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THE UNIVERSITY OF ALBERTA

THE EFFECTS OF NUTRITION AND MANAGEMENT ON THE PERFORMANCE, HEALTH AND BEHAVIOUR OF WEANLING PIGS

by

HOLLY SPICER

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

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Date. Nov. 14.. 1984. ....

Abstract

Two experiments were conducted to compare the performance, health and behaviour of 28 day old piglets subjected to different nutritional and (or) management programs for a four week period. In Experiment I, 201 crossbred pigs were assigned on the basis of initial weight to a 2 x 2 factorial arrangement of diet complexity (simple versus semi-complex) and method of weaning (no movement or movement of littermate pigs from the farrowing house immediately at weaning). Performance, number of pigs scouring and diet digestibility were used as response criteria. Pigs fed the semi-complex diet had significantly higher average daily gain (ADG) and efficiency of feed utilization. Average daily feed (ADF) intake was similar ($P>0.05$) for both diets. Incidence of diarrhea was not significantly influenced by diet complexity. Dry matter and energy digestibility coefficients were significantly better for the simple diet. Movement of the pigs at weaning did not significantly affect performance. Significantly more pigs scoured (31 versus 16) when the pigs were moved immediately at weaning. Movement of pigs resulted in decreased ($P<0.01$) dry matter, protein and energy digestibility. There were no significant diet by method of weaning interactions on piglet performance or nutrient digestibility.

Experiment II compared the performance and behaviour patterns of littermate pigs housed individually, pairwise or in groups of four. All pens were 1.2 x 1.2 m, so floor space

per pig was 1.44, 0.72 and 0.35 m^2 as the number of pigs in a pen increased from one to two to four respectively. Live weight gain and voluntary feed consumption were adversely affected ($P<0.01$) when the pigs were housed in groups of four. Feed conversion efficiency did not differ significantly between treatments. The amount of general activity was not significantly affected by stocking density. Pigs housed in pairs spent significantly more time feeding than pigs housed individually or in groups of four.

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Table of Contents

List of Tables

List of Figures

I. Introduction

Increased knowledge of the nutrient requirements and environmental needs, together with the incentive to improve the efficiency and profitability of swine production, has stimulated a move to weaning pigs at two to four weeks of age. The advantages claimed for weaning at an earlier age are increased sow productivity, reduced sow feed costs and improved piglet performance. However the practice of weaning piglets between the ages of two and four weeks has not met with widespread adoption because the potential improvements in terms of enhanced piglet performance or increased sow productivity have frequently not been realized. Problems which are frequently encountered during the first two weeks postweaning include; a reduced rate of growth, (Leibbrandt et al. 1975; Armstrong and Clawson 1980) diarrhea (Rivera et al. 1978; Ball and Aherne 1982) and a high rate of mortality (Rivera et al. 1978). In addition abnormal behavioural patterns have also been observed amoung early weaned pigs. These include a high rate of general activity, increased aggressiveness towards pen mates (Frazer 1978) and repeated vocalizations (Frazer 1975). In some circumstances behavioural vices such as persistent tail and ear biting (Blackshaw 1981) or belly nosing (Frazer 1978) have been observed. Problems such as these may reflect the difficulties newly weaned pigs have at adapting to the many changes that they encounter at weaning.

The performance of the piglet after weaning is governed by a number of factors and their interactions. These include the genetic potential of the pig, the environmental conditions to which he is exposed and the management techniques employed. Management and environment are probably more important determinants of a pigs postweaning performance than is genetics (Aherne 1977; Leece et al. 1979; Curtis 1983).

The environmental factors affecting pig performance include all factors, other than genetics, that affect the existence of the pig (Jensen 1971; Backstrom and Curtis 1981). These factors are dynamic and vary in different situations with time. However, it is the rate of environmental change that appears to be most important because abrupt changes are considered to be more stressful to the pig than those occurring over a longer period of time (Backstrom and Curtis 1981). At weaning the pig is exposed to many environmental changes. The removal of the sow results in significant dietary alterations. Frequently, litters are mixed after weaning resulting in an altered social structure. Changes in the physical environment include movement of the pigs to an unfamiliar pen, which may have a different type of floor or a different feeder or waterer than those found in the farrowing house. Environmental changes such as these can influence the health and performance of piglets postweaning. Reducing the number of such changes and the consequent stress at weaning may therefore allow the pig to adapt to the process of weaning more easily.

The purpose of the experiments presented in the following chapters was to further delineate dietary and management practices that may lessen the losses associated with early weaning. In addition the effects of penning pigs individually or in small groups on performance and behaviour of weaned pigs were examined. Though it is uncommon to pen pigs individually under commercial conditions, such penning systems are frequently used under experimental conditions. It has not been clearly established whether pigs penned individually perform or behave similarily to those penned in groups.

II. Literature Review

A. Social Environment

Intensive animal production requires the grouping of animals in close proximity to each other to make optimal use of available space. The social environment of an animal originates from the presence of other individuals within the immediate surroundings (Bryant 1972; Bielharz and Cox 1967). For animals to live in social groupings some form of social organization is necessary (Bryant 1972). The dominance hierarchy is one form of social organization that has been observed in several species of livestock. In this system animals of a high rank take precedence in a competitive situation over those of a lower rank (Meese and Ewbank 1972; Rasmussin et al. 1962). In some domesticated species such as poultry and cattle, the dominance order is unidirectional. This means that low ranking individuals do not show aggression towards higher ranking group members. However in swine, the relationships are bidirectional and a subordinate animal may indulge in aggressive behaviour aimed at a more dominant animal. The dominant members maintain their rankings by winning encounters more often than lower ranked animals (Signoret et al. 1975). Meese and Ewbank (1972) reported that although dominance rankings are fairly consistent over time, spontaneous changes in rank can occur. The importance of this dominance instability in terms of animal production, has not been well assessed.

When unacquainted pigs are placed together intense fighting usually occurs so that a social order may be established, usually within a few days of mixing (Scheel et al. 1977). Mixing of unacquainted pigs does not significantly affect long term performance (McConnell et al. 1982; Friend et al. 1983) unless additional stressors such as restricted feeding or reduced space are applied at the time of mixing (Sherritt et al. 1974; Graves et al. 1978).

Although most of the intense fighting observed amoung pigs occurs when unacquainted pigs are mixed, well acquainted pigs may show a variable amount of aggression ranging from a mild threat to a severe combat (Frazer 1984a). Bryant and Ewbank (1972) reported that pigs familiar with each other and who are living in small groups have a particularily high incidence of retaliation and an increased intensity of aggression. Such behaviour may be influenced by factors which cause restlessness or physical discomfort (Frazer 1974), the amount of floor space per pig (Bryant and Ewbank 1972), or group size (Ewbank and Bryant 1972).

The number of animals confined to an area (group size) is one of the factors that influences the social environment of an animal. Other factors include the available space (total area to which the members of the group are confined) and the stocking density (the area allowed per individual group member). In many studies the effects on the behaviour and performance of pigs have been studied by simply adding more pigs to a pen of a given size thus confounding group size with stocking density (Randolph et al. 1981). However both these factors, group size and space per pig may influence animal performance.

Group Size

Jensen et al. (1966) reported that housing 8, 16, or 24 pigs per pen with a constant floor space of 0.3 m² per pig caused a general deterioration in performance as the number of pigs in a pen increased but these differences were not significant. These results are in agreement with those reported by McConnell et al. (1982). Kornegay and Notter (1984) used literature data in a model to evaluate the relationship between floor space and the number of pigs per pen on performance. They concluded that when the floor area per pig was held constant there was a significant decrease in average daily gain and average daily feed intake when the number of starter pigs in a pen increased to more than eight. Feed efficiency however, tended to improve with increasing density.

Le Dividich (1979), as cited by Kornegay et al. (1981a), suggested that the optimum group size is between eight to ten pigs. Increasing the size of the group to greater than 20 to 25 individuals leads to social instability (Ewbank 1975) as cited by Tennesen (1983) and increased aggression (Randolph et al. 1981).

In many behavioural, nutritional and (or) performance studies pigs are housed in a variety of ways. These include individual penning, pairwise or in groups of four or more animals which may or may not be littermates. Mcbride (1959) suggested that competitiveness due to the dominance hierarchy increases the variation in animals penned together and that the performance of a pig housed individually may not be very representative of how that pig would perform in a commercial situation. The results from a digestibility study conducted by McKnutt and Ewan (1983) support this view. They reported that pigs grouped under pen conditions had significantly lower apparent energy digestibility but improved ($P<0.05$) efficiency of utilization of digestible energy and nitrogen compared to individually caged pigs. However, Sather (1982) concluded that individually penned boars with a stocking density of 2.88 m^2 did not perform significantly differently than did those penned in groups of two, three or four with a stocking density of 1.44, 1.92 or 1.44 m^2 per pig, respectively. The lack of concensus as to whether individually penned animals perform differently from tho[illegible] penned by other methods indicates that futher research is re[illegible]ed on this topic.

Stocking [illegible]ensity.

Cur[illegible] 198[illegible] suggested that in animal production systems the space allowed per animal is usually a more important determinant of productivity than is the size of the group. With[illegible] the limits of the experiments conducted by Randolph et al. (1981) space allowance had a greater effect on pig performance and behavioural patterns than did group size. Heitman et al. 1961; Gehlback et al. 1966; Bryant and Ewbank 1974; and Randolph et al. 1981; all reported that the performance of growing and finishing swine was affected by the stocking density. Performance of starter pigs reared in slotted floor nursery pens and battery cages is reduced when the floor space allowance is below 0.14 m^2 per pig for pigs weighing 5 to 12 kg and 0.18 m^2 per pig for pigs weighing 12 to 22 kg respectively (Harper and Kornegay 1983; NCR-89 1984; Kornegay et al. 1981a, b). Lindvall (1981) oncluded that the space allowance for five to ten week old pigs reared on partially slotted or expanded metal floors is 0.25 m^2 per pig.

A number of researchers have studied the effects of stocking density by varying the number of pigs in a pen of a constant size. As the number of starter pigs in a pen increases the rate of gain and feed consumption are depressed but feed efficiency is not usually affected (Lindvall 1981; Kornegay et al. 1981a, b).

Increasing the number of pigs confined to a fixed area means that individual space can not be maintained (Hansen and Hageslo 1980). Consequently there is an increase in agonistic behaviour (Ewbank and Bryant 1972; Hansen and Hageslo 1980; Randolph et al. 1981) when the area allowed per pig decreases. The degree of crowding does not appear to have any effect on the proportion of time that pigs spend feeding (Randolph et al. 1981; Ross and Curtis 1976) or actively moving about their pens (Randolph et al. 1981). Kornegay and Notter (1984) and Kornegay et al. (1979) suggested that the other factors to consider when making a decision about stocking density include; quality of the diet, method of feeding, feeder space, environmental temperature, sanitation and floor type.

B. **Nutritional Environment**

At weaning a piglets food source is suddenly changed from a highly digestible liquid diet, provided every sixty to ninety minutes by the sow, to a diet that is entirely composed of solids and which is available free choice. This dietary change together with the other social and environmental transpositions frequently results in a period during which the piglet consumes very little feed. If the pig is weaned before three weeks of age, the digestive system is still undergoing dramatic changes (Efird et al. 1982) and may not be sufficiently developed to allow for the proper digestion of a cereal based diet (Aumaitre 1972; Leibbrandt et al. 1975; Palmer and Hulland 1965; Corring et al. 1978). After a period of starvation the piglet may consume a large meal. The sudden intake of a large meal causes distension of the stomach and small intestine, resulting in a temporary stasis of the gastro-intestinal tract followed by fluid accumulation (Ball 1979). This results in rapid peristaltic activity leading to an increased rate of passage and the movement of incompletely digested feed into the lower intestine. The semi-digested feed subsequently becomes a nutrient substrate for the proliferation of intestinal micro flora, including E. coli which are frequently associated with gastroenteric disorders (McAllister et al. 1979; Armstrong and Clawson 1980). The products of bacterial fermentation along with the undigested and unabsorbed food residues increase the osmolarity of the intestinal contents (Etheridge et al. 1984a, b). This results in a lack of water reabsorption and a continued influx of water into the intestinal lumen causing dehydration and diarrhea (Etheridge et al. 1984a, b).

It is the lack of enzymatic developement of the gastro-intestinal tract, coupled with the insufficiency in feed consumption, digestion and absorption that results in a period following weaning where the piglet is not digesting or absorbing sufficient nutrients to maintain its preweaning growth rate. This phenomenon is commonly referred to as a "growth check" and has been described by Smith and Lucas (1956). The postweaning growth check may last from three to fourteen days following weaning depending upon the age of the pig at weaning, the diet fed and the method of feeding (Aherne 1977).

Age at Weaning

Increasing the weaning age to four weeks enhances the pigs ability to adapt to the postweaning environment (Leibbrandt et al. 1975). Pigs weaned before four weeks of age are under developed physiologically and are immunologically susceptible to diseases. This is due to the fact that the passive immunity derived from the sows colostrum diminishes slowly from 24 to 36 hours of age and active antibody production is minimal between 10 to 28 days of age.

It appears that the age at which to wean pigs is a compromise between waiting for the pigs to mature and obtaining increased through-put in the farrowing house (Backstrom and Curtis 1981). In most commercial situations this compromise means weaning the pigs between four to six weeks of age.

