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Behavioural responses affecting gilt and sow reproduction

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Summary. Behavioural responses can have direct effects on reproduction when the performance of the behaviour contributes to productivity (e.g. achievement of copulation). Alternatively, there are indirect effects where a behavioural change is insufficient to allow adaptation to an environmental change and so the animal has to resort to physiological mechanisms with potential adverse effects on productivity.

Boar contact has substantial effects on a number of female behaviours that can directly affect her productivity. Either daily introduction to a boar or continuous housing adjacent to boars is effective in stimulating the onset of oestrus in weaned sows. In addition, daily boar contact is necessary to maintain ovarian activity in post-pubertal gilts. The efficiency of the back-pressure test (BPT) in detecting sexually receptive females depends on females receiving intense and close boar contact at the time of testing. However, there are situations in which continuous stimulation from boars may adversely affect sexual behaviour; continuous housing of gilts adjacent to boars, with a wire-mesh division separating them, reduces the efficiency of detection of oestrus by means of the BPT or a boar. There is some evidence to indicate that housing weaned sows adjacent to boars may adversely affect the duration of oestrus but not detection rate of oestrus.

The effects of female contact on productivity are generally indirect with physiological responses (rather than behavioural responses) to suboptimal group size, space allowance or housing system predominantly responsible for any adverse effects on reproduction. The literature on the effects of individual or group housing on reproduction is equivocal, but there is a trend for a reduced conception rate or pregnancy rate in individual housing. Group size and space allowance may affect the efficiency of detection of oestrus. A space allowance of 1 m^2/animal appears to affect detection of oestrus adversely for gilts, probably via a chronic stress response associated with overcrowding. The literature on the effects of group size on sexual behaviour of female pigs is also equivocal, perhaps because in some studies there were suboptimal space allowances. Nevertheless, there appear to be problems with detection of oestrus in very small groups and in large groups.

The effects of human contact on female reproduction are indirect. There are no direct effects on the sexual behaviour of female pigs and the effects on reproduction are probably mediated by a chronic stress response. High levels of fear of humans may depress the reproductive performance of pigs and this fear response is probably affected by the behaviour of the stockperson.

The present knowledge of behavioural responses affecting reproduction of the female pig can be utilized to manipulate both the environment and management procedures to facilitate higher productivity. However, it is obvious that further research is required to improve the limited knowledge in this area.

Keywords: behaviour; oestrus; conception rate; litter size; gilts; sows

Introduction

There are two obvious ways in which behaviour can affect productivity of commercial pigs. Firstly, by direct effects whereby the performance of the behaviour contributes to productivity of the pig (e.g. achievement of copulation) and so changes in the level of the behaviour may result in changes in productivity. Secondly, by indirect effects in which behavioural change to an environmental change occurs, but is insufficient to allow adaptation and so the animal also has to resort (in addition to behavioural change) to physiological mechanisms with potential adverse effects on productivity.

In discussing direct effects, the following behavioural components of female reproduction will be considered; the onset of oestrus, detection of oestrus and sexual receptivity. In this paper oestrus will refer to the behavioural and physiological events surrounding ovulation and detection of oestrus will refer to the detection of females around this time. Sexual receptivity refers to the female's responses necessary and sufficient for success in achieving copulation (Beach, 1976). Sexual receptivity and detection of oestrus will be considered under one heading since receptivity is generally the criterion used in the main procedures of detection of oestrus (i.e. use of boars and the back-pressure test). Changes in the onset of oestrus, detection of oestrus or sexual receptivity can have marked effects on reproductive efficiency. For example, the failure to attain oestrus will delay the onset of breeding activity. Similarly, changes in the efficiency of oestrus detection or in sexual receptivity can affect the chances of being mated during oestrus or the number of matings during oestrus, which in turn may affect both conception rate and litter size.

