 lbs. live-wt. gain
lbs.		lbs.	lbs.
75-124	42	1.62	167
125-174	42	1.75	190
175-224	34	1.71	206
225-274	26	1.65	223
275-324	18	1.46	252
325-374	9	1.31	276

Fiber level in the ration was found by Axelsson and Eriksson (1953) to influence feed efficiency. They determined the optimum fiber level for feed efficiency to be 7.26% of the ration dry matter while the optimum for rate of gain was 6.57%. Lloyd and Crampton (1955) tested fiber levels ranging from 1.4 to 8.6% and found that increasing fiber level decreased the apparent digestibulity of protein by barrow pigs. Teague and Hanson (1954) obtained similar results.

Crampton and Ashton (1946b) did not obtain any difference in feed efficiency from replacing plant protein with animal protein in swine rations.

Injection of purified anterior pituitary growth hormone into barrow pigs resulted in lower feed requirement per unit gain although growth rate was not significantly affected in work by Turman and Andrews (1955).

Bridges _et al_ (1952) obtained greater efficiency of feed utilization per 100 lbs. gain when feeding penicillin, streptomycin or a combination of the two in swine rations.

3. _Dressing percentage_

Nutrition has been found to influence dressing percentage in some cases. Wilson _et al_ (1953), with pigs fed on protein levels of 20, 17 and 14% from 45 to 75 lbs. of 16, 13 and 11% from 75 to 150 lbs. and of 12, 10 and 9.5% above 150 lbs. obtained significantly higher dressing percents on the two lower levels. Catron _et al_ (1952) using protein levels of 20, 18, 16 and 14% with 3% reductions in each level at 75 and 150 lbs. live weight, however, found no effect on dressing percent at any level either with or without aureomycin.

High fiber rations apparently decrease dressing percent. Coey and Robinson (1955) found that high-fiber diets gave lower dressing percents. Increasing alfalfa level decreased dressing percent in work by Bohman _et al_ (1955).

Harrington and Taylor (1955) obtained higher dressing percentages with aureomycin supplement than with penicillin. They also obtained higher dressing percentages with animal protein than with vegetable protein in the hog ration.

Gilts fed from 115 lbs. to slaughter on 50% of the energy intake of full-feeding dressed at 76.4% while those on full-feed dressed at 78.7% in work by Haines et al (1956).

Wilcox et al (1953) increased dressing percent significantly in hogs by feeding sucrose before slaughter. It is thought that this increase occurred mainly as a result of increased carbohydrate in the muscle tissue.

A possible breeding difference in dressing percent is noted in data reported by Fraser and Stothart (1947) from a number of Canadian stations testing Landrace and Yorkshire hogs. Landrace were found to have a slightly lower dressing percent than Yorkshires. Although the difference was small it was consistent in the groups studied. Lush (1936) also reports differences between Danish Landrace and Yorkshires.

Lacey (1932) did not find significant differences between sexes in dressing percent. This result corresponds with that from other workers.

Turman and Andrews (1955) obtained lower dressing percents for pigs injected with anterior pituitary growth hormone as compared to non-injected controls.

4. Carcass quality

Carcass quality has become a very important consideration in swine production. Emphasis in both breeding and feeding is placed on production of carcasses containing more lean meat and less fat.

In regard to hereditary differences in body fatness it is interesting to note the work of Alonso and Moren (1955) with hereditary obese mice. They found that even when the obese mice lost weight on a restricted diet their bodies contained a greater proportion of fat than hereditary lean mice subjected to the same treatment. It was concluded that obese mice metabolise their food in a manner different from that of lean mice such that more fat is deposited per unit of food eaten.

Studying five breeds of pigs Weniger (1955) killed some from each breed at birth and at live weights of 30 kgs., 40 kgs., 106 kgs., and 136 kgs. Carcasses were analyzed for fat, protein, water and ash. The first breed differences were demonstrated at 106 kgs. body weight. At this and higher weights breeds differed as to ability to deposit protein and fat in the carcass.

Whiteman *et al* (1951) and Warren and Dickerson (1952) found distinct differences in carcass quality between breeds and between lines within breeds. The former did not obtain breed differences however when considering belly alone. Blackmore (1953) noted breed differences in percent lean cuts in the carcass. Fraser and Stothart (1947) found only small differences in carcass quality between Yorkshires and Swedish Landrace tested at several Canadian stations.

Large differences have been demonstrated in carcass quality between sexes. Lacy (1932) found that gilts produced significantly more ham and loin but about the same belly and shoulder as the barrows. Barrows had a larger proportion of total fat cuts and internal fat. Male pigs were fatter and had less bone and muscle in studies by McMeekan (1940). Miranda et al (1946) found strong enough differences in results using 8 breeds of hogs to conclude that, in allotting to experiments where carcass quality was to be measured, sexes should be considered. Hetzer et al (1950) observed highly significant differences in yield of five lean cuts (ham, loin, bacon, picnic and butt) between barrows and gilts. Gilts averaged 1.0% more lean cuts when these cuts were expressed as percentages of live weight at slaughter after 24 hours off feed.

In a study with carcasses from British Large White pigs Harrington and Pomeroy(1955) found that sides from gilts were longer, thicker in the belly, thinner in backfat and had better developed eye muscles than those from barrows. Working with Canadian Yorkshires, Bennet and Coles (1946), Crampton and Ashton (1945 and 1946a), Fredeen (1953) and Fredeen and Lambroughton (1956) all concluded that gilts produced leaner carcasses than barrows.

The role of nutrition in determining carcass quality was emphasized by the work of McMeekan (1940) and McMeekan and Hammond (1940) in studying the effect of low and high planes of nutrition on the development of the hog. These workers demonstrated that pigs fed on a high plane of nutrition to 16 weeks and then on low plane gave higher percentages of lean than those fed on a low plane to 16 weeks and then on high plane. They concluded that growth up to 16 weeks was mainly bone and muscle but after 16 weeks, mostly fat. Earlier work by Ellis and

Zeller (1934) had shown that pigs on 3/4 to ½ of a normal diet produced carcasses containing higher percentages of lean cuts. Crampton and Ashton (1945) supported the restriction of food intake in the late period to produce leaner carcasses.

High fiber rations can be useful in producing leaner carcasses. These rations would essentially have the same effect as restricting feed intake since less of the fibrous ration would be digested. Axelsson and Eriksson (1953) found a tendency to leaner carcasses as fiber level of the ration increased. Thinner backfat resulted from high fiber rations fed in work by Coey and Robinson (1955). Bohman et al (1955) fed levels of alfalfa up to 50% of the ration and found that with increasing alfalfa level the depth of backfat, percentage of bacon belly and fat back in the carcass decreased significantly while percentage ham, shoulder and loin increased significantly. However Teague and Hanson (1954) did not find any significant effect of high fiber levels on carcass quality when feeding purified diets with Ruffex as the fiber source. Failure to obtain a significant difference could have been due to the small number of pigs used, however.

The influence of protein levels on carcass quality has been of some interest. In studies with protein levels from 10% to 20% of the ration Ellis and Hankins (1935), Ashton et al (1955) and Stevenson et al (1955) all found that high protein levels produced leaner carcasses. High protein levels increased percent lean cuts but reduced percent belly in work by Wilson et al (1953). Catron et al (1952) and Crampton and Ashton (1946a) failed to obtain any effect of varying protein levels on carcass quality. In the former work, however, the type of pig used was consistently very fat at slaughter and since the number of carcasses was small this may have masked any differences. In the latter the criterion of carcass quality was perhaps not sufficiently accurate to demonstrate any differences that may have been present.

A low quality protein fed at 12% in the ration gave leaner carcasses than low quality protein at 16% or high quality protein at 12 or 16% in work by Kropf et al (1955). This was a result of the very low rate of gain in the pigs on the low quality protein at 12%.

Carcass weights are related to fatness of the carcass. It follows from observations by McMeekan and Hammond (1940) and Hammond (1940 that heavier pigs will tend to be fatter. Coey and Robinson (1955) found that backfat thickness was significantly positively correlated with carcass weight. Ellis and Hankins (1937) obtained similar correlations.

Season effects can influence carcass quality. Crampton and Ashton (1946a) found that cold weather produced leaner carcasses. Winter pigs give leaner carcasses than summer pigs in a study by Blackmore (1953). This leanness occurred despite the fact that the winter pigs grew faster than the summer pigs.

Leaner carcasses were obtained by Perry et al (1956) with methyl testosterone fed in the diet of hogs and by Turman and Andrews (1955) with injection of purified anterior pituitary growth hormone.

B. Organs

1. Digestive tract

Size and weight of stomach, small intestine and large intestine are mainly affected by the nature of the diets fed. McMeekan (1940) obtained heavier and larger intestinal tracts from pigs on a high plane of nutrition throughout their growing and fattening period. However, these pigs were also the ones depositing a large amount of fat throughout the body so perhaps the heavy weights were due to fat laid down in the walls of the intestine.

Wussow and Weniger (1954) took weights of stomach, small intestine and large intestine in pigs of three breeds on varied diets. They found that the weight of all three sections of the digestive tract were increased by bulky diets. No breed differences in digestive tract size were found. Horst (1954) obtained significantly heavier stomachs and small intestines in pigs receiving high ballast rations. Although total digestive tract was significantly heavier the colon and caecum were not significantly heavier on the high ballast feed. The latter worker also measured length and volume of the digestive tract but found no significant differences between diets.

In work with rats Wierda (1942) found that large intestine and caecum length were definitely increased by a bulky diet but the small intestine was not affected. In a later paper (Wierda, 1950) this worker found the small intestine to be heaviest on a high carbohydrate diet and lightest on a balanced, concentrated diet with these differences being statistically significant.