Diet Complexity

The type of ingredients to use in the diets for early weaned pigs has recieved considerable attention during the last few decades. Important characteristics of starter diets are that they be composed of easily digestible, high quality protein sources (Whitelaw et al. 1966) and be highly palatable (Walstrom et al. 1974).

Young pigs have shown a preference for diets containing sugar or other sweetening agents (Lewis et al. 1955; Aldinger et al. 1959) and for dried skim milk (DSM) or dried whey (DW) (Danielson et al. 1960). Meade (1967) reported that a simple corn soybean meal diet was adequate for three week old pigs and that the addition of sucrose or DSM to this diet did not significantly improve daily gain or nine week weight. These results are in agreement with those of Wahlstrom et al. (1974) and Kornegay et al. (1974) who reported that the addition of DSM or DW, with or without added sugar, to a basal diet had no significant effects on average daily gain or feed to gain ratio. When Meade (1967) modified the basal diet to contain three percent fish meal (FM) ten percent DSM and ten percent sucrose there was a significant improvement in nine week weight and feed conversion efficiency. Other experiments presented in the same article also confirmed the excellence of more complex starter diets. Numerous studies have subsquently been undertaken to examine the degree of diet complexity necessary to optimize postweaning piglet performance. A review of these experiments has established that more complex starter formulations (diets containing as many as six or more protein and energy sources) generally result in improved feed intakes, greater daily gains (Meade et al. 1969a; Bayley and Carlson 1970; Tanksley et al. 1978) and a reduced growth check when pigs are weaned earlier than five weeks of age (Okai et al. 1976). For pigs five weeks of age or older complex starter diets do not result in significant improvements in performance (Okai et al. 1976) and thus are considered uneconomical as they are more exspensive relative to simplier diets (Meade 1967).

Most of the aboved mentioned experiments involving complex diets were of three or more weeks duration. But when the performance of early weaned pigs is examined for a two week period immediately following weaning then improvements in piglet performance from feeding more complex diets is not evident (Ball and Aherne 1982). This may be due to the low intake of feed immediately after weaning and a high incidence of scouring.

Increasing the complexity of the starter diet increases the incidence of scouring in weaned pigs (Okai et al. 1976; Ball and Aherne 1982). A number of researchers have suggested that the increased incidence of scouring in pigs fed complex rations is due to the increased palatability of these diets which leads to overconsumption by the pigs (Smith and Lucas 1956; Okai 1974; Ball 1979). In order to reduce the incidence and severity of diarrhea different feeding methods have been examined.

Method of Feeding

Two methods for feeding pigs are restricted and ad libitum. Many swine producers have conventionally choosen to restrict the intake of feed for starter pigs. The main justification for this decision is that there is a greater incidence of digestive upsets and scouring when weaned pigs are fed ad libitum (Thomlinson 1969; Arambawela et al. 1975; English et al. 1978; Geve 1982).

To restrict the intake of feed a producer can either limit the amount of feed offered each day (weight limited) or limit the amount of time of access to the feeder (time limited). In a rescent study Ball and Aherne (1982) fed three week old weaned pigs either a simple or semi-complex diet ad libitum, restricted by the time limited method or restricted by the weight limited method. They reported that limiting the amount of time that the pigs were exposed to the feeder resulted in a greater incidence of diarrhea and for more days than did the other two feeding methods. The authors attributed this to the more erratic feed intake and the tendency of the pigs to overeat when the feeder was first placed in the pen each day. Danielson et al. (1975) as cited by Nielsen (1976) suggested that the amount of feed should be restricted to fifty percent of appetite during the first two weeks postweaning in order to reduce scouring.

Although the incidence of diarrhea is less when newly weaned pigs are restricted in the amount of feed they are allowed to consume, the performance of pigs fed ad libitum is better than that of restricted fed pigs (Aherne 1977; Arambawela et al. 1975; Ball and Aherne 1982). Bowland (1965) as cited by Okai (1974) suggested that in order to maximize profits young pigs should be fed so that they reach 25 kg live weight as soon as possible.

Social Facilitation of Feeding and Feeder Space

Social facilitation of feeding behaviour implies that all animals in a group are stimulated to eat when observing the eating activity of another group member and in that way may experience competition during feeding (Hansen et al. 1982). Competition for food is the major type of conflict to occur in established groups of pigs (Mcbride et al. 1964; Meese and Ewbank 1972; Ewbank and Bryant 1972; Frazer 1984a). The major components of competition at the feed trough are partly determined by the degree to which feeder space is limited and by the pigs level of desire to feed (Frazer 1984a).

In groups of growing pigs competition for food has been observed to have two affects. The first effect is that the dominant pigs are able to maintain their position at the feeder. Frazer (1984b) suggested that these animals not only eat normal meals but may in fact be stimulated to eat beyond satiety while the more subordinate animals, are prevented from eating enough feed. By the time the subordinate animals do gain access to the feeder, interest in feeding by other group members has declined so that these animals may be less stimulated to continue feeding (Frazer 1984b).

If several pigs are not allowed to eat simultaneously due to inadequate feeder space ad libitum feeding can present the same problems as mentioned above. This observation was confirmed by Hansen and Hagelso (1980) who separated pigs into groups of eight which were fed from either one or several feeders. These researchers reported that in pens with only one feeder a competitive situation arose. In these groups of pigs the level of aggression was high and weight gain and eating activity occurred according to rank. In contrast it was observed that in the groups with several feeders activity and weight gain were independent of rank order. It appears then that competition for food and intra pen variations in growth could be reduced by providing adequate feeder space and an adequate number of feeders placed so that all members of the group have access to them at the same time. The recommended feeder space for pigs between 7.5 and 20 kg live weight is 75 mm per pig when feed is available free choice (Brent et al. 1975). These researchers suggested that if feed is restricted then 75 mm per pig is required for pigs up to 12 kg and 100 mm for pigs weighing up to 20 kg.

C. Physical Environment

The health and performance of the starter pig is also markedly affected by other environmental factors such as temperature, drafts, floor type and sanitation. A number or researchers have suggested that the earlier the pig is weaned the more critical are the pigs requirements for these environmental factors (Brent et al. 1975; herne 1980; and Backstrom and Curtis 1981).

Temperature

At weaning the pig is subjected to a number of environmental changes which increase the maintenance energy requirements and increase its lower critical temperature for cold compared to that of the suckling pig (Close and Le Dividich 1982). The younger the pig is weaned the higher are its temperature needs and the more stable the temperature must be. The recommended temperature for 21 day old pigs reared in intensive conditions is 26 to 28 degrees centigrade for the first week after weaning, decreasing by two degrees per week to a temperature of 20 degrees centigrade for a pig weighing between 18 to 23 kg live weight (Le Dividich and Aumaitre 1978; Brent et al. 1975; Le Dividich 1981). Le Dividich and Noblet (1982) reported that below 22 degrees centigrade the rate of gain of newly weaned pigs is depressed by 12.2 gms per one degree reduction in temperature.

The presence of bedding, such as straw can help the pig create a micro climate that considerably reduces heat loss. However, its use has been abandoned by many producers because of its incompatability with many waste management systems (Backstrom and Curtis 1981). Close body contact is a normal behaviour for young pigs but marked huddling and shivering are signs of unsatisfactory climatic conditions that are likely to lead to health problems and poor postweaning performance (Feenstra 1983). The heat loss from a pig is not only determined by the air temperature but is also influenced by the air speed (drafts) and floor characteristics.

Drafts

Drafts may occur in the piggery when incoming air is denser than the air in the building (Backstrom and Curtis 1981). Air movement at the level of the pig should be as minimal as possible. A draft of 1.5 meters per second is equivalent to a drop in temperature of minus ten degrees centrigrade (Lynch 1980).

Floor Type

The nature of the flooring material used in a swine facility is partly determined by the type of waste management system employed (Backstrom and Curtis 1981) and by cost. The performance of starter pigs has generally been similar on different types of nursery floors (Kornegay et al. 1981a, b; Lindvall 1981). Small differences in foot pad lesion scores have been noted but the long term significance of these is not clear (Kornegay et al. 1981a).

Sanitation

The earlier the pig is weaned the cleaner the environment must be. Because early weaned pigs are immunologically susceptible to disease challenges, it is desirable that they be moved to a clean dry house at weaning. Schneider and Bronch (1973) as cited by Le Dividich and Aumaitre (1978) reported that the rate of gain and the feed per gain ratio were improved when an all-in all-out system was used instead of a continuous production system for pigs weaned at three weeks of age. The improvements in performance were largely due to a decreased frequency of scouring in pigs housed in an all-in all-out management system.

Postweaning diarrhea can be triggered by changes in the environment. It follows then that minimizing the number of changes and the stress at weaning should greatly improve the performance of the pigs after weaning.

III. Experimental

A. Objectives

The objectives of these studies were:

1. To assess the effect of movement of pigs from the farrowing area at weaning when fed either a simple or semi-complex diet on pig performance and health (incidence of diarrhea).
2. To assess the effects of weaning method and diet complexity on apparent digestibility of dry matter, protein and energy.
3. To determine the effects of individual penning versus grouping two or four pigs in a pen on postweaning performance.
4. To observe whether individually penned weaner pigs are more active or restless than their littermates penned in groups of two or four.
5. To examine if lack of social facilitation causes the eating behaviour of individually housed pigs to be different from that of their littermates penned in groups of two or four.

B. General Experimental Procedures

Approximately four days prior to farrowing the sows were moved into the farrowing barn. Thiry-two of the sows farrowed in raised, partially slotted farrowing crates measuring 1.5 x 2.1 m with two side creep areas. The remaining four sows farrowed in concrete floor pens measuring 1.9 x 2.6 m with a creep area in one corner. Straw was used as bedding. All litters were provided with a 250 watt heat lamp.

Normal routine operations such as ear notching, teeth clipping and iron injections were conducted before the pigs were three days of age. Creep feed was offered to all litters from ten days of age until they were weaned at twenty-eight days of age.

A total of 278 crossbred (Yorkshire x Landrace) pigs were used in these experiments. All feed was supplied ad libitum in commercial six hole 64 x 11 cm feeders. Water was available free choice from automatic drinking bowls or nipple drinkers. Feed disappearance on a pen basis was recorded daily for the first week after weaning and once weekly thereafter. Fresh feed was added as necessary. The diets were formulated to meet or exceed National Academy of Sciences National Research Council (NAS-NRC;1979) recommended levels of nutrient requirements for starter (6 to 20 kg) pigs. The percent crude protein, gross energy, dry matter and ash of the diets were determined according to the Association of Official Analytical Chemists (AOAC;1981) procedures.

IV. Experiment I

The Effects of Diet Complexity and Method of Weaning on the Performance, Incidence of Diarrhea and Nutrient Digestibility of Pigs Weaned at Four Weeks of Age

A. Abstract

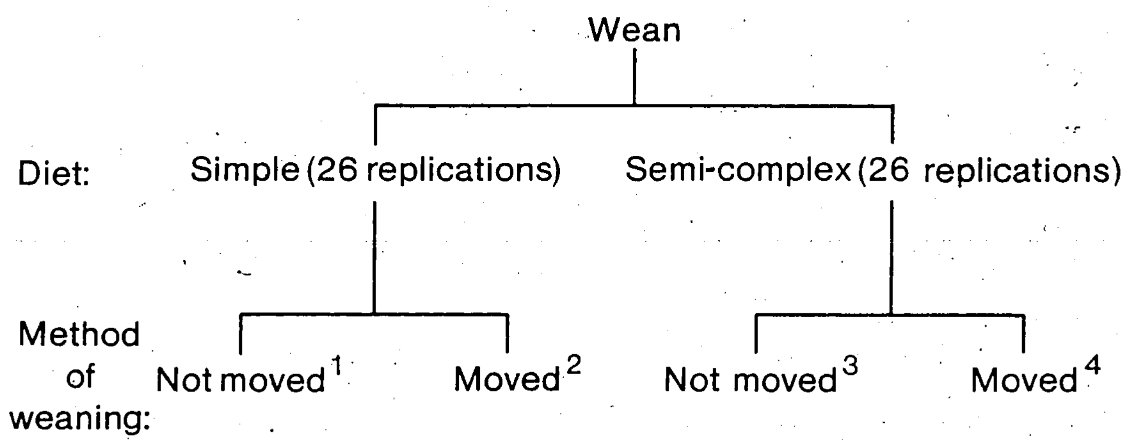
Two hundred and one four week old crossbred pigs were used in a 2 x 2 factorial arrangement of diet complexity (simple versus semi-complex) and method of weaning (no movement versus movement of the pigs from the farrowing house immediately at weaning). The effects of diet and method of weaning were assessed by monitoring piglet performance, incidence of diarrhea and nutrient digestibility. Pigs fed the semi-complex diet had increased (P<0.01) growth rates and efficiency of feed utilization. There were no significant differences in the incidence of diarrhea for pigs fed either of the diets. Dry matter and energy digestibility coefficients were significantly higher for pigs fed the simple diet. Movement of the pigs did not lower (P>0.05) piglet performance. However, more pigs had diarrhea when they were moved at weaning and consequently had lower digestibility coefficients (P<0.01) for dry matter, protein and energy. There were no significant diet by method of weaning interactions on pig performance or nutrient digestibility.

B. Materials and Methods

Two hundred and one four week old pigs from 26 sows were used in a 2 x 2 factorial arrangement of diet complexity (simple versus semi-complex) and method of weaning (no movement versus movement of the pigs from the farrowing house to the weaner house immediately at weaning). To obtain the necessary replications of treatments the experiment was conducted in two phases. Litters from 15 sows were used in phase one and those from 11 sows were used in phase two. Litters were assigned randomly to the four treatments as shown in Figure IV.1. Pigs were assigned to the treatments on the basis of initial weight. Sex was disregarded in the allotment.

