INFLUENCE OF ENVIRONMENTAL ENRICHMENT ON AGGRESSIVE BEHAVIOUR AND DOMINANCE RELATIONSHIPS IN GROWING PIGS

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Abstract *Animal Welfare 1999, **8:** 269-279*

This study examined the effects of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. Three hundred and twenty pigs were reared from birth to 15 weeks of age in either barren or enriched environments. The barren environments were defined by common intensive housing conditions (ie with slatted floors and in terms of recommended space allowances), while the enriched environments incorporated extra space and substrates for manipulation. Aggressive behaviour was observed in a social confrontation test during the suckling period and dominance relationships were assessed from a food competition test at 12 weeks of age. Animals were weighed at regular intervals throughout the experiment. Environmental enrichment reduced the expression of aggressive behaviour. Pigs from enriched rearing environments fought significantly less with unfamiliar animals than those from barren environments when tested under standard conditions (mean of 1.46 vs 2.75 fights per 30min test for enriched vs barren environments; SEM 0.20, $P < 0.001$). The nature of dominance relationships also appeared to differ between barren and enriched environments. In barren environments, dominance among pen mates was correlated with aggression ($r = 0.33$, $P < 0.01$), whereas in enriched environments it was correlated with body weight ($r = 0.24$, $P < 0.01$). Correlations between behaviour in the social confrontation and food competition tests suggested that dominance characteristics were established early in life and remained stable through the growing period.

Keywords: *aggression, animal welfare, behaviour, dominance, environmental enrichment, pigs*

Introduction

In most commercial operations, unfamiliar pigs are mixed together at least once during the production cycle to create groups of pigs which are balanced in weight. This mixing of unfamiliar animals leads to aggressive behaviour which is a common problem in intensive pig production. In addition to causing injury (Gonyou *et al* 1988) and elevated plasma cortisol levels (Moore *et al* 1994), mixing unfamiliar animals also has a negative effect on productivity (Tan *et al* 1991; Stookey & Gonyou 1994). Fighting between newly mixed pigs can be reduced through altering their physical environment by providing barriers (McGlone

& Curtis 1985; Barnett *et al* 1992) or toys (Schaefer *et al* 1990). However, aggressive behaviour is also influenced by individual characteristics and animals differ in its expression (Benus *et al* 1987; Hessing *et al* 1993).

The fighting which occurs at mixing is normally associated with the establishment of dominance relationships (Meese & Ewbank 1973; McGlone *et al* 1987). Among littermates, these relationships are largely learned at an early age through mock fighting bouts and social play (Craig 1986). One of the benefits of dominance relationships is that they ensure a recognized order of priority to resources and, therefore, reduce competitive aggression (Richards 1974). Relative positions in this order of priority are influenced by factors such as age (Hunter *et al* 1988), gender (Vargas *et al* 1987) and body weight (McBride *et al* 1965; Beilharz & Cox 1967; Scheel *et al* 1977).

Several studies have shown that enrichment with substrates or toys reduces aggression among pigs by increasing the time spent in exploratory behaviour (Schaefer *et al* 1990; Beattie *et al* 1995a, b). However, pigs from enriched environments are also less aggressive than pigs from barren environments in the absence of enriching stimuli (Beattie *et al* 1993; de Jonge *et al* 1996). This suggests that rather than just acting as a diversion, the presence of environmental enrichment during rearing affects how pigs perceive and react to social situations. The objective of the present study was to determine whether enrichment of the environment directly affects the social behaviour of pigs by examining: i) aggressive behaviour in a test box; and ii) social dominance in the home pen.

Methods

Design

The effect of rearing in different environments (barren and enriched) was examined in a two-treatment design with five replicates. The pigs were studied over a 15-week period which was divided into two stages: stage 1, 0–7 weeks of age; and stage 2, 8–15 weeks of age. The end of stage 1 was accompanied by a change of housing environment. The pigs were weighed at birth, 4, 7 and 15 weeks of age and exposed to four social confrontation tests and three food competition tests.