Intensification of animal production has involved increased control over the animal, to which pigs show a remarkable degree of adaptation. An environmental change (e.g. overcrowding or presence of a fear-producing stimulus) can initiate significant coping/adaptive responses by the animal which include behavioural and physiological changes. Productivity can be affected in situations in which behavioural change by the animal is insufficient and the animal has to resort to physiological coping mechanisms (i.e. a chronic stress response). Productivity may also be affected in situations in which concurrent short-term behavioural and physiological responses occur (i.e. acute responses) at critical times in the reproductive cycle (e.g. around ovulation). At the outset, it is worthwhile to distinguish between the short- and long-term responses of the animal to environmental change, and how these responses may affect reproduction.

Short- and long-term responses

McBride (1980) considers at least two levels of adaptation in response to changed environmental conditions. The first substantially involves behavioural responses (e.g. fight or flight in response to another animal or exploration in response to a new environment). This first level of response may also initiate physiological change (e.g. increases in adrenalin and corticosteroids) and these changes are generally short term (seconds, minutes or hours). The second level of response, although involving behavioural changes, substantially involves physiological mechanisms. Part of these mechanisms is the chronic stress response which was described by Selye (1946) within the framework of the General Adaptation Syndrome. The long-term (days, months or longer) consequences of a chronic stress response on the nervous, lymphatic, circulatory and hormonal systems are well documented, as are the subsequent consequences of hormonal change, particularly corticosteroids, on nitrogen metabolism and growth rate of young animals and reproductive performance of older animals (Selye, 1976).

While there is no doubt that various components of reproduction can be affected by stress responses (see Moberg, 1985) there are two important concepts to consider. The first is that not all stressors are harmful to production. For example, a short-term elevation of corticosteroid concentrations is a normal feature of mating, parturition and lactation (Selye, 1976); acute stress also appears to advance the onset of puberty in gilts (Hughes, 1982). The second concept is the continuum between acute and chronic stress responses, even though they tend to be described (for convenience) as distinct phenomena. For example, the event of lactation requires elevated corticosteroids for its initiation and for milk let-down (i.e. beneficial to reproduction) but a chronic stress response (i.e. a sustained elevation of corticosteroids) can decrease milk output (Selye, 1976).

The adverse effects of stress on reproduction in farm and laboratory animals are well documented, particularly for females (for reviews see Ramaley, 1981; Moberg, 1985). For example, puberty in mice can be delayed by heat, restraint or ether with a concomitant change in the diurnal rhythm of peripheral corticosterone concentrations (Paris & Ramaley, 1974). In cattle high temperatures and high humidity can result in poor expression of oestrus and, if conditions are severe enough, in anoestrus (see Moberg, 1985). In the pig similar adverse effects of stress on reproduction have been demonstrated. Liptrap (1970) has shown that multiple administrations of ACTH or corticosteroids can delay the onset, and shorten the duration of, oestrus. Acute treatment only affected the duration of oestrus. Esbenshade & Day (1980) have shown that multiple administration of corticosteroids can inhibit the expression of oestrus.

This paper therefore considers the main factors that can affect reproduction directly or indirectly through changes in the behaviour of the female pig. The major factors affecting female behaviour are social and physical and this paper will concentrate on these. Together with other factors, such as climate, season and nutrition, these have been considered in a number of reviews (for example, Hughes, 1982; Hemsworth, 1982, 1985; Fraser, 1983/84) and readers are referred to these.

Boar contact

Onset of oestrus

It is well established that the introduction of a mature boar to immature gilts induces the precocious attainment of puberty (Brooks & Cole, 1970; Hughes & Cole, 1976, 1978). The male effect on puberty in the gilt is reviewed by Hughes *et al.* (1990) and will not be considered in this article.