A high-fat and high agar (bulky) diet gave intermediate weights for the small intestine. The large intestine was significantly heavier on the bulky diet this being due both to a thickening of the intestinal wall and an increase in diameter. In this paper Wierda reports work by Wetzel in which he observed that rats on a pure meat diet had a heavier large intestine but a lighter small intestine than those on all plant or mixed diets. Wide weight differences between animals however may have caused this to occur as no corrections were made for body weight. Bohman et al (1955) found that weights of stomach and large intestine were increased as level of alfalfa fed to hogs was increased. Small intestine however was not affected. These differences were attributed to longer periods of feed storage in the stomach and large intestine than in the small intestine where feed passed through quite rapidly.

Workers have made some interesting observations on the affect of antibiotics on the digestive tract. Coates et al (1955) obtained increased growth and decreased weight of the small intestine in chicks receiving procaine penicillin in a normal mash. Upon raising chicks in an isolated, sterilized area however they did not obtain a growth increase or a decrease in intestine weight. These workers theorize that disease thickens the intestine wall resulting in lessened absorption of nutrients and therefore they got no effect under sterile conditions. The degree of sterility could be questioned however as no bacteriological checks were made on either the chicks or their environment. Taylor and Harrington (1955) report work by Gordon with chicks in which dietary supplements of both procaine penicillin and terramycin significantly reduced the weight of the small intestine.

Taylor and Harrington (1955) ran tests with Large White pigs and found that weights of stomach, caecum and large intestine were not significantly affected by either aureomycin or penicillin in the diet. The small intestine was significantly lighter in the penicillin-fed lots. Braude et al (1955) found a tendency to reduced intestinal tract weight in pigs receiving aureomycin in their diet. Length was not affected, however, indicating a possible thinning of the intestinal wall in treated groups. Bohman et al (1955) could find no influence of aureomycin on either large intestine, small intestine or stomach weights in pigs.

Khalilov (1955) studied the length and character of the intestine in carnivores, insectivores, and herbivores. He concluded that in hoofed animals the absorptive surface of the intestine was increased by an increase in length rather than any change in the villi themselves.

The interesting observation was made by Coates et al (1955) in their work with chicks that the weight of the small intestine increased when liver was added to the diet.

2. Heart

Heart size is closely related to body size and activity of the animal. Work by Walter and Addis (1939) demonstrated that any factor which changes the rate of volume flow of blood changes the amount of work performed by the heart. They found that decreasing metabolic rate in rats by thyroidectomy resulted in decreased heart weight. Administration of thyroxin, on the other hand, increased heart weight. They concluded that weight changes in heart result directly from the amount of work done by the heart.

McMeekan (1940) with hogs on various planes of nutrition found that those on the low plane from weaning to slaughter had higher heart to body ratios than those on other planes. This difference was attributed to the greater activity of the pigs on the low ration due to their searching for more food.

Work by Joseph (1908) with dogs, cats rabbits and guinea-pigs showed differences in heart size between animal species in that the more active species had larger heart. This worker also reports a study by Kulbs in which a dog kept in a cage had a smaller heart than a dog of the same body weight exercised regularly on a treadmill. Brody and Kibler (1941) and Quiring (1946) support the above finding that more active species have larger hearts. The former also showed that heart weight tends to increase with body weight and derived formulae to predict organ weights from body weights.

Addis and Gray (1950) found that the formula $\log Y = \log a + \log b \log x$ was sutiable for predicting organ weight from body weight. Latimer (1947) obtained a high correlation of .85 between heart and body weight.

Wilcox <u>et al</u> (1953) obtained heavier hearts from animals fed sucrose before slaughter.

3. Liver

The liver appears to be affected by a greater variety of conditions than the heart. Activity tends to increase liver weight just as it does heart weight. In this respect Walter and Addis (1939) found that liver weight paralleled heart weight in their study of metabolic rates. They concluded that liver weight changes with the amount of work done by the liver. McMeekan (1940) obtained heavier livers in those pigs on high rations from weaning to slaughter. This could indicate greater liver activity due to heavier feed consumption or else greater stores of glycogen and fat in the liver tissue.

Webster et al (1947) found that ratios of liver to body weight tended to decrease with increasing body weight. Dick (1956) obtained similar results with sheep foetuses. He found that the ratio of true hepatic tissue weight to foetus weight decreased as the foetus developed indicating a possible decrease in liver activity as the specific growth rate decreased or else and increase in functional capacity of the individual cells.

Liver weight can be influenced by pre-slaughter treatment. Madsen (cited by Gibbons and Rose, 1950), Gibbons and Rose (1950) and Wilcox et al (1953) all obtained heavier livers by feeding sucrose to pigs before slaughter. Gibbons and Rose found this increase to result mainly from greater glycogen storage in the livers.

Further evidence of the relationship of liver size to physiological activity is given in work by Bland et al (1952) and Harris et al (1953). In both cases administration of ACTH or cortisone resulted in large increases in liver weight with young guinea pigs. In the latter study the increase in liver weight was associated with increased glycogen, water and protein levels in the livers. These workers noted also that response to ACTH varied between species with rabbits showing similar results to guinea pigs but young rats, chicks or mice showing no change in liver weight. In a similar study Cherry et al (1954) received a greater increase in liver weight from cortisone than from ACTH. It was theorized that more cortisone was introduced into the circulatory system by direct injection than was produced through stimulation of the adrenals by ACTH.

No consistent sex effect on liver size has been noted. Webster et al (1947) noted a tendency to heavier livers in male laboratory animals. Crile and Quiring (1940) noted slightly heavier average liver weights for female pigs.

Certain other conditions have been demonstrated to influence liver weight. Kropf et al (1955) found that liver weight tended to increase as protein level in the ration increased.

Total body roentgen irradiation produced smaller livers in work by Azarnoff and Roofe (1951).

Barron and Litman (cited by Ahronheim, 1937) noted enlarged livers in certain disease conditions of both chronic and acute nature.

Blackmore (1953) found larger livers in pigs fed in the winter months than in those fed in the summer. He speculates that this may have resulted from greater use of feed in the cooler weather to maintain the pigs' body temperature. Feed records were not available however to prove this point.

Taylor and Harrington (1955) observed a large increase in liver size in pigs fed on a penicillin-supplemented ration.

4. Spleen

The spleen is closely associated with the use of red blood cells in the animal body. Its size in general is affected by conditions which alter the rate of blood use in the body. Barcroft et al (1925) demonstrated that the spleen could act as a reservoir for red blood corpuscles and that spleen size was decreased by haemorrhage. Method of slaughtering also influenced spleen weight in this study. They conjectured that the spleen would tend to be contracted by exercise since it used red blood cells. Support to this is given in later work by Barcroft and Stevens (1927) in which exercise upon a treadmill resulted in a loss of spleen weight.

Further evidence of the spleen's role in blood use in the body is given by the work of Hargis and Mann (1925) and Barcroft and Stevens (1928). The former found that gastro-intestinal activity affected spleen volume; the latter that estrous and pregnancy produced spleen shrinkage. All of these conditions tend to increase movement of blood to certain regions of the body, thus blood stored in the spleen would be drawn out for use.

Spleen size is influenced by environmental conditions also. Hargis and Mann (1925) observed that the spleen responded to external stimuli by a reduction in volume. Ahronheim (1937) found that spleen size was altered by various disease conditions of both a chronic and acute nature. Azarnoff and Roofe (1951) observed a 40% reduction in spleen size of rats subjected to complete irradiation.

Taylor and Harrington (1955) report a significant reduction in spleen weight with aureomycin-supplemented swine rations. Other workers (Bohman _et al_, 1955: Braude _et al_, 1955), however, failed to find any effect of aureomycin on spleen weights.

Webster _et al_ (1947) found that the ratio of spleen to body weight tended to decrease with increasing body weight. Latimer (1947) obtained a positive correlation of .65 between spleen weight and body weight.

5. Adrenals

The adrenals are intimately related to the physiological activities within the animal body. They are stimulated by the adrenocorticotropic hormone released from the anterior lobe of the pituitary. In turn they release adrenalin and cortin which are both important to body function. Ingle and Kendall (1937) found that administration of cortin to rats resulted in decreased adrenal size. They concluded that when sufficient cortin is present in the body fluids for all physiologic requirements the output of adrenotropic secretions from the pituitary is suppressed. This finding was confirmed by work of Ingle and Mason (1938), Harris _et al_ (1953) and Constable _et al_ (1956) who all obtained reduced adrenal size on administration of cortin compounds. The latter two papers also reported administration of ACTH (adrenocorticotropic hormone) to rats. The produced an increase in adrenal weight which was attributed to an increase in adrenal activity resulting from ACTH stimulation.

Stress conditions are recognized as important influences on adrenal activity. Azarnoff and Roofe (1951) found enlarged adrenals in rats exposed to irradiation. Hurley and MacKenzie (1954) obtained adrenal enlargement in rats under the stress conditions of fasting, pantothenic acid deficiency and lowered oxygen tension. Other stress factors causing adrenal hypertrophy include; skin denudation (Dumm et al, 1955), density of population (Christian, 1955), low temperatures (Nicholls and Rossiter, 1955), restricted feed intake (Campos Zamorano, 1955) and restricted salt intake (Goldman et al, 1956). Animals used in these studies included rats, mice and rabbits.

Adrenal weights apparently differ between sexes, at least in some animal species. Eaton (1938) found that adrenals were heavier in male guinea pigs. Christian (1953) studied adrenal weights in 25 species and observed that those of the mature female were heavier than the mature male in all species except the rabbit. He also found that adrenal gland weight followed a definite logarithmic relationship for all species examined. Dunn et al (1955) noted heavier adrenals in female rats.

Working with inbred and crossbred guinea pigs Eaton (1938) found differences in adrenal weights between breeds.

Mason (cited by Dumm et al, 1955) has suggested that a specific adrenal weight maintaining factor may be secreted by the anterior pituitary. Most workers however attribute adrenal hypertrophy to an increased output of adrenocorticotropic hormone from the pituitary.

