

Effects of Dry Sow Stall Use
for a Limited Period After
Mating

(Literature Review)

**EFFECTS OF DRY SOW STALL USE
FOR A LIMITED PERIOD AFTER MATING:
A LITERATURE REVIEW FOR THE
NEW ZEALAND PORK INDUSTRY**

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Executive Summary

- This review was commissioned to examine and summarise the scientific evidence regarding the welfare implications of using dry sow stalls to house sows in early gestation.
- The New Zealand pork industry accepts that the nett welfare of sows housed in dry sow stalls for their entire gestation period may be compromised. The industry is therefore moving to phase out this practice. However, the industry wishes to retain the option for producers to use dry sow stalls for up to 4 weeks following mating in any gestation period on the basis that there is an animal welfare, and hence productivity benefit, of doing so
- Stalls are currently used to house 44 percent of the sows in New Zealand for some time during the gestation period.
- The ‘homeostasis’ approach is recognised as being a valid method for scientifically assessing the welfare of animals, and is the approach that is used to measure welfare in this review. It focuses on using the physiological, behavioural and biological responses of an animal towards its environment, as a comprehensive indicator of its welfare.
- The mixing of pigs, such as that which occurs in group housing situations, results in aggressive interactions which are known to cause stress to the animals, as can an animal’s position in a hierarchy once it has been established. In group housing systems, dominant sows may receive more than their share of feed, whilst submissive sows may receive less.
- Due to the reproductive physiology of the pig, the embryo is susceptible to hormonal perturbations during early pregnancy, particularly during embryonic ‘implantation’ in

the uterine wall. Such perturbations are primarily caused by stress and uncontrolled feed intake. Implantation of the embryo is complete by about week four post-mating.

- Litter sizes and conception rates are key indicators of stress occurring in the sow in early pregnancy. The use of dry sow stalls for four weeks post-mating has been found to have beneficial effects in terms of these indicators. In that respect, sow welfare and reproductive performance are positively correlated.

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Introduction

The housing of pigs in dry sow stalls is a contentious issue among some sectors of society, and is a practice that has been attracting public attention of late. The New Zealand pork industry has recognised that the welfare of sows may be compromised by the use of dry sow stalls for their entire gestation period, and have consequently decided to phase out this practice by 2012. In doing so, however, the industry has sought to retain the optional use of stalls for up to four weeks following mating, on the basis that there is a nett animal welfare¹ benefit in doing so. There is a sound body of scientific knowledge that supports the use of stalls on welfare grounds during this critical phase of the production cycle.

The purpose of this review is, therefore, to examine the scientific literature surrounding the use of dry sow stalls in early gestation. As part of this review, a number of issues are examined, including current industry usage of stalls; the scientific basis for measuring animal welfare; sow social behaviour and its impact; the physiology of the sow during early gestation; and studies evaluating housing the sow individually during early gestation.

Current Industry Practice

There are currently several options available for housing sows during the gestation period. These include dry sow stalls, indoor group pens, group housing on 'deep litter' (such as straw or sawdust), and in groups outdoors in paddocks. This review is focused on dry sow stalls, which, as with all housing systems, can vary in the detail of their design. Broadly speaking however, they are typically 0.6-0.7 x 2.0-2.1 metres in area. Some allow the stall width to be altered depending on body size of the sow, and have partitions to allow visual contact but prevent aggression. Flooring is usually concrete, and is partially slatted to allow manure to fall through into a separate collection area at the rear of the stall, which is regularly flushed with water. A drinker and feeding trough are

¹ "Nett animal welfare" refers to the overall welfare of an animal, taking into account all the individual factors affecting that animal's welfare in any given situation.

located at the front of the stall, with sows commonly being fed a diet of wet or dry cereal based feed once or twice a day (Borell *et al.*, 1997).

Stalls are predominantly used to reduce aggression and control feed intake in gilts and sows (Barnett *et al.*, 2001). Through controlling these aspects of pig production, they have the potential to improve the health and welfare of the animals that they house. A recent survey (MM Research, 2001) of the New Zealand pig industry indicated that producers who are responsible for approximately 44 percent of the total New Zealand sow herd make use of this form of housing for some period of time during the gestation period. Of these sows, 56 percent (25 percent of the total sow herd) are housed in stalls for more than six weeks, 20 percent (8.6 percent of the total sow herd) for between four and six weeks and 24 percent (10.5 percent of the total sow herd) for less than four weeks. The aforementioned study also indicated that at any one point in time, only 26 percent of gestating sows are in stalls, with the remainder either housed outdoors or indoors in group pens.

