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THE EFFECTS OF FEED INTAKE, NUTRIENT DENSITY AND WEANING AGE ON THE PERFORMANCE, DIET DIGESTIBILITY AND INCIDENCE AND SEVERITY OF DIARRHEA IN YOUNG PIGS

by

Ronald O. Ball

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

IN

Animal Nutrition

Department of Animal Science

EDMONTON, ALBERTA

Fall 1979

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled THE EFFECTS OF FEED INTAKE, NUTRIENT DENSITY AND WEANING AGE ON THE PERFORMANCE, DIET DIGESTIBILITY AND INCIDENCE AND SEVERITY OF DIARRHEA IN YOUNG PIGS submitted by Ronald O. Ball in partial fulfilment of the requirements for the degree of Master of Science in Animal Nutrition.

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Date July 13, 1979

ABSTRACT

Two experiments were conducted to study the effects of diet composition and restriction of feed intake on performance and the incidence and severity of diarrhea (scours) in young pigs.

In the first experiment a total of 72 pigs, weaned at 3 weeks of age, were fed either a simple or a semi-complex diet at 3 levels of feed intake: ad libitum, restricted intake by time exposed to the feed (time-limited) and restricted intake by weight of food fed (weight-limited).

Diet complexity did not significantly affect performance during the 14 day trial. Restricting feed intake significantly reduced gain ($P<0.05$) and gain:feed ratio ($P<0.05$). There were no performance differences between the 2 methods of feed restriction. There was significantly more severe diarrhea ($P<0.01$) when the semi-complex diet was fed. The weight-limited method of restricting intake significantly ($P<0.05$) reduced both incidence and severity of diarrhea. The greatest diarrhea values occurred for pigs fed by the time-limited method. Diarrhea reduced gain ($P<0.05$) and gain:feed ratio ($P<0.05$) by 30 to 40%. The mean number of days required to reach 90 kg liveweight was not significantly affected by diet complexity, feeding method or diarrhea in the post-weaning period.

In the second experiment a total of 128 pigs were weaned at either 3 or 4 weeks of age, and fed a normal density (ND) or a high density (HD) diet for 4 weeks. Diets

were fed either ad libitum or restricted to 85% of the kcals of digestible energy (DE) consumed per kg of pig fed the ND diet ad libitum. Thus all restricted-fed pigs received the same daily nutrient intake, but a lower volume of feed when fed the HD diet.

Significantly greater gains were observed for the 4-week-weaned pigs, the HD diet and ad libitum feeding than for 3-week-weaned pigs, the ND diet and restricted feeding, respectively. The gain:feed ratio was significantly higher for the HD diet ($P<0.005$) and restricted feeding ($P<0.05$).

The HD diet and ad libitum feeding resulted in a higher incidence and more severe scouring than the ND diet and restricted feeding, respectively. The effect of weeks post-weaning was highly significant ($P<0.001$) for both incidence and severity of scours, being highest in week 1 and lowest in week 4.

Apparent digestibility values for gross energy, crude protein and ether extract were determined each week. There was no overall difference in digestibility values between 3- and 4-week-weaned pigs. The HD diet had a significantly greater digestibility for protein ($P<0.05$) and ether extract ($P<0.005$), but not for energy. Restricting feed intake significantly increased digestibility of energy and ether extract, but not of protein. All digestibility values increased significantly with week post-weaning ($P<0.005$). The greatest improvement (19%) occurred for ether extract digestibility. Pigs had similar digestibility values at the

same chronological age regardless of the age at weaning. By week 3 there was no difference in digestibility between ad libitum and restricted feeding.

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I. GENERAL INTRODUCTION

There are two principal objectives in pig production: (1) to supply meat to the human population and (2) to provide profit to the producer. In their efforts to achieve these two objectives, swine producers attempt to produce a maximum amount of lean meat as economically as possible. One of the many changes made in an effort to increase efficiency and profitability of swine production has been the move to the early weaning of pigs. The potential advantages of early weaning are: (1) improved sow productivity by shortening the interval between farrowing and successful mating, (2) reduced sow feed costs and (3) improved performance of the piglets (Aherne 1977). A frequent problem associated with the practice of early weaning is post-weaning diarrhea (scours) and consequent mortality and reduction in growth rate. Major economic losses are suffered by the swine industry every year due to death of scouring pigs. The potential improvement in performance as a result of early weaning, can only be achieved if the health of the piglets is maintained.

Of the many factors suggested to cause or predispose piglets to post-weaning scours, nutritional stress is most frequently cited. Other important factors are environmental and social stresses. The nutritional stress at weaning arises primarily due to change to a solid diet from a milk diet. For pigs weaned before 3 or 4 weeks of age their digestive enzyme system is not sufficiently developed to

allow proper digestion of cereal-based solid food diets (Catron et al. 1957; Lucas and Lodge 1961; Aumaitre 1972). The incomplete digestion of the solid diet which occurs during the adaptation period in early weaned pigs has two important consequences: (1) the pig is not digesting and absorbing sufficient nutrients to maintain its growth and (2) incomplete digestion results in high levels of available substrate for bacterial growth in the digestive tract.

The insufficiency of available nutrients during the early part of the enzyme adaptation period results in a 'post-weaning growth check'. This growth check has been described by several workers (Smith and Lucas 1957; Leibbrandt et al. 1975b; Okai et al. 1976; Rivera et al. 1978) and may last for 7 to 14 days, depending on managerial, environmental and nutritional factors.

The incomplete digestion may also result in explosive growth of pathogenic bacteria, primarily E. coli, in the small intestine. Kenworthy and Crabb (1963) reported that during scouring periods in weaned pigs weighing 4.5 kilograms, total bacterial counts increased significantly and E. coli made up the majority of the intestinal flora. Subsequently Kenworthy and Allen (1966) observed a temporary malabsorption of fat and carbohydrates in pigs weaned at 3 weeks of age, together with an increase in intestinal fluid and a reduction in fecal solids.

Thus the pig is confronted with a period in which his body reserves are low due to weight loss and he is

simultaneously challenged by higher than normal populations of enteropathogenic bacteria. The pig's capacity to recover body reserves and to fight off potential or actual disease is limited by the capacity of the digestive enzyme system to provide nutrients available to the animal.

Based on this knowledge several nutritional factors associated with the incidence and severity of post-weaning diarrhea in young pigs have been identified. These are: diet complexity - the number and quality of energy and protein sources; protein:calorie ratios - varying levels of protein and energy; nutrient density - digestible nutrients per kg of diet; feed intake - overeating; and dietary fibre levels.

The benefits of high dietary fibre levels may be related to the ability of fibre to absorb fluid from the digestive tract and reduce rate of passage, thus preventing the highly fluid diarrhea that leads to dehydration, at least until the pig has adapted to the diet (Richards and Frazer 1961). Much recent effort has been directed towards the use of oats in pig starters to increase fibre levels. Properly balanced diets with up to 30% oats have been fed with no significant effect on visual diarrhea score (Rivera et al. 1978; Watts and Moser 1979; Wahlstrom et al. 1977). Armstrong and Cline (1976, 1977) in comprehensive studies using the ligated intestinal loop technique, intestinal fistulation and intestinal titration, demonstrated that 20% oats did reduce fluid accumulation in the intestine over a corn-soybean control, but had no significant effect upon

fecal E. coli numbers, intestinal E. coli numbers or percent hemolytic E. coli following an oral E. coli challenge or visual observation of diarrhea.

All other nutritional factors associated with diarrhea, are functions of feed and/or nutrient intake. Prior to weaning the pig has very little control over his feed supply . Piglets nurse very frequently (16 to 20 times per day) and only receive small quantities of milk at each feeding (35 to 45 g per feeding at 20 days of age). The piglet would, therefore, appear to be very susceptible to the uncontrolled intake of a dry diet. Stevens (1963) and Thomlinson (1969) observed that post-weaning diarrhea is frequently associated with erratic post-weaning feed intake. They noted that pigs tend not to eat for a period of time following weaning and then to eat a large meal. During this period when the pig's digestive processes are adapting to solid food, a large meal may 'overload' the digestive system and result in diarrhea and discomfort. This discomfort will cause the pig not to eat for a period of time, then to consume another large meal resulting in another scouring episode. If the volume of feed intake is an important factor in post-weaning scours, then restricting intake should reduce the incidence and severity of diarrhea by encouraging smaller, more frequent meals. Arambawela et al. (1975) observed a higher frequency of digestive disturbances in 3-week-weaned pigs fed ad libitum than when fed restricted on a barley diet. Kruse et al. (1976) made the same observation and recommended restricted

feeding for the first 2 weeks post-weaning. Danielsen et al. (1975) recommended a 50% reduction of feed during the first 2 weeks post-weaning to reduce the incidence of scours.

Large single meals tend to alter the normal motile activity of the gut (Ruckebusch and Bueno 1976; Porter and Rolls 1971). Distension of the stomach and small intestine results in temporary stasis of the gastro-intestinal tract followed by fluid accumulation and rapid peristaltic activity. This results in an overall increased rate of passage and reduced nutrient digestibility. Kenworthy and Crabb (1963) postulated that a degree of gut-stasis and a sufficiency of nutrients are required for proliferation of hemolytic E. coli in the gut. Preventing the consumption of large single meals should, therefore, reduce the incidence of scouring. Also since the feed intake of adult pigs can be reduced by feeding high energy or high nutrient density diets (Likuski et al. 1961; Owen and Ridgman 1967, 1968; Cole et al. 1967; Lodge et al. 1972) it may also be possible to reduce the intake of weaned pigs by feeding high nutrient density diets. This has been shown to be true by O'Grady and Bowland (1972), Campbell et al. (1975) and Leibbrandt et al. (1975a) although none of these authors were studying the effect of intake on scouring. The metabolic regulation of feed intake is apparently sufficiently well developed even in the early-weaned pig to result in a reduced feed intake while not reducing nutrient intake. The feeding of a high nutrient density diet should, therefore, reduce the problems

associated with the intake of large infrequent meals.

If post-weaning diarrhea is primarily the result of relatively large quantities of undigested feed in the intestine stimulating bacterial growth, then restricting nutrient intake should further reduce the likelihood of diarrhea. Restricting the daily nutrient intake should reduce scouring by providing less substrate for bacterial growth. Indeed, Palmer and Hulland (1965) found that restricting feed intake reduced the counts of total and of hemolytic E. coli per g of feces in early weaned pigs. They speculated that digestive enzyme insufficiency and the consequent increase in undigested feed in the intestinal tract were likely responsible for the proliferation of E. coli in the early weaned, ad libitum fed pigs.

The complexity of the diet has frequently been implicated in post-weaning diarrhea. The complexity of the starter diet has been suggested to increase the potential for scouring due to the greater palatability of the diet, leading to over-consumption (Okai 1974; Bayley and Carlson 1970; Smith and Lucas 1956).

The consumption of simple diets by pigs weaned at 3 to 5 weeks of age has been shown to be less than the consumption of semi-complex or complex diets (Meade et al. 1969; Zimmerman 1972; Okai et al. 1976). The reduced consumption and poorer initial digestibility of the simpler diets has been shown by the same workers to result in lower rates of gain and poorer feed efficiencies to 5 or 7 weeks

of age, although these differences tend to disappear during the growing-finishing period. The reduced consumption and lower availability of nutrients in the simple diet conceivably should result in a lower incidence of scouring. Similar suggestions have been made by Richards and Frazer (1961), Goodwin (1957) and Jennings (1959).