Animals

Three hundred and twenty pigs were used in this study, equal numbers being allocated to barren and enriched rearing environments. Each of the five replicates was composed of the litters of eight Large White x Landrace sows (not always mated to the same boar) which farrowed in crates at approximately the same time. At 3 days post partum, four dams were selected at random and their litters transferred to enriched housing (pens with straw bedding and no constraints on the dams' movement). The remaining four dams and their litters stayed in farrowing crates until weaning at 4 weeks. In both environments, four boars and four gilts were chosen from each litter at weaning according to least variation from the average weight of the litter group. The selected boars and gilts from the four litters in the enriched housing were completely mixed and regrouped in groups of eight. These groups were made up of one boar and one gilt from each of the four litters. A similar process was performed on the pigs in barren accommodation. These groups of eight pigs remained together for the duration of the study.

Housing

Stage 1

In the first stage of life, piglets were housed either in a farrowing pen (barren environment) or a straw-bedded pen (enriched environment). The farrowing pen measured 2.6x1.6 m and had a floor made of plastic slats. The enriched pen measured 3.6x2.2 m and had a solid floor which was bedded with unchopped straw. The dams were present in both environments for the first 4 weeks. After weaning, the piglets remained in their respective environments until the end of stage 1 at 7 weeks of age.

Stage 2

The barren environment at stage 2 (8–15 weeks) consisted of flat deck cages, 2.4x1.2 m, with expanded metal floors. The enriched environment measured 3.1x4.5 m and was divided into five areas: a rooting area, straw area, sleeping area, feeding area and defecating area. The space allowance was $0.36m^2\ pig^{-1}$ in the barren pens and $1.75m^2\ pig^{-1}$ in the enriched pens.

A detailed description of the housing at stages 1 and 2 is given by Beattie *et al* (1995a).

Husbandry schedules

At all stages, both environments experienced a day/night cycle, with full lighting between 0800h and 1700h, and dimmed lighting for the remainder of the time. In the barren farrowing accommodation the environmental temperature was maintained at approximately 18°C, while the average temperature of the enriched farrowing environment was 15°C. Localized supplementary heating was supplied by heat lamps over the creeps[1] in both environments. Ambient temperature outside the sleeping kennels in stage 2 of the enriched environments ranged between 10°C and 22°C. Temperature was controlled in the stage 2 barren environments at 21°C.

Lactating sows were fed to appetite. From 10 days of age, a highly digestible feed was provided for the piglets in both environments. Water was available from birth for the piglets, via water nipples, in both environments. In stage 2 in both environments, feed was offered *ad libitum* in single-space wet and dry feeders (Verba Wet Feeder, L Verbakel BV, Sint-Oedenrode, The Netherlands). These allowed only one animal to feed at any time, supplying food and water on an operant basis. In enriched stage 2 housing, peat and straw were replenished as necessary.

Diet

Sows in both environments were offered on average $6.5kg\ day^{-1}$ of a cereal/soya-based diet during lactation. This was manufactured at the Agricultural Research Institute of Northern Ireland and supplied 13.4MJ digestible energy (DE) kg^{-1} diet in pelleted form. Piglets up to 7 weeks old were offered commercial creep feed (Milkiwean, SCA, Dublin, Eire) and stage 1 feed (Thrift, SCA, Dublin, Eire). Pigs at stage 2 were fed *ad libitum* on pelleted cereal/soya-based diets (manufactured at the Agricultural Research Institute of Northern Ireland) containing 14.2MJ DE kg^{-1} and 22 per cent crude protein.

[1] Areas of the pen sectioned off to allow access to the piglets but not to the sow.

Behavioural tests

Social confrontation test

During the suckling period (1–4 weeks of age) all pigs were subjected to social confrontation tests over 4 consecutive weeks. When 1 week old, three piglets (sometimes two) from one litter were placed in a wooden test box (1.6x1.6x0.78 m) together with three piglets (or two) from another litter. Individual pigs were identified by a number sprayed onto their backs. This social confrontation test lasted for 30min and was recorded in real time via a camera placed overhead. The test was repeated when the pigs were 2, 3 and 4 weeks old. The frequency of occurrence of each of the behaviours listed in Table 1 was recorded.