At weaning 13 litters chosen at random were fed the semi-complex diet that had been fed as a creep feed before weaning. The remaining 13 litters were fed a more simple starter diet. The composition and analysis of the diets appear in Table IV.1. Dysprosium chloride ($DyCl_3 6H_2O$) was incorporated into the feed at a concentration of 9.34 ppm elemental Dy.

Where possible four pigs from each litter were allocated to remain in the farrowing area for one week after weaning and then were moved as a littermate group to a 1.2 x 1.2 m fully slotted floor pen in a weaner house for the remainder of the 28 day study. On the day of weaning the remaining four pigs from each litter were moved to similar pens in the same house. Because four of the 26 litters,



[1-4] Treatment numbers. There were three pens that contained three littermate pigs for treatments three, two pens of three littermate pigs for treatment four and one pen of three littermate pigs for both treatments one and two. All other pens contained four littermate pigs.

Figure IV.1 Experimental Design

Table IV.1. Formulation and composition of the diets.

	Simple	Semi-complex[1]
Ingredients %		
Wheat	25.0	25.0
Barley	23.0	13.6
Oat groats	25.0	25.0
Lard	3.0	3.0
Soybean meal (47% CP)[2]	20.0	13.0
Fish meal	—	6.4
Dried whey	—	10.0
Iodized salt	0.5	0.4
Calcium phosphate	1.5	1.0
Calcium carbonate	1.0	0.8
Vitamin-mineral premix[3]	1.0	1.0
Lysine-HCl	—	.25
Composition Analyzed		
Dry matter (%)	89.0	89.5
Crude protein (%)	18.9	19.8
Gross energy (MJ/kg)	17.1	17.0
Ash (%)	7.3	7.0
Lysine (%)	.90	1.3

[1] Diet fed as a creep feed from 10 days of age to weaning.
[2] CP, crude protein.
[3] Supplied the following per kg of diet: 120.0 mg zinc; 12.0 mg manganese; 150.0 mg iron; 12 mg copper; .1 mg selinium; 500 mg choline chloride; 5000 IU vitamin A; 500 IU vitamin D_3; 22 IU vitamin E; 12 mg riboflavin; 45 mg niacin; 200 ug biotin; 25 mg calcium pantothenate; 30 ug vitamin B_{12}; 275 mg ASP250.

contained less than eight satisfactory pigs, seven of the comparisons were conducted with three pigs per pen.

Grab samples of feces were collected from each pig in a pen in phase one of the experiment on days 3, 7, 14 and 21 postweaning. Fecal samples were pooled by pen for each day and frozen in plastic bags. Feed and freeze dried fecal samples were analyzed for Dy by instrumental neutron activation analysis (INAA) according to the procedure of Kennelly et al. (1980). The remainder of the fecal samples were dried in a forced air oven at 60°C for three days to determine dry matter content. Gross energy and crude protein content of the feces were determined according to AOAC (1981) procedures.

The temperature of the farrowing barn and weaner house were maintained at 23° ± 3°C. The pigs were weighed on the day of weaning and on days 7, 14, 21 and 28 postweaning. A daily record was kept of the number of pigs scouring. All scouring pigs were treated with 0.5 ml of Trivetrin[1] per 4.5 kg of body weight.

C. Statistical Analysis

Data were analyzed by least squares analysis of variance (Steele and Torrie 1980). When preceded by a significant F test multiple comparisons of the treatment means were made at the five percent level ($P<0.05$) of

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[1] Trivetrin. Each ml contains 40 mg trimethoprim and 200 mg sulfadoxine. Wellcome Veterinary Division Burroughs Wellcome Inc. Kirkland, Quebec.

probability using Student Newman Keuls (SNK) multiple range test (Steel and Torrie 1980). The standard errors presented in the tables are computed considering unequal numbers. To make comparisons within the day by diet interaction table, the largest standard error was used in determining significance. A Fisher's Exact Test (Steele and Torrie 1980) was used to determine differences in the number of pigs scouring between the treatments. Multiple regression equations were computed according to Steel and Torrie (1980) to determine whether diarrhea affected performance.

D. Results

Performance of Pigs Fed Simple Versus Semi-complex Diets

Figure IV.2 illustrates the average daily feed intake (ADF) of the pigs fed the two diets during the first week after weaning. There were no significant differences in feed consumption between the treatment groups for any of the days.

The mean weekly performance of the pigs fed the two diets is shown in Table IV.2. During the first and second week of the trial, there were no significant differences in average daily gain (ADG) or ADF intake between the treatment groups. There were significant differences in the efficiency of feed utilization during the first week postweaning. In the second week the best gain to feed ratio was obtained with pigs fed the semi-complex diet but the difference was

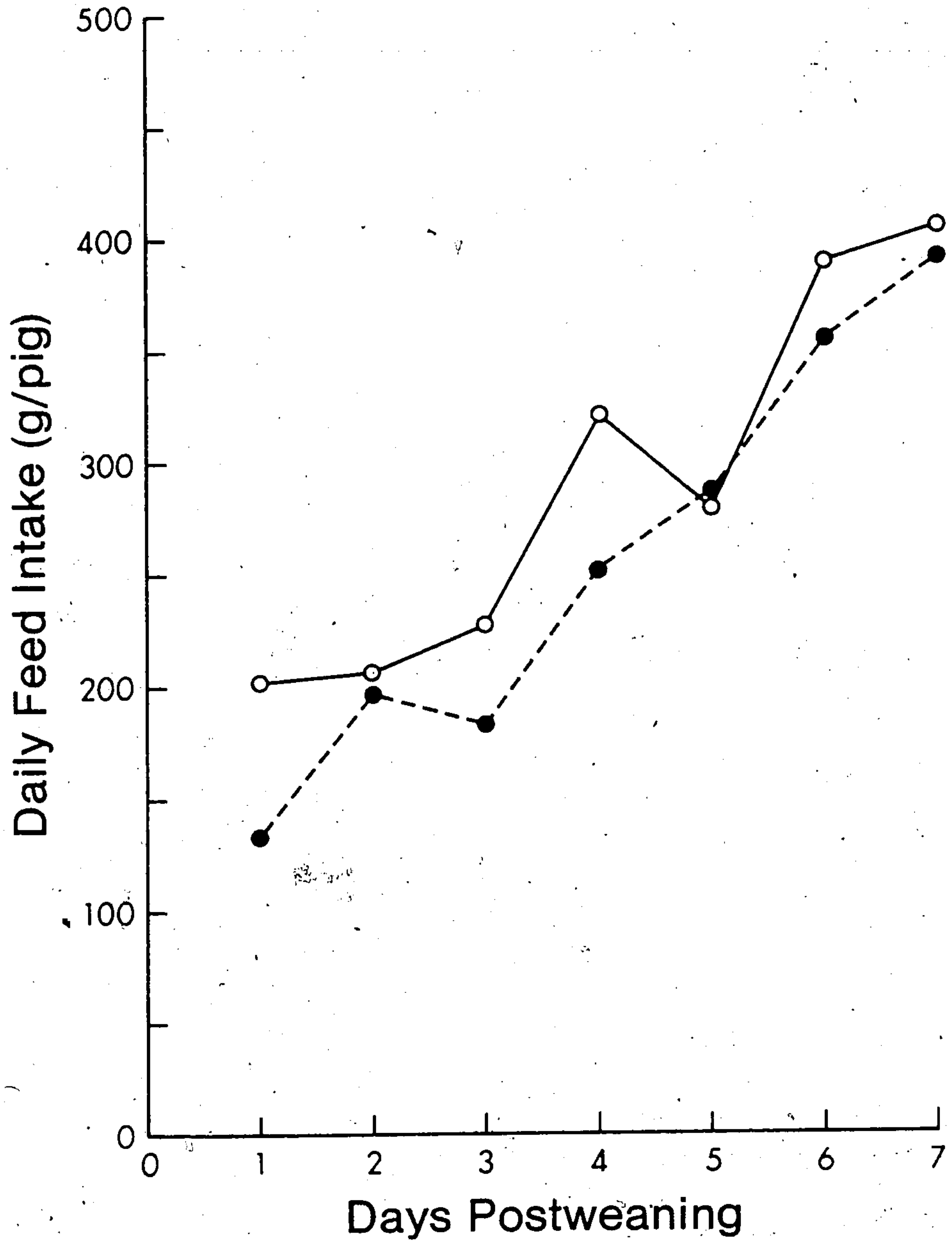

Figure IV.2. Average daily feed intake during the first week postweaning of pigs fed simple (o) or semi-complex (●) diets.

Table IV.2. The performance[1] of pigs fed either simple or semi-complex starter diets.

Diet	Simple	Semi-complex	Sig[2]
Criteria:			
Gain (g/pig/day)			
Week 1	97±23.13	138±23.69	NS
2	311±14.87	340±15.24	NS
3	387±18.54	526±18.99	.01
4	462±20.55	590±21.06	.01
Mean	314±13.52	399±13.86	.01
Feed intake (g/pig/day)			
Week 1	289±18.69	256±19.15	NS
2	506±20.17	511±20.67	NS
3	754±21.52	799±22.06	NS
4	901±37.80	1047±38.73	.05
Mean	618±20.57	653±21.09	NS
Gain per kg of feed (kg)			
Week 1	0.335±.06	0.536±.06	.05
2	0.617±.03	0.680±.03	NS
3	0.517±.02	0.660±.02	.01
4	0.513±.01	0.569±.01	.05
Mean	0.512±.01	0.615±.01	.01

[1]Values represent means of 26 pens per treatment ± standard error.
[2]Statistical significance; NS=nonsignificant (P>0.05).

not significant. In the third week the semi-complex diet produced significantly better gain and feed efficiencies. During week three more of the semi-complex diet was eaten compared to the simple diet however, the differences in feed intake were not significant. In the final week the performance of the pigs fed the semi-complex diet was significantly better than that of the pigs fed the simple diet. For the total experimental period, the best ($P<0.01$) rate of growth and efficiency of feed utilization was obtained with the semi-complex diet. Although ADF intake was greatest for the semi-complex diet this value was not significantly different from the intake of pigs fed the simple diet.

Performance of Pigs Not Moved or Moved at Weaning

During the first week of the trial ADG and feed efficiency were better for the pigs that were not moved at weaning but the difference was not significant (Table IV.3). In the second week after weaning the pigs housed in the farrowing area were moved to the nursery. This movement appeared to reduce piglet performance slightly although the differences between the groups were not significant. For weeks three, four and the overall experimental period there were no significant differences between treatment groups for ADG, ADF or gain per feed. There was no significant interaction of diet by method of weaning on pig performance as shown in Table IV.4.

Incidence of Diarrhea

Table IV.3. The performance[1] of pigs either not moved or moved at weaning.

Method of weaning	Not Moved	Moved	SE[2]	Sig[3]
Criteria:				
Gain (g/pig/day)				
Week 1	126	108	10.73	NS
2	319	333	15.69	NS
3	469	445	12.71	NS
4	533	519	12.27	NS
Mean	362	351	7.74	NS
Feed intake (g/pig/day)				
Week 1	263	282	8.12	NS
2	513	503	15.27	NS
3	780	773	18.88	NS
4	992	956	18.36	NS
Mean	637	629	12.55	NS
Gain per kg of feed (kg)				
Week 1	0.472	0.399	0.03	NS
2	0.639	0.658	0.03	NS
3	0.601	0.577	0.01	NS
4	0.540	0.542	0.01	NS
Mean	0.569	0.559	0.01	NS

[1]Values represent means of 26 pens per treatment.
[2]SE = standard error of the mean.
[3]Statistical significance; NS = nonsignificant (P>0.05).

Table IV.4. The performance[1] of pigs fed simple or semi-complex diets and not moved or moved at weaning.

Diet	Simple		Semi-complex		
Method of weaning	Not moved	Moved	Not moved	Moved	Sig[2]
Criteria:					
Initial wt (kg)	8.0	8.0	7.8	7.7	NS
Final wt (kg)	17.2	16.5	18.9	18.9	NS
Daily gain (g)	326±10.83	303±10.83	398±11.03	399±11.03	NS
Daily feed (g)	620±17.59	605±17.59	655±17.91	652±17.91	NS
Gain:Feed	0.523±.01	0.500±.01	0.613±.01	0.617±.01	NS

[1]Values represent means of 13 pens per treatment ± standard error.
[2]Statistical significance; NS=nonsignificant (P>0.05).

Composition of the diet did not significantly influence the number of pigs having diarrhea (Table IV.5). Thirty-one of the pigs that were moved at weaning showed some degree of diarrhea and this was a significantly greater number of cases compared to those pigs that were not moved (Table IV.5).

To determine whether scours affected performance multiple regression equations were computed. The sources of variation in these equations were diets, method of weaning and scours. The scours regression coefficients (Table IV.6) indicated that scours did not significantly affect ADG, ADF or gain per feed.

Digestibility

The average digestibility coefficients for dry matter, protein, and energy of the two diets appear in Table IV.7. The dry matter and energy digestibility values were significantly greater for the simple diet. With regard to protein the diets did not differ significantly.

Table IV.8 shows the digestibility coefficients for the two methods of weaning. Movement of the pigs at weaning resulted in significantly lower dry matter, energy and protein digestibilities.