A difference in susceptibility to diarrhea due to age has also been noted. Kenworthy and Crabb (1963) produced severe diarrhea in pigs weaned at 24 days of age whereas the same treatment produced only minor diarrhea in those weaned at 6 weeks of age and none at all in those weaned at 8 weeks of age. Smith and Jones (1963) produced disease and death in pigs weaned at 24 hr and 14 days, but not in 9 week old pigs dosed with much higher levels of pathogenic E.coli. Some of the differences in age susceptibility are undoubtedly due to the stage of development of the digestive enzymes. However, part of the difference is also due to the developing immunological system in the piglet. The piglet's immunity system is not fully developed to handle serious enteric disease challenge until about 35 days of age, as measured by immunoglobin secretory ability of the intestine (Porter 1976). Prior to weaning, maternal immunoglobin in the milk has afforded the piglet protection from enteric disease (Leece 1975; Porter 1976). When weaned at 3 to 4 weeks of age pigs are, therefore, more susceptible to enteric diseases than younger or older pigs. Since 3 and 4 weeks of age are the most popular ages at which to wean pigs for

those practising early weaning, a comparison between these two ages in terms of susceptibility to diarrhea would be valuable.

The factors of volume of feed consumed, nutrient intake, diet composition and weaning age have been identified as being associated with post-weaning diarrhea in young pigs. The assessment of interactions between and relative importance of these factors would contribute to our knowledge of the problem.

II. EXPERIMENT I: EFFECT OF DIET COMPLEXITY AND FEED INTAKE ON PERFORMANCE AND SCOURING OF 3-WEEK-WEANED PIGS

A. Objective

The objective of this study was to compare the effects of a simple and a semi-complex diet, fed ad libitum or by 2 methods of restriction, on performance and the incidence and severity of scours in 3-week-weaned pigs.

B. Materials and Methods

Animals and Diets

Seventy-two crossbred pigs from 12 litters were used in this study. All sows were farrowed in raised, partially slatted farrowing crates. Farrowing barn temperature was maintained at 20 C and litters were given supplemental heat by means of 250 watt infra-red bulbs. Piglets were injected with an iron dextran before 3 days of age and needle teeth were clipped at that time. Males were castrated at 10 days of age. No creep feed was offered, although the pigs had access to feed spilled by their dams.

The piglets were weaned at 21 days of age and fed for 14 days on either a simple or semi-complex diet. The composition and analysis of diets appears in Table 1. The diets contained no antibiotic or growth promotant and were based on the regular test station diet calculated to meet NAS-NRC 1973 nutrient requirements. Each diet was fed at 3

TABLE 1: FORMULATION AND COMPOSITION OF STARTER DIETS

	Simple	Semi-Complex
Ingredients (%):		
Wheat	25.0	35.0
Barley	25.0	20.0
Oat Groats	25.0	15.0
Tallow	3.0	2.0
Soybean meal	18.0	7.0
Herring meal	-	5.0
Dried skim milk	-	2.5
Dried whey	-	10.0
Iodized salt	0.5	0.5
Calcium phosphate	1.5	1.25
Calcium carbonate	1.0	0.75
Vitamin-mineral premix[1]	1.0	1.0
Composition (Analyzed):		
Crude protein (%)	18.7	18.5
Crude fibre (%)	4.3	2.8
Calcium (%)	0.93	1.1
Phosphorus (%)	0.77	0.76
DE (kcal/kg-calculated)	3376	3370

[1] Supplied the following per kg of diet: 4,400 IU vitamin A; 665.5 IU vitamin D_2; 11 IU vitamin E; 66 mg vitamin B_{12}; 11.1 mg riboflavin; 22.2 mg calcium pantothenate; 50.5 mg niacin; 55.7 mg choline chloride; 1.65 mg folic acid; 2.8 mg cobalt; 24.6 mg copper; 294.1 mg iron; 76.2 mg manganese; 88.5 mg zinc and 1.5 mg iodine.

levels of feed intake: ad libitum, restricted feeding by limiting the time exposed to the feeder (time-limited) and restricting intake by regulating the amount of food fed (weight-limited). The feeding schedule for the timed group started with feed available for 2 hours per day and was increased by 2 hours every 3 days. On days 13 and 14, when the feed was available for 10 hours per day, 11 of the 12 time-limited pens of pigs were consuming an amount of feed equivalent to the ad libitum fed group (calculated as a percent of body weight). For the weight-limited group, the weight of food fed was calculated as a percentage of the feed consumption of the ad libitum pigs on the previous day. On day 1 the weight-limited group received 20 g of feed and on day 2 they received 20 g or 50% of the amount consumed by their littermates fed ad libitum, whichever was greater. Thereafter the allotment increased by 10% every 3 days so that on day 13 and 14 these pigs were offered 90% of the feed consumed by the pigs fed ad libitum. All weight-limited pigs failed to consume their daily allotment on days 13 and 14 due to their smaller body weight compared to the ad libitum fed group. An outline of the experimental design appears in Table 2.

Twelve litters of 8 to 10 pigs were randomly assigned to diets at weaning. The 6 pigs in each litter weighing closest to the mean litter weight were allotted in pairs to the 3 feed intake treatments within a diet on the basis of sex. Thus each pen contained 1 barrow and 1 gilt from the

TABLE 2: DESIGN OF EXPERIMENT I

Restriction:	Time-limited	Weight-limited
Day	Hours exposed to feeders	Feed offered as % of ad libitum
1 - 3	2	50[1]
4 - 6	4	60
7 - 9	6	70
10 - 12	8	80
13 - 14	10	90

[1] Day 1 = 20 g/pig
Day 2 = 20 g/pig or 50% of ad libitum if greater

same litter and all 6 pigs were fed the same diet.

The pigs were housed in half-slatted concrete floor pens measuring 1.22 m X 1.22 m. Environmental temperature was maintained at 23 C and water was available ad libitum from automatic drinking bowls. The feed was supplied in commercial 3-hole feeders. The previous day's feed was removed and fresh feed was added daily. Pig weights and feed intakes were recorded daily. Care was taken to sweep-up spilled feed every day to ensure accurate feed intake data.

The incidence and severity of diarrhea were recorded daily for each pig based on observations during a 3 to 4 hour period each morning. The incidence of scouring was measured as the number of days that each pig scoured. The severity of scouring was determined by visual observation and recorded on a scale of 0 to 3 according to the parameters outlined below:

0 - firm -normal feces,

1 - slight - feces very soft, unable to maintain shape,

2 - moderate - complete lack of definition, partly fluid but not free flowing

3 - severe - very fluid, free flowing.

Statistical Analysis

Analysis of variance was performed on the data to determine significant differences between treatments. The Student Newman-Keuls multiple range test was used to determine differences between groups of means. A Students

t test was used to determine differences between pairs of means (Steel and Torrie 1960).

C. Results and Discussion

Effect of Diet Complexity on Performance

The effects of diet complexity on pig performance are shown in Table 3. There were no significant differences between the two diets for average daily gain (ADG), average daily feed intake (ADF) or gain to feed ratio although there was a slight tendency towards increased performance for pigs fed the semi-complex diet. A significant improvement in feed intake and gain due to increasing diet complexity was reported by Okai et al. (1976) when similar diets were fed to 3-week-weaned pigs for 4 weeks post-weaning. Improved performance in 3-week-weaned pigs due to diet complexity has also been reported by Meade et al. (1969), Bayley and Carlson (1970) and Zimmerman (1972). The lack of difference found in this trial was partly due to the short experimental period (14 days) and partly due to the difference in scouring, as discussed later. Okai (1974) obtained no differences in gain between a simple and semi-complex diet when compared after 2 weeks post-weaning.

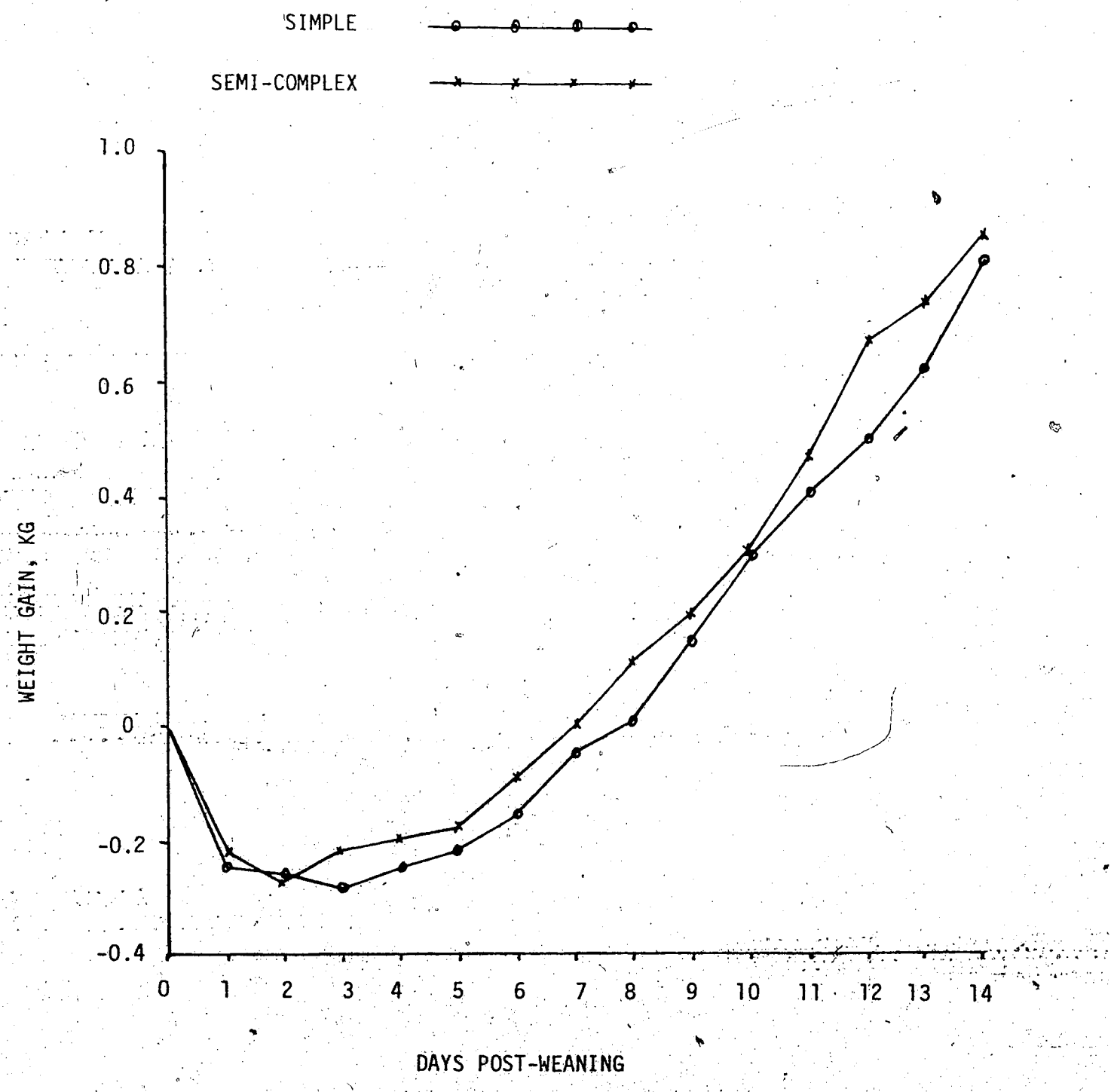
Figure 1 shows daily post-weaning growth rate of pigs fed the 2 diets. There was virtually no difference in total gain between the 2 diets. Pigs fed the simple diet lost more weight and required 1 more day to regain their weaning weight (8 vs. 7 days) than pigs fed the semi-complex diet. Okai et al. (1976) reported a post-weaning growth check very

TABLE 3: EFFECT OF DIET COMPLEXITY ON PIG PERFORMANCE

Diet	Initial Weight (kg)	Final Weight (kg)	ADG (g)	ADF (g)	Gain/Feed
Simple	5.08	5.89	58	165	.352
Semi-Complex	4.72	5.57	61	146	.418
Significance	NS	NS	NS	NS	NS
SE[1]	.161	.261	10.5	10.6	.049

[1]Standard Error

FIGURE 1 : EFFECT OF DIET COMPLEXITY ON WEIGHT GAIN



similar to this. His pigs fed the simple diet also required 1 more day to regain their weaning weight.