Table 1 Ethogram of behaviours recorded from the social confrontation test for each subject animal.

Behaviour	Description
Sniff	Sniffing any part of another pig, ie any contact of the subject's nose with any part of another pig.
Threat	Facing or being in head to head contact with another pig and the other pig actively withdrawing.
Headthrust	Ramming or pushing another pig with the subject's head in an event that is not recorded as part of a fight.
Bite	Forceful nosing or chewing of any part of a pen mate.
Fight	Pushing parallel or perpendicular to, ramming or pushing of an opponent with the head in rapid succession, with or without biting. Lifting an opponent by pushing the snout under its body. (Individual behaviours within a fight were not recorded.)
Chase	Actively following another pig.
Flee	Running away from another pig.
Withdraw	Following head to head contact with another pig, the subject actively moves away.
Initiate fight	Whether the subject was the initiator of the fight or its passive recipient.

Food competition test

At 12 weeks of age, each group of pigs was subjected to a food competition test in the home pen on 3 consecutive days. The feeders were turned off for 18h before each test.

When the feeders were turned on, the pigs were observed for 15min. As it was only possible for one pig to eat from the feeder at a given time and as individual pigs were identified by a number sprayed onto their backs, an observer recorded which pig was using the feeder, the duration it remained using the feeder and the pig which displaced it. Once a pig was displaced from the feeder, the number of fights it engaged in was recorded continuously until a subsequent animal was displaced. Recordings were made by direct observation using a hand-held data recorder (Microscribe; Modµlec Technology Ltd, Gwent, UK).

Data from the three tests were combined and the total time spent at the feeder, the mean time per bout at the feeder and the total frequency of fighting after displacement from the feeder were calculated. Measurements of the last two parameters could not be made for all animals as a small number of them did not use the feeder during the observation period. Individual pigs were also assigned a dominance score based on the number of times they displaced a pen mate from the feeder (Table 2). Dominance scores ranged from 1 (highest) to 8 (lowest), ie the more often a pig displaced a pen mate from the feeder the lower the score it was assigned. If two or more pigs displaced the same number of pen mates then their

Table 2 **Example of dominance scores of individual pigs based on the number of pen mates displaced during the food competition test.**

Pig number	Number of pen mates displaced	Dominance score
1	7	1.5
2	4	4.0
3	7	1.5
4	2	5.0
5	1	6.0
6	0	7.5
7	0	7.5
8	6	3.0

dominance scores were averaged. An example of the methodology used is given in Table 2. The mean dominance score from all three days of tests was calculated.

Body weight

The weight of each animal was recorded at birth, weaning (4 weeks) and the end of stages 1 and 2 (7 and 15 weeks, respectively).

Statistical analysis

The data were analysed using Genstat, version 5 (Lawes Agricultural Trust 1989). An analysis of variance (ANOVA) was carried out to examine the effects of rearing environment on behaviour and body weight[2]. Pearson's product-moment correlations (Swinscow 1996) were calculated between different behavioural tests, between different behaviours within a test and between behaviour and body weight. In the social confrontation test, inter-test correlations were calculated using the mean frequency of fighting from all four tests. As fighting following displacement from the feeder in the food competition test was observed for unequal time periods between pigs, the average frequency of fighting during the first 30s of this period was used to compare means and to calculate correlations. This time period was chosen as it was estimated that, on average, there was at least a 30s gap between displacement of successive pigs from the feeder. The level of statistical significance for all tests was set at $P < 0.05$.