Recent tests have shown that adrenal weight is increased when stilbestrol is administered. Clegg and Cole (1954) and Cahill et al (1956) observed this with cattle and Hartsook and Magruder (1956) with rats.

Dickson et al (1954) found an indication of adrenal weight increase in rats receiving terramycin or fish solubles in their ration.

Injection of testosterone propionate in mice decreased adrenal size in tests by Homburger and Pettengill (1955).

C. Relationships

1. Between economic characteristics

Rate of gain and feed requirements per unit gain are closely related. Evvard et al (1927) found a strong correlation of -.59 between daily gain and feed requirements in data from the Iowa State College herd. Other workers who support this relationship include Lush (1936), Stothart (1938), Zeller (1944), Dickerson (1947) and Warren and Dickerson (1952). Fredeen (1953) found a strong correlation of .51 between feed per 100 lbs. of carcass gain and age at slaughter. He attributes this to the larger maintenance requirement for the slower growing pig.

Analysis of data by Weniger (1955) in which carcasses were tested for fat and protein deposition at various weights showed that pigs gaining at the rate of 600 to 700 grams per day gave higher protein deposition than pigs gaining at higher rates. As daily gain increased over 700 grams fat deposition also increased. This relationship of fast gain and carcass fatness was also demonstrated in earlier papers by Donald (1940), Bennet and Coles

(1946), Blunn and Baker (1947) and Dickerson (1947). Contrary to the above findings, Winters et al (1949) demonstrated a positive relationship between rate of gain and leanness in data where corrections had been made for maintenance allowances. Methods of correction are not clearly outlined in this paper however. In a later study Cummings and Winters (1951) corrected data for slaughter weight and breed differences and obtained a positive correlation between age at 200 lbs. and yield of five primal carcass cuts. This was interpreted as indicating a positive relationship between growth rate and lean in the carcass. The inclusion of belly in the primal cuts may have confused the relationship however. Belly would appear to be affected more by fat than by lean in the carcass.

Blunn and Baker (1947) suggest the possibility of breed differences in the relation between fatness and rate of gain. They found less genetic but more environmental association between rapid gain and fatness in Duroc-Jerseys than had been found in other work with Poland Chinas. Winters et al (1949) and Blackmore (1953) also put forward the possibility of breed differences in their data considering the above relationship.

A strong positive correlation between slaughter weight of the hog and fat on the carcass is evident from work by Stothart (1938), Hazel et al (1943) and Willman and Krider (1943).

It is interesting to note the work of Donald (1940) where the relationship between daily gain and fatness was stronger for one group with fat measured over the loin while in another it was stronger for fat measured over the rump.

In data from Danish test stations Lush (1936) found a positive relationship between dressing percent and fat in the carcass. Aunan and Winters (1949) obtained a correlation of .66 between dressing percent and percent fat in the carcass. This correlation is highly significant. A positive relationship was also found by Blackmore (1953).

2. Between economic characteristics and organs

Schmidt and Vogel (cited by Blackmore, 1953) presented correlations between heart size and days from 30 to 100 kgs. in pigs; and between heart size and fat/lean ratios. Both correlations were negative and quite low. Kraybill et al (1954) obtained the following range of correlations with data from various groups of beef cattle;

Liver and lean body mass from .17 to .98

heart and lean body mass from .12 to .97

spleen and lean body mass from .41 to .95

These correlations are generally high. However, no mention is made of possible treatment effects that may be present since the data were taken from a number of research stations.

Blackmore (1953) found a negative regression of gain on spleen weight, positive regressions of lean cuts on liver, heart and spleen and negative regressions of fat cuts on liver, heart and spleen within breed classes of hogs. These regressions were non-significant.

3. Between organs

Ahronheim (1937) observed a possible positive relationship between liver and spleen size. He found that under many disease conditions spleen and liver were affected similarly.

Latimer (1947) obtained all positive correlations when considering various organs in the cat. Table 2 gives the correlations found by this worker.

Table 2

Correlations Between Organs in the Cat

Organs	Males	Females
Heart and spleen	.65	.56
Heart and digestive tube wt.	.68	.56
Heart and liver	.78	.62
Spleen and dig. tube wt.	.45	.07
Spleen and liver	.37	.19
Dig. tube wt. and liver	.65	.67

Grahn (cited by Blackmore, 1953) found only non-significant correlations between various organs in mice. Correlations were negative for heart and spleen and for heart and liver, but positive for liver and spleen.

Blackmore (1953) obtained non-significant positive correlations between liver and heart and between liver and spleen in pigs. A significant positive correlation was obtained between heart and spleen in one group of pigs used in this study while the same correlation was positive but non-significant in other groups.

II. MATERIALS AND METHODS

Data used in this study were taken from three experiments conducted at the Experimental Farm, Agassiz, B.C. These experiments were planned primarily to test treatment differences, but the data collected were also considered suitable to give information on the relationships included in this study. Large differences between experiments necessitated separate analysis of the data from each experiment. Pigs from the three experiments will be denoted Group A (48 pigs), Group B (24 pigs) and Group C (60 pigs).

A. Animals

Pigs used in all three groups were purebred Yorkshires bred and raised at the Experimental Farm, Agassiz, B.C. All pigs in Groups A and B, were sired by one boar. Those in Group C were all sired by a second boar.

Both female and castrate male pigs were used in Groups A and C. Since limited numbers prevented balancing the sexes, pigs in these groups were allotted at random to treatments, regardless of sex. Data from these groups were corrected for sex differences prior to statistical analysis. Pigs in Group B were all castrated males and were allotted at random to treatments.

B. Treatments

1. Group A (summer 1955)

These pigs were used to test forage utilization and ration balancing by self-selection of grain mix and protein supplement.

Treatments and numbers of pigs used were as follows:

1. On pasture (2 replicates)

    (a) Grain mix and protein supplement in separate self-feeders (4 pigs per replicate)

    (b) Complete ration (4 pigs per replicate)

2. In drylot with fresh cut forage (2 replicates)

    (a) Grain mix and protein supplement separate (4 pigs per replicate)

    (b) Complete ration (4 pigs per replicate)

3. In drylot without forage (2 replicates)

    (a) Grain mix and protein supplement separate (4 pigs per replicate)

    (b) Complete ration (4 pigs per replicate)

A pasture area seeded to orchard grass and ladino clover was divided into 32 plots of one-twentieth acre each. Sixteen plots made up a replicate. Within each replicate the plots were divided into groups of four, each group being allotted at random to a pasture or cut forage treatment. Thus each pig receiving cut forage in drylot was allotted a plot in the same manner as those pigs actually fed on pasture and received only forage cut from this plot. Table 3 gives ingredients of rations used.

TABLE 3.

Ration Ingredients Used in Forage Utilization Trial

Balanced Ration				
	Period 1 (90-110 lbs.)	Period 2 (110-200 lbs.)	Grain mix	Protein supplement
	lbs.	lbs.	lbs.	lbs.
Barley	60.2	65.8	70	-
Oats	25.8	28.2	30	-
Meat scrap	4.2	1.8	-	30
Soyameal	4.9	2.1	-	35
Linseed Oilmeal	2.8	1.2	-	20
Dehydrated grass	2.1	0.9	-	15
Salt	0.5	0.5	0.5	0.5
Limestone	0.5	0.5	0.5	0.5

2. Group B (winter 1955-56)

These pigs were used to test the utilization of dried apple pomace in the swine ration. Treatments and numbers of pigs used were as follows:

1. Balanced ration without dried apple pomace
   (2 replicates, 3 pigs per replicate)
2. Ration containing 10% dried pomace
   (2 replicates, 3 pigs per replicate)
3. Ration containing 20% dried pomace
   (2 replicates, 3 pigs per replicate)

4. Ration containing 30% dried pomace

(2 replicates, 3 pigs per replicate)

All rations were balanced to the same protein and crude fiber level. All pigs were fed in drylot. Table 4 gives ingredients of rations used.

TABLE 4

Ration Ingredients in Test of Dried Pomace Utilization

Period	Growing (50-110 lbs.)				Fattening (110-200 lbs.)			
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Apple pomace	-	10	20	30	-	10	20	30
Barley	54	51	50	50	60	58	55	55
Oats	30	20	10	-	29	20	10	-
Meat scrap	8	9	10	10	4	5	7	7
Soyameal	5	7	7	7	4	4	5	5
Linseed oilmeal	2	2	2	2	2	2	2	2
Salt	.5	.5	.5	.5	.5	.5	.5	.5
Limestone	.5	.5	.5	.5	.5	.5	.5	.5

3. <u>Group C (summer (1956)</u>

These pigs were used to test dried apple pomace utilization at two levels of protein. Treatments and numbers of pigs used were as follows:

1. Ration without dried apple pomace (2 replicates)

(a) Standard protein - 15% crude protein from 50 to 110 lbs.; 13% from 110 to slaughter (5 pigs per replicate)

(b) High protein - 18% crude protein from 50 to 110 lbs.; 15% from 110 to slaughter (5 pigs per replicate)

2. Ration containing 20% dried pomace (2 replicates)

   (a) as above

   (b) as above

3. Ration containing 40% dried pomace (2 replicates)

   (a) as above

   (b) as above

Rations were balanced to crude fiber levels considered reasonable for feeder pigs. All pigs were fed in drylot. Table 5 gives ingredients of rations used.

C. Feed and Body Weight Records

Pigs in the three groups were all individually self fed. In Group A, however, the wooden self-feeders used were penetrated by moisture due to the very wet season. It was felt that the feed records on this group were inaccurate so they have been eliminated from this study.

Pigs in Group A were put on test rations at body weights of approximately 90 lbs. In Groups B and C pigs were put on at approximately 50 lbs. Pigs were taken off test for slaughter at a live weight which would give a shrunk weight in the range 190 to 210 lbs. Shrunk weights were taken after 21 hours off feed and water.