Effect of Feeding Method on Performance

Table 4 shows the effect of feeding method on piglet performance. The ad libitum fed pigs had the lowest initial weight ($P<0.05$), significantly greater average daily gain ($P<0.05$), average daily feed intake ($P<0.01$) and gain to feed ratio ($P<0.05$) than either group of pigs fed at a restricted level. There were no significant differences in ADG, ADF or gain to feed ratio between the 2 methods of feed restriction, although the time-limited pigs did slightly better in all 3 parameters. The weight-limited pigs gave the overall lowest performance of all groups. Although pigs were randomly allotted to treatments, initial weight was significantly different between the 3 feeding methods.

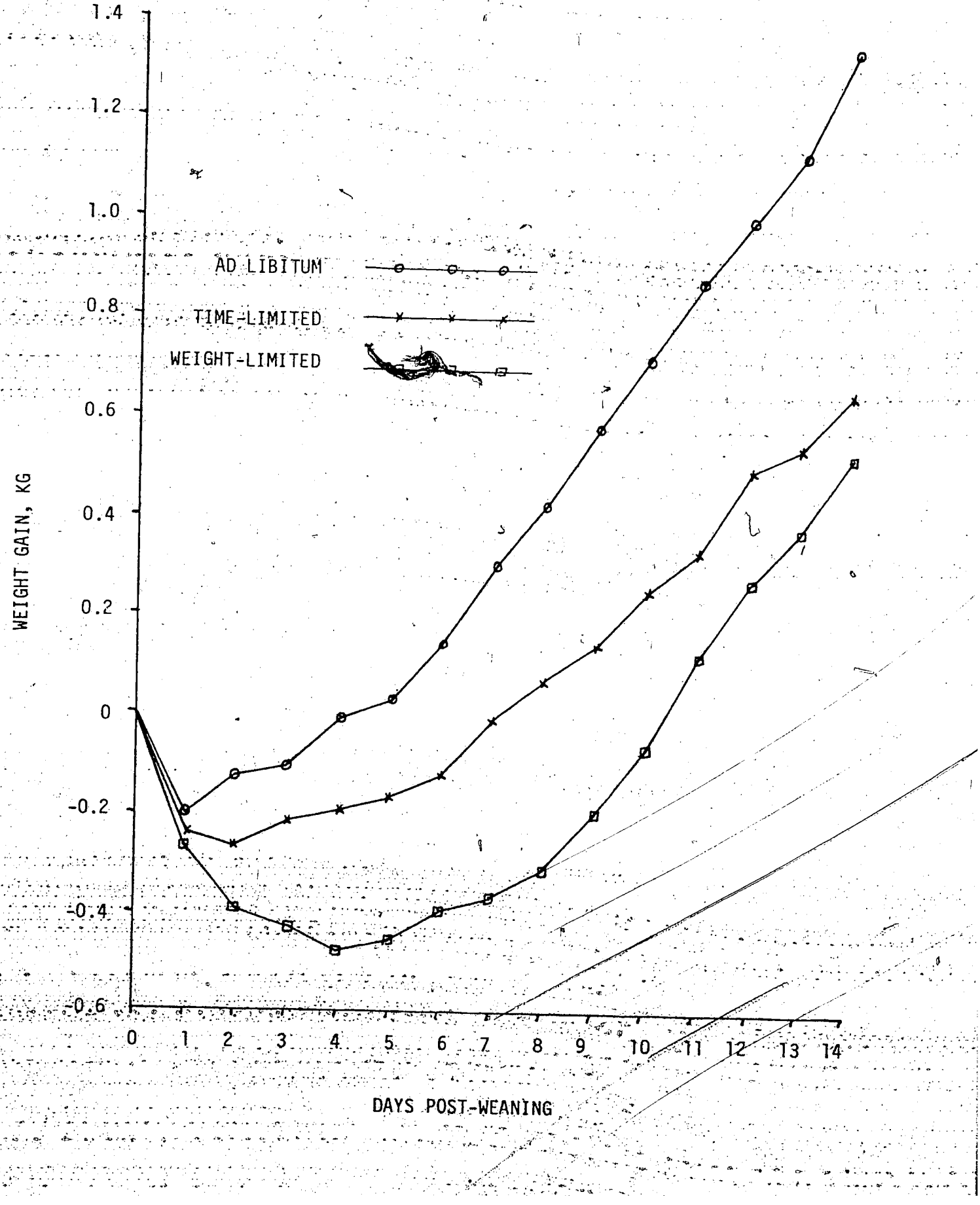
Figure 2 displays the daily weight change of pigs fed by the different methods. The ad libitum fed pigs began gaining weight after the first day and regained their weaning weight at an average of 4.5 days. The time-limited and weight-limited pigs regained their weaning weights in 7.2 and 10.4 days, respectively. Figure 2 shows why the overall difference in gain between the 2 methods of restriction was not significant. Although the weight-limited pigs lost nearly twice as much weight as the time-limited pigs their total gain for the period was similar. Between day 7 and 14 the weight-limited pigs had a significantly

TABLE 4: EFFECT OF FEEDING METHOD ON PIG PERFORMANCE[1]

Feeding Method	Initial Weight (kg)	Final Weight (kg)	ADG (g)	ADF (g)	Gain/Feed
Ad Libitum	4.69[a]	6.03[a]	97[a]	208[a]	.466[a]
Time-Limited	4.85[b]	5.47[b]	45[b]	165[b]	.273[b]
Weight-Limited	5.12[c]	5.69[b]	37[b]	140[b]	.264[b]
SE	.035	.106	5.3	11.4	.017

[1]Means within columns with the same superscript are not significantly different ($P > 0.05$).

FIGURE 2 : EFFECT OF FEEDING METHOD ON WEIGHT GAIN



greater ADG ($P<0.01$) than the time-limited pigs (64 g/day versus 44 g/day). By 14 days the weight-limited pigs had caught up to the time-limited pigs in gain. This phenomenon of compensatory growth has been frequently described (Elsley 1963; Lucas et al. 1959).

Effect of Diet Complexity and Feeding Method on Scouring

Table 5 shows that when fed the simple diet there were fewer pigs scouring, fewer days of scouring, a lower average number of days of scour per pig (incidence) and a lower average scour number (severity) than when fed the semi-complex diet. The only significant difference, however, was for average scour number where the pigs fed the semi-complex diet scoured more severely ($P<0.01$) than pigs fed the simple diet. This is likely part of the reason why no difference in performance was observed between the 2 diets. Several other researchers have reported that scours occur less frequently on simple diets (Okai 1974; Bayley and Carlson 1970; Smith and Lucas 1956). Scouring has also been shown to lead to a reduced feed intake and lower weight gain (Stevens 1963; Palmer and Hulland 1965; Thomlinson 1969).

Feeding methods had an important effect upon scouring as shown on the bottom half of Table 5. The most pigs scoured when they were fed by the time-limited method. They also scoured for more days ($P<0.05$) than pigs fed either ad libitum or on a weight-limited basis. The weight-limited fed pigs scoured for significantly fewer days than the ad

TABLE 5: EFFECT OF DIET COMPLEXITY AND FEEDING METHOD[1] ON INCIDENCE AND SEVERITY OF SCOURS

	Number of Pigs Scouring[2]	Total Number of Days	Average Number of Days[3]	Average Scour Number[3]
Diet:				
Simple	23	90	3.8	6.8
Semi-Complex	26	142	5.3	11.2
Significance		NS	NS	**
SE		25.5	.71	1.47
Feeding Method:				
Ad Libitum	15	87[a]	5.4[a]	11.5[a]
Time-Limited	20	103[b]	5.2[a]	9.4[b]
Weight-Limited	15	43[c]	2.9[b]	5.9[c]
SE		14.1	.59	.84

[1]Means within columns with the same superscript are not significantly different ($P > 0.05$).

[2]Thirty-six pigs per diet; twenty-four pigs per feeding method.

[3]per pig scouring

** ($P < 0.01$)

libitum fed pigs. There was no difference in average number of days scouring for pigs fed either ad libitum or time-limited, but the weight-limited fed pigs scoured significantly less than the other 2 feeding methods. The time-limited method of restricting intake was not satisfactory since it resulted in a greater incidence of scours than ad libitum feeding. The greater incidence of scouring for the time-limited pigs is probably due to their more erratic feed intake and tendency to overeat when the feeder was first placed in the pen each day. Since the pigs were allowed to eat as much as they wanted while the feeder was in the pen, they tended to eat as much as they could. Large single meals tend to result in temporary stasis of the gastro-intestinal tract, followed by fluid accumulation and rapid peristaltic activity resulting in reduced digestibility and increased rate of passage (Ruckebusch and Bueno 1976; Porter and Rolls 1971). Kenworthy and Crabb (1963) suggested that gut stasis may allow the proliferation of hemolytic E. coli in the gut and thus result in scouring. This is probably what happened to the time-limited fed pigs.

All 3 methods of feeding had significantly different scour numbers, with the ad libitum fed pigs scouring most severely and those fed by the weight-limited method scouring least severely. Thus the overall lowest level of scouring occurred with pigs fed on the weight-limited basis. These results are in agreement with those of Lynch (1975) who reported that restricting post-weaning feed intake on an

increasing scale for 14 days reduced incidence of scouring and piglet mortality in pigs weaned at 4 weeks of age. English et al. (1978) have also reported a decrease in mortality and number of veterinary treatments for scours when complex diets were similarly restricted on a large commercial operation. There was no mortality in the experiment reported here. Restricting feed intake by weight would reduce scouring by preventing over-eating and by reducing the availability of nutrients in the gut for bacterial growth.

Effect of Scouring on Performance

The total gain and gain to feed ratio of scouring pigs are compared to that of non-scouring pigs in Table 6. Scouring caused a significant reduction in gain when either diet was fed ($P<0.05$). Between the 2 diets there was no difference in the gain of scouring piglets, but non-scouring piglets gained significantly more on the semi-complex diet ($P<0.05$). Since there were only 10 of 36 pigs that did not scour on the semi-complex diet (Table 5), this explains the lack of difference in gain overall between the two diets.

The gain to feed ratio of scouring pigs fed either diet was significantly less ($P<0.05$) than the non-scouring pigs. Scouring pigs required 65 to 72% more feed per unit of gain than non-scouring piglets. The effect of scouring upon feeding economics is plainly apparent.

Within feeding method the loss in gain and reduced gain

TABLE 6: PERFORMANCE OF SCOURING VERSUS NON-SCOURING PIGLETS[1]

	Total Gain (g)[2]			Gain/Feed		
	Scouring	Non-Scouring	Sig[3]	Scouring	Non-Scouring	Sig[3]
Diet:						
Simple	673	1050	*	.283	.440	*
Semi-Complex	713	1167	*	.336	.459	*
Significance	NS	*		NS	NS	
SE	145			.049		
Feeding Method:						
Ad Libitum	1135[a]	1700[a]	***	.431[a]	.543[a]	***
Time-Limited	570[b]	875[b]	***	.272[b]	.384[b]	***
Weight-Limited	365[c]	750[b]	***	.228[b]	.421[b]	***
SE	74			.017		

[1] Means within columns with the same superscript are not significantly different ($P > 0.05$).

[2] per pig from 3 weeks to 5 weeks of age.

[3] Significance

* ($P < 0.05$)

*** ($P < 0.005$)

to feed ratio due to scouring was very highly significant ($P<0.001$). The total gain of scouring piglets was significantly different for each feeding method, being highest for ad libitum feeding and lowest for weight-limited feeding.

Greater gains were achieved by the non-scouring piglets. The highest gain was naturally achieved by the ad libitum fed pigs ($P<0.05$). There was no significant difference in gain between the 2 methods of restriction when no scouring occurred. Scouring reduced the gain of ad libitum fed pigs by 565 g/pig while restricting intake by time or weight reduced performance of non-scouring piglets by 825 g and 950 g/pig, respectively. Thus these methods of restriction reduced performance to a greater degree than did scouring during the 2 week experimental period.