As for the performance criteria, there was no significant interaction of diet by method of weaning on dry matter, protein and energy digestibility (Table IV.9).

Days postweaning had no significant effect on the digestibility of dry matter or energy. Protein digestibility

Table IV.5. The effect of diet and method of weaning on the number of pigs scouring.

	Number of Pigs Scouring
Diet:	
Simple	22
Semi-complex	23
Significance	NS
Method of weaning:	
Not moved	16
Moved	31
Significance	.02

[1] 102 pigs fed the simple diet; 99 pigs fed the semi-complex diet; 100 pigs not moved at weaning; 101 pigs moved at weaning.

Table IV.6. Multiple correlation of scours to pig performance.

Dependent variable	Multiple correlation	Regression	Standard error	Probability
Average daily gain	.64	.002	.004	.61
Average daily feed	.60	.008	.006	.21
Gain:Feed	.84	.010	.009	.29

Table IV.7. Digestibility coefficients[1] for dry matter, protein and energy of pigs fed simple or semi-complex diets.

Diet	Simple (54)[2]	Semi-complex (55)	Sig[3]
<u>Digestibilities (%)</u>			
Dry matter	79.75±.33	77.88±.34	.01
Protein	77.28±.43	76.68±.44	NS
Energy	77.87±.47	76.35±.49	.05

[1]Values represent means ± standard error.
[2]Number of observations per treatment in parenthesis.
[3]Statistical significance; NS=nonsignificant (P>0.05).

Table IV.8. Digestibility coefficients[1] for dry matter, protein and energy of pigs either not moved or moved at weaning.

Method of weaning	Not moved (54)[2]	Moved (55)	Sig[3]
Digestibilities (%)			
Dry matter	79.27±.24	78.36±.23	0.01
Protein	77.78±.41	76.18±.39	0.01
Energy	77.80±.30	76.44±.29	0.01

[1]Values represent means ± standard error.
[2]Number of observations per treatment in parenthesis.
[3]Statistical significance.

Table IV.9. Digestibility coefficients[1] for dry matter, protein and energy for pigs fed simple or semi-complex diets and either not moved or moved at weaning.

Diet	Simple		Semi-complex		
Method of weaning	Not moved (26)[2]	Moved (28)	Not Moved (28)	Moved (27)	Sig[3]
<u>Digestibility (%)</u>					
Dry matter	80.02± .33	79.45± .31	78.52± .33	77.24± .33	NS
Protein	77.96± .57	76.60± .54	77.60± .58	75.76± .57	NS
Energy	78.50± .42	77.27± .39	77.10± .42	75.61± .42	NS

[1]Values represent means ± standard errors.
[2]Numbers of observations per treatment in parenthesis.
[3]Statistical significance; NS=nonsignificant (P>0.05).

improved with increasing age (Table IV.10). The differences in protein digestibility between day three and days fourteen and twenty-one postweaning were significant.

Table IV.11 shows the interaction of diet by days postweaning on nutrient digestibility. There were no significant differences in nutrient digestibility between the two diets at three and seven days after weaning. By day 14 and 21 there were significant differences in digestion coefficients for dry matter and energy, these differences being in favor of the simple diet. At day fourteen the digestibility of protein of the simple diet was greater ($P<0.05$) than that of the semi-complex diet.

E. Discussion

Performance of Pigs Fed Simple Versus Semi-complex Diets

There have been many studies of the effects of diet complexity on the performance of weaned pigs. The results have been controversial. In a two week study Ball (1979) observed no significant differences in performance when three week old pigs were fed simple or semi-complex diets. The data from the first two weeks of the present study support Ball's (1979) results. However, despite the insignificant differences in growth rate between the two diets during the initial part of this study, there was an improvement ($P<0.05$) in ADG for the overall experimental period when the

Table IV.10. Digestibility coefficients[1] for dry matter, protein and energy of pigs during different days postweaning.

Days postweaning	3(23)[2]	7(26)	14(30)	21(30)	Sig[3]
Digestibility (%)					
Dry matter	79.20±.37	78.49±.33	78.61±.30	78.59±.30	NS
Protein	75.28±.63a	76.16±.58ab	77.53±.52bc	78.94±.52c	.01
Energy	77.08±.46	76.68±.42	77.03±.38	77.69±.38	NS

[1]Values represent means ± standard error.
[2]Numbers of observations per day in parenthesis.
[3]Statistical significance; NS = nonsignificant ($P>0.05$).
a-c, means within rows followed by the same or no letter are not significantly different.

Table IV.11. Interaction of diet by days postweaning on diet digestibility coefficients for dry matter, protein and energy.

	Days Postweaning				
Diet	3	7	14	21	SE[1]
<u>Digestibility (%)</u>					
Dry Matter					
Simple	79.39	79.06	80.36	80.19	.49
Semi-complex	79.01	77.92	76.87	77.71	.58
SE	.58	.49	.44	.44	
Sig	NS	NS	*	*	
Protein					
Simple	74.30a	76.19a	78.79b	79.82b	.85
Semi-complex	76.25	76.14	76.27	78.06	1.0
SE	1.00	.85	.77	.77	
Sig	NS	NS	*	NS	
Energy					
Simple	76.98	77.16	78.62	78.78	.62
Semi-complex	77.18	76.20	75.44	76.60	.73
SE	.73	.62	.56	.56	
Sig	NS	NS	*	*	

[1]SE=standard error.
a-b, means within rows followed by the same or no letter are not significantly different.
*Means within columns significantly differ ($P<0.05$).

pigs were fed the semi-complex diet. Okai (1974) also observed significantly better growth rates when three week old pigs were fed diets of increasing complexity. He attributed this to a greater intake of feed when the pigs were fed more complex rations. Similar observations have been reported by a number of researchers (Combs et al. 1963; Meade et al. 1969a; Tanksley et al. 1978). In the current experiment increasing the complexity of the diet did not result in a significant improvement in feed consumption. These results agree with those of Meade et al. 1969b; Young and Jamieson 1970; Graham et al. 1981 and the results of Okai (1974) when five week old pigs were fed increasingly complex diets. Feeding the semi-complex diet resulted in a significant improvement in the gain per feed ratio. Other researchers have reported that more complex starter diets promote better feed conversion efficiencies than do simple diets (Meade 1967; Bayley and Carlson 1970). In contrast Okai (1974) reported no significant improvements in feed conversion efficiency when complex diets were fed to five week old pigs for a four week period. The discrepency in the results of the published reports in terms of improved pig performance when diets of varying complexity are fed to starter pigs may be related to such factors as age or weight of the pigs at weaning, level of milk or other products added to the diet, length of the study and incidence of diarrhea. In the current experiment the significant improvement in growth and feed utilization of pigs fed the semi-complex diet may have been due to the higher lysine content of this diet. Several researchers have reported that there is a significant improvement in rate of gain and feed efficiency for starter pigs when the diet contains greater than 0.95% lysine (Campbell 1978; Lewis et al. 1981; Aherne and Neilsen 1983). Aherne and Neilsen (1983) reported that pigs weighing between 7 to 19 kg and fed barley-wheat-soybean meal based diets containing 18% to 20% crude protein require 1.15% lysine.

Performance of Pigs Moved or Not Moved at Weaning

Curtis (1983) suggested that environmental stressors may affect animal performance but it would be an oversimplification to assume that environmental stressors necessarily depress health and performance. In the current experiment movement of the pigs immediately at weaning did not significantly depress weekly or overall performance. This may be a reflection that newly weaned pigs are capable of acclimatization ithin a relatively short time period to variations in the physical surroundings that occur in conjunction with nutritional or social changes. The data suggests that unfamiliarity with the surroundings is not a severe stress on pigs at weaning. Funderburke et al.

(1983) reported that nutritional stress at weaning exerted a greater detrimental effect on performance and produced higher ($P<0.01$) plasma cortisol and free fatty acid levels than psychological or environmental stress. The results of the present experiment tend to support this view. When the effects of change in diet and method of weaning were combined there were still no significant reductions in piglet performance.

Incidence of Diarrhea

Feed conversion efficiency (Okai 1974; Ball and Aherne 1982) and growth rates (Ball and Aherne 1982) were slightly but insignificantly improved when increasingly complex diets were fed to starter pigs. These authors attributed this to the greater incidence and severity of diarrhea for the pigs consuming these formulations. Increased feed consumption due to the enhanced palatability of more complex rations has been postulated to be an initiating factor in postweaning diarrhea (Okai 1974). In the present experiment feeding the semi-complex diet did not result in a significantly greater intake of feed compared to that of the simple diet even during the first week after weaning. This probably accounts for the lack of differences in the incidence of diarrhea between pigs fed the two diets.

A significantly greater number of pigs scoured when they were moved at weaning compared to those that were not moved. This difference in scouring, could not be attributed to a greater intake of feed. Thomlinson (1969) suggested that movement of the pigs at weaning may act as a triggering mechanism for the multiplication of *E. coli* as movement to a new location, leads to unrest and irregular feeding behaviour.

Csermely and Wood-Gush (1981) reported that the sounds of piglets suckling and the grunts emitted by nursing sows had a significant stimulatory effect on the feeding behaviour of weaned pigs. Some of the pigs that were not moved were in the presence of lactating sows and their litters for one week after weaning. No attempt was made to determine if the pigs that remained in the farrowing house were stimulated by the sows and their litters to feed. However, these pigs may have been stimulated to feed when the nursing pigs fed. In contrast the pigs that were moved at weaning probably spent a considerable amount of time exploring their new surroundings. These pigs may have had a much longer interval of time from their last nursing period to their first meal. Consequently they may have been more inclined to consume large erratic meals. This would result in a greater number of pigs scouring. Palmer and Hulland (1965) concluded that large intakes of feed predispose pigs to outbreaks of diarrhea.

Furthermore the increased incidence of scouring in the pigs that were moved immediately at weaning may have been a direct result of the stress due to the changes in the physical surroundings. Changes in the environment provoke functional and behavioural reactions within an animal and may lead to reduced productivity and impaired disease resistence (Curtis 1983). Frazer (1978) observed that newly weaned pigs have a high level of general activity, aggressiveness towards pen mates and reluctance to lie down together. He suggested that the consequences of such behaviour is that the pigs become fatiqued and may be more suseptible to disease. Curtis (1983) reported that many normal inhabitants of the pigs gastro-intestinal tract infect or cause disease only when the pigs disease resistence is reduced as when it is under environmental stress of one type or another. It is possible that the added stress of movement at weaning decreased disease resistence and resulted in a greater number of pigs scouring.

Digestibility

The reduced performance observed when starter pigs are fed simple diets has been attributed to poorer digestibility of such diets (Meade et al. 1969a). The results of the present experiment are in agreement with those of Bayley and Carlson (1970) and Okai (1974) in that there was no significant difference in protein digestibility of the simple and semi-complex diets. Although significant differences in the digestibility of dry matter and energy of the two diets were detected, these differences are probably biologically unimportant. Bayley and Carlson (1970) reported no significant difference in dry matter digestibiliy between simple and complex diets. Okai (1974) indicated that energy digestibility was significantly greater for a semi-complex diet than for a simple diet. These results clearly contradict those obtained in the current experiment. The improved rate of growth and feed utilization of the pigs fed the semi-complex diet does not appear to be the result of a greater digestibility of the diet but may be related to the higher lysine content and better quality protein sources added to this diet.

Several researchers have reported that there is an increase in the apparent digestibility of dry matter, nitrogen and energy with increasing age (Combs et al. 1963; Ball 1979). Lloyd et al. (1957) observed that age had no effect on total carbohydrate digestibility while protein digestibility improved with age. In the present experiment only protein digestibility significantly improved with increasing age. The improvement in protein digestibility with increasing age may be related to the young pigs ability to digest plant proteins due to the increased activity of proteolytic enzymes. Shields et al. (1980) reported that protease and amylase activity increased concurrently with enhanced feed consumption.

There was a significant interaction of diet by days postweaning on the digestibilty coefficients. The digestibility of dry matter and energy of both diets did not significantly improve with increasing age of the piglets. Bayley and Carlson (1970) reported that the major portion of improved digestibility of dry matter, energy and nitrogen occurs when pigs are two to four weeks old. The lack of improvement in the digestibility of all measured coefficients of the semi-complex diet and in dry matter and energy of the simple diet may be due to the fact that the pigs were four weeks old at the time of weaning. However the cause of improved protein digestibility only in the simple diet is unknown.

It is possible that reduced digestibility of the diet when the pigs were moved at weaning was related to the additional stress of the unfamiliar surroundings together with the other changes. In some species, including the young pig, stress has been reported to reduce gastric motility (English 1977; Lister et al. 1981). Kenworthy and Crabb (1963) as cited by Ball (1979) postulated that a certain degree of gut stasis allows the proliferation of *E. coli*. It has since been discovered, that these micro organisms produce lactic acid which irritates the intestinal lumen resulting in an enhanced rate of passage and decreased digestibility

(Etheridge et al. 1984b). The lowered digestibility coefficients when the pigs were moved at weaning probably was due to the greater incidence of scouring.

In summary dietary and management practices that reduce the stress at weaning are not well substantiated. The data collected in this experiment indicate that the performance of the pigs after weaning could be improved by supplying a semi-complex diet. Although changes in the environment may alter disease resistence and reduce productivity, movement of the piglets to an unfamiliar environment on the day of weaning does not appear to be a substantial stress.