Dry sow stalls are also used in overseas countries, including both Australia and Canada, which are the source of the majority of pig meat imports into New Zealand. Estimates of stall use in Australia (Peterson *et al.*, 1997, cited in Barnett *et al.*, 2001) are that about 62 percent of sows are housed in stalls for part of their reproductive cycle, and 26 percent are housed in stalls for most of their reproductive cycle. Similarly, figures from Canada (Chambers and Fraser, 2001, pers. comm.) indicate that between 95 and 99 percent of sows are housed in stalls for the entire gestation period.

Based on these research results it is apparent that the use of stalls for a limited period during early gestation is an important management tool in New Zealand pork production. It is also evident that the overall use of stalls is less prevalent in New Zealand compared to those overseas countries that are currently the major source of pig meat imports into the country.

Scientific Assessment of Animal Welfare

The role of science in assessing animal welfare is to establish the biological response (both behavioural and physical) of animals to any given practice. These biological facts become integrated with moral views when determining whether an animal's welfare is seriously compromised, causing the assessment of welfare to be a controversial subject.

Barnett *et al.* (2001) provide an explanation of the scientific assessment of animal welfare, based around the 'homeostasis' approach to its measurement. They explain:

“...the definition that underpins this [homeostasis] approach is ‘the welfare of an individual is its state as regards its attempts to cope with its environment’ (Broom, 1986). In this definition the ‘state as regards its attempts to cope’ refers to both how much has to be done by the animal in order to cope with the environment and the extent to which the animal’s coping attempts are succeeding. Attempts to cope include the functioning of body repair systems, immunological defences, physiological stress response, and a variety of behavioural responses. Therefore, using such a definition, the risks to welfare of an animal by an environmental challenge can be assessed at two levels: firstly the magnitude of the behavioural and physiological responses; and secondly, the biological cost of these responses (Barnett and Hutson, 1987; Broom and Johnson, 1993; Hemsworth and Coleman 1998). These behavioural and physiological responses include the stress response, whereas the biological cost includes adverse effects on the animal’s ability to grow, reproduce and remain healthy” (pages 2-3).

The credibility of this approach to measuring animal welfare is supported by Barnett *et al.* (2001) on the basis that:

“...it contains some widely accepted criteria of poor welfare such as health, immunology, growth rate, and nitrogen balance. Furthermore, there are some excellent examples of the value of this ‘homeostasis’ approach in assessing

animal welfare (Hemsworth and Coleman, 1998). For example, handling studies on pigs have shown that fearful pigs have a sustained elevation of plasma free corticosteroid concentrations (Hemsworth *et al.*, 1981, 1986; Hemsworth and Barnett, 1991). The consequences of this chronic stress response in these fearful animals include depressions in growth and reproductive performance (Hemsworth *et al.*, 1981, 1986; Hemsworth and Barnett, 1991)” (page 3).

So strong is the relationship between stress and biological performance that Moberg (1985) explains how reproductive performance can be used as a tool for measuring well-being in animals:

“Reproductive performance can serve as a barometer of animal well-being... an animal will make considerable physiological sacrifices to ensure reproductive success; only the most severe threats will prevent the animal from reproducing.

Because of the sensitivity of reproduction to the effects of stress, monitoring fertility offers a potential measurement of stress in animals” (page 245).

This review then, assesses the welfare of pigs kept in stalls for a limited period of time on the basis of biological (i.e. behavioural and physiological) responses to different stressors that are part of an animal’s environment.

Social Behaviour and Stress in the Sow

Selection by humans over the last 200 years means that the modern pig is genetically remote from its wild ancestors. While domestication of the pig has changed it from a free-ranging, foraging animal, to one that more easily handled, some of the original behavioural traits can still be observed (Love *et al.*, 1990). These traits, in combination with the physical characteristics of the modern pig, dictate the requirements necessary to

ensure their health and welfare are maintained. One of the most important behavioural traits of pigs that must be considered if this is to be achieved is that:

“The mixing of unfamiliar pigs usually results in fighting which leads to formation of a stable social hierarchy (Meese and Ewbank, 1973)” (Arey, 1999, page 200).