The gain to feed ratio of ad libitum fed pigs was significantly greater than the 2 methods of feed restriction for both scouring and non-scouring piglets. There was no difference in gain to feed ratio between time-limited or weight-limited fed pigs, whether scouring or non-scouring. The weight-limited fed pigs tended to give a greater gain to feed ratio than the time-limited fed pigs when not scouring. The lower gain to feed ratios for the restricted fed pigs is a reflection of the amount of feed eaten relative to their maintenance requirement (Elsley 1963). For both restricted fed groups, there was very little feed above that required for maintenance left over for growth, therefore, there was

reduced growth and a low gain to feed ratio.

Since the non-scouring, ad libitum fed pigs performed at a normal level during the study, the overall poor performance reported can be explained by the high percentage of pigs that scoured (Table 5) and the large reduction in performance due to scouring (Table 6).

Effect of Diet Complexity, Feeding Method and Scouring on Days to 90 kg Liveweight

In spite of the poor post-weaning performance the number of days required to reach 90 kg liveweight was relatively normal (Table 7). There was no significant effect on days to 90 kg due to composition of post-weaning diet or method of feeding. A number of authors have noted that lowering feed intake and gain in the post-weaning period results in more rapid gain and better feed conversion during the subsequent growing and finishing period which allows the restricted pigs to 'catch-up' (Nielsen 1964, 1976; Elsley 1963; Lucas et al. 1959). In this experiment even the very severe restriction suffered by the weight-limited pigs during the 2 week post-weaning period did not significantly reduce their subsequent growth rate. The degree of post-weaning scouring also had no effect upon growth rate to 90 kg liveweight. This data indicates that dietary treatments immediately post-weaning may not have a significant effect on overall pig performance to 90 kg. However, this experiment only lasted for 14 days which may

TABLE 7: EFFECT OF DIET, FEEDING METHOD AND SCOURING ON DAYS TO 90 KG LIVEWEIGHT

	Days to 90 kg	Number of Pigs
Diet:		
Simple	163.0	36
Semi-Complex	169.0	36
Significance	NS	
SE	2.3	
Feeding Method:		
Ad Libitum	168.5	24
Time-Limited	163.4	24
Weight-Limited	166.2	24
Significance	NS	
SE	2.2	
Scours:		
Scouring	167.7	49
Non-Scouring	162.6	23
Significance	NS	
SE	2.9	

not have been long enough to affect subsequent performance by dietary methods. Scouring on the other hand has been shown to damage intestinal villi and reduce absorptive capacity (Scrimshaw 1977). It is surprising therefore that scouring pigs in this experiment achieved the same days to 90 kilograms as non-scouring pigs. The scouring in this study may not have been severe enough to cause intestinal damage.

D. Summary

Diet complexity did not significantly affect pig performance. Restriction of feed intake significantly reduced performance compared to that of pigs fed ad libitum. There was no significant difference in performance between pigs on the 2 methods of feed restriction.

The scouring which occurred on the semi-complex diet was significantly more severe than that which occurred on the simple diet. The restriction of starter feed intake by weight of food fed significantly reduced the incidence and severity of post-weaning scours. Limiting time exposed to the feeder was not a satisfactory method of reducing scours as it resulted in greater incidence of scouring than did ad libitum feeding. Scouring caused by either diet or either feeding method significantly reduced performance. Restricting feed intake by the methods used in this experiment reduced performance more than did scouring.

The number of days taken to reach 90 kg liveweight was not affected by diet complexity, feeding method or scouring in the immediate post-weaning period.

III. EXPERIMENT II: EFFECT OF AGE, DIET AND FEED INTAKE ON PERFORMANCE AND SCOURING

A. Objective

The objective of this experiment was to assess the effects of weaning age, nutrient density of the diet and level of feed and nutrient intake on performance and the incidence and severity of diarrhea in piglets.

B. Materials and Methods

Animals and Diets

One hundred and twenty-eight pigs from 16 cross-bred sows were used in this study. There were 8 sows in each of 2 parity groups, being either first litter or fifth litter sows. Creep feed (Table 8) was offered to all piglets ad libitum beginning at 14 days of age. One half of the pigs (64) were weaned at each of 3 weeks and 4 weeks of age. The initial weight averaged 5.03 kg. for the 3-week-weaned pigs and 6.94 kg. for the 4-week-weaned pigs. A weaning age by parity interaction was developed by weaning litters from both parity groups at both ages. The standard baby pig management practices were as described in Experiment I.

Two different semi-complex type diets were fed to pigs of each age group. The diets were a 'normal nutrient density' (ND) based on the NAS-NRC (1973) recommendations and a diet formulated with 10% higher nutrient density (HD).

TABLE 8: FORMULATION AND COMPOSITION OF CREEP DIET

Ingredients (%):	
Wheat	25.0
Barley	13.0
Oat Groats	25.0
Tallow	2.0
Soybean Meal	13.0
Herring Meal	6.0
Dried Skim Milk	10.0
Iodized Salt	0.5
Calcium Phosphate	1.5
Calcium Carbonate	1.0
Vitamin-Mineral Premix[1]	1.0
Composition (calculated):	
Crude Protein (%)	22.5
Calcium (%)	0.9
Phosphorus (%)	0.8
Digestible Energy (kcal/kg)	3.49
Lysine (%)	1.2

[1]Supplied the following per kg of diet: 4,400 IU vitamin A; 665.5 IU vitamin D_2; 11 IU vitamin E; 66 mg vitamin B_{12}; 11.1 mg riboflavin; 22.2 mg calcium pantothenate; 50.5 mg niacin; 55.7 mg choline chloride; 1.65 mg folic acid; 2.8 mg cobalt; 24.6 mg copper; 294.1 mg iron; 76.2 mg manganese; 88.5 mg zinc and 1.5 mg iodine.

The composition of the diets appears in Table 9. The diets contained no antibiotic or growth promotant. Chromic oxide was added at a level of 0.5% for the digestibility determinations. Soybean oil was used at a level of 10% in the HD diet to increase the energy content. Soybean oil was used rather than tallow as 10% tallow in the diet has been shown to be unpalatable to young pigs, since it reduces feed intake more than would be expected from the change in the energy concentration of the diet (Frobish et al. 1970). The fibre levels in the diets were kept constant to eliminate the possible complicating effects of fibre level upon scouring.

Table 10 demonstrates that considerable care was taken in the formulation of the diets to ensure that the level of each nutrient supplied per 1000 kcal of digestible energy was nearly identical in both rations.

Each diet was fed at 2 different intake levels. The 2 feed intake levels were ad libitum and restricted. The level of restriction was 85% of the kcals of digestible energy consumed per kg of pig by pigs fed the ND diet ad libitum. The calculation was based on the ad libitum intake of 2 pens of pigs of the same age and sex. Thus the pigs fed the restricted level of the HD diet were receiving a lower volume of feed than those on the restricted level of the ND diet, but both were calculated to receive the same amounts of the various nutrients.

The pigs were penned by sex and balanced as closely as

TABLE 9: FORMULATION AND COMPOSITION OF STARTER DIETS

Diet:	ND	HD
Ingredients (%):		
Wheat	25.0	20.0
Barley	15.25	9.4
Oat Groats	25.0	20.0
Soybean Meal	11.0	20.0
Herring Meal	6.4	6.0
Dried Whey	10.0	10.0
Tallow	3.0	-
Soybean Oil	-	10.0
Iodized Salt	0.4	0.5
Calcium Phosphate	1.0	1.45
Calcium Carbonate	0.7	0.65
Vitamin-mineral Premix[1]	1.5	1.5
Lysine - HCl (76%)	0.25	-
Chromic Oxide	0.5	0.5
Composition (Calculated):		
Crude Protein (%)	20.4	22.3
Crude Fibre (%)	2.8	2.6
Ether Extract (%)	5.8	12.2
Calcium (%)	0.79	0.85
Phosphorus (%)	0.69	0.76
Digestible Energy (kcal/kg)	3378	3737

[1] For composition see Table 1.

TABLE 10: RELATIVE NUTRIENT DENSITY, CALCULATED

Diet:	ND	HD
g/1000 kcal of Digestible Energy:		
Crude Protein	60.4	59.8
Lysine	3.62	3.61
Methionine & Cystine	1.89	1.85
Threonine	2.38	2.38
Tryptophan	0.74	0.74
Calcium	2.30	2.28
Phosphorus	2.04	2.03

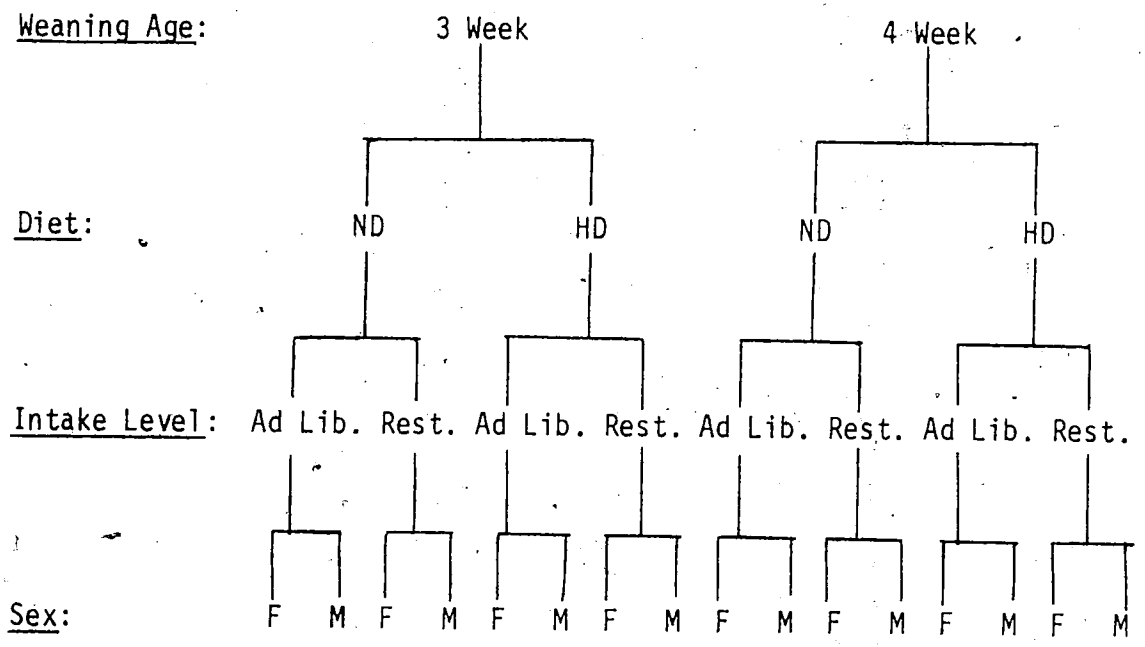
possible for weight and litter within each age group. The experimental design is shown in Figure 3. Pigs were penned by sex and balanced by litter and parity, so that the genetic effects of sex and dam, and the effect of age of dam upon pig performance could be separated out in the analysis. The error mean square was thus reduced, providing a more sensitive test of the differences due to main effects.

The pigs were housed, 4 per pen on half-slatted concrete floor pens measuring 1.22 m X 1.22 m. The environmental temperature was kept at 27 C. Water was available ad libitum in automatic drinking bowls throughout the experiment. The feed was supplied in commercial 6-hole feeders equipped with a movable slide bar to reduce feed wastage. The slide bars on feeders of the restricted-fed pigs were set such that some feed was retained behind the slide bar after the morning feeding. The remaining feed was then pushed within reach of the pigs approximately 8 hours later.

All pigs were weighed at weaning and at 3, 5, 7, 10, 14, 17, 21, 24 and 28 days post-weaning. The feeding trial concluded 28 days post-weaning. Feed intake was recorded daily by weigh-back and fresh feed was added. All spilled feed was carefully swept-up every day with a camel-hair brush, weighed and used to adjust feed intake.