V. Experiment II

The Effects of Stocking Density on Weanling Pig Performance and Behaviour

A. Abstract

An experiment involving 77 four week old pigs was conducted to assess the performance and behavioural patterns of pigs housed individually, pairwise or in groups of four. Floor space allowances were 1.44, 0.72 and 0.35 m^2 per pig for the one, two and four pig groups respectively. There were no significant differences in the performance of pigs housed singly or in pairs. Pigs housed four to a pen had lower ($P<0.01$) average daily gain (ADG) and average daily feed (ADF) intakes. Feed conversion efficiency did not differ significantly between treatments. The proportion of intervals that the pigs were observed to be active, lying, drinking or aggressive did not differ significantly between stocking densities. Pigs housed in groups of two were observed to spend significantly more time feeding than those housed individually or in groups of four. Possible reasons for this behaviour are discussed.

B. Materials and Methods

Seventy-seven 28 day old crossbred (Yorkshire x Landrace) pigs (seven from each of seven litters, ten from each of two litters and eight from one litter) were assigned as littermates on the basis of initial weight to one of three stocking densities (one, two or four pigs per pen). The number of pens for each of the three densities one, two and four was thirteen, twelve and ten respectively.

The pigs were housed in fully slotted floor pens with wire mesh partitions which allowed for visual and limited physical contact between pigs in adjacent pens. The pens measured 1.2 x 1.2 m which allowed a total pen area of 1.44 m^2 and a floor space of 1.44, 0.72 and 0.35 m^2 per pig for the three group sizes one, two and four respectively. Pigs housed in pairs were always penned between the pigs housed individually and in groups of four.

All pigs were fed ad libitum the semi-complex diet that was fed in Experiment I. Feed disappearance on a pen basis was recorded daily for the first seven days of the experiment and once weekly thereafter. Fresh feed was added as necessary. One nipple waterer and one six hole (64 x 11 cm) metal feeder was provided in each pen. The house temperature was maintained at 28 ± 3°C throughout the 28 day trial. All pigs were weighed on the day of weaning and on days 1, 3, 5, 7, 14, 21 and 28 postweaning.

The behaviour patterns of thirty-five piglets consisting of five replications of each stocking density was monitored by direct observation. During the periods of observation the observer sat outside the pens in full view of the pigs. The pens were studied in groups of three, comprising of one pen of each stocking density. Each group was observed for 120 minutes two times per day, 1000 to 1200 hou[illegible]00 to 1600 hours on the day of weaning and dur[illegible]1, 2, 3, 7, 11, 14, 18 and 21 after weaning. The gene[illegible]ctivity of each of the pig(s) in each pen was noted at one minute intervals throughout the observation period. This method of recording behaviour does not take into account the absolute rate, frequency or duration of a particular behaviour. However the percentage of scans showing pigs engaged in a particular behaviour will give some indication of a time budget. The behaviour patterns that were recorded are outlined in Table V.1. All pigs were individually marked with color codes on their backs and sides.

C. Statistical Analysis

Preliminary analysis indicated that variation within sow by density cells was not significantly different from the variation between sow by density cells for all the major production traits. Therefore these two sources of variation were pooled to form an estimation of error (Appendix Table 2). The performance data were analyzed as described in Experiment I.

Table V.1. Description of recorded behaviour.

General Behaviour	
Lying	– a pig lies on its side or on its belly area.
Active	– includes standing, scratching or moving about the pen.
Sitting	– sitting on the posterior, fore limbs stretched, head free from any support.
Feeding	– scored whenever a pig places its head in the feeder.
Drinking	– drinking water from the nipple drinker.
Aggressive Behaviour	
Aggressive biting	– one pig opens and closes its mouth on or near another pig.

In analyzing the behaviour data a record was made of the number of minutes of observation in which a pig was scored for each behaviour. Since the behaviour of the two and of the four pigs in a pen was most likely influenced by the behaviour of their pen mates, their behaviour could not be regarded as independent observations. The data for these pens was therefore formed into a composite. The pen was considered to be the experimental unit. The analysis gave an overall score for each pen representing the percentage of minutes for which each behaviour was scored during the daily observation periods. The scores were treated with a repeated measures analysis of variance (Steele and Torrie 1980). When preceded by a significant F test the means were compared using Student Newman Kuels (SNK) multiple range test (Steele and Torrie 1980). Significant day by behaviour category interactions were analyzed by a one way analysis of variance for the separate days.

Russel and Rao matching coefficients (Anderberg 1973) were calculated to test for synchronization of feeding between all possible pairs of pigs within stocking densities two and four and between stocking densities one versus two and two versus four. The mean coefficients for each of the four comparisons were analyzed by repeated measures analysis of variance (Steele and Torrie 1980). When preceded by a significant F test multiple range tests using SNK values at the five percent level of probability were used to compare the means.

D. Results

Piglet Performance

Average daily feed (ADF) intake during the first week postweaning for pigs within each treatment group is shown in Figure V.I. There were differences in feed intakes across all treatments but the differences were significant only during the second day after weaning. During day two after weaning pigs housed individually consumed the greatest amount of feed. There were no significant differences in feed intake for pigs housed in groups of two or four.

Figure V.2 shows the postweaning growth curves for the pigs. Pigs on all three treatments lost weight during the first day of weaning. The individually penned pigs lost the most weight but this value was not significantly different from that of pigs penned in groups. Pigs on all treatments had regained their weaning weights by the third day postweaning. At five and seven days after weaning average daily gain (ADG) was not significantly different for pigs penned individually, in pairs or in groups of four (Figure V.2).

The mean weekly performance of the pigs housed in the three group sizes is shown in Table V.2. During the first week pigs housed in groups of two had slightly higher ADG and ADF intakes than those housed singly or in groups of four but these differences were not

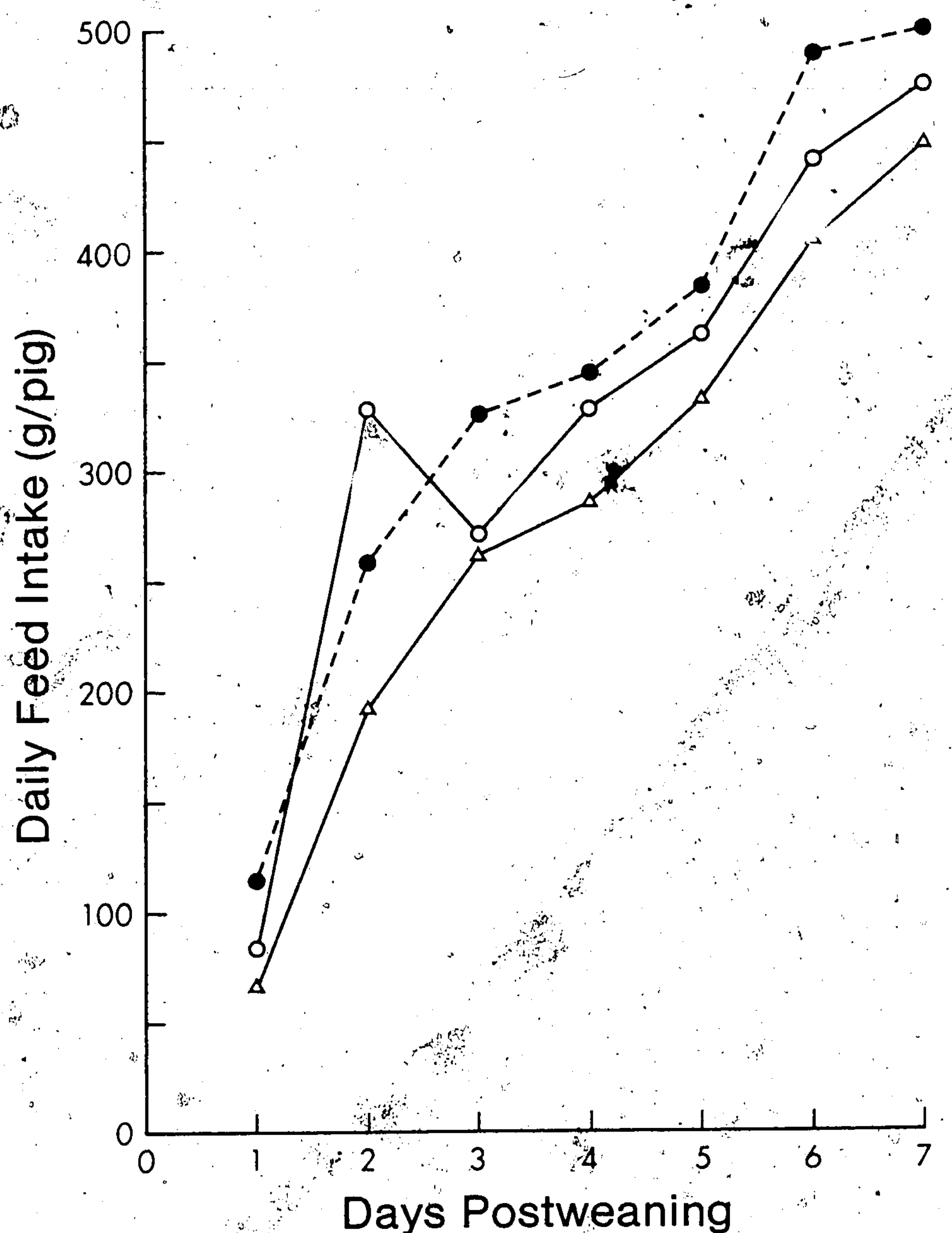

Figure V.1 Average daily feed intake during the first week postweaning of pigs housed individually (o) pairwise (●) or groups of four (Δ).

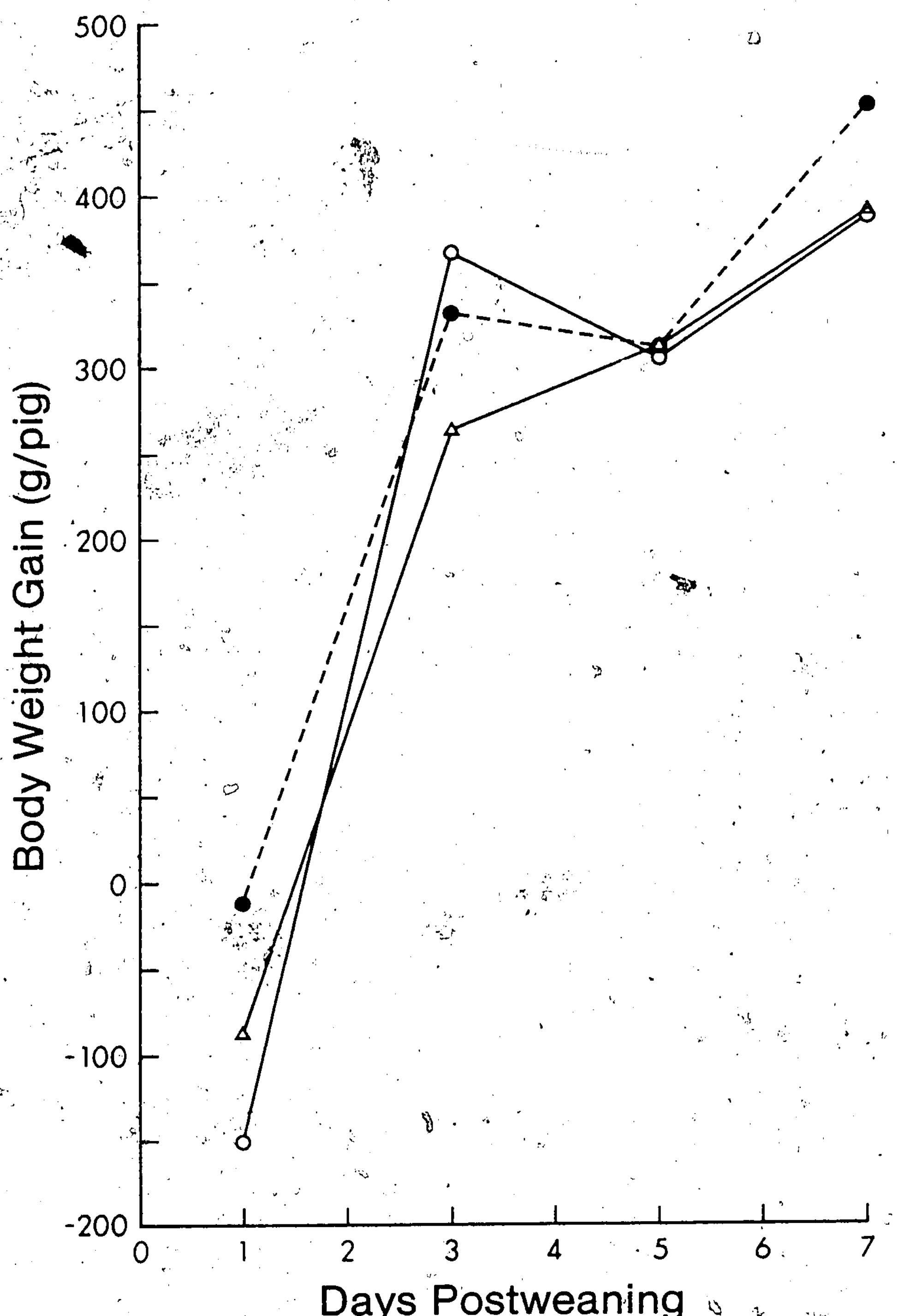

Figure V.2 Average daily weight gain during the first week postweaning of pigs housed individually (o) pairwise (●) or groups of four (Δ).

Table V.2. The mean weekly performance[1] of pigs housed individually or in groups of two or four.