It has been shown that daily introduction of weaned sows to a boar in his pen is associated with an earlier onset of oestrus after weaning: sows introduced to a boar in his pen for several minutes had a shorter weaning-to-mating interval than did sows housed near but not adjacent to boars (Hemsworth *et al.*, 1982a). In contrast, penning a boar in an area adjacent to weaned sows for 10 min/day had little effect on the weaning-to-mating interval (Hemsworth *et al.*, 1982a). Walton (1986) found that continuous housing of sows adjacent to boars resulted in an earlier oestrus after weaning than did housing sows in isolation from boars. Dyck (1988) reported a weaning-to-mating interval for sows housed adjacent to boars similar to that of sows that were considered to be 'isolated' from boars. However, the isolated sows received boar introduction for 5 min daily (during detection of oestrus) and thus this so-called isolated treatment was probably similar to the boar introduction treatment in the study by Hemsworth *et al.* (1982a). In contrast, in a survey of Norwegian herds, Karlberg (1980) reported that the presence of a boar had little effect on the weaning-to-mating interval, although proximity to boars (i.e. amount and type of boar contact) was not considered. Therefore, either brief boar exposure, involving introduction to a boar rather than fence-line contact, or continuous housing adjacent to boars is effective in stimulating oestrus in the weaned sow. The practice of isolating sows from boars for several days after weaning until detection of oestrus commences is likely to delay the onset of oestrus. The boar stimuli or the mechanism(s) involved in this effect are unknown, but they may be similar to those involved in puberty stimulation.

Maintaining ovarian activity

In addition to stimulating oestrus, it appears that boar contact is important in maintaining oestrous activity. Paterson & Lindsay (1981) observed a greater percentage of gilts in oestrus at the anticipated time of the second oestrus when gilts were introduced to boars daily after their pubertal oestrus (87%) rather than isolated from boars after their pubertal oestrus (52%). Following slaughter it was found that failure to ovulate, rather than failure to detect oestrus, was responsible for the lower percentage of gilts detected in oestrus in the latter treatment. This result supports that of Signoret & Mauleon (1962) in which olfactory bulbectomy disrupted the ovarian activity of sexually mature gilts.

Detection of oestrus and sexual receptivity

The most common procedure for detection of oestrus other than the use of boars is the back-pressure test (BPT) or riding test (Signoret, 1970). The efficiency of this procedure is dependent on the female receiving intense boar contact at the time of testing. Signoret (1970) reported that the maximum percentage of gilts displaying the standing response to the BPT in the absence of boars was 59% between 24 and 36 h after the start of oestrus. This percentage was increased to 90% by providing the gilts with auditory and olfactory contact with boars and further increased to 100% with the addition of visual and tactile contact with boars.

While boar contact is an essential ingredient in the success of the BPT, recent research has demonstrated the importance of proximity to the boar at the time of testing: testing the female at a distance of 1 m or more from the boar will reduce the efficiency of the test. As shown in Table 1, a higher rate of detection of oestrus (percentage of oestrous females detected) was achieved when post-pubertal gilts were daily checked for oestrus in a corridor adjacent to boars rather than in their home pens, which were separated from the boar pens by a 1 m-wide corridor.

Table 1. The effect of conducting the BPT in the corridor adjacent to boars or in the gilts' pen (1 m from boar pens with wire-mesh fronts) on the rate of detection of oestrus in gilts (N = 32) (from Hemsworth *et al.* 1984)

	Location	
	Corridor	Gilts' pen
Gilts detected in oestrus (%)	90[x]	52[y]
Gilts mated (%)	87[x]	52[y]

[x,y]Percentages in same row with different superscripts differ significantly ($P < 0{\cdot}01$, χ^2 test).