The incidence and severity of scours were recorded daily. The incidence of scours was measured as the number of scour days occurring per pen. The severity of scouring was

FIGURE 3: EXPERIMENTAL DESIGN



based on a daily visual score on a scale of 0 to 3 based on fecal consistency. As in Experiment I, 3 was a severe, highly fluid scour; 2 was a moderate scour; 1 was a slight scour; and 0 indicated no scour. Scores were recorded on a pen basis following observation for signs of scouring on individual pigs, consistency of feces in the pen and consistency of feces voided during a 3 to 4 hour period each morning. The daily scores were summed to give an index of scour severity for each pen. This method of evaluating scours has been used previously by O'Grady (1978), Rivera et al. (1978) and Arambawela et al. (1975).

Statistical Analysis

Analysis of variance for a factorial design was performed on the data collected. Three pigs died and 1 pig was removed during the experiment. Analysis of covariance was used to estimate the missing observations (Steel and Torrie 1960) and the estimated values were then used for the analysis of variance. An F-test of the mean squares was used to determine significance of main factors. All other pairs of means were evaluated using a t test. The Student Newman-Keuls multiple range test (Sokal and Rolf 1969) was used to determine significant differences between groups of treatment means at the 5% level of probability ($P<0.05$).

C. Results and Discussion - Piglet Performance

Three pigs died during the course of the study and were submitted to the Alberta Agriculture, Veterinary Services Division, Diagnostic Laboratory for post-mortem examination. The cause of death was determined for 2 pigs as enteric colibacillosis. Bacterial examination demonstrated hemolytic coliforms agglutinating with K88 antigen. One pig was from the 3-week-weaned, restricted group, fed the ND diet and the other pig was from the 4-week-weaned, ad libitum group, fed the HD diet. The third pig's death was diagnosed as due to an infection resulting from castration. A fourth pig was removed due to a broken foot. Following the death of the 2 pigs to colibacillosis all pigs were treated for 3 days with 1/4 cc Gallimycin-200 Injectable (Abbot Laboratories, Montreal, Can.) and 1 ml. Neomix-Pamine (Tuco Products, Orangeville, Ontario, Can.).

Main Effects

The mean pen performance data subdivided by main effect is shown in Table 11. Pigs weaned at 4 weeks of age had a significantly greater average daily gain (ADG) ($P<0.005$) and average daily feed intake (ADF) ($P<0.001$) than pigs weaned at 3 weeks of age. Three-week-weaned pigs had a higher ($P<0.10$) gain to feed ratio. The bodyweight of pigs weaned at 3 or 4 weeks of age was not significantly different

TABLE 11: MEAN PEN[1] PERFORMANCE BY MAIN EFFECT

	Average Daily Gain(g)	Average Daily Feed(g)	Overall Gain/Feed
Weaning Age:			
3 Week	815	1381	.590
4 Week	1003	1758	.570
Significance	***	****	NS
Diet:			
ND	883	1621	.545
HD	935	1518	.616
Significance	**	NS	***
Intake Level:			
Ad Libitum	955	1714	.557
Restricted	864	1425	.605
Significance	*	****	*
Sex:			
Female	900	1544	.583
Male	918	1595	.576
Significance	NS	NS	NS
Standard Error	31.4	44.5	.017

[1] Four pigs/pen.

* (P<0.05)

** (P<0.01)

*** (P<0.005)

**** (P<0.001)

(10.86 kg versus 10.74 kg) at 7 weeks of age. Similar observations have been made by Leibbrandt et al. (1975a).

The HD diet supported significantly greater gains ($P<0.01$) than the ND diet on less feed, thus resulting in a markedly improved gain to feed ratio ($P<0.005$). The reason for this difference will be elaborated on during the discussion.

As dictated by the experimental design, the pigs fed ad libitum had greater feed intakes ($P<0.001$) and thus greater gains ($P<0.05$) but had a lower gain to feed ratio ($P<0.05$) than restricted fed pigs.

There was no significant effect of sex upon gain, feed intake or feed conversion, but the normal trend of faster growth rate, greater feed intake and lower feed conversion efficiency of castrated males was observed (ARC 1967).

Weeks post-weaning (Table 12) had a highly significant effect upon all 3 performance parameters. Feed consumption was low the first week resulting in a post-weaning 'check' in growth rate.

Interaction of Weaning Age and Diet

The effect of weaning age and diet on pig performance is shown in Table 13. The HD diet allowed greater gains than the ND diet for both age groups, but the difference was significant ($P<0.005$) only for the pigs weaned at 3 weeks of age. There was no significant difference between the 2 diets within age groups for feed intake. However, when age groups

TABLE 12: MEAN WEEKLY PEN[1] PERFORMANCE

	Average Daily Gain(g)	Average Daily Feed(g)	Overall Gain/Feed
Week:[2]			
1	88[a]	563[a]	.156[a]
2	669[b]	1110[b]	.603[b]
3	1227[c]	2004[c]	.612[bc]
4	1653[d]	2603[d]	.635[c]
Significance	****	****	****
Standard Error	30.9	36.5	.027

[1]Four pigs/pen.

[2]Means within columns with the same superscript are not significantly different (P>0.05).

****(P<0.001).

TABLE 13: EFFECT OF WEANING AGE AND DIET ON PIGLET PERFORMANCE

Weaning Age:	3 Week		4 Week		
Diet:	ND	HD	ND	HD	SE[1]
ADG (g)[2]	780[a]	851[b]	986[bc]	1019[c]	44.4
ADF (g)	1440[a]	1322[a]	1802[b]	1714[b]	62.9
Gain/Feed	.542[a]	.644[b]	.547[a]	.595[ab]	.024

[1]Standard Error

[2]Means within rows with the same superscript are not significantly different ($P > 0.05$).

are compared, the 4-week-weaned pigs gained significantly more on each diet than did the 3-week-weaned pigs. This is likely a direct result of the greater feed intake by the 4-week-weaned pigs.

Interaction of Diet and Level of Intake

The data in Table 14 shows that the restricted fed pigs ate significantly less feed than the ad libitum fed pigs, gained less and had a slightly improved gain to feed ratio. This is the normal effect of moderate feed restriction on pig performance (ARC 1967). Pigs fed the HD diet ad libitum consumed 6.7% less feed than those fed the ND diet ad libitum and grew 3.8% faster. Reference to Table 15 shows that virtually the same kcal of digestible energy (DE) per kg of pig were consumed for the 2 diets when fed ad libitum. The slightly greater ADG of pigs fed the HD diet ad libitum on the same level of energy intake as pigs fed the ND diet, suggests that the HD diet was used more efficiently for growth. Campbell et al. (1975) have also noted that the efficiency of utilization of DE for growth tends to increase with increasing dietary concentration of energy, when the calorie:protein ratio is maintained. Restricting the intake of the HD diet improved gain to feed ratio more (9.5%) than restricting the ND diet (6.5%). The slightly higher DE intake on the HD diet compared to the ND diet when both were restricted, Table 15, may account for the slight difference in gain. The gain to feed ratios were increased but not

TABLE 14: EFFECT OF DIET AND LEVEL OF INTAKE ON PIGLET PERFORMANCE

Diet:	ND		HD		
Intake Level:	Ad Libitum	Restricted	Ad Libitum	Restricted	SE
ADG (g)[1]	937[a]	830[a]	973[a]	897[a]	44.4
ADF (g)	1773[a]	1469[b]	1655[a]	1381[b]	62.9
Gain/Feed	.528[a]	.565[a]	.588[ab]	.650[b]	.024

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

TABLE 15: MEAN KCAL OF DIGESTIBLE ENERGY CONSUMED PER KG PIG

Diet:	ND	HD
Intake Level:		
Ad Libitum	4928	4948
Restricted	4140	4240

significantly, by the restriction of either diet.

Table 15 also indicates that the pigs did control their ad libitum intake according to nutrient density of the diet, as shown previously by Campbell et al. (1975) and Leibbrandt et al. (1975b), and that the intention of the experiment to limit intake of both diets to the same level of energy intake was achieved. Table 16 shows the DE intake for all treatments as a percent of the DE intake of pigs fed the ND diet ad libitum. The desired intake of 85% was nearly achieved.

Interaction of Weaning Age and Level of Intake

There was a significant interaction ($P<0.05$) of weaning age and level of intake on ADG as shown in Table 17. This interaction occurred because for 4 week weaning the restricted fed pigs had similar gain to those fed ad libitum while for the 3-week-weaned pigs the restricted fed pigs gained much less ($P<0.05$). This can be explained by the greater number of days and more severe scouring suffered by the 4-week-weaned, ad libitum fed pigs, as compared to the other 3 groups, as shown in Table 22. The higher level of scouring resulted in decreased feed efficiency and lower daily gains. This effect of scouring has been noted by many workers (Lloyd et al. 1957; Smith and Lucas 1956; Goodwin 1957; Jennings 1959). The daily gain was thus reduced to the same level as that achieved by the restricted fed pigs and gain to feed ratio was low, indicating that scouring in the

TABLE 16: DIGESTIBLE ENERGY CONSUMED PER KG OF PIG AS A % OF THE ND DIET FED AD LIBITUM

Diet:	ND	HD
Intake Level:		
Ad Libitum	100.0	100.4
Restricted	84.0	86.0

TABLE 17: EFFECT OF WEANING AGE AND LEVEL OF INTAKE ON PIGLET PERFORMANCE

Weaning Age:	3 Week		4 Week		
Intake Level:	Ad Libitum	Restricted	Ad Libitum	Restricted	SE
ADG (g)[1,2]	905[a]	726[b]	1005[a]	1001[a]	44.4
ADF (g)	1554[a]	1209[b]	1875[c]	1641[a]	62.9
Gain/Feed	.582[a]	.600[a]	.536[b]	.610[a]	.024

[1]Significant interaction for ADG ($P < 0.01$).

[2]Means within rows with the same superscript are not significantly different ($P > 0.05$).

4-week-weaned pigs resulted in a greater loss in overall performance than did restricting feed intake. The difference in performance between the ad libitum and restricted fed pigs when weaned at 3 weeks of age was mainly due to actual feed restriction and not any difference in scouring.

Interaction of Diet and Weeks Post-weaning

Table 18 shows the performance values of diets for each week post-weaning. Within each diet ADG and ADF increased significantly each week. The gain to feed ratio increased but the difference was not always significant.

Although the differences were not significant there were generally greater gains and less feed eaten each week on the HD diet than on the ND diet. The difference in feed intake the first week was only 1.2% compared to the other 3 weeks which were 4.1%, 7.4% and 7.6%, respectively. This indicates that the pig requires time to adapt to the diet before it can control feed intake according to its energy requirements. This result agrees with the findings of Owen and Ridgman (1967, 1968) for growing and finishing pigs.

There was a significant interaction ($P<0.05$) between diet and week for gain to feed ratio. Gain per unit feed for both diets improved significantly between week 1 and week 2. The low gain to feed ratio in the first week was associated with the loss of weight during the 'check' period. Between week 2 and week 3 the gain to feed ratio of pigs fed the ND diet increased by 0.027 units whereas the HD diet increased

TABLE 18: EFFECT OF DIET ON WEEKLY PIGLET PERFORMANCE

	Diet	Weeks Post-weaning 1	2	3	4	SE
ADG (g)[1]:	ND	52[a]	672[b]	116[illegible]	1640[d]	43.7
	HD	124[a]	666[b]	1285[c]	1665[c]	
Significance		NS	NS	NS	NS	
ADF (g):	ND	566[a]	1133[b]	2080[c]	2705[d]	51.5
	HD	559[a]	1086[b]	1927[c]	2500[d]	
Significance		NS	NS	NS	NS	
Gain/Feed[2]:	ND	.069[a]	.589[b]	.616[b]	.635[b]	.039
	HD	.211[a]	.617[b]	.706[c]	.704[c]	
Significance		*	NS	NS	NS	

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

[2]Significant interaction for gain/feed ($P < 0.05$).