Results

Social confrontation test

Table 3 shows that piglets from barren environments showed more aggressive behaviour than those from enriched environments and that this difference became more evident over time. In the first test in their first week of life, piglets from barren environments sniffed conspecifics more than those from enriched environments ($P < 0.001$). In the second test at 2 weeks of age the greater amount of sniffing among piglets from barren environments ($P < 0.01$) was accompanied by greater numbers of headthrusts ($P < 0.05$). In the third test at 3 weeks of age piglets from barren environments showed greater amounts of sniffing, headthrusting and biting than piglets from enriched environments (all $P < 0.001$). This was also the case in the fourth test where, in addition, pigs from barren environments also fought significantly more than their enriched counterparts ($P < 0.001$).

[2] A single SEM was calculated as the ANOVA assumed equal variability within treatments since there were equal numbers of observations per treatment.

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Table 3 **Mean incidence (and SEMs[2]) of behaviours during a 30-min social confrontation test by pigs from barren and enriched environments in weeks 1–4. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; ns - not significant.**

Behaviour	Environment		SEM	*P*
	Enriched	Barren		
Week 1				
Sniff	10.11	17.95	1.21	***
Headthrust	1.08	0.64	0.37	ns
Bite	3.3	4.8	0.62	ns
Fight	0.25	0.09	0.06	ns
Week 2				
Sniff	11.47	19.01	1.50	**
Headthrust	0.69	1.07	0.12	*
Bite	4.69	5.76	0.46	ns
Fight	0.396	0.427	0.08	ns
Week 3				
Sniff	10.16	21.56	1.05	***
Headthrust	1.1	4.88	0.65	***
Bite	6.98	16.35	1.55	***
Fight	1.06	1.59	0.22	ns
Week 4				
Sniff	13.35	19.79	0.88	***
Headthrust	0.74	4.46	0.65	***
Bite	5.79	13.94	1.05	***
Fight	1.46	2.75	0.20	***

Food competition test

In the barren environments, pigs which fought more frequently after displacement from the feeder spent a greater total time at the feeder ($r = 0.33$, $P < 0.01$), had longer average bouts at the feeder ($r = 0.18$, $P < 0.05$) and lower dominance scores ($r = -0.27$, $P < 0.01$). In enriched environments, the frequency of fighting after displacement from the feeder was not significantly correlated with the total time spent at the feeder, the mean time per bout at the feeder or with the mean dominance score.

There were no significant effects of rearing environment on the total time spent at the feeder, the mean time per bout at the feeder or the mean dominance score (Table 4). Similarly, the mean frequency of fights after displacement from the feeder did not differ significantly between the two environments (0.19 vs 0.11 fights per 30s test for barren vs enriched; SEM 0.04).

Table 4 **Duration/frequency of behaviours or dominance scores (and SEMs[2]) during a 15-min food competition test of pigs from barren and enriched rearing environments at 12 weeks of age. ns - not significant.**

Behaviour	Environment		SEM	*P*
	Enriched	Barren		
Total time at feeder (s)	342.3	346.4	30.63	ns
Time per bout at feeder (s)	96.15	88.18	10.14	ns
Total number of displacements	9.83	10.19	1.60	ns
Total dominance score	4.33	4.17	0.24	ns
Mean dominance score	4.32	4.16	0.19	ns

Body weight

There were no significant treatment effects on body weight throughout the trial. The average body weight of pigs from both barren and enriched rearing environments was 1.7kg at birth; 8.5kg at 4 weeks; 17.0kg at 7 weeks and 57.3kg at 15 weeks.

Correlations

Inter-test

In barren environments, the frequency of fighting in the social confrontation test was positively correlated with the total time spent at the feeder ($r = 0.18$, $P < 0.05$) and negatively correlated with the dominance score ($r = -0.23$, $P < 0.005$) during the food competition test. The frequency of fighting in the social confrontation test for pigs from enriched environments was positively correlated with their dominance score during the food competition test ($r = 0.15$, $P < 0.05$) but not significantly correlated with the time (both total time and time per bout) that they spent at the feeder. Fighting in the food competition test was not significantly correlated with fighting in the social confrontation test for pigs from either barren or enriched environments.