While it appears that boar contact has an important role in stimulating the female's sexual behaviour, there are situations in which continuous stimulation from the boar may adversely affect sexual behaviour. Research at this laboratory (Hemsworth *et al.*, 1984, 1986a, 1988) has shown that housing post-pubertal gilts (N = 36) adjacent to boars, with a wire-mesh wall separating them, results in a significantly ($P < 0{\cdot}05$) lower rate of detection of oestrus (69% compared with 97% for gilts housed 1 m from boars). All gilts were held in the corridor at the time of testing with the BPT. Housing gilts adjacent to a boar with a solid wall separating them, which presumably reduced the amount of boar contact that the gilts received, improved the detection rate (Hemsworth *et al.*, 1988). It has been proposed that habituation by gilts to the important boar stimuli (e.g. auditory and olfactory stimuli) which facilitate the standing response of the oestrous female to pressure on her back (Signoret, 1970), is responsible for this detection problem (Hemsworth *et al.*, 1988). Recent research has also indicated that this housing procedure, which is common in the industry, may also produce oestrus detection problems when boars are used for detection of oestrus (Hemsworth *et al.*, 1987a). The results of these studies therefore indicate that the common practice of housing post-pubertal gilts adjacent to boars, with a wire-mesh or barred wall separating them, may adversely affect the sexual behaviour of the gilts to the extent that there are difficulties with detection of oestrus.

These results on housing adjacent to boars are obviously relevant to unmated post-pubertal gilts, but the implications for weaned sows are less clear. The short period that the weaned sow is normally housed (adjacent to a boar) before the onset of oestrus may be insufficient time to enable habituation to boar stimuli to occur. Dyck (1988) found that sows that were housed adjacent to boars had a shorter duration of oestrus than did sows housed away from boars (1·6 and 2·4 days, respectively). Similarly, we have observed differences in the duration of oestrus (i.e. difference in no. of matings) of commercial sows housed either adjacent or opposite to boars (Table 2). These data indicate some problems with detection of oestrus in sows housed adjacent to boars which may affect the duration of detected oestrus but not the oestrus detection rate. Further research is clearly warranted.

Table 2. The influence of housing weaned sows adjacent or opposite to boars on the onset and duration of oestrus (P. H. Hemsworth & C. Hansen, unpublished data)

	Housing	
	Adjacent	Opposite
Weaning–mating interval (days)		
Study 1 (N = 188)	5·5	5·5
Study 2 (N = 169)	6·4	5·7
Sows mated within 10 days of weaning (%)		
Study 1	94·8	95·6
Study 2	88·4	95·2
Sows mated within 21 days of weaning (%)		
Study 1	97·9	100
Study 2	95·3	97·6
No. of matings per sow†		
Study 1	2·3^{a}	2·5^{b}
Study 2	1·8	1·9
Sows mated only once (%)‡		
Study 1	9·6^{y}	1·1^{x}
Study 2	26·8^{b}	12·5^{a}

Boars were used for oestrus detection in Study 1 and in the Adjacent treatment in Study 2. The BPT was used in the Opposite treatment in Study 2.

^{a,b} and ^{x,y} figures with different superscripts are significantly different ($P < 0·05$ and $P < 0·01$, respectively; †ANOVA, ‡χ^2 test).

There is substantial variability in the industry in procedures that use a boar to detect oestrous females and yet the factors that affect the efficiency of detection of oestrus by boars have been little studied. Research in this area may yield very useful information for the industry. For example, the study by Hughes *et al.* (1985) found that the proportion of oestrous females mated by 6–7-month-old boars was increased with the addition of auditory and olfactory boar stimuli, indicating that these young boars may be deficient in the amount or type of sexual stimulation that they provide to the female pig. In addition to mating rate, this has practical implication for the oestrus detection rate of young post-pubertal boars. Research is required to examine the effects of factors such as sexual motivation and mating frequency of the boar, testing time and group size of females tested on the oestrus detection rate of procedures that actively utilize boars.

There is some evidence to suggest that isolation from boars before oestrus may affect the sexual behaviour of gilts. Gilts not previously exposed to boars exhibited agitation, an inadequate standing response and a marked reduction in mating rate when first introduced to boars at their second oestrus (Hughes & Cole, 1978). Similarly, Hemsworth *et al.* (1982b) observed that gilts reared in isolation from boars had a lower mating rate at their pubertal oestrus than those that received mature boar contact before puberty. A lower oestrus detection rate with the BPT and a lower level of sexual receptivity of gilts introduced to mating tests were responsible for the lower mating rate of those isolated from boars. The mechanism involved is unknown but these results have little practical implication since gilts are unlikely to be isolated from boars and the effects of isolation from boars are probably not permanent, because sexual experience appears to improve the level of sexual behaviour (Hemsworth *et al.*, 1982b; Hemsworth, 1985).