*($P < 0.05$)

by 0.089 units. A further increase occurred for the ND diet between week 3 and week 4, but there was no change in gain to feed ratio for the HD diet. This would indicate that the HD diet was being utilized as efficiently as possible by week 3, but efficiency of use of the ND diet was still increasing. A gradual improvement in feed efficiency over a 3 week period following weaning has also been noted by Okai (1974).

There was no significant difference between diets within weeks except for week 1 where the HD diet gave a significantly ($P<0.05$) higher gain to feed ratio. This is a result of the slightly lower ADF and greater ADG during week 1 for pigs fed the HD diet. Pigs fed the HD diet tended to recover from the post-weaning growth check more quickly than pigs fed the ND diet. Thus pigs fed the HD diet had a significantly better gain to feed ratio in the first week. Several authors have shown that semi-complex and complex diets, which generally have a greater concentration of DE, tend to reduce the post-weaning growth check (Okai et al. 1976; Meade et al. 1965; Bayley and Carlson 1970).

Effect of Parity

The effect of parity on piglet performance was examined and Table 19 shows that pigs born to gilts gained as much weight during the experiment as pigs born to fifth-litter sows. Pigs born to gilts are generally more susceptible to scouring during the nursing period than pigs born to older

TABLE 19: EFFECT OF PARITY ON PIGLET GAIN (DAY 1 - 28)

Parity:	1	5
Pig Gain (kg)	6.089	6.094
Standard Error	.2789	.2369

sows because the colostrum and milk from gilts has a less complete complement of antibodies. The pigs born to gilts will, therefore, have less disease resistance (Porter 1976). If a difference in scouring had occurred between pigs born to first or fifth parity sows then a difference in gain would also have occurred. There was no difference due to parity observed in this experiment.

D. Results and Discussion - Scours

Main Effects

The incidence and severity of scours, subdivided by main effects is shown in Table 20. Piglets weaned at 4 weeks of age had a greater severity ($P<0.10$) and incidence of scours than pigs weaned at 3 weeks of age. This is contrary to results which have shown that younger pigs tend to scour more than older pigs (Kenworthy and Crabb 1963; Smith and Jones 1963). However, calculation of the kcals of digestible energy (DE) and g of digestible crude protein (DCP) consumed per kg of pig shows that the 4-week-weaned pigs consumed more energy and more protein per kg of bodyweight than 3-week-weaned pigs. This data is discussed later and lends support to the hypothesis that nutrient intake predisposes young pigs to diarrhea.

The HD diet caused more severe scouring ($P<0.10$) for more days than the ND diet. Ad libitum feeding resulted in a higher incidence ($P<0.05$) and greater severity ($P<0.10$) of scouring than restricted feeding. These results suggest that both volume of feed consumed and total nutrient intake influence both incidence and severity of scouring.

Females had more severe scours ($P<0.10$) and a higher incidence of scouring ($P<0.10$) than males. This was true for every interaction examined except for 4-week-weaned pigs with restricted intake. The sex difference in scouring was

TABLE 20: INCIDENCE AND SEVERITY OF SCOURS BY MAIN EFFECT

	Severity	Incidence
Weaning Age:		
3 Week	261	115
4 Week	345	142
Significance	NS	NS
Diet:		
ND	264	113
HD	342	144
Significance	NS	NS
Intake Level:		
Ad Libitum	346	150
Restricted	260	107
Significance	NS	*
Sex:		
Female	350	148
Male	256	109
Significance	NS	NS
Standard Error	33.0	14.5

*($P < 0.05$)

likely due to the difference in feed intake, since females always had a lower feed intake than males, except for 4-week-weaned pigs fed at the restricted level, in which case females had a greater feed intake and higher scour indices than males.

The effect of weeks post-weaning, shown in Table 21, was highly significant ($P<0.001$) for both severity and incidence of scours, being highest in the first week and gradually decreasing to week 4. Although the scour values were lowest for week 4, they were not significantly different from the incidence and severity recorded during week 3. This data again emphasizes how critical the first 2 weeks post-weaning are.

Interaction of Diet, Weaning Age and Level of Intake

The effects of diet, weaning age and level of intake on the incidence and severity of scours are shown in Table 22. The 3-week-weaned pigs fed the HD diet had a significantly greater severity ($P<0.05$) and incidence ($P<0.01$) of scouring than those fed the ND diet. Complex diets, which often have high nutrient densities, have frequently been implicated in post-weaning diarrhea (Smith and Lucas 1956; Bayley and Carlson 1970; Okai 1974).

There was significantly more severe and greater incidence of scouring by the 4-week-weaned pigs than the 3-week-weaned pigs when fed on the ND diet ($P<0.05$).

Pigs fed the HD diet ad libitum had slightly higher

TABLE 21: INCIDENCE AND SEVERITY OF SCOURS BY WEEK

	Severity	Incidence
Week[1]:		
1	267[a]	100[a]
2	200[b]	86[a]
3	93[c]	45[b]
4	46[c]	26[b]
Standard Error	18.9	7.9

[1] Means within columns with the same superscript are not significantly different ($P > 0.05$).

TABLE 22: EFFECT OF DIET, WEANING AGE AND LEVEL OF INTAKE ON INCIDENCE AND SEVERITY OF SCOURS

	Severity			Incidence		
Diet:	ND	HD	Sig[1]	ND	HD	Sig[1]
Weaning Age:						
3 Week	105	156	*	46	69	**
4 Week	159	186	NS	67	75	NS
Significance	*	NS		*	NS	
Intake Level:						
Ad Libitum	162	184	NS	71	79	NS
Restricted	102	158	**	42	65	**
Significance	**	NS		***	NS	
Standard Error	22.3			10.2		

[1]Significance

*(P < 0.05)

**(P < 0.01)

***(P < 0.005)

values for scouring than pigs fed the ND diet but the differences were not significant. However, the HD diet gave significantly greater ($P<0.01$) severity and incidence of scours than the ND diet when fed at a restricted level. Restricting the intake of the ND diet significantly reduced the severity and incidence of scours but restricting the HD diet did not.

Every significant difference between 3- and 4-week-weaned pigs for severity and incidence of scours, shown in Table 22, can be explained by the difference in intake of DE and DCP as shown in Table 23. The scouring differences between pigs fed the ND diet ad libitum or restricted can also be explained by the differences in nutrient intake shown in Table 23. There is disagreement in significance, however, between the 2 tables concerning intake levels involving the HD diet. In both tables there was no difference between the 2 diets when fed ad libitum. When both diets were restricted a similar pattern was displayed in each table, but the differences in scouring were deemed significant while the differences in energy and protein intake were not. These differences, however, were found to be significant at $P<0.10$.

This data on levels of nutrient intake and the high degree of agreement in differences between treatments, in Tables 22 and 23, suggests that nutrient intake may be the controlling factor in predisposing early-weaned piglets to diarrhea. Although 'over-eating' has often been suggested as

TABLE 23: EFFECT OF DIET, WEANING AGE, AND LEVEL OF INTAKE ON AVERAGE DAILY DIGESTIBLE ENERGY AND DIGESTIBLE CRUDE PROTEIN CONSUMPTION PER KG OF PIG

	DE[1] (kcal/kg pig) DCP			DCP[1] (g/kg pig)		
Diet:	ND	HD	Sig	ND	HD	Sig
Weaning Age:						
3 Week	127.3	141.9	*	5.49	6.07	*
4 Week	137.4	141.3	NS	6.01	6.19	NS
Significance	*	NS		*	NS	
Intake Level:						
Ad Libitum	141.9	150.0	NS	6.22	6.57	NS
Restricted	122.7	129.4	NS	5.29	5.68	NS
Significance	***	***		***	***	
Standard Error	4.44			.214		

[1] For weeks 1, 2, and 3 only.

*(P<0.05).

***(P<0.005).

the cause of scouring (Stevens 1963; Kenworthy and Crabb 1963; Palmer and Hulland 1965; Thomlinson 1969), to the best of the author's knowledge no one has attempted to separate the effects of feed volume and nutrient intake.

Effect of Week Post-weaning

Table 24 shows the effect of weeks post-weaning and main factors on the incidence of scouring. In general, incidence of scours was greater for 4-week-weaned pigs than for 3-week-weaned pigs, but the difference was significant only in week 1 and week 3. Ad libitum fed pigs scoured for significantly more days than restricted fed pigs in weeks 1 and 2 ($P<0.005$) and week 4 ($P<0.05$) but not in week 3. Pigs fed the HD diet scoured more days than pigs fed the ND diet but this was significant only in week 2.

For all factors the incidence of scours was highest in week 1 and lowest in week 4. In general, there was little difference between weeks 1 and 2 which had greater incidence than weeks 3 and 4. These results indicate that about 2 weeks is required for the pig to adapt to the altered environment. By this time the pig is eating well, has regained its weaning weight, the digestive system is becoming adapted to solid food and immunity is building up.

A similar overall pattern for severity is shown in Table 25. Again the 4-week-weaned pigs scoured significantly more severely in week 1 and restricting intake significantly reduced the severity of scouring in weeks 1 and 2. The

TABLE 24: EFFECT OF WEANING AGE, LEVEL OF INTAKE, DIET AND WEEK POST-WEANING ON INCIDENCE OF SCOURS

Week:	1	2	3	4
Weaning Age[1]:				
3 Week	39^{a}	46^{a}	15^{b}	15^{b}
4 Week	61^{a}	40^{b}	30^{bc}	11^{c}
Significance	***	NS	**	NS
Intake Level:				
Ad Libitum	59^{a}	52^{a}	20^{b}	19^{b}
Restricted	41^{a}	34^{ab}	25^{b}	7^{c}
Significance	***	***	NS	*
Diet:				
ND	46^{a}	38^{a}	18^{b}	11^{b}
HD	54^{a}	48^{a}	27^{b}	15^{b}
Significance	NS	*	NS	NS

Standard Error = 5.65

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

*($P < 0.05$)

**($P < 0.01$)

***($P < 0.005$)

TABLE 25: EFFECT OF WEANING AGE, LEVEL OF INTAKE, DIET AND WEEK POST-WEANING ON SEVERITY OF SCOURS

Week:	1	2	3	4
Weaning Age[1]:				
3 Week	96^{a}	104^{a}	36^{b}	25^{b}
4 Week	171^{a}	96^{b}	57^{c}	21^{c}
Significance	***	NS	NS	NS
Intake Level:				
Ad Libitum	157^{a}	120^{b}	37^{c}	32^{c}
Restricted	110^{a}	80^{ab}	56^{b}	14^{c}
Significance	***	***	NS	NS
Diet:				
ND	124^{a}	87^{b}	33^{c}	20^{c}
HD	143^{a}	113^{a}	60^{b}	26^{b}
Significance	NS	*	*	NS

Standard Error = 13.1

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

*($P < 0.05$)

**($P < 0.01$)

***($P < 0.005$)

scouring was more severe on the HD diet and the difference was significant in weeks 2 and 3.

Comparison of Table 26 with Tables 24 and 25 shows that there is a great deal of agreement between them. Within week 1 and week 2 every difference declared significant for severity and incidence of scouring between main factors shows a significant difference in intake of energy.

This data lends strong support to the hypothesis that nutrient intake is an important factor in predisposing weaned pigs to diarrhea. The volume of feed consumed was less important than nutrient intake since there was less weight of feed consumed on the HD diet than on the ND diet but there was more scouring on the HD diet.