TABLE 5

Ration Ingredients in Testing Effect of Protein Levels on Dried Apple Pomace Utilization

Pomace	0%			20%			40%		
Protein	Standard		High*	Standard		High*	Standard		High*
Weight	50 -110	110 -200	50 -110	50 -110	110 -200	50 -110	50 -110	110 -200	50 -110
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Apple pomace	-	-	-	20	20	20	40	40	40
Barley	55	60	50	52	55	40	39	44	31
Oats	30	30	27	10	12	14	-	-	-
Meat scrap	8	4	12	9	7	16	12	9	18
Soya-meal	6	5	10	8	5	9	8	6	10
Salt	.5	.5	.5	.5	.5	.5	.5	.5	.5
Lime-stone	.5	.5	.5	.5	.5	.5	.5	.5	.5

* High protein 110-200 same as Standard Protein 50-110.

D. Slaughtering and Organ Weights

Pigs in all groups were taken by truck from Agassiz to the slaughterhouse of Clappison Packers Ltd. at Haney, B.C. for slaughtering. The same slaughtering procedure was used for all pigs.

The intact digestive tract of each pig with the spleen attached was dropped from the carcass into a pail marked with that pig's number. The heart and liver were removed, cleaned of extraneous tissue (including the bile duct) and weighed to the nearest gram. In Group C the adrenal glands were removed from each pig and placed in marked plastic containers.

The intact digestive tracts, spleens and adrenal glands were returned to Agassiz. The digestive tract was freed of fat, pancreatic tissue and other extraneous tissue and emptied of all contents. The duodenum was cut from the stomach and the small intestine from the caecum. The stomach, small intestine and large intestine (including caecum and rectum) were weighed separately to the nearest gram.

The spleen and adrenals were freed of fat and weighed to the nearest gram and 10 milligrams respectively.

E. Carcass Cutting and Weighing

Hot carcass weight was taken immediately after eviscerating. Carcasses were split down the back and weighed with kidneys and leaf-fat in; head and feet on. Cold carcass weights were taken after chilling for approximately 84 hours.

Carcasses were cut into regular commercial cuts by experienced cutters. Weights to the nearest one-quarter pound were recorded for feet, head, leaf-fat, kidneys, shoulder, loin, ham, and belly. Both rough and trimmed weights of the shoulder, loin ham and belly were taken.

F. Treatment of Data

Since carcass weights varied, the use of absolute measures of organs and carcass cuts would have introduced a bias. Therefore the values for organs and carcass measures were calculated in percentages as follows:

1. Lean cuts - the sum of shoulder, loin and ham after trimming as a percentage of the cold carcass weight minus head, feet and kidneys.
2. Fat cuts- leaf-fat plus the fat trim from the shoulder, loin, ham and belly as a percentage of the cold carcass minus head, feet and kidneys.
3. Belly - trimmed belly as a percentage of the cold carcass minus head, feet and kidneys.
4. Organs - each as a percentage of the hot carcass weight (adrenals x 100).
5. Digestive tract - each section as a percentage of the hot carcass weight.

Dressing percentage was the hot carcass as a percentage of the shrunk live weight. Daily gain was calculated as the difference between live weight on test and shrunk live weight off test divided by the total number of days on test.

Feed efficiency was calculated both on the basis of feed required per 100 lbs. of total body gain and feed per 100 lbs. carcass gain. Total body gain is the difference between shrunk live weight off test and weight at start of test. Carcass gain is the difference between hot carcass weight and live weight at start of test x .65. The factor .65 is based on the assumption that the pig at 50 lbs. live weight would have a dressing percentage of 65. This figure has been adopted by the Canadian Advanced Registry Board for use in calculating carcass gain on test pigs.

The three experimental groups were treated separately for statistical analysis since large between-group differences were apparent. Preliminary analysis showed sex differences in Groups A and C. Before further analysis corrections were made in these two groups. In both cases female values were corrected to the male average.

Corrected data were tested for treatment differences within groups by regular analysis of variance procedures. Regressions and correlations between treatments as well as within treatments were calculated in each group.

III. RESULTS

Results are presented in tabular form at the end of this section. Means of economic characteristics in all groups are presented in Table 6. Means of organs in all groups are presented in Table 7.

A. Analysis of Variance

1. Group A

Sex differences were determined by preliminary analysis and all data corrected before treatment differences were considered. There are significant sex differences for daily gain, dressing percent, percent lean cuts, percent fat cuts, percent belly, and spleen.

Mean squares from the analysis of variance for treatment differences are presented in Tables 8 and 9. There were no significant differences between the complete ration and the self-selected ration. Significant differences between forage feeding treatments were found for daily gain, percent lean cuts, percent fat cuts, percent belly, heart spleen and stomach. All significant differences were between the pasture-fed group and the two drylot groups. No significant differences occurred between the cut forage and no forage treatments.

2. Group B

All pigs in this group were males thus no sex correction was required.

Mean squares from the analysis of variance for treatment differences are presented in Tables 10 and 11. Percent belly showed the only significant difference between dried apple pomace levels.

3. Group C

Sex differences were determined by preliminary analysis and all data corrected before treatment differences were considered. There were significant sex differences for daily gain, percent lean cuts, percent fat cuts, percent belly, heart and spleen.

Mean squares from the analysis of variance for treatment differences are presented in Tables 12 and 13. There were no significant differences between the two protein levels. Significant differences between pomace levels occurred for daily gain, dressing percent, percent lean cuts, percent fat cuts, liver, stomach, and large intestine. Significant differences were mainly between the 40% pomace level and the other two levels used. The only significant difference between 0% pomace and 20% pomace was for stomach.

B. Analysis of Covariance

1. Correlations

Simple correlations between economic characteristics, between economic characteristics and organ weights and between organ weights were calculated in each group. Within treatment correlations are presented in Table 14 and between treatment correlations in Table 15.

2. Regressions

Simple regressions of economic characteristics on organ weights were calculated for each group. Organ weights, rather than percentages, were used to permit easier interpretation. For example, the regression (Table 16) of percent lean on heart of 2.44 indicates that for each increase of 25 grams in heart there is an increase of 2.44% in lean cuts. Within treatment regressions are presented in Table 16 and between treatment regressions in Table 17.

TABLE 6

Treatment Means of Economic Characteristics and Feed Consumption

Group	Treatment	No. of pigs	Wt. on test lbs.	Shrunk weight lbs.	Daily gain lbs.	Feed/ body gain	Feed/ carc. gain	Dress-ing %	Lean cuts %	Fat cuts %	Belly %
A	Pasture	16	91.9	185	1.39	-	-	80.0	63.3	22.8	13.7
	Cut forage	16	92.8	191	1.51	-	-	80.1	60.4	24.6	14.7
	Drylot	16	92.7	193	1.56	-	-	80.7	60.4	24.8	14.6
B	0% pomace	6	50.7	190	1.52	391	444	81.3	58.8	26.8	14.5
	10% pomace	6	50.8	192	1.49	391	451	80.8	59.4	26.7	13.9
	20% pomace	6	51.0	188	1.51	408	467	81.2	59.0	26.5	14.6
	30% pomace	6	52.0	189	1.58	415	483	80.1	57.8	28.2	14.0
C	0% pomace	20	50.6	193	1.36	441	514	80.4	62.0	24.5	13.5
	20% pomace	20	50.8	191	1.36	468	551	79.8	62.5	24.0	13.5
	40% pomace	20	50.9	190	1.27	505	601	78.9	64.1	22.5	13.4

TABLE 7

Treatment Means of Organs

Group	Treatment	Heart	Liver	Spleen	Stomach	Small intestine	Large intestine	Adrenals
A	Pasture	.447	2.09	.194	1.030	1.97	1.96	-
	Cut forage	.374	1.93	.168	.844	2.08	2.02	-
	Drylot	.390	1.91	.164	.912	2.09	1.97	-
B	0% pomace	.362	1.92	.163	.879	1.94	1.57	-
	10% pomace	.361	2.22	.172	.789	1.99	1.70	-
	20% pomace	.351	1.97	.170	.774	1.99	1.74	-
	30% pomace	.365	2.12	.166	.810	1.96	2.04	-
C	0% pomace	.413	2.04	.167	.871	1.69	1.81	.557
	20% pomace	.408	2.08	.162	.761	1.63	2.20	.535
	40% pomace	.428	2.22	.159	.826	1.74	2.41	.544

TABLE 8

Analysis of Variance - Mean Squares of Economic Characteristics in Group A

Sources of variation	d.f.	Daily gain	Dressing %	Lean cuts %	Fat cuts %	Belly %
Between managements	2	.1102**	.94	36.41**	16.33**	4.21**
Between rations within managements	3	.0150	.54	2.41	2.17	.02
Between reps within rations within managements	6	.0101	1.11	1.47	.66	.51
Error	35	.0120	1.02	3.69	1.94	.59

** Significant at the 1% level.

TABLE 9

Analysis of Variance - Mean Squares of Organs in Group A

Sources of variation	d.f.	Heart	Liver	Spleen	Stomach	Small intestine	Large intestine
Between managements	2	.0213**	.1296	.0038**	.0571**	.0635	.0035
Between rations within managements	3	.0005	.0803	.0006	.0057	.1946	.2269
Between reps within rations within managements	6	.0011	.0195	.0016	.0132	.1069	.0263
Error	35	.0018'	.0467'	.0007	.0097	.1147	.0899

** Significant at the 5% level.

' - 34 degrees of freedom.

TABLE 10

Analysis of Variance - Mean Squares of Economic Characteristics And Feed Consumption in Group B

Sources of variation	d.f.	Daily gain	Feed consumption Body gain	Feed consumption Carcass gain	Dressing %	Lean cuts %	Fat cuts %	Belly %
Between reps	1	.0028	92	104	.15	.70	.12	.24
Between pomace levels within reps	6	.0171	730	1246	1.72	5.26	3.90	.79*
Error	16	.0293	645	1005	1.81	2.54	1.72	.22

* Significant at the 5% level.