Female contact

This section concentrates on the effects of housing system (individual or group housing), group size and space allowance. Although there are some limited data that indicate that these factors, particularly space allowance, may have marked effects on reproduction, they have received very little research attention.

Onset of oestrus

The effects of group size and space allowance on puberty attainment are discussed by Hughes *et al.* (1990).

Several experiments and surveys have examined the effects of individual and group housing after weaning on the onset of oestrus, but the results are contradictory. While England & Spurr (1969), Fahmy & Dufour (1976), Karlberg (1980) and Lynch & O'Grady (1984) reported no significant difference between the two housing systems in the weaning-to-mating interval, Sommer (1980) and Hemsworth *et al.* (1982a) reported an increase in the interval for weaned sows housed in stalls. In contrast, MacLean (1969) and Hurtgen (1980) reported an increase in the weaning-to-mating interval with group housing. In many of these studies there is a paucity of information on the conditions in the studies that may affect the onset of oestrus or the detection rate such as space allowance, group size, detection procedure, boar contact and pen design, and therefore variation in these factors between studies may be responsible for the varied results.

Detection of oestrus and sexual receptivity

There are several reports to indicate that group size and stocking density may influence the efficiency of oestrus detection. In a study of 2484 gilts at a commercial piggery, Cronin *et al.* (1983) reported that 10·5% of gilts were not mated between 29 and 35 weeks of age: 70% of the unmated gilts had ovulated during this 6-week period, but the majority were not detected in oestrus when the BPT in the presence of boars was used. Group size and space allowance before entry to the mating shed were implicated in this problem because increasing group size above 50 gilts per pen and concomitantly reducing space allowance below 0·9 m^2 per gilt were associated with an increase in the percentage of post-pubertal gilts not detected in oestrus (3·6 *vs* 8·0%).

Christenson & Ford (1979) reported two experiments that examined the influence of group size (8 *vs* 24 gilts with a constant space allowance of 1·2 m^2/gilt) from 6 to 12 months of age on the sexual behaviour of gilts. In one of the experiments, more crossbred gilts were regularly detected in oestrus when in groups of 8 than in groups of 24 (96·8 and 85·4%, respectively). Presuming that all gilts had reached puberty, a reduction in the detection rate appears to be responsible for the slightly poorer performance of groups of 24. In the other experiment, using purebred gilts and conducted at a different time of the year, there was no difference in the percentage of gilts detected in oestrus in groups of 8 or 24. However, the percentage of gilts that were regularly detected in oestrus in both treatments was extremely low (56·3 and 58·7%, respectively). In another study at the same laboratory, Christenson (1984) found that a lower percentage of gilts was regularly detected in oestrus between 7 and 9 months of age when housed in groups of 3 rather than 9, 17 or 27 (56·9% *vs* 78·0, 80·4 and 80·7%, respectively). Space allowance for all groups was 1·1 m^2 per gilt. An increase in the percentage of prepubertal gilts and an increase in the percentage of post-pubertal gilts not detected in oestrus were responsible for the poorer performance of gilts housed in groups of 3.