TABLE 26: EFFECT OF WEANING AGE, LEVEL OF INTAKE, DIET AND WEEK POST-WEANING ON AVERAGE DAILY CONSUMPTION OF DIGESTIBLE ENERGY (KCAL/KG OF PIG)

Week	1	2	3
Weaning Age:[1]			
3 Week	67.3^{a}	135.5^{b}	195.3^{c}
4 Week	79.8^{a}	137.7^{b}	200.5^{c}
Significance	**	NS	NS
Intake Level:			
Ad Libitum	85.3^{a}	144.3^{b}	208.3^{c}
Restricted	61.9^{a}	128.8^{b}	187.4^{c}
Significance	***	**	***
Diet:			
ND	70.8^{a}	132.4^{b}	193.6^{c}
HD	75.3^{a}	141.7^{b}	202.1^{c}
Significance	NS	*	NS

Standard Error = 4.23

[1]Means within rows with the same superscript are not significantly different (P>0.05).

*(P<0.05).

**(P<0.01).

***(P<0.005).

E. Summary

Overall performance was greater for 4-week-weaned pigs, the HD diet and ad libitum feeding than for 3-week-weaned pigs, the ND diet and restricted feeding, respectively.

The 3-week-weaned pigs had a greater improvement in performance when fed the HD diet compared to the ND diet than did pigs weaned at 4 weeks. Restricting feed intake reduced performance more for 3-week-weaned pigs than for 4-week-weaned pigs. Restricting intake significantly improved gain to feed ratios for 4-week-weaned pigs and the HD diet.

Weeks post-weaning had a significant effect on performance. The gain to feed ratio of the HD diet increased more rapidly than the gain to feed ratio of the ND diet. The feed intake of pigs fed ad libitum was less for pigs fed the HD diet than for those fed the ND diet. Restricting feed intake reduced growth rate, but improved gain to feed ratio for both diets at both ages. Overall performance was better for pigs fed the HD diet.

The scouring data presented indicates that volume of feed consumed is less important in predisposing piglets to post-weaning scours than is total nutrient intake. The 4-week-weaned pigs scoured more than the 3-week-weaned pigs and this appeared to be related to a higher relative level of nutrient intake. Pigs fed ad libitum a HD diet ate less

feed than those fed the ND diet, but due to the higher density had a slightly higher intake of DE and DCP than those on the ND diet. The pigs fed the HD diet suffered a greater incidence and severity of scouring than pigs fed the ND diet. When both diets were restricted to the same estimated level of DE and DCP per kg of pig (based on table values) the HD diet still produced a higher level of scouring in the pigs even though the volume of feed consumed was much less than that of the ND diet. Calculation of actual DE and DCP intake based on the digestibility data indicates that higher nutrient intake is related to the incidence and severity of scouring in weaned pigs. It is possible that the greater scouring observed in pigs fed the HD diet or fed ad libitum was due to the increased availability of nutrients in the intestine for bacterial growth.

IV. EXPERIMENT III: EFFECT OF AGE, DIET AND FEED INTAKE ON APPARENT DIGESTIBILITY

A. Objective

The objective was to determine the effects of weaning age, nutrient density of the diet and level of feed and nutrient intake on the apparent digestibility of energy, protein and ether extract.

B. Materials and Methods

Animals and Diets

The diets, animal management and statistical treatment were as described in Experiment II. In addition, simple correlations between pens were generated to determine the effects of weekly scour severity and incidence upon nutrient digestibility. The interaction effects of the digestibility of each nutrient upon the others was also determined by simple correlations.

Digestion Trial

Apparent digestibility values for crude protein, gross energy and ether extract were determined using the chromic oxide procedure (0.5% inclusion level). Feces were collected from each pen during 3 separate collection periods. These post-weaning collection periods were: Week 1 - days 5, 6, 7; Week 2 - days 12, 13, 14; and Week 3 - days 19, 20, 21. On

each collection day feces voided over a 4 hour period after the morning feeding were collected. Only fresh, intact and uncontaminated feces were collected. To make good collections possible, the pens were thoroughly cleaned after the waste feed was swept-up and before any feces were collected. Fecal samples were pooled by pen and stored at 5 C during the 3 day collection period.

Laboratory Analyses

At the end of each collection period, the feces were dried in a forced-air oven at 60 C for 72 hours. Both feed and feces were ground in a laboratory mill and representative samples were used for the following determinations: a) chromic oxide was determined as described by Czarnocki et al. (1961) with the modifications of Fenton and Fenton (1979); b) gross energy was determined in a Parr Oxygen Bomb Calorimeter (Parr Instrument Co., Moline, Illinois); c) Kjeldahl crude protein (N x 6.25) determinations were as described in AOAC (1975); d) ether extract was determined by extracting with anhydrous diethyl ether for 6 hours. The apparent digestibility values were calculated using the formula described by Lloyd et al. (1978).

C. Results and Discussion

Main Effects

The mean apparent digestibility coefficients for energy, protein and ether extract, subdivided by main effect, appear in Table 27. Neither age at weaning nor sex had any effect upon the digestibility coefficients measured. This agrees with the findings of Leibbrandt et al. (1975a). There was no effect of diet upon the digestibility of energy, however, the HD diet had significantly greater digestibility of protein ($P<0.05$) and of ether extract ($P<0.001$). The greater digestibility of protein for the HD diet is likely due to the replacement of grain with soybean meal, since soybean meal protein is relatively more digestible for the young pig than cereal protein (Lucas and Lodge 1961). The difference in digestibility of ether extract is partly a reflection of the high level (10%) of soybean oil used in the HD diet. Soybean oil is known to be more digestible than tallow for growing pigs (Braude and Newport 1973). With a low level of added fat, a high percentage of the fecal fat will be from endogenous fat excretion thus giving a low digestibility value. Also a high percentage of the fat in the ND diet comes from the cereals which have a poor ether extract digestibility (Lowery et al. 1962; Frobish et al. 1970; Leibbrandt et al. 1975a). That these differences in ether extract digestibility were

TABLE 27: MEAN DIGESTIBILITY (%) OF ENERGY, PROTEIN AND ETHER EXTRACT BY MAIN EFFECT

	Energy	Protein	Ether Extract
Weaning Age:			
3 Week	79.6	77.3	61.2
4 Week	80.6	78.7	64.6
Significance	NS	NS	NS
Diet:			
ND	80.0	77.0	54.6
HD	80.3	79.1	71.3
Significance	NS	*	***
Intake Level:			
Ad Libitum	79.4	77.3	59.7
Restricted	81.0	78.7	66.1
Significance	*	NS	*
Sex:			
Female	80.3	78.1	64.0
Male	80.1	78.0	61.8
Significance	NS	NS	NS
Standard Error	.539	.623	1.693

*(P<0.05)

***(P<0.005).

accurately taken into account during diet formulation is evidenced by the fact that there was no difference in the digestibility of energy between the 2 diets.

Restricting feed intake increased the digestibility of energy by 1.6% ($P<0.05$), of ether extract by 6.4% ($P<0.05$) and of protein by 1.4% (NS). An increase in digestibility due to restricting intake has been observed in growing swine (ARC 1967). Restricting intake by 15% in growing pigs generally results in an increase in digestibility of 7 to 10% for energy. To the best of the author's knowledge, no comparisons have appeared in the literature for digestibility on ad libitum versus restricted feeding of normal diets for early-weaned pigs. De Goey and Ewan (1975) fed 3-week-weaned pigs at 2, 3, 4 or 5% of body weight on diets formulated to twice NAS-NRC (1968) requirements and found no significant effect on digestibility of nitrogen or energy. This cannot be considered restricted feeding due to the high nutrient level of the diet.

Week post-weaning had a significant effect on the digestibility of energy, protein and ether extract as shown in Table 28. The digestibility of energy increased significantly from week 1 to week 2 ($P<0.05$) and from week 2 to week 3 ($P<0.05$). The digestibility of both protein and ether extract increased significantly from week 1 to week 2 ($P<0.001$) but not from week 2 to week 3.

The digestibility coefficients presented are in agreement with the results of many workers who have found

TABLE 28: MEAN WEEKLY DIGESTIBILITY (%) OF ENERGY, PROTEIN AND ETHER EXTRACT

	Energy	Protein	Ether Extract
Week[1]:			
1	76.5[a]	71.9[a]	50.6[a]
2	80.8[b]	81.2[b]	68.5[b]
3	83.4[c]	81.0[b]	69.6[b]
Significance	***	***	***
Standard Error	.616	.718	1.968

***(P<0.005).

[1]Means within columns with the same superscript are not significantly different (P>0.05).

similar digestibility values over these age periods (Leibbrandt et al. 1970; Lloyd et al. 1957; Lloyd and Crampton 1958: Blair 1961; Combs et al. 1963; Bayley and Carlson 1970). However, all the cited authors conducted their digestibility trials during the first week of their experiment and again at the end and assumed a linear increase in digestibility during this period. The data presented here would indicate that a very rapid change occurs in the digestive tract during the first 2 weeks after weaning with much less change occurring thereafter. Even in digestibility of energy where the difference was significant ($P<0.05$) between week 2 and week 3 this change is only 2.6% compared to 4.3% from week 1 to week 2.

Interaction of Weaning Age and Diet

Table 29 shows the interaction effect of weaning age and diet on digestibility. There was no difference in the digestibility of energy of the 2 diets at either 3 or 4 weeks of age. This indicates that for the overall experimental period, 3-week-weaned pigs digested the energy from each diet as well as the 4-week-weaned pigs. This shows that the growth advantage achieved on the HD diet, as discussed previously, was not due to increased digestibility but entirely due to increased intake of feed. The HD diet had a slightly higher value for digestibility of protein than the ND diet at both 3 ($P<0.05$) and 4 weeks of age. Both diets had a higher digestibility of protein when the pigs

TABLE 29: EFFECT OF WEANING AGE AND DIET ON DIGESTIBILITY

Weaning Age:	3 Week		4 Week		
Diet:	ND	HD	ND	HD	SE
Digestibility[1] (%):					
Energy	79.5[a]	80.0[a]	80.6[a]	80.7[a]	.763
Crude Protein	76.0[a]	78.6[b]	78.0[ab]	79.5[b]	.882
Ether Extract	51.6[a]	70.8[b]	57.5[a]	71.8[b]	2.394

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

were weaned at 4 weeks but this was not significant.

The digestibility of ether extract was significantly higher ($P<0.001$) for the HD diet than for the ND diet for both weaning ages. There was no significant difference in the digestibility of ether extract for either diet for 3-week-weaned versus 4-week-weaned pigs. This has also been noted by Leibbrandt et al. (1975a).

Interaction of Diet and Level of Intake

There was no interaction effect of diet and level of intake on energy or protein digestibility as shown in Table 30. There was a higher level of digestibility of both energy and protein for the HD diet at both feeding levels. The difference was approaching significance for protein ($P<0.10$). The diets fed at a restricted level of intake had a higher level of digestibility for energy, protein and ether extract on both the ND and the HD diets. However, only for the ether extract from the ND diet was the difference significant ($P<0.05$).

Interaction of Weaning Age and Level of Intake

Restricting the level of intake also increased digestibility when compared between 3- and 4-week-weaned pigs (Table 31). Although De Goey and Ewan (1975) restricted feed volume to young pigs and found no difference in digestibility, the nutrient level of the diet was so high that there was no effective restriction of nutrient intake.

TABLE 30: EFFECT OF DIET AND LEVEL OF INTAKE ON DIGESTIBILITY

Diet:	ND		HD		
Intake Level:	Ad Libitum	Restricted	Ad Libitum	Restricted	SE
Digestibility[1] (%):					
Energy	79.3[a]	80.8[a]	79.5[a]	81.2[a]	.763
Crude Protein	76.4[a]	77.6[a]	78.3[a]	79.8[a]	.882
Ether Extract	50.0[a]	59.1[b]	69.5[c]	73.1[c]	2.394

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

TABLE 31: EFFECT OF WEANING AGE AND LEVEL OF INTAKE ON DIGESTIBILITY

Weaning Age:	3 Week		4 Week		
Intake Level:	Ad Libitum	Restricted	Ad Libitum	Restricted	SE
Digestibility[1] (%):					
Energy	79.1[a]	80.4[a]	79.7[a]	81.6[b]	.763
Crude Protein	77.7[a]	76.9[a]	76.9[a]	80.5[b]	.882
Ether Extract	56.4[a]	66.0[b]	63.1[ab]	66.2[b]	2.394

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

Highest digestibility coefficients were obtained with 4-week-weaned pigs fed at a restricted level. Restricted feeding did not increase the digestibility coefficients for energy or protein for 3-week-weaned pigs, but did for 4-week-weaned pigs. For ether extract the reverse was true. For pigs weaned at 4 weeks of age, restricted feeding did increase the digestibility of energy and protein but not of ether extract. The 4-week-weaned pigs generally had a slightly higher digestibility than 3-week-weaned pigs fed at the same level.