Arey and Edwards (1998) explain that this period of aggression will potentially involve all animals within the group:

“In newly formed groups of sows, almost all individuals are involved in agonistic interactions with some pigs carrying out most of the aggression and others mainly receiving aggression (Mount and Seabrook, 1993)”(page 62).

The outcome of the aggressive encounters serves to establish the relative social ranking of individuals within the group (Meese and Ewbank, 1973), such that dominant animals have precedence in access to resources such as feed, water and space. Social ranking serves to reduce the need for outright aggression to settle future disputes that may arise between animals (Arey and Edwards, 1998). It is well established that aggression reduces to lower levels once a hierarchy has been formed (Arey, 1999; Arey and Edwards, 1998). However, the agonistic encounters that are involved in its formation, have been identified by Arey and Edwards (1998) as posing a potential welfare threat to the animals involved:

“The level of stress and the number of injuries caused by mixing unfamiliar sows remains a major welfare concern (Oldigs et al. 1992; Mendl et al. 1993)” (page 62).

Similarly, Varley and Stedman (1994) also identify that:

“The components of a high stress system may include... new social grouping[s]... which cause physical or psychological trauma to the animals” (page 277).

This stress can have wide-ranging effects on the animals involved, with Smidt (1983, cited in Arey and Edwards, 1998; Varley and Stedman, 1994) linking it to changes in both physiology and endocrinology. Varley and Stedman (1994) explain:

“The principle effects of acute or chronic stress are on the endocrine system, the immune system and the central nervous system (CNS) and are associated with profound changes in the animals’ behaviour. All of these adaptations are components of the overall attempt by the animal to maintain homeostasis in a rapidly changing and unpredictable world” (page 277).

Arey and Edwards (1998) further explain the specific effects of mixing stress:

“Mixing stress has been shown to activate both [sympathetic adrenomedullary and hypothalamic-pituitary adrenal] pathways in the pig. Sows involved in physical interactions have elevated heart rates, an indication of increased sympathetic activity, which is greater in losers than in winners (Marchant *et al.*, 1995). Since both winners and losers exhibited a similar amount of locomotory activity, the elevated heart rate cannot be attributed to solely physical causes, indicating a psychological component to the physiological response to social stress” (page 65).

The hierarchical nature of the sow can therefore expose animals to significant levels of stress in group-housing situations, which may have both behavioural and physiological effects.

Time Period for Hierarchy Formation

Stress is associated with the aggressive encounters that are an inherent part of hierarchy formation. The length of time taken for hierarchical development therefore dictates the time period during which an animal will experience acute or chronic stress. Arey (1999) explains that this time period may vary greatly:

“Time for aggression to subside and for groups of sows to become relatively stable ha[s] been reported to take between 3 and 10 days (Van Putten and Van de Burgwal, 1990; Oldigs *et al.*, 1992). However, other studies have reported much longer periods for sows to become fully integrated into new groups (Moore *et al.*, 1993; Spoolder *et al.*, 1996)” (page 200).

For example, Arey and Edwards (1998) reported that it can take up to 8 weeks after mixing for aggression to subside and for group structure to become stable:

“In groups formed of 6 unfamiliar sows, levels of aggression, as measured from lesion scores, did not fall to near constant levels until 28 days after mixing (Arey and Jamieson, 1997). However, aggression during floor feeding tests did not fall to near constant levels until 56 days after mixing.” (page 63).

The reason that the time taken to establish a hierarchy can vary is a function of many factors, the most crucial of which may be the housing system. Attributes of the housing system that can affect hierarchical development include space allowances, pen shape, opportunities for escape, feeding system, and group size and structure (stable or dynamic) (Arey and Edwards, 1998; Barnett, 2001).

Sows in newly formed groups can therefore experience stress associated with hierarchy formation for a significant period of time, depending on the interaction of these factors in any given group housing situation. This stress may have profound behavioural and physiological effects as the animal attempts to maintain homeostasis in this environment.