Two experiments have been conducted at this laboratory to examine the effects of space allowance and group size. The first (Hemsworth *et al.*, 1986b) examined the effects of housing groups of adult post-pubertal gilts (6 pigs per group) with a space allowance of 1, 2 or 3 m^2/gilt on sexual behaviour. A lower percentage of gilts was detected in oestrus and a lower percentage of gilts was mated when housed with a space allowance of 1 m^2/gilt than with a space allowance of 2 or 3 m^2/gilt (oestrus detection rates of 79, 88 and 100% and mating rates of 77, 85 and 97%, respectively). There was a significant increase in plasma free corticosteroid concentrations when gilts were housed with a space allowance of 1 m^2/gilt (mean concentrations at the end of the experiment were 4·0, 2·5 and 3·2 ng/ml for space allowances of 1, 2 and 3 m^2/gilt, respectively). The results suggest that the impaired expression of oestrus in pigs housed with a space allowance of 1 m^2 may have been due to a chronic stress response. This appears to be an example of what McBride (1980) would consider as a second level of adaptation to an environmental change. The consequences of an increase in corticosteroid concentrations of this magnitude on conception rate and litter size of female pigs are unknown but it is possible that both conception and litter size would be at risk and research is therefore warranted in this area.

These results were obtained with animals approximately the size of mature gilts or first-litter sows and since the spatial requirements of the animal will increase with age, the minimum space allowance for older sows at which oestrus detection is not affected is likely to be greater than that identified here. Clearly more comprehensive research is required, but in the meantime it is suggested that post-pubertal gilts around the time of mating should be provided with at least 2 m^2 per animal and weaned sows should have at least 2–3 m^2 per animal. In a survey of 33 Victorian piggeries (P. H. Hemsworth unpublished data) it was found that, at 54% of the farms, post-pubertal gilts were often kept in groups with less than 1·5 m^2 per animal and that at 42% of farms, weaned sows were often kept in groups with less than 2 m^2 per animal. Therefore, there would appear to be an opportunity to improve detection of oestrus by providing oestrous gilts and sows with more space.

The second experiment (Barnett *et al.*, 1986) examined the effects of group size of 2, 4 or 8 with a space allowance of 1·4 m^2 per gilt on the sexual behaviour of post-pubertal gilts. Although the plasma free corticosteroid concentrations of gilts in groups of 2 were elevated (3·1 *vs* 2·3 and 2·9 ng/ml in the groups of 4 and 8 respectively), there were no significant effects on oestrus detection rate. Since the oestrus detection rate was low for all group sizes ($<60\%$), it is possible that there were no significant treatment effects because of the suboptimal space allowances. Suboptimal space allowances in the studies conducted by Christenson & Ford (1979) and Christenson (1984) (as reflected in the overall low detection rates) may also have masked the treatment effects and so further studies on group size are warranted.

The literature on the effects of group size on sexual behaviour of female pigs is equivocal. It is difficult to compare reported studies due to differences in factors such as boar contact, age of females and season, but there appear to be problems with oestrus detection in small groups (Christenson, 1984) and in large groups (Christenson & Ford, 1979; Cronin *et al.*, 1983). The interaction between group size and space allowance must be examined to clarify the optimal social and spatial conditions for group-housed female pigs.

Conception rate and litter size

Housing females around mating in groups with a space allowance of 1 m^2 per animal has been shown to elevate the plasma corticosteroid concentrations significantly (see above and Hemsworth *et al.*, 1986b). The magnitude of the increase in corticosteroid concentrations may place conception rate and litter size at risk and clearly research is required on the effects of space allowance.

As with the onset of oestrus after weaning, the effects of housing system around mating on conception rate, pregnancy rate and litter size are somewhat contradictory. Again, variation in other factors such as space allowance and boar contact may contribute to this confusion. Nevertheless, a review of the studies on the effects of housing system around mating indicates a tendency for a reduction in conception rate or pregnancy rate with individual housing (see Table 3). The results of a number of the studies presented in Table 3 indicate a tendency for individual housing to be associated with a reduction in litter size (for example, Jensen *et al.*, 1970; Hemsworth *et al.*, 1982a; Schmidt *et al.*, 1985).