Interaction of Weaning Age and Week Post-weaning

Table 32 shows the interaction effects of weaning age and week post-weaning on nutrient digestibility. The energy digestibility increased significantly between week 1 and week 3 for both 3- and 4-week-weaned pigs. The 4-week-weaned pigs increased their capacity to digest feed energy, protein and ether extract more rapidly than did the 3-week-weaned pigs. The 3-week-weaned pigs increased their energy digestibility only slightly from week 1 to week 2 (1.6%) and considerably from week 2 to week 3 (4.4%), while the 4-week-weaned pigs increased their energy digestibility 7% from week 1 to week 2 and only 0.5% from week 2 to week 3. This could be expected since the digestive capability of a pig is developing rapidly at this stage. Therefore, an older pig (4 versus 3 weeks old) should be able to adapt to a change in diet more rapidly. However, it should be noted

TABLE 32: EFFECT OF WEANING AGE AND WEEK POST-WEANING ON DIGESTIBILITY

	Weaning Age	Weeks Post-weaning 1	2	3	SE
Digestibility[1] (%):					
Energy:	3	77.2^{a}	78.8^{a}	83.2^{b}	.872
	4	75.8^{a}	82.8^{b}	83.3^{b}	
Significance		NS	**	NS	
Crude Protein:	3	72.0^{a}	78.5^{b}	81.4^{c}	1.015
	4	71.8^{a}	83.8^{b}	80.6^{c}	
Significance		NS	**	NS	
Ether Extract:	3	51.9^{a}	62.9^{b}	68.8^{b}	2.788
	4	49.2^{a}	74.2^{b}	70.5^{b}	
Significance		NS	*	NS	

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

*($P < 0.05$)

**($P < 0.01$)

that the energy, protein and ether extract digestibilities were not different for both weaning age groups 3 weeks post-weaning. At this stage the 3-week-weaned pigs were 6 weeks old and the 4-week-weaned pigs were 7 weeks old. When the 4-week-weaned pigs were 6 weeks old (2 weeks post-weaning) their energy and protein digestibilities were not different from the 3-week-weaned pigs at 6 weeks old (3 weeks post-weaning). The digestibility of ether extract was higher at 6 weeks of age for 4-week-weaned pigs (74.2%) than for 3-week-weaned pigs (68.8%), but this difference was not significant.

This data would indicate that at about 6 weeks of age the pigs' digestive systems were equally capable of digesting the nutrients in the rations regardless of whether the pig was weaned at 3 or 4 weeks of age and providing that the pig has had some time to adapt to the diet.

The effect of time for adaptation on digestibility can be seen by comparing all pigs at 5 weeks of age. In every case the 3-week-weaned pigs had higher digestibilities at 5 weeks old (2 weeks post-weaning) than the 4-week-weaned pigs at 5 weeks old (1 week post-weaning). The development of the digestive enzyme system is obviously not entirely passive at this age, but can be stimulated by a change in diet.

The above observations are confirmed by work on digestive enzymes by Hartman et al. (1961) who observed that levels of most enzymes reach a maxima between 6 and 7 weeks of age. They also observed that digestive enzyme development

appears to be entirely passive until about 3 weeks of age since weaning prior to this had no effect on enzyme levels or activity. Blair (1961) also found that at 6 to 7 weeks of age there was little difference in energy digestibility regardless of the age at weaning.

Interaction of Diet and Week Post-weaning

The digestibility of energy, protein and ether extract of both diets increased from week 1 to week 2 to week 3 as shown in Table 33. Increasing digestibility with increasing age has been shown by Lloyd et al. (1957), Combs et al. (1963), Frobish et al. (1970) and Leibbrandt et al. (1975b). All second week values were significantly greater than those observed in the first week of the digestion trial ($P<0.05$). It can be concluded from the data presented in Table 33 that a higher level of adaptation to the diets occurs between week 1 and week 2 than between week 2 and week 3. The only significant difference between week 2 and week 3 was for the digestibility of energy on the HD diet. This difference is likely due to the fact that 22.5% of the kcals in the HD diet are derived from added fat while only 7.3% of the kcals in the ND diet are derived from added fat. By week 2 digestibility of ether extract on the ND diet had reached a maximum, however, for the HD diet ether extract digestibility increased by 6.2% from week 2 to week 3. The difference in digestibility of energy for the HD diet between week 2 and week 3 was, therefore, a result of the

TABLE 33: EFFECT OF DIET AND WEEK POST-WEANING ON DIGESTIBILITY

	Diet	Weeks Post-weaning 1	2	3	SE
Digestibility[1] (%):					
Energy:	ND	76.9[a]	80.9[b]	82.3[b]	.872
	HD	76.1[a]	80.7[b]	84.2[c]	
Significance		NS	NS	NS	
Crude Protein:	ND	71.2[a]	80.4[b]	79.4[b]	1.015
	HD	72.5[a]	82.0[b]	82.6[b]	
Significance		NS	NS	NS	
Ether Extract:	ND	41.2[a]	63.3[b]	59.2[b]	2.788
	HD	60.0[a]	73.8[b]	80.0[b]	
Significance		**	*	*	

[1]Means within rows with the same superscript are not significantly different ($P > 0.05$).

*($P < 0.05$)

**($P < 0.01$)

greater ether extract digestibility. Within each week the HD diet had a significantly greater digestibility of ether extract due to the higher level of fat inclusion as discussed earlier.

There was no difference in digestibility of the 2 diets within weeks for energy and protein. Protein digestibility, however, was consistently higher for the HD diet, leading to the overall significant difference mentioned earlier.

Interaction of Level of Intake and Week Post-weaning

The interaction effects of level of intake and week post-weaning are shown in Table 34. Restricted fed pigs had higher digestibilities every week than did the ad libitum fed pigs, but the differences were not significant. Digestibility coefficients of the ad libitum fed pigs increased each week. These increases in digestibility were significant ($P<0.05$) for energy and protein, but not for ether extract between week 2 and week 3. The digestibility of energy, crude protein and ether extract for the restricted fed pigs also increased significantly from week 1 to week 2. In week 1 and week 2 the restricted fed pigs had higher digestibility values than the ad libitum fed pigs. In week 3, however, the differences were very small. The digestibility values in week 2 for the restricted fed pigs were nearly identical to the values obtained in week 3. These data would suggest that for pigs fed at a restricted level a limit to their ability to digest energy, protein and

TABLE 34: EFFECT OF LEVEL OF INTAKE AND WEEK POST-WEANING ON DIGESTIBILITY

	Intake Level	Weeks Post-Weaning 1	2	3	SE
Digestibility[1] (%)					
Energy:	Ad Libitum	75.5^{a}	79.3^{b}	83.2^{c}	.872
	Restricted	77.5^{a}	82.3^{b}	83.3^{b}	
Significance		NS	*	NS	
Crude Protein:	Ad Libitum	70.9^{a}	79.1^{b}	81.9^{c}	1.015
	Restricted	72.8^{a}	80.2^{b}	83.2^{c}	
Significance		NS	NS	NS	
Ether Extract:	Ad Libitum	46.7^{a}	63.5^{b}	66.9^{b}	2.788
	Restricted	54.5^{a}	71.5^{b}	72.3^{b}	
Significance		NS	NS	NS	

[1]Means within rows with the same superscript are not significantly different ($P>0.05$).

*($P<0.05$).

ether extract was reached in the second week of the trial.

The implications are that with ad libitum feeding more nutrients are available in the digestive tract for bacterial growth than with restricted feeding and that with restricted feeding the pig is required to digest feed to its maximum ability thus reducing the likelihood of bacterial diarrhea. Palmer and Hulland (1965) restricted the feed intake of weaned pigs to 50% of ad libitum intake and found a significant reduction in total and percent hemolytic E. coli and reduced number of pig days of diarrhea from 14 for the ad libitum fed group to 10 for the restricted fed group.

Correlation of Scouring to Digestibility

The weekly digestibility measurements for each pen were correlated with the weekly incidence and severity of scours. The correlations for week 1 are shown in Table 35. There was a significant negative correlation between the digestibility of energy and protein and scour severity and incidence. Scour severity was more highly correlated with these digestibility coefficients than scour incidence indicating that severity may be a better measure of scouring than incidence. The significant negative correlation for week 1 indicates that a low level of digestibility is significantly related to a high level of scouring. Scouring pigs have been shown to have a 5 to 7% lower digestibility than normal pigs for energy and protein (Lloyd et al. 1957). However in this experiment only visually normal, intact feces were collected

TABLE 35: CORRELATION OF DIGESTIBILITY AND SCOURING - WEEK 1

	Scour Severity	Scour Incidence
Scour Severity	1	.964
Scour Incidence	.964	1
Digestible Energy (%)	-.467**	-.427*
Digestible Protein (%)	-.394*	-.333
Digestible Ether Extract (%)	-.296	-.275

**P < .01 for r = .449
*P < .05 for r = .349

for the digestibility determinations. In this case the correlations indicate that scouring was likely a result of poor digestibilty and not that the poor digestibilty was a result of scouring. Arambawela et al. (1975) and Aumaitre (1967) observed that a lower digestibility may be associated with a higher incidence of scouring. In week 2 and week 3 the scouring was less influenced by digestibility, since digestibility values were much higher and the scouring was lower than in week 1. Scouring after the first week was likely related more to nutrient intake, as described in Experiments I and II, than to digestibility.

D. Summary

There was no difference in digestibility between 3- and 4-week-weaned pigs for energy, protein or ether extract. The HD diet had a significantly greater digestibility for protein and ether extract but was not different from the ND diet in digestibility of energy. Restricting feed intake significantly increased the digestibility of ration nutrients. There was no difference between diets in response to restriction but the 4-week-weaned pigs increased their digestibility when feed intake was restricted while the 3-week-weaned pigs did not. Digestibility of all nutrients increased significantly from week 1 to week 3. The greatest improvement occurred for ether extract. Pigs had similar digestibilities at the same chronological age regardless of the age at weaning. By week 3 there was no difference in digestibility between ad libitum and restricted feeding. Poor digestibility in the first week post-weaning probably predisposes piglets to scouring.

V. GENERAL SUMMARY

The experiments presented herein have examined the effects of weaning age, diet complexity, nutrient density of the diet, nutrient intake, volume of feed consumed and digestibility of the starter diet upon the incidence and severity of scours. In general the incidence and severity of post-weaning scours can be reduced by restricting post-weaning feed intake. The total nutrient intake is more important in predisposing pigs to scours than is volume of feed consumed. A simple diet produces less scouring than a semi-complex diet and a normal density diet produces less scouring than a high density diet. Greater performance, however, was achieved during the post-weaning period by feeding a semi-complex or high density diet, but there was no difference in subsequent performance to 90 kg liveweight. Pigs weaned at 4 weeks of age tended to be more susceptible to scours than did pigs weaned at 3 weeks of age when they were treated similarly, due to a greater relative nutrient intake. The poor digestibility that occurred when pigs were first weaned onto a solid diet, at a stage when the digestive enzyme complement was not fully developed, most probably facilitated the onset of scouring. Support for the hypothesis that digestive enzyme insufficiency is likely responsible for scouring in early-weaned pigs is provided by these experiments.

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