TABLE 11

Analysis of Variance - Mean Squares of Organs in Group B

Sources of variation	d.f.	Heart	Liver	Spleen	Stomach	Small intestine	Large intestine
Between reps	1	.0019	.0451	.0005	.0053	.0210	.0160
Between pomace levels within reps	6	.0003	.0421	.0003	.0111	.0414	.1243
Error	16	.0014	.0357	.0005	.0070	.0895	.0543

TABLE 12

Analysis of Variance - Mean Squares of Economic Characteristics

And Feed Consumption in Group C

Sources of variation	d.f.	Daily gain	Feed consumption Body gain	Feed consumption carcass gain	Dressing %	Lean cuts %	Fat cuts %	Belly %
Between pomace levels	2	.0618*	20485**	38135**	10.54**	23.22**	20.60**	.09
Between protein levels	1	.0011	633	851	.24	.02	.27	.16
Between replicates	1	.0031	2954	3053	.81	14.31*	4.27	2.95*
Interactions;								
Protein x reps	1	.0022	2101	3840	1.74	4.64	1.73	.71
Pomace x reps.	2	.0032	655	1915	2.26	1.28	.14	.59
Protein x pomace	2	.0018	17	117	.78	.27	.39	.01
Protein x pomace x reps.	2	.0179	1222	1749	3.10	2.74	3.54	.63
Error	48	.0161	2964	3961	1.65	3.39	2.50	.53

* Significant at the 5% level.
** Significant at the 1% level.

TABLE 13

Analysis of Variance - Mean Squares of Organs in Group C

Sources of variation	d.f.	Heart	Liver	Spleen	Stomach	Small intestine	Large intestine	Adrenals
Between pomace levels	2	.0021	.1758	.0003	.0608**	.0719	1.9160**	.0024
Between protein levels	1	.0005	.1066	.0002	.0005	.0114	.0035	.0026
Between replicates	1	.0066	.0380	.0006	.0375	.0799	.0017	.0001
Interactions:								
Protein x reps.	1	.0002	.0177	.0000	.0031	.0433	.0113	.0024
Pomace x reps.	2	.0007	.2644**	.0008	.0024	.0530	.1285	.0055
Protein x pomace	2	.0002	.0971	.0004	.0203	.0075	.1891**	.0118
Protein x pomace x reps.	2	.0008	.0124	.0001	.0198	.0124	.1195	.0399**
Error	48	.0012	.0367	.0009	.0084	.0454	.0528	.0047

* Significant at the 5% level.
** Significant at the 1% level.

TABLE 14

Simple Correlations Within Treatments by Experimental Groups

Characteristics	Group A	Group B	Group C
Daily gain & feed/body gain	-	-.53*	-.59**
Daily gain & feed/carcass gain	-	-.51*	-.55**
Daily gain & dressing %	-.41*	-.04	-.24
Daily gain & lean cuts %	-.10	-.66*	.04
Daily gain & fat cuts %	.04	.68*	-.11
Daily gain & belly %	.16	.33	.12
Daily gain & heart	-.17	.39	-.35*
Daily gain & liver	.14	.33	.31*
Daily gain & spleen	-.61**	-.38	.02
Daily gain & stomach	.34*	.13	-.18
Daily gain & small intestine	.41*	.12	.19
Daily gain & large intestine	.47*	.13	.40**
Daily gain & adrenals	-	-	-.24
Feed/body gain & dressing %	-	.00	.20
Feed/body gain & lean cuts %	-	.26	-.44**
Feed/body gain & fat cuts %	-	-.25	.49**
Feed/body gain & belly %	-	-.19	.06
Feed/body gain & heart	-	-.04	.29*
Feed/body gain & liver	-	.02	-.30*
Feed/body gain & spleen	-	.60*	.17
Feed/body gain & stomach	-	-.16	.09
Feed/body gain & small intestine	-	-.03	-.23
Feed/body gain & large intestine	-	.01	-.31*
Feed/body gain & adrenals	-	-	.38**
Feed/carcass gain & dressing %	-	-.26	.01
Feed/carcass gain & lean cuts %	-	.27	-.41**
Feed/carcass gain & fat cuts %	-	-.30	.44**
Feed/carcass gain & belly %	-	.07	.08
Feed/carcass gain & heart	-	-.10	.32*
Feed/carcass gain & liver	-	.16	-.18
Feed/carcass gain & spleen	-	.51*	.19
Feed/carcass gain & stomach	-	-.09	.17
Feed/carcass gain & small intestine	-	.08	-.12
Feed/carcass gain & large intestine	-	.09	-.21
Feed/carcass gain & adrenals	-	-	.36*
Dressing % & lean cuts %	-.26	-.10	-.25
Dressing % & fat cuts %	.38*	.21	.53**
Dressing % & belly %	-.02	-.24	-.09
Dressing % & heart	-.08	.08	-.19

TABLE 14 (continued)

Characteristics	Group A	Group B	Group C
Dressing % & liver	-.56**	-.51*	-.55**
Dressing % & spleen	-.22	.21	.11
Dressing % & stomach	-.63	-.26	-.48**
Dressing % & small intestine	-.47**	-.40	-.58**
Dressing % & large intestine	-.54**	-.26	-.58**
Dressing % & adrenals	-	-	.17
Lean cuts % & belly %	-.79**	-.69**	-.53**
Lean cuts % & heart	.49**	.06	.31*
Lean cuts % & liver	.06	-.10	.16
Lean cuts % & spleen	.09	-.08	.20
Lean cuts % & stomach	.33*	.01	.05
Lean cuts % & small intestine	-.01	-.26	.21
Lean cuts % & large intestine	-.00	-.03	.16
Lean cuts % & adrenals	-	-	-.02
Fat cuts % & belly %	.53**	.48*	.15
Fat cuts % & heart	-.45**	.09	-.24
Fat cuts % & liver	-.13	.04	-.21
Fat cuts % & spleen	-.03	.01	-.18
Fat cuts % & stomach	-.38*	-.06	-.09
Fat cuts % & small intestine	-.04	.12	-.33*
Fat cuts % & large intestine	.08	.02	-.26
Fat cuts % & adrenals	-	-	-.00
Belly % & heart	-.42*	-.05	-.25
Belly % & liver	.08	.26	.04
Belly % & spleen	.16	.24	-.13
Belly % & stomach	-.15	.13	.06
Belly % & small intestine	.09	.56*	.18
Belly % & large intestine	.15	.15	.16
Belly % & adrenals	-	-	.05
Heart & liver	.03	.43	-.07
Heart & spleen	.27	-.08	.41**
Heart & stomach	-.01	.22	.25
Heart & small intestine	-.23	.19	-.10
Heart & large intestine	-.13	.27	-.09
Heart & adrenals	-	-	.75**
Liver & spleen	-.31	-.24	-.05
Liver & stomach	.46**	.68**	.29*
Liver & small intestine	.60**	.60*	.60**

TABLE 14 (continued)

Characteristics	Group A	Group B	Group C
Liver & large intestine	.41*	.70**	.66**
Liver & adrenals	-	-	.06
Spleen & stomach	-.21	.05	-.02
Spleen & small intestine	-.59**	.14	-.10
Spleen & large intestine	-.31	-.23	.02
Spleen & adrenals	-	-	.28
Stomach & small intestine	.45**	.52*	.43**
Stomach & large intestine	.40*	.67**	.44**
Stomach & adrenals	-	-	-.10
Small intestine & large intestine	.52*	.20	.60**
Small intestine & adrenals	-	-	-.34*
Large intestine & adrenals	-	-	-.16
d.f.	34	15	47

* Significant at the 5% level.
** Significant at the 1% level.

TABLE 15

Simple Correlations Between Treatments by Experimental Groups

Characteristics	Group A	Group B	Group C
Daily gain & feed/body gain	-	.09	-.91
Daily gain & feed/carcass gain	-	.06	-.91
Daily gain & dressing %	.93	.24	.88
Daily gain & lean cuts %	-.89	-.83*	-.98
Daily gain & fat cuts %	.92	.82*	.97
Daily gain & belly %	.82	.33	.99
Daily gain & heart	-.82	.12	.98
Daily gain & liver	-.84	.69	-.98
Daily gain & spleen	-.97	-.42	.81
Daily gain & stomach	-.87	.46	-.11
Daily gain & small intestine	.99	.31	-.81
Daily gain & large intestine	.99	.35	.77
Daily gain & adrenals	-	-	.10
Feed/body gain & dressing %	-	-.36	-.99**
Feed/body gain & lean cuts %	-	-.35	.98
Feed/body gain & fat cuts %	-	.29	-.98
Feed/body gain & belly %	-	.26	-.84
Feed/body gain & heart	-	-.43	.79
Feed/body gain & liver	-	.26	.98
Feed/body gain & spleen	-	-.25	-.98
Feed/body gain & stomach	-	-.35	-.32
Feed/body gain & small intestine	-	-.53	.48
Feed/body gain & large intestine	-	.72	.98
Feed/body gain & adrenals	-	-	-.51
Feed/carcass gain & dressing %	-	-.56	-.99**
Feed/carcass gain & lean cuts %	-	-.26	.98
Feed/carcass gain & fat cuts %	-	.29	-.98
Feed/carcass gain & belly %	-	.02	-.84
Feed/carcass gain & heart	-	-.25	.79
Feed/carcass gain & liver	-	.33	.98
Feed/carcass gain & spleen	-	-.10	-.98
Feed/carcass gain & stomach	-	-.42	-.31
Feed/carcass gain & small intestine	-	-.45	.49
Feed/carcass gain & large intestine	-	.84*	.97
Feed/carcass gain & adrenals	-	-	-.51
Dressing % & lean cuts %	-.66	-.30	-.98
Dressing % & fat cuts %	.71	-.00	.98
Dressing % & belly %	.55	.79*	.86
Dressing % & heart	-.54	-.52	-.81
Dressing % & liver	-.58	-.10	-.98