Table 3. The influence of the penning system at mating on the fertility of the gilt and sow

Study	No. of pigs	Conception or pregnancy rate with housing	
		Individually	In groups
Knap (1969)*	325 sows	81·4[a]	87·2[b]
England & Spurr (1969)*	140 gilts	73·0	67·0
	153 sows	71·0	82·0
Jensen *et al.* (1970)*	174 gilts	79·7	82·5
Schlegel & Sklenar (1972)	809 gilts	58·8	62·2
	1765 sows	69·4[a]	73·5[b]
Klatt & Schlisske (1975)	23 sows	90·0	81·9
Fahmy & Dufour (1976)*	177 sows	66·5[a]	81·1[b]
Hemsworth *et al.* (1978)	68 sows	58·3	70·5
Hemsworth *et al.* (1982a)			
Exp. 1	452 sows	87·4	88·2
Exp. 2	448 sows	85·7	90·5
Schmidt *et al.* (1985)			
Weaning treatment	223 sows	70·7	72·0
Post-weaning treatment	223 sows	65·5	77·6

*Housing treatment imposed before mating and during gestation.
[a,b]Figures with a different superscript are significantly different ($P < 0·05$).

In a study still underway a comparison has been made of individually and group housed pigs (J. L. Barnett & P. H. Hemsworth, unpublished data). In this study we have controlled pre-experimental housing and attempted to optimize boar contact for efficient detection of oestrus. To date 53, 11-month-old post-pubertal gilts have been studied. These pigs were housed in neck tethers in partial stalls or in groups of 7–8 (space allowance of 1·6 or 1·8 m^2/gilt) for a 2-week pretreatment period and then half the animals underwent a housing treatment cross-over. When detected in oestrus by the BPT the pigs were mated and observations on sexual behaviour were recorded. Pregnancy rate and potential litter size were determined at slaughter, 6-weeks after mating. The differences in pregnancy rate (62 *vs* 83% for individual and group housing during treatment, respectively) are approaching significance at the 5% probability level. Only minor differences in sexual behaviour were observed (a lower receptivity in individually housed pigs) and are unlikely to account for the relatively large differences in reproductive performance. Clearly further research is required. Nevertheless, these data may provide another example of animals invoking physiological responses (McBride, 1980) that result in adverse effects on reproduction. There is clear evidence that the individual partial stalls used in this experiment result in a chronic stress response in pregnant pigs (see Barnett *et al.*, 1987).

Physical conditions at the time of mating

A recent study at this laboratory has indicated that the physical conditions at the time of mating may have considerable effects on the sexual behaviour of pigs (Hemsworth *et al.*, 1989b). Sixteen 7-month-old boars and 48 7-month-old ovariectomized gilts were studied in one of two treatments; the pigs were mated in either the boar's accommodation pen or a mating pen. The boar pen was $1{\cdot}9 \times 2{\cdot}2$ m in size with a floor area of $4{\cdot}2$ m^2 and had a concrete floor with wire-mesh walls. In contrast, the mating pen was octagonally-shaped with a floor area of $10{\cdot}5$ m^2 and had a concrete floor and solid walls. One of two groups of gilts in each treatment was induced into behavioural oestrus in alternate weeks during a 15-week period and gilts were given daily opportunity while in oestrus to mate with a boar in the appropriate treatment. Similar numbers of mating tests were conducted for each treatment group, but the percentage of mating tests which resulted in successful copulations was significantly lower for pigs mating in the boar pen than for those mating in the mating pen (76% and 88%, respectively). The sexual behaviour of the gilts in the two treatments was similar, but there was a consistent trend for the sexual behaviour of the boars in the treatments to differ, suggesting that the low mating rate of pigs mating in the boar pen treatment may have been mediated through an effect on the sexual behaviour of the boar rather than of the gilt. Nevertheless, further research is required, not only on the factors in the boar-pen treatment that are responsible for these effects but also on the sexual behaviour of the gilt, particularly the intact oestrous gilt. The boar-pen treatment in this study is similar to the mating conditions for many commercial pigs and the results therefore have considerable practical implications.