Social Ranking and Stress

Regardless for the length of time taken for formation of a stable hierarchy, Barnett (1999) has reported that, social ranking within a hierarchy can cause stress-related welfare problems for some animals:

“A common criticism of individual housing systems for pigs is that social contact is disrupted. However, the effects of social rank on reproductive success of group-housed sows indicate potential problems for certain animals. For example, Mendl *et al.* (1992) reported that submissive pigs, based on their ability to be displaced by other pigs, had higher concentrations of salivary cortisol, were more responsive to an ACTH challenge, indicative of a chronic stress response and had lighter piglets” (page 32).

Nicholson *et al.* (1993) found evidence of a similar stress response in socially intermediate sows compared to submissive and dominant animals within a group-housing situation, and compared to sows housed in individual stalls. In this study, socially intermediate sows showed specific signs of physiological stress (reduced natural killer cell activity, elevated basal cortisol concentrations) which was further evidenced by reduced farrowing rate, and smaller litter size, compared to other sows in the group, and sows housed in dry sow stalls.

In both of the aforementioned studies, one of the manifestations of stress associated with hierarchy development and subsequent social ranking is a detrimental effect on reproductive physiology of the pig. To gain an insight into why this is so, it is therefore necessary to examine the physiological processes involved with reproduction in the pig.

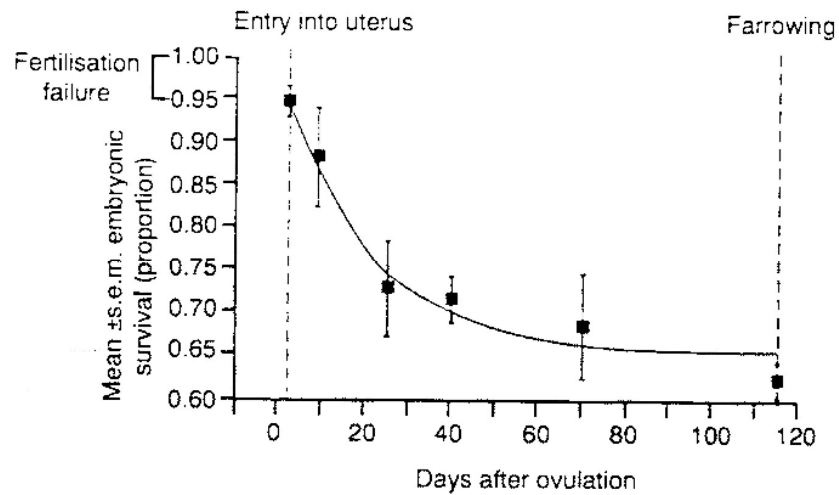
Reproductive Physiology of the Pig

The female domestic pig attains sexual maturity at 5.5-6.5 months of age (approximately 90 kilograms live weight). Once puberty is attained, pigs will show signs of oestrus every 21 days on average, with each oestrus lasting for about 50-60 hours, during which time ovulation occurs. The number of ova shed varies from 10-25, and, after mating and conception, the length of the gestation period ranges from 110-119 days. Hughes and Varley (1980) describe the processes involved with early pregnancy in the pig:

“Pregnancy or gestation begins at fertilization... In the ensuing three weeks the ova change from ‘self-supporting’ eggs into rapidly developing embryos implanted on the uterine wall and becoming increasingly dependant on maternal blood supply. This process of attachment or implantation begins at day 12 or 13 post coitum and is complete by about week 4 of gestation” (page 93).

During this gestation period a wide range of environmental, genetic, nutritional, hormonal and biochemical factors interact and, through their impact on embryo implantation and mortality, ultimately affect litter size (Ashworth and Pickard, 1998). The stage during which these factors can have the largest impact is the period up to day 30 of the reproductive cycle, which has been identified as being the time that the majority of embryonic losses can occur (Figure 1). (Ashworth and Pickard, 1998; Flower, 1998).

Figure 1: Estimates of prenatal mortality throughout gestation. From Ashworth and Pickard (1998).



Implantation

Within the larger 30-day period of early gestation, it is known that a particularly sensitive stage is the implantation phase (Hughes and Varley, 1980; van der Lende *et al.* 1993).