Pigs per	1(13)[1]	2(12)	4(10)	Sig[2]
Floor space per pig	1.44	0.72	0.35	
Criteria:				
Gain (g/pig/day)				
Week 1	283	307	262	NS
2	564	520	471	NS
3	687	685	638	NS
4	765	756	704	NS
SE[3]	16.61	17.12	18.42	
Feed intake (g/pig/day)				
Week 1	332	338	284	NS
2	693	644	588	NS
3	937	1009	817	NS
4	1209	1142	1033	NS
SE	33.98	35.12	37.68	
Gain per kg of feed (kg)				
Week 1	0.878	0.915	0.932	NS
2	0.820	0.819	0.802	NS
3	0.742	0.696	0.792	NS
4	0.638	0.673	0.684	NS
SE	0.03	0.03	0.04	

[1]Number of observations per treatment in parenthesis.
[2]Statistical significance; NS = nonsignificant ($P>0.05$).
[3]SE = standard error.

significant. In weeks two, three and four of the experiment pigs penned individually had non significantly higher ADG than those penned in groups of two or four. There were no significant differences between treatments for efficiency of feed utilization during any of the four weekly periods.

Table V.3 shows the performance of pigs housed by the different methods for the total experimental period. Pigs individually penned had the greatest rate of gain but this was not significantly different from that of pigs housed in pairs. Pigs housed in groups of four had the smallest (P<0.01) ADG and ADF intake. There were no significant differences in feed efficiency for the pigs housed by the three stocking densities.

Piglet Behaviour

The means of the percentage scores averaged across all the days of observation for the observed behaviour categories are shown in Table V.4. The percentage of intervals that the pigs were observed to be lying, active, drinking or aggressive did not significantly differ between treatments. Sitting and feeding behaviour however did differ significantly between stocking densities.

Pigs housed individually spent a greater proportion of time (P<0.05) sitting than pigs housed in pairs (Table V.4). Although pigs penned in groups of

Table V.3. The performance[1] of pigs housed individually or in groups of two or four.

Pigs per pen Floor space m^2 per pig	1(13)[2] 1.44	2(12) 0.72	4(10) 0.35	Sig[3]
Criteria:				
Initial wt (kg)	8.2±.13	8.1±.14	8.1±.15	NS
Final wt (kg)	24.2±.30a	24.1±.31a	22.6±.33b	.01
Daily gain (g)	575±9.39a	567±9.66a	519±10.18b	.01
Daily feed (g)	793±19.22a	783±19.77a	680±20.84b	.01
Gain:Feed	0.769±.02	0.776±.02	0.802±.02	NS

[1]Values represent means ± standard error.
[2]Number of observations per treatment in parenthesis.
[3]Statistical significance; NS = nonsignificant ($P>0.05$).
a-b, means within rows followed by the same letter are not significantly different ($P>0.05$).

Table V.4. The behaviour[1] of pigs housed individually or in groups of two or four.

Pigs per pen	1	2	4	Sig[3]
Floor space m² per pig	1.44	0.72	0.35	
Behavioural category:[2]				
Lying	76.2	74.8	76.0	NS
Active	12.0	13.9	13.2	NS
Sitting	2.8a	1.3b	2.0ab	.037
Feeding	7.9a	8.6b	7.6a	.021
Drinking	0.9	1.2	1.1	NS
Aggression	0.0	0.1	0.2	NS

[1]Values represent means of five replications per treatment.
[2]Values expressed as a percentage of total intervals pigs observed performing behaviours. Observations at one minute intervals for nine, four hour periods.
[3]Statistical significance, NS = nonsignificant (P>0.05).
a-b, means within rows followed by the same or no letter are not significantly different (P>0.05).

four spent more time sitting than those housed in pairs the differences were not significant.

Pigs housed in pairs spent more time feeding (P<0.05) than pigs housed individually or in groups of four. There were no significant differences in the amount of time spend feeding for pigs housed singly or four to a pen.

There was a significant day effect (Appendix Table 3) for the behaviour categories active, sitting and feeding. Averaged across all treatments the results indicate that the level of activity was greatest on the day of weaning but this value was not significantly different from that observed during the first day after weaning (Table V.5). Activity progressively decreased with increasing age of the piglets.

The amount of time that the pigs spent sitting varied from day to day so that no trend was observed (Table V.5).

The pigs spent significantly less time feeding on the day of weaning compared to all other days (Table V.5) The proportion of intervals that the pigs were observed to feed increased to a maximum during the seventh day after weaning.

A significant interaction between stocking density and day with respect to activity (P<0.034) and sitting behaviour (P<0.002) was observed. Figure V.3 illustrates the percentage of intervals that the pigs

Table V.5. The behaviour[1] of pigs during different days postweaning.

Behaviour category	Active	Feeding	Sitting
Day Postweaning[2]			
0	21.6a	1.8a	2.3ab
1	18.2ab	6.4b	1.1b
2	12.5bc	6.7b	1.3b
3	12.4bc	10.5cd	1.6ab
7	14.0bc	11.5d	2.0ab
11	11.1bc	10.8cd	2.6ab
14	11.0bc	8.6bcd	1.7ab
18	8.4c	8.8bcd	3.4a
21	8.0c	7.6bc	2.5ab
SE	2.03	0.85	0.44

[1]Values represent means of fifteen pens.
[2]Values expressed as a percentage of of total intervals pigs observed performing behaviours. Observations at one minute intervals for four hours per day.
SE = standard error.
a-d, means within columns followed by the same letter are not significantly different (P>0.05).

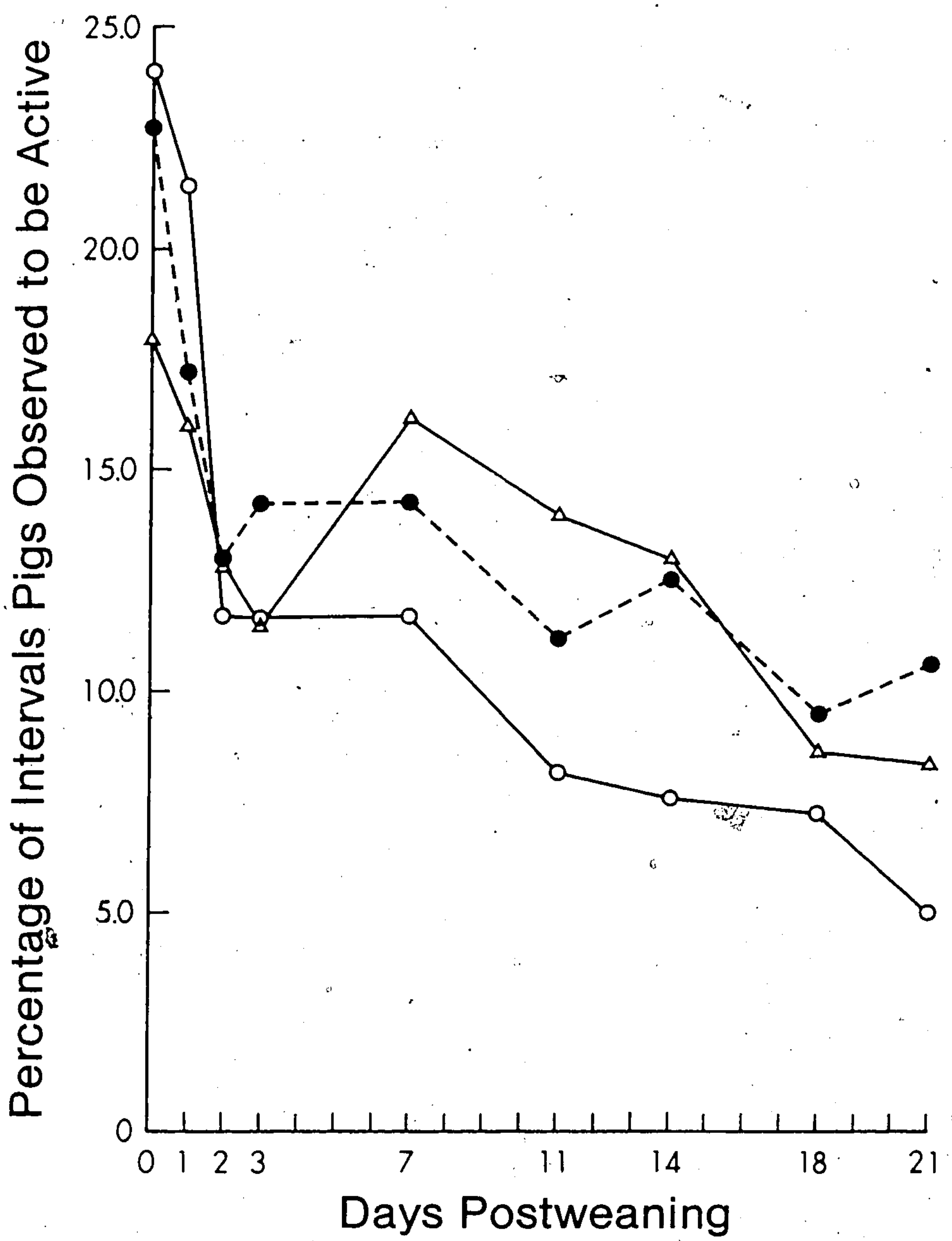

Figure V.3. The effects of housing pigs individually (o) pairwise (●) or groups of four (△) on activity.

on the three treatments were observed to be active during the different days postweaning. There were significant differences in activity between the three treatments only during the eleventh day after weaning. On day eleven pigs penned in groups of four were significantly more active than those housed individually. There were no significant differences between the mean percent scores for pigs housed individually or in pairs.

Pigs housed individually spent significantly more time sitting during days 3 and 21 after weaning compared to those penned in pairs or groups of four (Table V.6).

Synchronization of feeding behaviour between pairs of pigs occured at significantly more intervals within the pens containing two pigs than within the pens containing four pigs (Table V.7). Individually penned pigs did not synchronize their feeding bouts with pigs housed in pairs any more (P>0.05) than pigs housed in groups of four.

E. Discussion

Studies involving the behaviour of newly weaned pigs indicate that these animals are particularily active during the first day after weaning (Frazer 1978; Jeppensen 1980). These results are consistent with those obtained in this study. Pigs on all treatments had a high level of activity

Table V.6. Sitting behaviour[1] of pigs housed individually or in groups of two or four.

Pigs per pen Floor space m^2 per pig	1 1.44	2 0.72	4 0.35	Sig[3]
Day Postweaning[2]				
0	2.7	1.9	2.3	NS
1	1.3	0.7	1.4	NS
2	1.1	1.2	1.5	NS
3	2.5a	0.9b	1.4b	.004
7	2.4	1.4	2.0	NS
11	4.2	1.9	1.6	NS
14	1.6	1.4	1.9	NS
18	6.3	1.0	3.0	.003
21	3.2a	1.4b	2.7b	NS

[1]Values represent means of five replications per treatment.
[2]Values expressed as a percentage of intervals pigs observed to be sitting. Observations at one minute intervals for four hours per day.
[3]Statistical significance; NS = nonsignificant (P>0.05).
a-b, means within rows followed by the same or no letter are not significantly different (P>0.05).

Table V.7. Synchronization of feeding behaviour between pairs of pigs housed in the same or adjacent pens[1].

Comparison	Russel and Rao Coefficients[2]
Between pairs of pigs housed together in groups of two	2.8a
Between pairs of pigs housed together in groups of four	1.8b
Between pigs housed individually and in adjacent pens in groups of two	1.3b
Between pigs housed in groups of two and in adjacent pen in groups of four	1.2b

[1]Values represent the means of 45 Russel and Rao coefficients

[2]Values expressed as a percentage of time pairs of pigs were observed to feed simultaneously.

a-b, means within columns followed by the same letter are not significantly different (P>0.05).

during the first 24 hours following weaning. Frazer (1978) suggested that the increased activity may be the result of physical discomfort arising from the sudden intake of a solid feed diet. He however observed an increase in both activity and feeding behaviour on the day of weaning. The results of the current experiment indicate that the pigs spent significantly less time feeding and consequently had reduced feed intakes on the day of weaning compared to the other days. It is unlikely therefore that the high level of activity during the first two days of the study was the result of the piglets consuming the solid feed diet. Increased activity immediately following weaning may be a behavioural response to environmental changes such as unfamiliarity with the surroundings and separation from the sow or littermates. Frazer (1975) suggested that the vigorous activity combined with repeated vocalizations when piglets are separated from their dams may be an indication that they are trying to maintain contact with the sow.

During the first week of the study ADF consumption was low although the differences between the days were not significant. A possible reason for the poor intake of feed during the first week after weaning may be due to the reluctance of the pigs to consume a solid feed diet. Faulty regulation of feed consumption including failure to eat is one of the behavioural problems observed amoung early weaned pigs (Frazer 1978).

The initial heightened activity and low ·ake of feed during the first day after weaning, probably a ·ounted for the observed growth check. Close and LeDividich (1982) suggested that the loss of body weight after weaning is associated with the pigs inability to consume sufficient feed and an increase in energy expenditure caused by high levels of physical activity.

Previous studies have shown that the behaviour and performance of pigs can be influenced by group size (McConnell et al. 1982; Bryant and Ewbank 1972) and stocking density (Ross and Curtis 1976; Bryant and Ewbank 1974). McConnell et al. (1982) reported that increasing the number of starter pigs in a pen from 8 to 16 to 24 with an equal floor area per pig resulted in a general deterioration in performance. In contrast Sather (1982) reported no significant differences in pe· rmance when growing boars were housed in groups or two or four with a constant housing density.