TABLE 15 (continued)

Characteristics	Group A	Group B	Group C
Dressing % & spleen	-.81	-.40	.97
Dressing % & stomach	-.63	.40	.28
Dressing % & small intestine	.96	.09	-.52
Dressing % & large intestine	.87	-.69	-.92
Dressing % & adrenals	-	-	.48
Lean cuts % & belly %	-.99	-.05	-.94
Lean cuts % & heart	.99	.33	.91
Lean cuts % & liver	.99	-.73	1.00**
Lean cuts % & spleen	.97	.82*	.91
Lean cuts % & stomach	.99*	-.23	-.10
Lean cuts % & small intestine	-.84	-.05	.67
Lean cuts % & large intestine	-.94	-.39	.89
Lean cuts % & adrenals	-	-	-.31
Fat cuts % & belly %	.98	.02	.93
Fat cuts % & heart	-.98	-.06	-.90
Fat cuts % & liver	-.98	.86*	-.99**
Fat cuts % & spleen	-.99	-.70	.92
Fat cuts % & stomach	-.99	.11	.12
Fat cuts % & small intestine	.88	.20	-.65
Fat cuts % & large intestine	.96	.58	-.90
Fat cuts % & adrenals	-	-	.33
Belly % & heart	-1.00**	-.72	-1.00**
Belly % & liver	-1.00**	-.04	-.94
Belly % & spleen	-.93	-.57	.72
Belly % & stomach	-.99	.35	-.26
Belly % & small intestine	.76	-.31	-.89
Belly % & large intestine	.88	-.28	-.67
Belly % & adrenals	-	-	-.04
Heart & liver	.99**	-.04	.91
Heart & Spleen	.93	.54	-.66
Heart & stomach	.99	.35	.33
Heart & small intestine	-.75	.31	.92
Heart & large intestine	-.88	.10	.61
Heart & adrenals	-	-	.13
Liver & spleen	.94	-.38	-.91
Liver & stomach	.99**	-.11	-.10
Liver & small intestine	-.77	.24	.66
Liver & large intestine	-.89	.64	.89
Liver & adrenals	-	-	-.31

TABLE 15 (continued)

Characteristics	Group A	Group B	Group C
Spleen & stomach	.96	-.14	.50
Spleen & small intestine	-.94	.14	.30
Spleen & large intestine	-.99	.09	-.99*
Spleen & adrenals	-	-	.67
Stomach & small intestine	-.82	-.19	.68
Stomach & large intestine	-.92	-.41	-.55
Stomach & adrenals	-	-	.98
Small intestine & large intestine	.97	.00	.25
Small intestine & adrenals	-	-	.50
Large intestine & adrenals	-	-	-.71
d.f.	1	5	1

* Significant at the 5% level.
** Significant at the 1% level.

TABLE 16

Regressions Within Treatments by Experimental Groups

Characteristics	Group A	Group B	Group C
Daily gain on heart	-.05	.18	-.12*
Daily gain on liver	.01	.02	.02*
Daily gain on spleen	-.24	-.26	-.01
Daily gain on stomach	.04	.01	-.03
Daily gain on small intestine	.01	.01	.01
Daily gain on large intestine	.02	.01	.02**
Daily gain on adrenals	-	-	-.05
Feed/body gain on heart	-	-2.61	41.48**
Feed/body gain on liver	-	2.84	-8.18*
Feed/body gain on spleen	-	60.41*	28.82
Feed/body gain on stomach	-	-5.16	5.49
Feed/body gain on small intestine	-	-.23	-7.13
Feed/body gain on large intestine	-	.08	-6.97*
Feed/body gain on adrenals	-	-	30.24*
Feed/carcass gain on heart	-	-8.08	53.00*
Feed/carcass gain on liver	-	2.75	-5.55
Feed/carcass gain on spleen	-	64.17*	37.01
Feed/carcass gain on stomach	-	-3.65	12.46
Feed/carcass gaon on small intestine	-	.89	-4.56
Feed/carcass gain on large intestine	-	1.43	-5.52
Feed/carcass gain on adrenals	-	-	32.89*
Lean cuts % on heart	2.44**	-.23	1.52*
Lean cuts % on liver	.06	-.09	.15
Lean cuts % on spleen	.63	-.49	1.15
Lean cuts % on stomach	.63*	.01	.11
Lean cuts % on small intestine	-.00	-.14	.22**
Lean cuts % on large intestine	-.00	-.02	.12
Lean cuts % on adrenals	-	-	-.05
Fat cuts % on heart	-1.60**	.30	-1.03
Fat cuts % on liver	-.09	.03	-.16
Fat cuts % on spleen	-1.54	.07	-.85
Fat cuts % on stomach	-.51*	-.10	-.16
Fat cuts % on small intestine	-.02	.05	-.30
Fat cuts % on large intestine	-.04	-.01	-.17
Fat cuts % on adrenals	-	-	-.00
Belly % on heart	-.84*	-.07	-.49

TABLE 16 (continued)

Characteristics	Group A	Group B	Group C
Belly % on liver	.03	.06	.02
Belly % on spleen	-.45	.04	-.30
Belly % on stomach	-.11	.08	.05
Belly % on small intestine	.02	.09*	.07
Belly % on large intestine	.04	.03	.05
Belly % on adrenals	-	-	.05
d.f.	34	15	47

* Significant at the 5% level.
** Significant at the 1% level.

The units are: gain =.1 lb./day; feed/body gain =1 lb. per 100 lbs. live weight gain; feed/carcass gain =1 lb. per 100 lbs. carcass gain; % lean, fat and belly= 1% in cold carcass minus head, feet and kidneys; heart = 25 grams; liver = 140 grams; spleen = 10 grams; stomach = 60 grams; small intestine = 140 grams; large intestine = 140 grams; adrenals = 375 milligrams.

TABLE 17

Regressions Between Treatments by Experimental Groups

Characteristics	Group A	Group B	Group C
Daily gain on heart	-.21	.10	-.48
Daily gain on liver	-.08	.04	-.06
Daily gain onspleen	-.47	-.27	1.03
Daily gain on stomach	-.11	.06	-.01
Daily gain on small intestine	.13	.02	-.10
Daily gain on large intestine	.58	.01	-.01
Daily gain on adrenals	-	-	.05
Feed/body gain on heart	-	-7.01	225.36
Feed/body gain on liver	-	3.43	32.13
Feed/body gain on spleen	-	-31.87	-723.26
Feed/body gain on stomach	-	-9.57	-19.74
Feed/body gain on small intestine	-	-7.17	32.13
Feed/body gain on large intestine	-	6.37	9.42
Feed/body gain on adrenals	-	-	-148.78
Feed/carcass gain on heart	-	-53.19	308.38
Feed/carcass gain on liver	-	5.70	43.89
Feed/carcass gain on spleen	-	-17.58	-985.89
Feed/carcass gain on stomach	-	-15.00	-26.61
Feed/carcass gain on small intestine	-	-8.11	44.12
Feed/carcass gain on large intestine	-	9.63	12.80
Feed/carcass gain on adrenals	-	-	-201.71
Lean cuts % on heart	4.44	4.50	8.70
Lean cuts % on liver	1.72	-. 81	1.11
Lean cuts % on spleen	8.59	8.97**	22.52
Lean cuts % on stomach	2.40	-.53	-.20
Lean cuts % on small intestine	-1.95	-.06	1.49
Lean cuts % on large intestine	-9.87	-.30	.29
Lean cuts % on adrenals	-	-	-3.02
Fat cuts % on heart	-2.93	-.69	-8.10
Fat cuts % on liver	-1.13	.83*	-1.04**
Fat cuts % on spleen	-5.83	-6.55	21.56
Fat cuts % on stomach	-1.60	.21	.25
Fat cuts % on small intestine	1.36	.21	-1.36
Fat cuts % on large intestine	6.76	.38	- .27
Fat cuts % on adrenals	-	-	3.05
Belly % on heart	-1.53	-3.81	-.60*

TABLE 17 (continued)

Characteristics	Group A	Group B	Group C
Belly % on liver	-.59	-.02	-.07
Belly % on spleen	-2.80	-.24	1.11
Belly % on stomach	-.82	.31	-.03
Belly % on small intestine	.60	-.14	-.12
Belly % on large intestine	3.13	-.08	-.01
Belly % on adrenals	-	-	-.03
d.f.	1	5	1

* Significant at the 5% level.
** Signifidant at the 1% level.

The units are: gain = .1 lb./day; feed/body gain = 1 lb. per 100 lbs. live weight gain; feed/carcass gain = 1 lb. per 100 lbs. carcass gain; 1% lean, fat and belly = 1% in cold carcass minus head, feed and kidneys; heart = 25 grams; liver = 140 grams; spleen = 10 grams; stomach = 60 grams; small intestine = 140 grams; large intestine = 140 grams; adrenals = 375 milligrams.

IV. DISCUSSION

A. Sex Effects

The significant sex differences in groups A and C agree with those noted in the literature. In both groups males grew faster, produced lower percent lean cuts, higher percent fat cuts, higher percent belly and smaller spleens than females. Males also had smaller hearts but the difference was significant in Group C only.

Faster growth rate in male pigs has been established by other workers including Lacy (1932), Donald (1940), Crampton and Ashton (1945 and 1946a), Bennet and Coles (1946) and Fredeen (1953).

Fatter carcasses in males have been found also by many workers including Crampton and Ashton (1945 and 1946a), Bennet and Coles (1946) and Fredeen (1953).