The implantation process is particularly susceptible to perturbation by factors such as feeding level, and the occurrence of stress, during early pregnancy (Borrel *et al.*, 1997; Barnett *et al.*, 1993; Dutt and Chaney, 1968, cited in Hughes and Varley, 1980; Einarsson and Rojkittikhun, 1993; Moberg, 1985; van der Lende *et al.* 1994).

Effect of stress in early pregnancy on implantation

The general impact that stress can have on biological performance of pigs has been well documented. Varley and Stedman (1994), for example, note that:

“It is well established... that stress does have a profound effect on the biology of pigs (Wood-Gush, 1983; Stephens 1980; Baldwin and Stephens, 1973; Kyriakis, 1989) and one outcome of high stress is reduced reproductive efficiency.

Some of the manifestations of stress are reduced litter size...[and] poor conception rates” (page 277).

The fact that stress can negatively affect the critical early period of pregnancy, is further emphasised by van der Lende *et al.* (1994):

“Stress, for example due to high ambient temperatures, too much commotion in the stable or fighting during establishment of a social hierarchy in newly formed groups, can increase the extent of embryo mortality, especially during the first month of pregnancy (Schnurrbusch and Elze, 1981; Varley 1991)” (pages 304-305).

Hughes and Varley (1980) suggest the reason why this period when implantation is occurring is particularly sensitive to the effects of stress, may be because of the delicate hormonal balance that is required. They note:

“The uterine wall is pre-sensitised for implantation by the balance of steroid hormones. Oestrogen followed by rising progesterone leads to the endometrial lining being at the optimum state to accept [embryo] attachment. Any disturbance in endocrine balance therefore inhibits implantation rate (Hughes and Varley, 1980, page 101).

An example of a stress response that can cause the aforementioned disruptions to the critical early phase of pregnancy during which implantation is occurring (and which was alluded to by van der Lende *et al.* (1994) above), is the mixing of unfamiliar pigs, and the associated aggression (see 'Social Behaviour and Stress in the Sow' in this review). Barnett *et al.* (1993) explain the negative effects of these aggressive interactions on welfare, as evidenced by its effect on reproductive processes:

“Grouping of unfamiliar sows and gilts...after mating...poses a welfare risk from injuries because of fighting during the establishment of hierarchies, in the short term, and from the restriction or prevention of feeding of subordinate pigs in the longer term. In addition, an acute or chronic physiological stress response from such activity around the time of mating or in early pregnancy is likely to have detrimental effects on the occurrence or synchrony of hormonal events that effect reproductive processes (Moberg, 1985; Rivier and Rivest, 1991), such as sperm and egg transport, implantation and embryo development, with consequent effects on conception rate and litter size” (pages 111-112).

Thus it can be seen that stress suffered by the sow during early pregnancy has an irrefutable effect on embryo implantation (Varley and Stedman, 1994). Given the fact that animals will make “considerable physiological sacrifices” (Moberg, 1985, page 245) before reproductive performance is affected, it is therefore reasonable to conclude that stress during early pregnancy does indeed constitute a significant welfare risk to the sow.

A further factor to be considered is the impact of nutrition on embryonic survival. There is clear evidence that suggests over-eating in early pregnancy, as may occur amongst the dominant sows in a group, can have a negative effect on embryonic survival (Toplis *et al.* 1983; Den Hartog and Van Kempen, 1980; Goode *et al.*, 1965; Gossett and Sorensen, 1959).

Housing in Early Gestation

Use of group housing immediately after mating has been associated with a reduction in conception rate (Brouns and Edwards, 1992; Bokma, 1990) and reduced litter size (Fisker, 1997; Hansen and Ruby, 2000; Nielsen *et al.*, 1997; Agribiz Engineering, 1999) compared to sows housed in stalls for early gestation (data are summarised in Table 1). This is indicative of a detrimental effect of group housing during this time on sow welfare, and hence embryo implantation and survival. Results of this nature have led Barnett *et al.* (2001) to suggest:

“...that there may be some advantage, in terms of... welfare, from stall housing, at least for a limited time [in early gestation]” (page 6).