Several researchers have studied the effects of crowding by adding more pigs to a pen of a constant size (Kornegay et al. 1981a, b; Lindvall 1981). The results of Kornegay et al. (1981b) show that as the number of starter pigs in a pen increases ADG and ADF intake are significantly reduced. In the present experiment number of pigs per pen and floor space per pig were confounded. The performance of pigs housed individually or in pairs did not differ significantly. However pigs penned by these methods had significantly higher ADG and ADF intakes compared to those penned in groups of four. This does not agree with the results of Sather (1982) who reported that indiviudally penned boars with a floor space of 2.88 m² per pig did not perform differently form those penned in groups of two or four with a stocking density of 1.44 m² per pig.

Gain per feed ratio was not significantly affected by stocking density. Similar observations have been reported by Gehlback et al. 1966; Kornegay et al. 1981a, b; Lindvall 1981; Bryant and Ewbank 19[illegible] Bryant and Ewbank (197[illegible] suggested that since efficiency of feed conversion [illegible] usually unaffected, the major influence of a dense stocking density is to reduce voluntary feed consumption. In the present experiment the slower rate of growth of pigs reared in groups of four appears to be related to the significant reduction in voluntary feed consumption.

The reduction in ADF intake when pigs are housed four to a pen does not appear to be the result of the pigs having less space to move about in and therefore making fewer trips to the feeder because the amount of time spent feeding was similar (P>0.05) when pigs were housed individually or in groups of four. In additon, the level of general activity was not affected by housing treatment. These results are in agreement with those reported by Randolph et al.(1981) and Ross and Curtis (1976). Since none of the treatments subjected the pigs to severe floor space restrictions, other factors must be responsible for the reduction in ADF intake and consequent reduced rate of growth when pigs are penned in groups of four.

Several researchers have reported that aggression is increased when the area allowed per pig is reduced and this leads to hierarchy instability and reduced productivity (Heitman et al, 1961; Ewbank and Bryant 1972; Ross and Curtis 1976; Hansen and Hageslo 1980; Randolph et al. 1981). In the current experiment the amount of time that the pigs spent engaged in aggressive behaviour did not differ significantly between groups. Although the intensity or frequency of agonistic behaviour was not measured, the level of aggression may have been greater when pigs were confined in groups of four.

It was noted during the experiment that pigs penned four to a group had difficulty feeding together. The Russel and Rao coefficients also indicate that synchronization of feeding was significantly reduced between pairs of pigs when the pigs were penned in groups of four compared to pigs penned in groups of two. This may be interpreted as a possible sign of increased aggression within the larger groups.

The inability of all four pigs in a pen to feed together may also be an indication that feeder space was limited. Rasmussen et al. (1962) and Hansen et al. (1982) reported that aggression is increased due to competition for feeder space when all members of a group can not feed together. In this type of situation not only is the performance of the lower ranking individuals depressed, but also the mean performance of the pen (Bryant 1972).

Furthermore if the level of aggression had been greater in the pens containing four pigs possibly due to inadequate feeder space, the pigs may have exchanged places at the feeder more often than those penned in pairs or individually. This type of behaviour would reduce the amount of feed consumed per unit of time spent at the feeder resulting in a reduced feed intake. Increased feed consumption per unit of time spent at the feeder for pigs housed individually would also account for the similar performance (P>0.05) between these pigs and those housed in pairs even though the pigs penned in pairs spent significantly more time feeding.

In addition, the amount of feed consumed by the individually penned pigs may have been influenced by the design of the pens. Graig (1981) suggested that the sound of feeding is an adequate stimulus to feeding behaviour and that the physical presence of another pig within the pen is not required so long as other pigs are nearby. The pens used in the current experiment were separated by wire mesh. This allowed for auditory, visual and limited physical contact between pigs in adjacent pens. Consquently pigs housed individually could have seen or heard the pigs in surrounding pens feeding and this could have stimulated them to consume more feed during a given feeding bout.

In summary the results of this experiment provide further evidence that the method of penning influences the performance of starter pigs. The reduction in voluntary feed consumption when pigs are reared in groups of four appeared to have accounted for the observed differences in growth rates between pigs penned by this system and those penned individually or in pairs. Possible reasons for the reduction in feed intake when pigs are penned in groups of four may be due to the level of aggression and (or) the availability of feeder space.

VI. Conclusion

At weaning pigs are exposed to a number of nutritional, social and environmental changes that constitute a considerable stress on the young pig. These changes are sufficient to make some pigs susceptible to disease and cause a reduction in the rate of growth at weaning.

In order to help increase the acceptability of the solid feed diet and help alleviate the growth check, diets of varying complexity are fed to starter pigs. The results of Experiment I provide further evidence that the rate and efficiency of gain is significantly improved when four week old pigs are fed a semi-complex diet rather than a simple diet.

The stress of weaning is thought to be further aggravated by moving the pigs to a new environment on the day of weaning. Movement of the pigs to an unfamiliar pen did not significantly affect postweaning performance although a greater number of pigs were observed to scour. Within the limits of this experiment nutritional stress at weaning appeared to have a more detrimental influence on piglet performance after weaning than did movement to an unfamiliar pen.

Experiment II was undertaken on the premise that the performance of pigs housed individually may not be very representative of how pigs perform in group situations. Feed conversion efficiency was unaffected by group size. Housing pigs in groups of four significantly reduced voluntary feed consumption and average daily gain compared to those housed individually or in pairs. This effect could not be attributed to a higher level or activity or to the pigs having less space and therefore making fewer trips to the feeder. Possible reasons for the reduction in voluntary feed intake when pigs are housed in groups of four may be due to a higher level of aggression associated with competition for feeder space. Although each feeder contained six holes and the recommended amount of feeder space was exceeded, pigs housed in groups of four appeared to have difficulty feeding side by side. This may be due to the fact that individual space could not be maintained during feeding. Providing feeders where the pigs could not see one another while feeding may reduce the level of aggression and increase performance when pigs are housed in groups.

In conclusion this experiment provides evidence that the performance of starter pigs housed individually or in pairs is not representative of how pigs perform in group situations. In the future the influence of social behaviour on the performance of pigs may have to be considered or the applicability of the results from some experiments to commercial situations may be limited.

References

Aherne, F. X. 1977. Conventional weaning systems for pigs. *IN* Proceedings of the Alberta Pork Seminar. Jan. 19-21. Banff, Alberta. pp. 46-70.

Aherne, F. X. 1980. Management and nutrition of the newly weaned pig. *IN* University of Illinois Pork Industry Conference Proceedings. College of Agriculture. Department of Animal Science, University of Illinois. pp. 1-42.

Aherne, F. X. and Nielsen, H. E. 1983. Lysine requirement of pigs weighing 7 to 19 kg liveweight. Can. J. Anim. Sci. 63:221-224.

Aldinger, S. M., Speer, V. C., Hays, V. W. and Catron, D. V. 1959. Effect of saccharin on consumption of starter rations by baby pigs. J. Anim. Sci. 18:1350-1355.

Anderberg, M. R. 1973. Cluster Analysis For Applications. Academic Press, New York.

Arambawela, W. J., Nielsen, H. E., Danielsen, V. and Eggum, B. O. 1975. Effect of replacing barley with tapioca meal at two different levels of feeding on the growth and health of early weaned pigs. Livest. Prod. Sci. 2:281-288.

Armstrong, W. D. and Clawson, A. J. 1980. Nutrition and management of early weaned pigs: effect of increased nutrient concentrations and or supplemental liquid feeding. J. Anim. Sci. 50:377-384.

Association of Official Analytical Chemists. 1981. Official Methods of Analysis. 14th ed. AOAC, Washington, DC.

Aumaitre, A. 1972. Developement of enzyme activity in the digestive system of the suckling pig: nutritional significance and implications for weaning. World Rev. Anim. Prod. 8:55-68.

Backstrom, L. and Curtis, S. E. 1981. Housing and environmental influences on production. *In* Diseases of Swine. 5th ed. *Edited by* A. D. Leman, R. D. Glock, W. L. Mengeling, R. H. C. Penny, E. Scholl and B. Straw. The Iowa State University Press, Ames, Iowa. pp. 737-783.

Ball, R. O. 1979. The effects of feed intake, nutrient density and weaning age on the performance, diet digestibility and incidence and severity of diarrhea in young pigs. M. Sc. Thesis, The University of Alberta. Edmonton, Canada.

Ball, R. O. and Aherne, F. X. 1982. Effect of diet complexity and feed restriction on the incidence and severity of diarrhea in early-weaned pigs. Can. J. Anim. Sci. 62:907-913.

Bayley, H. S. and Carlson, W. E. 1970. Comparisons of simple and complex diets for baby pigs: effect of form of feed and of glucose addition. J. Anim. Sci. 30:394-401.

Bielharz, R. G. and Cox, D. F. 1967. Social dominance in swine. Anim. Behav. 15:117-122.

Blackshaw, J. K. 1981. Some behavioural deviations in weaned domestic pigs: persistant inguinal nose thrusting and tail and ear biting. Anim. Prod. 33:325-332.

Brent, G., Hovell, D., Ridgeon, R. F. and Smith, W. J. 1975. Early Weaning of Pigs. Farming Press Ltd., Fenton House Pub., Ipswich, Suffolk.

Bryant, M. J. 1972. The social environment: behaviour and stress of housed livestock. Vet. Rec. 90:351-359.

Bryant, M. J. and Ewbank, R. 1972. Some effects of stocking rate and group size upon agonistic behaviour in groups of growing pigs. Br. Vet. J. 128:64-70.

Bryant, M. J. and Ewbank, R. 1974. Effects of stocking rate upon the performance, general activity and ingestive behaviour of groups of growing pigs. Brit. Vet. J. 130:139-149.

Campbell, R. G. 1978. The response of early-weaned pigs to sub-optimal protein diets supplemented with synthetic lysine. Anim. Prod. 26:11-18.

Close, W. H. and Le Dividich, J. 1982. Nutritional and environmental factors influencing the growth and developement of the young pig. IN Proc. 33rd. Annual Meeting of the European Association for Animal Production. Lenigrad, USSR. pp. 1-8.

Combs, G. E., Osegueda, F. L., Wallace, H. D. and Ammerman, C. B. 1963. Digestibility of rations containing different sources of supplementary protein by young pigs. J. Anim. Sci. 22:396-398.

Corring, T., Aumaitre, A. and Durand, G. 1978. Development of digestive enzymes in the piglet from birth to eight weeks. Nutr. Metab. 22:231-237.

Craig, J. V. 1981. Domestic Animal Behaviour: Causes and Implications for Animal Care and Management. Printice-Hall Inc., New Jersey.

Csermely, D. and Wood-Gush 1981. Artificial stimulation ingestive behaviour in early-weaned pigs. Biol. of Behav. 6:159-165.

Curtis, S. E. 1983. Environmental Management in Animal Agriculture. The Iowa State University Press. Ames, Iowa.

Danielson, D. M., Peo, E. R. Jr., and Hudman, D. B. 1960. Ratios of dried skim milk and dried whey for pig starter rations. J. Anim. Sci. 19:1055-1061.

Efird, R. C., Armstrong, W. D. and Herman, D. L. 1982. The developement of the digestive capacity in young pigs: effects of weaning regime and dietary treatments. J. Anim. Sci. 55:1370-1379.

English, P., Smith, W. and MacLean, A. 1977. The Sow Improving Her Efficiency. A Pig Farming Press Book. Great Britian.

English, P. R., Deligeorgis, F. M., Davidson, M. F., Dias, M. and Smith, W. J. 1978. Evaluation of alternative diets and feeding systems for early-weaned piglets. Anim. Prod. 26:398 (Abst.).

Etheridge, R. D., Seerley, R. W. and Wyatt R. D. 1984a. The effect of diet on performance, digestibility, blood composition and intestinal microflora of weaned pigs. J. Anim. Sci. 58:1396-1402.

Etheridge, R. D., Seerley, R. W. and Huber, T. L. 1984b. The effect of diet on fecal moisture, osmolarity of fecal extracts, products of bacterial fermentation and loss of minerals in feces of weaned pigs. J. Anim. Sci. 58:1403-1411.

Ewbank, R. and Bryant, M. J. 1972. Aggressive behaviour amoungst groups of domesticated pigs kept at various stocking rates. Anim. Behav. 20:21-28.

Feenstra, A. 1983. Temperature for early weaning. Pig Amer. 8:16-18.

Frazer, D. 1974. The behaviour of growing pigs during experimental social encounters. J. Agric. Sci. 82:147-163.

Frazer, D. 1975. Vocalizations of isolated piglets. I.

Sources of variation and relationships amoung measures. Appl. Anim. Ethol. 1:387-394.

Frazer, D. 1978. Observations on the behavioural developement of suckling and early-weaned piglets during the first six weeks after birth. Anim. Behav. 26:22-30.

Frazer, D. 1984a. The role of behaviour in swine production: A review of research. Appl. Anim. Ethol. 11:317-339.

Frazer, D. 1984b. Behaviour and productivity of pigs. *IN* Proceeding of the Alberta Pork Seminar. Jan. 18-20. Banff, Alberta. pp. 1-12.

Friend, T. H., Knabe, D. A. and Tanksley, T. D. 1983. Behaviour and performance of pigs grouped by three different methods at weaning. J. Anim. Sci. 57:1406-1411.