Behaviour and body weight

In enriched environments, the body weight of pigs at 4, 7 and 15 weeks of age was positively correlated with the total time spent at the feeder and the mean time per bout at the feeder, and negatively correlated with dominance scores during the food competition test (see Table 5). No significant correlation was found between the behaviour of pigs from barren environments during the food competition tests and their body weight.

Table 5 **Pearson's correlation coefficients between the behaviour of pigs from enriched environments in a food competition test at 12 weeks and their body weights at 4, 7 and 15 weeks of age. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.**

Parameter (no)	(1)	(2)	(3)	(4)	(5)	(6)
(1) Total time at feeder (s)	-					
(2) Mean time per bout at feeder (s)	0.82***	-				
(3) Mean dominance score	-0.60***	-0.29***	-			
(4) 4-week weight (kg)	0.29***	0.21**	-0.21**	-		
(5) 7-week weight (kg)	0.22**	0.20*	-0.22**	0.72***	-	
(6) 15-week weight (kg)	0.24**	0.25**	-0.23**	0.52***	0.80***	-

Discussion

Earlier work found that enriching the rearing environment of pigs with substrates such as peat and straw reduced aggression among pen mates (Beattie *et al* 1995a, b). This was attributed to the fact that enrichment increases the time spent exploring substrates and consequently reduces the amount of behaviour directed towards pen mates. This study examined whether environmental enrichment also plays a direct role in shaping the social behaviour of pigs by examining its influence on aggressive behaviour in a test box and social dominance in the home pen.

Environmental enrichment significantly reduced the amount of aggressive behaviour between unfamiliar animals in the test box. This treatment effect was apparent as early as the second week of life and became stronger over the following 2 weeks. The strengthening of a

behavioural effect has also been seen in chickens (Jones 1995). Work with handled and non-handled chicks revealed differences between the two groups in their behavioural responses to humans. These differences are first apparent at an early age and become progressively stronger as the chicks mature (Jones 1995).

Previous research found that aggression among pigs was reduced in enriched environments due to a reduction in overall social behaviour, as more time was devoted to exploring substrates (Beattie *et al* 1993; 1995a, b). However, this study and others (Beattie *et al* 1993; de Jonge *et al* 1996) show that pigs from enriched rearing environments are also less aggressive than those from barren environments in the absence of enriching stimuli. Therefore, in addition to diverting attention from pen mates to substrates, it appears that environmental enrichment also reduces the expression of aggressive behaviour. This finding is supported by work which shows that temperamental characteristics such as fearfulness (Pearce *et al* 1989; Jones & Waddington 1992) and learning ability (Warren *et al* 1982) are also affected by environmental enrichment.

It is possible that pigs from barren environments were more aggressive during the social confrontation test because they were more stressed: Dantzer *et al* (1980) have shown that stress can lead to aggression in pigs. This agrees with earlier work which found that animals reared in barren environments were more fearful during challenging situations than those reared in enriched environments (Pearce *et al* 1989; Jones & Waddington 1992). In addition to the influence of enrichment, differences in space allowance between treatments may also have affected behaviour during the social confrontation tests. Although it was impossible to distinguish the relative importance of space and enrichment in the present study, an earlier study by Pearce and Paterson (1993) found that environmental enrichment during rearing had a greater influence than space allowance on the behaviour of pigs during stressful situations.

The aggression which occurs when unfamiliar animals are newly mixed is largely due to the formation of dominance hierarchies (Meese & Ewbank 1973; McGlone *et al* 1987). The results of our study show that this process involves significantly more aggression when animals are reared under barren, rather than enriched, conditions. Although social dominance was only assessed over short observation periods and, therefore, could not be reliably calculated, the results suggest that rearing conditions affected the nature of dominance relationships between pen mates. In enriched environments dominance was related to body weight, which is in agreement with the results of previous studies on growing pigs (Beilharz & Cox 1967; Scheel *et al* 1977). In barren environments, however, dominance was not related to weight but was positively correlated with the frequency of fighting following displacement.