Table 1. Effect of housing system after mating on reproductive performance in sows.

Study	No. of pigs	Conception rate		Litter size	
		Grouped after mating	Grouped ≈4 weeks after mating	Grouped after mating	Grouped weeks after mating
Agribiz Engineering (1999)*	670 sows	-	-	10.8 ^a	11.8
Fisker (1995) ^φ	1352 sows	83.6	83.7	11.8 ^c	12.1
Nielsen <i>et al.</i> (1997)	554 sows	84	86	12.1 ^e	12.1
Schmidt et al (1985)	537 sows	90	94	13	12.1
Bokma (1990) ^φ	223 sows & gilts	78 ^a	66 ^b	9.8	9.8
	345 sows	80	90	10.5	10.5

* Sows housed individually for 5 weeks after mating.

^φ Housing system employed both prior to and after mating.

^{a,b} Figures with different superscript are significantly different (P < 0.05).

^{c,d} Figures with different superscript are significantly different (P < 0.0005).

^{e,f} Figures with different superscript are significantly different (P < 0.07).

^φ Sows mixed 1-8 days or 22-29 days after mating.

The results summarised above are also supported by the work of Hurtgen *et al.* (1980), which found that sows housed in individual stalls for 30 days after mating had an

improved farrowing rate compared to group-housed sows. Reduced stress and better nutrition were implicated as reasons for these results.

The weight of evidence from the above studies indicates that group housing can be detrimental to the welfare of the sow in early pregnancy. Data from Schmidt *et al.* (1985) is the exception to this trend, indicating that in some circumstances, group housing can afford welfare that is as good as that experienced by sows housed in stalls. However, the combination of factors necessary to achieve high animal welfare standards in group housing will not be achievable in all situations. Hence, the optional use of stalls can be seen to offer the best opportunity for net animal welfare to be maximised in any given situation.

The potential for stall use in early gestation to improve sow health and welfare is not restricted to measures of reproductive performance, however, as is evidenced by Barnett *et al.* (2001):

“The survey data of Paterson *et al.* (1997)... showed improved overall performance, on the basis of a lower removal rate due to a combination of reproductive failure, lameness and locomotor problems, age, death, and euthanasia, in farms that had both pens and stalls compared to those that only had pens. Our interpretation of “pens and stalls” in the study of Paterson *et al.* is that after mating, sows were housed for a time in stalls followed by the remainder of gestation in groups” (page 6).

The improvements in both reproductive performance and other physiological measures of animal welfare resulting from stall housing, taken in conjunction with the controversial nature of their use from a societal perspective, led Barnett *et al.* (2001) to conclude:

“...housing in stalls for a defined period that is considerably less than the period of gestation may be a reasonable compromise” (page 6).

Conclusion

This review has shown, through the use of the “homeostasis” approach to welfare measurement, that the use of dry sow stalls for a period of four weeks after mating can afford an improvement in nett welfare compared to those sows that are housed in groups immediately after mating. This improvement in nett animal welfare is primarily due to reduced stress compared to that which can be experienced in some group housing systems as a result of aggression associated with hierarchy formation and social contact between animals. This reduction in stress is evidenced by reduced embryonic mortality during the critical implantation phase of the reproductive cycle. The optional use of dry sow stalls for four weeks after mating therefore offers the flexibility to ensure that in any given farming situation, nett animal welfare benefit can be maximised.