Smaller hearts and spleens in castrate male pigs were reported by Crile and Quiring (1940). The literature does not offer possible explanations of these sex differences in heart and spleen size. That the heart and spleen are probably influenced by common cause is indicated by the positive correlations between these organs obtained by Latimer (1947) and Blackmore (1955). If a strong physiological relationship does exist it is likely governed by the blood flow in the body since the heart maintains this flow and the spleen stores red blood cells for use in periods when blood flow is rapid such as during digestive processes or exercise. Differences in heart and spleen size between the sexes could possibly result from differences in metabolic rate. Walter and Addis (1939) found smaller hearts in animals with reduced metabolic rate. This factor could possibly also affect the spleen size since it is so closely associated with the use of blood in the body through its role in the formation and destruction of red blood cells.

Castration may be a contributing factor to any difference in metabolic rate. It is recognized that castration affects the endocrine relationships in the body with resulting reduction in metabolic rate (Maynard and Loosli, 1956).

B. Treatment Effects

1. Group A

(a) Daily gain. Reduced gain in the pasture fed pigs could result from greater activity. These pigs were free to move over a much larger area than those in drylot. The increased activity would require more energy from the nutrients consumed with less remaining for growth. This restriction in available nutrients would mean that the pigs could not attain the growth rate of which they were genetically capable.

(b) Lean and fat. The higher pereent lean and lower percent fat in the pasture-fed pigs can be explained also on the basis of greater activity. Thus, the more active pig has less nutrients left for the deposition of fat in the body. Increase in lean through restriction of nutrients has been previously demonstrated in work by Ellis and Zeller (1934), McMeekan (1940) and McMeekan and Hammond (1940).

(c) Belly. Lower percent belly in the pasture-fed pigs may be a result of less fat deposition.

(d) Heart. Activity will increase heart size according to work by Kulb (cited by Joseph, 1908), McMeekan (1940) and Brody and Kibler (1941). The increased heart size of the pasture-fed pigs is then to be expected.

(e) Spleen. Larger spleens in the pasture-fed pigs could result from exposure to mild infections according to work by Ahronheim (1937). This worker reported increased spleen size resulting from chronic and acute disease.

Increased body responses due to greater nervous stimuli is considered as another possible cause of larger spleens in the pasture pigs. That nervous stimuli can affect spleen size has been shown by Hargis and Mann(1925). Repeated stimuli would be expected to increase spleen activity with a resulting increase in size if the spleen reacts to increased activity in the same way as other organs.

(f) Stomach. The increased stomach weight of the pasture pigs is expected to be a result of the diet eaten by these pigs. One possibility is that the increase was due to stimulation from forage consumed. Since forage contains less nutrients per unit volume than grain concentrate the pigs would eat a greater volume of it with a resulting increase in stomach size to accomodate it. If this were the case, however, it would be expected from work by Wierda (1950) and Bohman et al (1955) that the large intestine would show a corresponding increase in size. However, this does not occur in these pigs.

A second possible explanation would assume that the pigs on pasture ate more grain while they were at the feeder than those in drylot. The pasture pigs were able to get as far as 150 feet away from the feeder whereas the drylot pigs could get only about 7 feed away from the feeder. The pig in drylot would be expected to eat more often just from the proximity of his feeder. If the pasture pig ate less often he would be expected to have a larger appetite and eat a greater volume of feed per feeding. This would distend the stomach and repeated many times during the pig's life could conceivably increase the stomach wall tissue and its weight. In this case an increase in the large intestine size would not be expected since the food being handled is the grain concentrate and the residue passing into the large intestine would not be any bulkier than that consumed by the drylot pigs.

The second explanation above seems to fit the situation best. Since, however, the pigs on pasture were consuming some forage, it is likely that both factors were having some influence on the stomach size.

2. Group B

(a) Feed per unit gain. The differences in this characteristic are not significant but a strong trend to greater feed consumption per unit gain as pomace level increases can be readily seen. Apparently the digestibility of the feed is decreasing as the pomace level increases. This is to be expected due to the high crude fiber content of the pomace. Results by Lloyd and Crampton (1955) indicate that increasing fiber level decreases the digestibility of nutrients in a ration.

(b) Belly. The significant difference in this characteristic does not appear to have a plausible explanation in physiological terms. There is, of course, one chance in twenty that the magnitude of difference observed here was due to causes other than the treatment difference of this experiment.

(c) Large intestine. Differences in this characteristic are not significant but a strong trend to greater large intestine weight with increasing pomace level is apparent. This could again be the result of lower digestibility in the high pomace rations. The residue passed into the large intestine in this case would be quite bulky and tend to stimulate increases in intestine size.

3. Group C

(a) Daily gain. The decrease in gain with increased pomace level can be attributed to lowered digestibility of the ration as pomace level increases. The pig is unable to consume sufficient of the bulkier 40% pomace ration to provide all the nutrients needed for maximum growth. The lowering of digestibility by adding pomace can be seen in results from the 0 and 20% pomace rations. In these two rations the daily gain is the same. However, with the 20% pomace ration the feed consumption per unit gain has markedly increased, indicating that more feed has been required to obtain the same assimilated nutrients.

(b) Feed per unit gain. Increased feed consumption per unit gain by pigs on the 40% ration arises from both an increased maintenance requirement due to slower gain and lower digestibility of the ration. That the increase is not due entirely to maintenance follows from the earlier observation that feed consumption increased when 20% pomace was added even though growth rate was the same. This can be seen also in results from Group B where growth at 30% pomace was higher than that at 0% pomace yet the feed consumption per unit gain was higher at the 30% level.

(c) Dressing percent. Lower dressing percentage in the pigs fed 40% pomace could result from increased organ size, especially digestive tract, due to the bulky nature of the ration. Coey and Robinson (1955) and Bohman et al (1955) obtained results which would support this. Effective restriction of the nutrient assimilation resulting from lower digestibility of the high pomace ration may have lowered the dressing percentage as found in work by Haines et al (1956).

(d) Lean and fat. The higher proportion of lean cuts in pigs from the 40% pomace level would result from the restricted assimilation of nutrients due to the low digestibility of the ration. This effect has been established in work by Ellis and Zeller (1934), McMeekan (1940) and McMeekan and Hammond (1940).

(e) Liver. The increase in liver size with increase in pomace level would indicate greater activity of this organ, a view supported by work by Walter and Addis (1939). One possible cause of greater liver activity may be a shortage of energy producing nutrients digested by the animal. If this were the case, any protein available over that required for tissue maintenance and growth would be deaminized by the liver to produce keto acids which can be used in the production of energy. This process plus the conversion of the released ammonia to urea would increase liver activity considerably. Points supporting this possibility are:

1. It has been shown that in feed with high crude fiber content the digestibility of the simpler carbohydrates is low (Maynard and Loosli, 1956). Thus the high pomace ration would tend to be less digestible.
2. Protein content of the high pomace ration was apparently sufficient since no interaction was observed between pomace level and protein level.

A second possible explanation for the increased liver size is indicated from work by Gibbons and Rose (1950) and Wilcox et al (1953). In these papers the feeding of sucrose produced heavier livers in swine as a result of greater carbohydrate storage in the liver. It may be that the digestible carbohydrate of the pomace is mainly simple sugars and could produce a similar effect. However the observations already made that high crude fiber rations are less digestible and that sufficient nutrients are not available to permit maximum growth suggest that the above explanation is not tenable here.

It is suggested, therefore, that increased liver activity is probably responsible for the increase in liver size, observed in this experiment.

(f) Stomach. While the differences in stomach weight appear to be somewhat inconsistent they are statistically significant. When the trend of stomach weights between pomace levels is compared with the trend in Group B a similarity can be seen. In both groups the highest stomach weight is in the pigs receiving no pomace with lower weights at the 20% pomace level increasing again above 20% pomace. It would appear that some factor in connection with the addition of pomace to the ration is affecting stomach size.

From the work of Wussow and Weniger (1954) and Bohman et al (1955) a strong trend to increasing stomach weight with increasing pomace level would be expected. This would explain the increase in stomach size above 20% pomace. The apparent trend of decreasing stomach size from 0% pomace to 20% pomace, however, must be explained on some other basis. One possibility could be the amount of fat deposited in the tissue of the stomach wall. The pigs on 0% pomace tended to be slightly fatter than those on 20% pomace. Perhaps this added fatness was sufficient that more fat was deposited in the stomach wall.

(g) Large intestine. The increase in large intestine weight is attributable to the increase in bulk of the ration as pomace level increased. This agrees with findings of Wierda (1942 and 1950) and Bohman et al (1955). It also parallels results in group B of the present study.

C. Relationships

1. Correlations within treatments.

(a) Between economic characteristics. The high negative correlations between daily gain and feed per 100 lbs. body gain and feed per 100 lbs. carcass gain agree with results of Evvard *et al* (1927), Lush (1936), Stothart (1938), Zeller (1944), Dickerson (1947), Warren and Dickerson (1952) and Fredeen (1953). This strong relationship would result from the higher maintenance requirement for the slow-gaining pig.

The negative correlations between daily gain and dressing percentage agree in direction with those of Blackmore (1953) but are lower in magnitude. This relationship could be a result of the faster-growing pig eating more feed per unit of time. This would tend to increase the intestinal tract size. This greater use of feed would also increase the heart and liver size to some degree although the change in heart size would influence the dressing percentage very little.

The positive correlations between daily gain and percent belly could indicate that deposition of fat is influencing the proportional belly weight since Donald (1940), Bennet and Coles (1946), Blunn and Baker (1947), Dickerson (1947) and Blackmore (1953) have shown that faster gaining pigs tend to be fatter.

The negative correlations between dressing percent and lean cuts and the positive correlations between dressing percent and fat cuts agree with those of Jesperson and Madsen (reported by Lush, 1936), Aunan and Winters (1949) and Blackmore (1953). They are higher than those of Blackmore but lower than those of Aunan and Winters. The latter workers, however, appeared to include breed class differences which is not the case in the present study nor in that of Blackmore. This relationship would indicate that fattening pigs deposit proportionately more fat on the carcass than on the internal organs.