Research with rhesus monkeys, *Macaca mulatta,* shows that dominance relationships within stable groups of animals are formed through a number of learning processes such as social play (Rowell 1974). It is possible that in the present study the small space allowances in barren environments restricted play behaviour and affected how dominance relationships were learned. De Jonge *et al* (1996) suggested that semi-natural rearing environments, with large space allowances and social contact between neighbouring litters, facilitated play behaviour and, therefore, the social development of pigs. Under intensive conditions where play was restricted, they found that pigs developed poor social skills which led to greater amounts of aggression within dominance relationships. It is not clear from their study whether social or physical factors were more important in encouraging play and social skill development in semi-natural environments.

In barren environments, pigs which were more aggressive towards unfamiliar animals also ranked higher in dominance relationships among their pen mates, whereas the opposite was true in enriched environments. This provides further evidence that, under intensive housing conditions, there is a relationship between dominance and aggression which is not shown when enrichment is provided. It is possible that the pigs in barren environments did not learn to associate dominance with weight during early play behaviour and, therefore, that dominance had to be asserted through aggression. Richards (1974) also noted that the nature of dominance relationships differed within a given species depending on environmental conditions, and warned against making generalizations between observations made in different environments.

The fact that the pigs showed consistency in behaviour between the social confrontation test and food competition test suggests that dominance characteristics are relatively stable within individuals. This corresponds with previous work with rhesus monkeys which found a similar stability in dominance characteristics using a variety of tests including competitive and confrontational ones (Richards 1974). The present results also show that these characteristics are established relatively early in life in the pre-weaning period. This agrees with the findings of Scheel *et al* (1977), demonstrating that social relationships formed by pigs during the suckling period form the basis of future dominance relationships.

Animal welfare implications

Enrichment was previously shown to improve the welfare of group-housed pigs by providing an outlet for rooting and foraging and subsequently reducing the amount of behaviour directed towards pen mates (Beattie *et al* 1995a). The present results show that rearing environments enriched with substrates and extra space also improve welfare by directly affecting the social behaviour of pigs. Enrichment significantly reduced aggressive behaviour in a test box and this effect may be extrapolated to any situation where unfamiliar pigs are mixed in confined spaces. Enrichment also appeared to facilitate the development of social skills which resulted in body weight, rather than aggression, determining dominance. This would appear to be more beneficial – both from an evolutionary and welfare perspective – as aggressive interactions are energy-consuming and often lead to stress or injury. However, more extensive assessments of social dominance are needed before any conclusive evidence can be provided on the influence of environmental enrichment. Future research should also examine the relative importance of enriching agents and space allowance on the social behaviour of pigs.

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References

Barnett J L, Hemsworth P H, Cronin G M, Newman E A, McCallum T H and Chilton D 1992 Effects of pen size, partial stalls and method of feeding on welfare-related behavioural and physiological responses of group-housed pigs. *Applied Animal Behaviour Science 34*: 207-220

Beattie V E, Sneddon I A and Walker N 1993 Behaviour and productivity of the domestic pig in barren and enriched environments. *Livestock Environment IV. Proceedings of the Fourth International Symposium of the American Society of Agricultural Engineers* pp 43-50. American Society of Agricultural Engineers: St Joseph, Michigan, USA

Beattie V E, Walker N and Sneddon I A 1995a Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare 4*: 207-220

Beattie V E, Walker N and Sneddon I A 1995b Effect of rearing environment and change of environment on the behaviour of gilts. *Applied Animal Behaviour Science 46*: 57-65

Beilharz R G and Cox D F 1967 Social dominance in swine. *Animal Behaviour 15*: 117-122

Benus R F, Koolhaas J M and Van Oortmerssen G A 1987 Individual differences in behavioural reaction to a changing environment in mice and rats. *Behaviour 100*: 105-122

Craig J V 1986 Measuring social behavior: social dominance. *Journal of Animal Science 62*: 1120-1129

Dantzer R, Arnone M and Mormede P 1980 Effects of frustration on behaviour and plasma corticosteroid levels in pigs. *Physiology & Behavior 24*: 1-4

de Jonge F H, Bokkers E A M, Schouten W P G and Helmond F A 1996 Rearing piglets in a poor environment: developmental aspects of social stress in pigs. *Physiology & Behavior 60*: 389-396