Reference List

- Agribiz Engineering. (1999). Welfare implications and recommendations for outdoor sows. Report to the pig research and development corporation, Canberra.
- Ashworth, C.J. and Pickard, A.R. (1998). Embryo and prolificacy. In: Wiseman, J., Varley, M.A. and Chadwick, J.P. (Eds.), *Progress in Pig Science*. Nottingham University Press, United Kingdom, pp 303-325
- Arey, D.S. (1999). Time course for the formation and disruption of social organisation in group-housed sows. *Applied animal behaviour science*, 62:199-207.
- Arey, D.S. and Edwards, S.A. (1998). Factors influencing aggression between sows after mixing and the consequences for welfare and production. *Livestock production science*, 56:61-70.
- Barnett, J.L. (1999). Review of pig housing. Report to the Pig Research and Development Corporation. Pig Research and Development Corporation, Canberra, Australia.
- Barnett, J.L., Cronin, G.M., McCallum, T.H. and Newman, E.A. (1993). Effects of pen size / shape and design on aggression when grouping unfamiliar adult pigs. *Applied animal behaviour science*, 36:111-122.
- Barnett, J.L., Hemsworth, P.H., Cronin, G.M., Jongman, E.C. and Hutson, G.D. (2001). A review of the welfare issues for sows and piglets in relation to housing. *Australian journal of agricultural research*, 52:1-28.
- Bokma, S. (1990). Housing and management of dry sows in groups in practice: partly slatted systems. In: *Electronic identification in pig production. Proceedings of an international symposium*. RASE, Stoneleigh, United Kingdom, pp 37-45.
- Borell, E. van, Broom, D.M., Csermely, D., Dijkhuizen, A.A., Edwards, S.A., Jensen, P., Madec, F. and Stamataris, C. (1997). The welfare of intensively kept pigs. Report of the scientific veterinary committee. Commission of the European Community,

Brussels.

- Brouns, F. and Edwards, S.A. (1992). Future prospects for housing of non-lactating sows. *Pig news and information*, 13:47N-50N.
- Chambers, R. and Fraser, H.W. (2001). Personal communication. Ministry of Agriculture, Food and Rural Affairs, Ontario, Canada.
- Einarsson, S. and Rojkittikhun, T. (1993). Effects of nutrition on pregnant and lactating sows. *Journal of reproduction and fertility supplement*, 48:229-239.
- Fisker, B. N. (1995). Strategy for introduction of group-fed gestant sows to loose housing systems. Danish applied pig research scheme. Danske Slagterier, Copenhagen, Denmark.
- Flower, W.L. (1998). Management of Reproduction. In: Wiseman, J., Varley, M.A. and Chadwick, J.P. (Eds.), *Progress in Pig Science*. Nottingham University Press. Pp 383-405.
- Hansen, L.U. and Ruby, V. (2000). Mating unit with individual or group housing of pigs. Proceedings of the 16th international pig veterinary society congress, Melbourne, Australia.
- Hughes, P.E. and Varley, M.A. (1980). *Reproduction in the pig*. Butterworths, London.
- Hurtgen, J.P. Leman, A.D. Crabo, B. (1980). Effect of season, parity and housing factors on estrus and fertility in swine. *Proceedings of the International Pig Veterinary Society 6th Congress*, Copenhagen, Denmark.
- Love, R.J., Peacock, A.J. and Evans, G. (1990). Seasonal infertility in pigs. In Smith, W.C. (Ed). *Proceedings of the Inaugural Massey Pig and Poultry Symposium*. Monogastric Research Centre, Palmerston North.
- Meese, G.B., and Ewbank, R. (1973). The establishment and nature of the dominance hierarchy in the domesticated pig. *Animal behaviour*, 21:326-334.

- MM Research. (2001). Sow housing survey. New Zealand Pork Industry Board, Wellington.
- Moberg, G.P. (1985). Influence of stress on reproduction: measure of well-being. In: Moberg, G.P. (Ed.) *Animal stress*. American Physiological Society, Bethesda, Maryland, USA.
- Nicholson, R., McGlone, J.J. and Reid, L.N. (1993). Quantification of stress in sows: comparison of individual housing versus social penning. *Journal of animal science*, 71 (Supplement 1):112.
- Nielsen, N.P., Fisker, B.N., Hansen, L.U. and Ruby, V. (1997). Strategy for mixing sows in small static groups. Danish applied pig research scheme. Danske Slagterier, Copenhagen, Denmark.
- Paterson, R., Pointon, A. and Cargill, C.F. (1997) Sow wastage in the Australian pig herd - degree, cost and prevention. Report to the Pig Research and Development Corporation, Canberra.
- Schmidt, W.E., Stevenson, J.S. and Davis, J.L. (1985). Reproductive traits of sows penned individually or in groups until 35 days after mating. *Journal of animal science*, 60:755-759.
- Van der Lende, T., Soede, N.M. and Kemp, B.V. (1994). Embryo mortality and prolificacy in the pig. In: Cole, D.J.A., Wiseman, J. and Varley, M.A. (Eds.), *Principles of Pig Science*. Nottingham University Press, pp 297-317.
- Varley, M., and Stedman, R. (1994). Stress and reproduction. In Cole, D.J.A., Wiseman, J. and Varley, M.A. (Eds.), *Principles of Pig Science*. Nottingham University Press, pp 277-296.