The high negative correlations between percent lean cuts and percent belly and the high positive correlation between percent fat cuts and belly would indicate that the belly is influenced more by fat deposition than it is by lean deposition in the body. This would indicate that the belly should be classified as a fat cut rather than a lean cut in studies where fat and lean content of the carcass is being considered.

(b) Between economic characteristics and organs. The positive correlation between daily gain and liver could result from greater feed consumption in the faster growing pig. The liver would increase in size as its activities, including deamination, transamination, formation and storage of glycogen and detoxification, increased. It may be also that the pig with the larger liver is better able to handle ingested nutrients and thus grows faster.

The strong positive correlations between daily gain and small intestine and daily gain and large intestine may indicate that pigs which have large intestinal tracts can handle feed more efficiently and gain faster. It may be also that the faster gaining pig eats more feed and the intestinal tract enlarges to supply the extra digestive capacity required.

The negative correlation between daily gain and adrenals could indicate that the pig which is more esponsive to outside stimuli gains more slowly. This response to outside stimuli would amplify body processes resulting in increased use of energy for these processes with less remaining for growth. The general observation that the more docile animal tends to gain faster would support this theory. This explanation would also apply to the positive correlations between feed per 100 lbs. body gain and adrenals and feed per 100 lbs. carcass gain and adrenals.

The positive correlations between feed per unit gain and spleen could indicate the presence of disease of some minor type which is acting on the system of the animal to reduce growth rate and possibly affect digestive processes. The reduction in growth rate is shown also in the negative correlations between daily gain and spleen in groups A and B. Ahronheim (1937) has demonstrated that disease conditions, both chronic and acute, can influence spleen size.

The positive correlations between feed per unit gain and adrenals could be a result of the animals response to external stimuli. This may result in greater feed consumption per unit gain through reduction in rate of gain as discussed earlier in this section, or through some effect on the digestive organs. This latter point would be supported by the significant negative correlation between small intestine and adrenals obtained in the present study.

The strong negative correlations of dressing percentage with liver, stomach, small intestine and large intestine indicate that the size of these organs influences dressing percentage to a large degree. Since these are the largest visceral organs this relationship is automatic.

Positive correlations obtained between percent lean cuts and heart could suggest that the more active pig produces a leaner carcass. That activity has a strong influence on heart size has been shown by Joseph (1908), Eaton (1938) and Latimer (1947). Another factor influencing this relationship could be stress conditions which would amplify the heart rate. This increase of heart and general organ activity would use up energy from the nutrients which would otherwise be used in the formation of fat. Therefore the pig which reacts to stress conditions would tend to be leaner. The negative correlation between heart and percent belly may be explained on the same basis since from observations earlier in this study it would seem that percent belly is mainly affected by fat deposition in the carcass.

The positive correlation between percent lean cuts and stomach and the negative correlation between percent fat cuts and stomach may arise from the tendency of the fattening pig to deposit more fat on the carcass than on the viscera. The positive correlation of percent belly with small intestine and large intestine could be explained on the same basis.

(c) Between organs. The highly significant positive correlation between heart and adrenals would be expected since the adrenal secretion, adrenalin, acts to increase blood flow in the body and thus increase heart activity.

The high positive correlations of liver with stomach, small intestine and large intestine would be expected since these organs are so intimately connected with digestion and assimilation of ingested nutrients. Feed intake therefore would be expected to influence all of these organs similarly.

The positive correlation between spleen and adrenals may indicate a common response to stress conditions. The production of adrenalin under stress conditions and the subsequent increase in blood flow could produce greater spleen activity with a resulting increase in size.

The positive correlations of stomach with small intestine and large intestine and of small intestine with large intestine result from the intimate relationship of these organs in the process of digestion.

It is interesting to note the negative correlation of adrenals with stomach, small intestine and large intestine. This may indicate a direct influence of the adrenal secretions on digestion. Repeated response of the adrenals to stress conditions may result in failure of the digestive tract to develop properly and result in less efficient utilization of ingested nutrients. This is supported by the significant positive correlation between adrenals and feed per unit gain obtained in this study.

2. Correlations between treatments.

These correlations are the result of treatment effects and therefore vary widely between experimental groups. The significant between treatment correlations will be discussed for each experimental group.

(a) Group A. The positive correlation of percent lean with stomach would result from the effects of pasture feeding. The pasture fed hogs had leaner carcasses due to reduced rate of gain and larger stomachs possibly from eating larger amounts of feed while at the feeder.

The increased lean content of the pasture fed pigs would result in a decrease in the percent belly but an increase in liver to carcass ratio. This situation would cause the negative correlation between liver and percent belly.

The positive correlations of heart with liver and liver with stomach could result from a general increase in these organs in the pasture-fed pigs. This increase could be caused by greater digestive activity in an attempt to furnish the additional energy needed for exercise.

(b) Group B. The increase in growth rate and in percent fat at the 30% pomace level would cause the negative correlation of daily gain with percent fat.

Since it has been shown that fatter pigs have higher dressing percentages and that percent belly is influence by fat deposition it seems likely that the positive correlation between dressing percentage and percent belly is a result of the increased fatness of the pigs on 30% pomace.

The decrease in digestibility of the ration as pomace level increases could explain the positive correlation between feed per 100 lbs. carcass gain and large intestine. In the high pomace rations the residue after digestion would be more bulky and would increase the size of the large intestine. Also in these rations the digested nutrients per unit of feed ingested would be lower, thus more feed per unit gain would have to be ingested to meet tissue building and energy requirements.

The positive correlation of percent fat cuts with liver would indicate that the ration is tending to increase both carcass fatness and liver weight. This increase in liver weight could result from greater storage of glycogen.

(c) Group C. Increasing pomace content of the rations has increased feed per unit gain due to reduced digestibility and has decreased dressing percentage due to increased digestive tract and liver size. Thus, increasing the pomace level has produced the negative correlations of feed per 100 lbs. body gain with dressing percentage and feed per 100 lbs. carcass gain with dressing percentage.

The positive correlation of percent lean cuts with liver and the negative correlation of percent fat cuts with liver would arise from the tendency of rations containing higher levels of pomace to reduce carcass fatness and increase the ratio of visceral organs to carcass. This could also explain the negative correlation between percent belly and heart.

3. Regressions within treatments.

The physiological relationships involved in these regressions have been discussed under the correlations within treatments section. The regressions give further information however in that they show just how much increase in an economic characteristic can be expected from a given increase in organ size. The units used for organs are such that one unit will represent an increase of approximately 10% in the weight of the organ.

4. Regressions between treatments

The physiological relationships involved have been discussed earlier under the correlations between treatments section. As in these correlations the effect of treatments should be kept in mind when considering the regressions.

5. Application of relationships in swine breeding.

Selection is a major factor in improving efficiency and carcass quality in swine. The effectiveness of this selection depends upon the characteristics included in the selection index and the heritability of these characteristics. The relationships determined in this study have no value in assessing heritability. They have some value, however, in determining which characteristics to include in the selection index.

In determining the characteristics to be included in the index important considerations are: (a) the ease and accuracy of measuring the characteristics and (b) the physiological relationships between the characteristics. The characteristics utilized are preferrably those for which measurements can be obtained under ordinary circumstances. The activity of the adrenal glands could be of value in a selection index but the difficulty of measuring it would prohibit its use. This difficulty applies to most organs and glands. The characteristics used are therefore restricted mainly to those of major economic importance such as daily gain, feed per unit gain, dressing percent, and percent lean meat in the carcass.

The relationships given in this study show that selection for one characteristic alone may have undesirable effects on other characteristics. This is demonstrated by the following relationships:

(a) Increased daily gain is accompanied by increased fatness,

(b) Increased lean cuts are accompanied by increased feed requirement,

(c) Increased belly is accompanied by increased fat cuts,

(d) Increased feed efficiency is accompanied by increased digestive tract weight and decreased dressing percentage.

It appears from these relationships that measures of growth rate, dressing percentage, lean content of the carcass, bacon belly and feed efficiency are desirable in a selection index for swine. Inclusion of this many characteristics will reduce the progress for any one of them but should give better overall improvement toward a more efficient pig giving a greater percentage of lean meat.

V. SUMMARY

Development of the market hog was studied by determination of treatment effects on and interrelationships among, certain economic characteristics and organ weights. Measurements were taken on 48 pigs from a study of forage utilization and self-selection of protein supplement, 24 from a preliminary test of dried apple pomace utilization and 60 from a test of dried apple pomace utilization at two levels of protein. Economic characteristics measured were; daily gain, dressing percent, feed per unit gain and carcass quality (lean cuts, fat cuts and belly). Organ weights taken were; heart, liver, spleen adrenals and digestive tract (cleaned of all ingesta and extraneous tissue). All pigs were purebred Yorkshires bred and raised at the Experimental Farm, Agassiz. Treatment effects were studied by analysis of variance and relationships by within and between treatment correlations and regressions.

Pigs fed in drylot gained faster and had fatter carcasses than those on pasture. The pigs on pasture had larger hearts, spleens and stomachs than those in drylot.

Feeding dried apple pomace at 20% of the ration by weight had no significant effect on the characteristics measured. A trend to greater feed consumption per unit gain and a heavier large intestine were noted, however. Increasing pomace to 40% of the ration reduced rate of gain, increased feed required per unit gain, lowered dressing percent, increased lean percent in the carcass, increased liver weight and increased large intestine weight. These effects were all statistically significant.

Relationships among the economic characteristics which agree closely with those reported by other workers are:

1. Negative between daily gain and feed per unit gain.
2. Positive between dressing percent and percent fat cuts.
3. Negative between dressing percent and percent lean cuts.

The positive relationship between percent fat cuts and percent belly would indicate that belly weight is determined largely by fat deposition.

The relationships presented in this study could be of value in determining characteristics to be included in a selection index for swine improvement.

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