Human contact

Over the past 8 years the consequences of high levels of fear of humans by pigs have been studied. In modern animal husbandry little scientific regard has been given to the important role of the stockperson and, in particular, his or her behaviour, on production. This is surprising when one considers that the process of domestication has relied on reducing the level of fear of humans by animals. Our experiments have consistently shown that pigs displaying high levels of fear of humans, measured on the basis of the approach behaviour of pigs to a human in a standard test, show evidence of a chronic stress response (i.e. sustained elevation of plasma concentrations of free corticosteroids) with detrimental effects on production (Gonyou *et al.*, 1986; Hemsworth *et al.*, 1981a, 1986c, 1987b). The major reproductive effect of high levels of fear appears to be on conception rate and litter size rather than on sexual behaviour (Hemsworth *et al.*, 1981b, 1986c; Paterson *et al.*, 1987). If the pig is highly fearful of humans and if a behavioural change such as fleeing is ineffective in avoiding this fear-provoking stimulus, then the animal may have to resort to physiological coping mechanisms (i.e. a chronic stress response). The consequences of this second level of response (as proposed by McBride, 1980) are adverse effects on reproduction. Thus, while the magnitude of the production losses may be large, the nature of the response is not unexpected, as fear is known to be a potent influence on the pituitary–adrenal axis in animals (Selye, 1976).

This research has been extended to the commercial situation to examine the practical implications of high levels of fear of humans by pigs. In a recent study of 19 commercial farms in Australia (Hemsworth *et al.*, 1989a) the relationships between behaviour of the stockperson towards female pigs around the time of mating and the level of fear of humans and productivity of pigs were examined. There were several important findings in this study. Firstly, as in a previous study (Hemsworth *et al.*, 1981b), there were highly significant negative correlations between the level of fear of humans by sows and the reproductive performance of the farm: sows displayed a decreased approach to the experimenter at farms where reproductive performance was low. For example, the amount of approach behaviour to a stationary experimenter accounted for more than 20% of the variation between farms in the total number of pigs born per sow per year (Hemsworth *et al.*, 1989a). This finding indicates that there may be considerable potential to improve productivity in the industry by reducing the pig's level of fear of humans. The second important finding from this on-farm study was that the behaviour of the stockperson was significantly correlated with both the level of fear of humans by sows and the productivity of the farm. These relationships indicate that the behaviour of the stockperson may be a major determinant of the level of fear of humans by pigs, which in turn may limit the productivity of the pigs via a chronic stress response.

The relationship between behaviour of the stockperson, fear of humans by sows and reproductive performance does not necessarily indicate a cause and effect relationship. It is possible that another factor, which is correlated with the behaviour of both the stockperson and the sows, may be responsible for this difference between farms in reproductive performance. Our present research is examining the effects of modifying the behaviour of stockpersons on fear of humans by pigs and the results of this study should confirm whether fear of humans is a major limitation to the productivity of commercial pigs.

Conclusions

Although it is well recognized that the behaviour of the female pig has major consequences on her productivity, research on this subject has been sparse relative to that in other disciplines. There is a clear need to promote the study of farm animal behaviour.

The modern study of behaviour involves three main kinds of problems; its immediate cause, its ontogeny and its functional and evolutionary aspects (Hinde, 1970). The scientist who is studying the behaviour of farm animals to improve their productivity is generally concerned with the first two of these three problems. Through this type of research a better understanding of both the immediate cause and the ontogeny of the behaviour will lead to better prediction and control of the behaviour. If this behaviour has important consequences on the productivity of the pig, a better understanding may enable manipulation of both the environment and the management procedures to facilitate higher productivity from the animal. This is an area where the science of animal behaviour can provide major benefits in the productivity of farm animals. Some of the major factors that have been identified that can affect the productivity of female pigs by affecting their behaviour include type and amount of boar contact, amount of female contact, housing system (i.e. individual or group), and human contact.

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