Funderburke, D. W., Seerley, R. W. and Mabry, J. W. 1983. Growth rate and blood parameter changes associated with postweaning stress. J. Anim. Sci. 57:246 (suppl. 1).

Gehlbach, G. D., Becker, D. E., Cox, J. L., Harman, B. G. and Jensen, A. H. 1966. Effects of floor space allowance and number per group on performance of growing-finishing swine. J. Anim. Sci. 25:386-391.

Geve, B. 1982. Periweaning nutrition of the young pig implications in feeding and developement. *In* Proc. 33rd. Annual Meeting of the European Association for Animal Production. Lenigrad, USSR. pp. 1-12.

Graham, P. L., Mahan, D. C. and Shields, R. G. 1981. Effect of starter diet and length of feeding regime on performance and digestive enzyme development of 2-week old weaned pigs. J. Anim. Sci. 53:299-307.

Graves, H. B., Graves, K. L. and Sherritt, G. M. 1978. Social behaviour and growth of pigs following mixing during the growing-finishing period. Appl. Anim. Ethol. 4:169-180.

Hansen, L. L. and Hagelso, A. M. 1980. A general survey of environmental influence and the social hierarchy in function in pigs. Acta. Agr. Scandinavica. 30:388-392.

Hansen, L. L., Hagelso, A. M. and Madsen, A. 1982. Behavioural results and performance of bacon pigs fed ad libitum from one or several self-feeders. Appl. Anim. Ethol. 8:307-333.

Harper, A. F. and Kornegay, E. T. 1983. The effects of restricted floor space allowance and virginiamycin supplementation on the feedlot performance of swine. Livest. Prod. Sci. 10:397-409.

Heitman, H. Jr., Hahn, L., Kelly, C. F. and Bond, T. E. 1961. Space allotment and performance of growing-finishing swine raised in confinement. J. Anim. Sci. 20:543-546.

Jensen, A. H., Becker, D. E. and Hermon, B. G. 1966. Management factors and young pig performance. J. Anim. Sci. 25:1273 (Abst.).

Jensen, A. H. 1971. Biological implications of intensive swine rearing systems. J. Anim. Sci. 32:560-565.

Jeppensen, L. E. 1980. Behavioural vices in young pigs. *IN* The Veterinary Society Proceedings. May 13-14. Liecester, UK. pp. 43-53.

Kennelly, J. J., Apps, M. J., Turner, B. V. and Aherne, F. X. 1980. Dysprosium, cerium and chromium marker determination by instrumental neutron activation analysis. Can. J. Anim. Sci. 60:749-761.

Kornegay, E. T., Thomas, H. R. and Kramer, C. Y. 1974. Evalutation of protein levels and milk products for pig starter diets. J. Anim. Sci. 39:527-535.

Kornegay, E. T., Tinsley, S. E. and Bryant, K. L. 1979. Evaluation of rearing systems and feed flavors for pigs weaned at two to three weeks of age. J. Anim. Sci. 48:999-1006.

Kornegay, E. T., Thomas, H. R., Arthur, S. R., Gaines, C. L., Bryant, K. L. and Knight, J. W. 1981a. Pigs per cage, flooring materials and use of soybean meal hulls in starter diets for pigs housed in triple deck nurseries. J. Anim. Sci. 51:285-2

Kornegay, E. T., Thomas, H. R. and Bryant, K. L. 1981b. Flooring material, pigs per cage and use of oats in starter diets for pigs housed in triple deck nurseries. J. Anim. Sci. 53:130-137.

Kornegay, E. T. and Notter, D. R. 1984. Effects of floor space and number of pigs per pen on performance. Pig News and Information 5:23-33.

Le Dividich, J. and Aumaitre, A. 1978. Housing and climatic conditions for early weaned piglets. Livest. Prod. Sci. 5:71-80.

Le Dividich, J. 1981. Effects of environmental temperature on the growth rates of early-weaned piglets. Livest. Prod. Sci. 8:75-86.

Le Dividich, J. and Noblet, J. 1982. Growth rate and protein and fat gain in early-weaned piglets housed below thermoneutrality. Livest. Prod. Sci. 9:731-742.

Leece, J. G., Armstrong, W. D., Crawford, P. C. and Ducharme, G. A. 1979. Nutrition and management of early-weaned piglets: Liquid versus dry feeding. J. Anim. Sci. 48:1007-1014.

Leibbrandt, V. D., Ewan, R. C., Speer, V. C. and Zimmerman, D. R. 1975. Effect of weaning and age at weaning on baby pig performance. J. Anim. Sci. 40:1077-1080.

Lewis, C. J., Catron, D. V., Combs, G. E. Jr., Ashton, G. C. and C. C. Culbertson. 1955. Sugar in pig starters. J. Anim. Sci. 14:1103-1115.

Lewis, C. J., Peo, E. R. Jr., Moser, B. D. and Crenshaw, T. D. 1981. Lysine requirement of pigs weighing 5 to 15 kg fed practical diets with and without added fat. J. Anim. Sci. 51:361-366.

Lindvall, R. N. 1981. Effect of flooring material and number of pigs per pen on nursary pig performance. J. Anim. Sci. 53:863-868.

Lister, D. Gregory, N. G. and Warris, D. D. 1981. Stress in meat animals. *IN* Developments in Meat Science. 2nd ed. *Edited by* R. L. Lawrie. Applied Science Publications, London.

Lloyd, L. E., Crampton, E. W. and Mackay, V. G. 1957. The digestibility of ration nutrients by three versus seven week old piglets. J. Anim. Sci. 16:383-388.

Lynch, P. B. 1980. Nutrition and environment interactions in pig feeding . *IN* Proceeding of the Dairy Cattle and Pig Nutrition Conferrence. Oct. 7-8. Cork, Ireland. pp. 75-87.

McAllister, J. S., Kurtz, H. J. and Short, E. C. 1979. Changes in the intestinal floora of young pigs with post-weaning diarrhea or edema disease. J. Anim. Sci. 49:868

Mcbride, G. 1959. The influence of social behaviour and experimental design in animal husbandry. Anim. Prod. 1:81-84.

Mcbride, G., James, J. W. and Hodgens, N. 1964. Social behaviour in domestic animals IV. Growing pigs. Anim.

Prod. 6:129-139.

McConnell, J. C., Waldorf, R. C. and Grimes, L. W. 1982. Housing management for early weaned pigs. J. Anim. Sci. 55:19 (Abst.).

McNutt, S. D. and Ewan, R. C. 1983. Energy utilization of weanling pigs raised individually, in cages or grouped under pen conditions. J. Anim. Sci. 57:257 (Suppl 1).

Meade, R. J. 1967. Pig starters influences of kind and form of starter on rate and efficiency of gain of pigs weaned at an early age. Feedstuffs 39:18-29.

Meade, R. J., Rust, J. W., Miller, K. P. Hanke, H. E., Grant, R. S., Vermadahl, L. D., Wass, D. F. and Hanson, L. E. 1969a. Effects of protein level sequence and kind or starter on rate and efficiency of gain of growing swine, and on carcass characteristics. J. Anim. Sci. 29:303-308.

Meade, R. J., Dukelow, W. R., Grant, R. S., Miller, K. P., Hanke, H. E., Vermedahl, L. D. and Wass, D. F. 1969b. Influence of age at weaning and kind and protein content of starter on rate and efficiency of gain of growing swine and carcass characteristics. J. Anim. Sci. 29:309-319.

Meese, G. B. and Ewbank, R. 1972. A note on instability of the dominance hierarchy and variations in level of aggression within groups of fattening pigs. Anim. Prod. 14:359-362.

National Academy of Science-National Research Council. 1979. Number 2. Nutrient Requirements of Swine. 8th ed. NAS-NRC. Washington, D. C.

NCR-89 Committee on Confinement Management of Swine. 1984. Effect of floorspace allowance and antibiotic feeding on performance of nursery pigs. J. Anim. Sci. 58:801-804.

Nielsen, H. E. 1976. Nutrition of early weaned piglets and resulting carcass quality. *IN* Proc. 27th Annual Meeting European Association for Animal Production. Zurich, Switzerland. pp. 1-24.

Okai, D. B. 1974. Effects of diet complexity on feed intake and performance of piglets and effects of creep intake and composition on starter intake and baby pig performance. M. Sc. Thesis. The University of Alberta. Edmonton, Canada.

Okai, D. B., Aherne, F. X. and Hardin, R. T. 1976. Effects of creep and starter composition of feed intake and performance of growing pigs. Can. J. Anim. Sci. 56:573-586.

Palmer, N. C. and Hulland, T. J. 1965. Factors predisposing to the developement of coliform gastro-enteritis in weaned pigs. Can. Vet. J. 6:310-316.

Randolph, J. H., Cromwell, G. L., Stahly, T. S. and Kratzer, D. D. 1981. Effects of group size and space allowance on performance and behaviour of swine. J. Anim. Sci. 53:922-927.

Rasmussin, O. G., Banks, E. M., Berry, T. H. and Becker, D. E. 1962. Social dominance in gilts. J. Anim. Sci. 21:520-522.

Rivera, E. R., Armstrong, W. D., Clawson, A. J. and Linnerud, A. C. 1978. Effect of dietary oats and kaolin on performance and incidence of diarrhea of weanling pigs. J. Anim. Sci. 46:1685-1693.

Ross, M. C. and Curtis, S. E. 1976. Space allowance and pig behaviour. J. Anim. Sci. 43:1339 (Abst.).

Sather, A. P. 1982. The effect of group size and housing density upon boar performance. Can. J. Anim. Sci. 45:219-229.

Scheel, D. E., Graves, H. B. and Sherritt, G. W. 1977. Nursing order, social dominance and growth in swine. J. Anim. Sci. 45:219-229.

Sherritt, G. W., Graves, H. B., Gobblee, J. L. and Hazlett, V. E. 1974. Effects of mixing pigs during the growing and finishing period. J. Anim. Sci. 39:834-837.

Shields, R. G. Jr., Ekstrom, K. E. and Mahan, D. C. 1980. Effects of weaning age and feeding method on digestive enzyme developement in swine from birth to ten weeks. J. Anim. Sci. 50: 257-265.

Signoret, J. P., Baldwin, B. A., Frazer, D. and Hafez, E. S. E. 1975. The behaviour of swine. *IN* The Behaviour of Domestic Animals. 3rd ed. *Editied by* E. S. E. Hafez. Williams and Wilkins Co., Baltimore, USA.

Smith, H. and Lucas, I. A. M. 1956. The effect upon growth of variations in protein, fat, sucrose, antibiotic, vitamin and mineral contents of diets for pigs of 8-25 lbs. liveweight and a comparison of wet and dry feeding. J. Anim. Sci. 48:220-235.

Steele, R. G. D. and Torrie, J. H. 1980. Principles and

Proceedings of Statistics. McGraw-Hill Book Co. Inc., New York.

Tanksley, T. D., Walch, G. L. Jr., Purser, K. W., Real, C. E. and Gregg, E. J. 1978. Effect of starter diet on pig performance from weanling to market. J. Anim. Sci. 47:275 (Abst.).

Tennesen, T. 1983. An ethological investigation into the husbandry of bulls. Ph. D. Thesis. The University of Alberta. Edmonton, Canada.

Thomlinson, J. R. 1969. Post-weaning enteritis and dysentery. Vet. Rec. 85:298-300.

Wahlstrom, R. C., Hauser, L. A. and Libal, G. W. 1974. Effects of low lactose whey, skim milk and sugar on diet palatability and performance of early weaned pigs. J. Anim. Sci. 38:1267-1271.

Whitelaw, A. W. W., Elsley, F. W. H., Jones, A. S. and Boyne, A. W. 1966. The effect of protein level in creep feed on the growth rate and body composition of suckling pigs. J. Agric. Sci. 66:203-209.

Young, L. G. and Jamieson, J. D. 1970. Protein and copper supplementation of corn-soybean meal diets for young pigs. Can. J. Anim. Sci. 50:727-733.

Appendix Table 1. Sources of Variation for Experiment 1.

Source of Variation	Degrees of Freedom
Block	1
Diet	1
Block x diet	1
Sow/block x diet	22
Movement	1
Movement x block	1
Movement x diet	1
Error	23

Block, Diet, Block x diet are all tested against Sow/block x diet.

Appendix Table 2. Sources of Variation for Experiment 2.

Source of Variation	Degrees of Freedom
Sow	9
Stocking density	2
Sow x density	18
Pen/sow/density	5
Week	3
Week x sow	27
Week x density	6
Error	69

Sow x density and Pen/sow x density were pooled to form the error term for sow and stocking density.

Appendix Table 3. Summary of the Analysis of Variance of the Behaviour Categories for Stocking Density, Days and Stocking Density by Days Interaction.

Behaviour Category	Factor	DF	F	P
Lying	Stocking density	2	1.015	0.405
	Day	8	1.597	0.165
	Stocking density x day	16	0.996	0.472
Active	Stocking density	2	2.524	0.141
	Day	8	4.727	0.001
	Stocking density x day	16	1.922	0.034
Sitting	Stocking density	2	5.141	0.037
	Day	8	2.694	0.022
	Stocking density x day	16	2.725	0.002
Feeding	Stocking density	2	6.455	0.021
	Day	8	12.044	0.001
	Stocking density x day	16	0.639	0.840
Drinking	Stocking density	2	2.582	0.136
	Day	8	1.138	0.365
	Stocking density x day	16	1.220	0.278
Aggression	Stocking density	1	5.698	0.075
	Day	8	1.496	0.198
	Stocking density x day	8	2.078	0.068