Gonyou H W, Rohde Parfet K A, Anderson D B and Olson R D 1988 Effects of amperozide and azaperone on aggression and productivity of growing-finishing pigs. *Journal of Animal Science 66*: 2856-2864

Hessing M J C, Hagelso A M, Van Beek J A M, Wiepkema P R, Schouten W P G and Krukow R 1993 Individual behavioural characteristics in pigs. *Applied Animal Behaviour Science 37*: 285-295

Hunter E J, Broom D M, Edwards S A and Sibly R M 1988 Social hierarchy and feeder access in a group of 20 sows using a computer-controlled feeder. *Animal Production 47*: 139-148

Jones R B 1995 Ontogeny of response to humans in handled and non-handled female domestic chicks. *Applied Animal Behaviour Science 42* : 261-269

Jones R B and Waddington D 1992 Modification of fear in domestic chicks, *Gallus gallus domesticus*, via regular handling and early environmental enrichment. *Animal Behaviour 43*: 1021-1033

Lawes Agicultural Trust 1989 *Genstat 5 Reference Manual*. Clarendon Press: Oxford, UK

McBride G, James J W and Wyeth G S F 1965 Social behaviour of domestic animals VII. Variation in weaning weight in pigs. *Animal Production 7*: 67-74

McGlone J J and Curtis S E 1985 Behavior and performance of weanling pigs in pens equipped with hide areas. *Journal of Animal Science 60*: 20-24

McGlone J J, Stansbury W F and Tribble L F 1987 Effects of heat and social stressors and within-pen weight variation on young pig performance and agonistic behavior. *Journal of Animal Science 65*: 456-462

Meese G B and Ewbank R 1973 The establishment and nature of the dominance hierarchy in the domesticated pig. *Animal Behaviour 21*: 326-334

Moore A S, Gonyou H W, Stookey J M and McLaren D G 1994 Effect of group composition and pen size on behavior, productivity and immune response of growing pigs. *Applied Animal Behaviour Science 40* : 13-30

Pearce G P and Paterson A M 1993 The effect of space restriction and provision of toys during rearing on the behaviour, productivity and physiology of male pigs. *Applied Animal Behaviour Science 36*: 11-28

Pearce G P, Paterson A M and Pearce A N 1989 The influence of pleasant and unpleasant handling and the provision of toys on the growth and behaviour of male pigs. *Applied Animal Behaviour Science 23*: 27-37

Richards S M 1974 The concept of dominance and methods of assessment. *Animal Behaviour 22*: 914-930

Rowell T E 1974 The concept of social dominance. *Behavioral Biology 11*: 131-154

Schaefer A L, Salomons M O, Tong A K W, Sather A P and Lepage P 1990 The effect of environment enrichment on aggression in newly weaned pigs. *Applied Animal Behaviour Science 27*: 41-52

Scheel D E, Graves H B and Sherritt G W 1977 Nursing order, social dominance and growth in swine. *Journal of Animal Science 45*: 219-229

Stookey J M and Gonyou H W 1994 The effects of regrouping on behavioral and production parameters in finishing swine. *Journal of Animal Science 72*: 2804-2811

Swinscow T D V 1996 *Statistics at Square One, 9th edition*, BMJ Publishing Group: London, UK

Tan S S L, Shackleton D M and Beames R M 1991 The effect of mixing unfamiliar individuals on the growth and production of finishing pigs. *Animal Production 52*: 201-206

Vargas J V, Craig J V and Hines R H 1987 Effects of feeding systems on social and feeding behavior and performance of finishing pigs. *Journal of Animal Science 65*: 463-474

Warren J M, Zerweck C and Anthony A 1982 Effects of environmental enrichment on old mice. *Developmental Psychobiology 15*: 13-18

https://doi.org/10.1017/S0962728600021758 Published online by Cambridge University Press