References Cited by Other Authors

- Arey, D.S. and Jamison, W.G. (1997). Time course for the formation of a stable social

hierarchy in group-housed sows. *Proceedings of the British Society for Animal Science*, pp 108.

Barnett, J.L. and Hutson, G.D. (1987) Objective assessment of welfare in the pig: contributions from physiology and behaviour. In: Australasian Pig Science Association Committee (Eds.) *Manipulating pig production*. APSA, Werribee, Victoria, pp 1-22.

Bielharz, R.G. (1982). Genetic adaptation in relation to animal welfare. *International journal of the study of animal problems*, 3:117-124.

Bielharz, R.G. and Zeeb, K. (1981). Applied ethology and animal welfare. *Applied animal ethology*, 7:3-10. Baldwin, B.A. and Stehpens, D.B. (1973). The effects of conditioned behaviour and environmental factors on plasma corticosteroid level in pigs. *Physiology and behaviour*, 1:267-274.

Broom, D.M. (1986). Indicators of poor welfare. *British veterinary journal*, 142:524-526.

Broom, D.M. and Johnson, K.G. (1993). *Stress and animal welfare*. Chapman and Hall, London, United Kingdom.

Den Hartog, L.A. and Van Kempen, G.J.M. (1980). Relation between nutrition and fertility in pigs. *Netherlands journal of agricultural science*, 28:211-227.

Goode, L., Warnick, A.C. and Wallace, H.D. (1965). Alkaline and acid phosphate activity in the endometrium and ovary of swine. *Journal of animal science*, 24:955-958.

Gossett, J.W. and Sorensen, A.M. (1959). The effects of two levels of energy and seasons on reproductive phenomena of gilts. *Journal of animal science*, 18:40-47.

Hemsworth, P. H. and Barnett, J. L. (1991). The effects of aversively handling pigs either individually or in groups on their behaviour, growth and corticosteroids. *Applied animalbehaviour science*, 30:61-72.

- Hemsworth P.H., Barnett, J.L. and Hansen, C. (1981). The influence of handling by humans on the behaviour, growth and corticosteroids in the juvenile female pig. *Hormones and behaviour*, 15:396-403
- Hemsworth, P.H., Barnett, J.L. and Hansen, C. (1986). The influence of handling by humans on the behaviour, growth and corticosteroids of male and female pigs. *Applied animal behaviour science*, 15:303-314.
- Hemsworth, P.H. and Coleman, G.J. (1998). Human livestock interactions. The stockperson and the productivity and welfare of intensively farmed animals. CAB International, Oxon, United Kingdom. Kyriakis, S.C. (1989). New aspects of the prevention and/or treatment of the major stress induced diseases of the early weaned piglet. *Pig news and information*, 10:177-181.
- Marchant, J.N., Broom, D.M., Rudd, A.R. and Mendl, M.T. (1995). The effect of agonistic social interactions on the heart rate of group-housed sows. (*Abstract*). *Animal Science*, 60:565.
- Mendl, M., Zanella, A.J. and Broom, D.M. (1992). Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal behaviour*, 44:1107-1121.
- Mendl, M., Broom, D.M., Zanella, A.J. (1993). The effects of three types of dry sow housing on sow welfare. In: Collins, E., Boon, C. (Eds.), Proceedings of livestock Environment IV, Coventry, UK, pp 461-468.
- Moore, A.S., Gonyou, H.W. and Ghent, A.W. (1993). Integration of newly introduced and resident sows following grouping. *Applied animal behaviour science*, 38:257-267.
- Mount, N.C. and Seabrook, M.F. (1993). A study of aggression when group housed sows are mixed. *Applied animal behaviour science*, 36:377-383.
- Oldigs, B., Schlichting, M.C., Ernst, E. (1992). Trial on the grouping of sows.

Proceedings of the 23rd International Conference on Applied Ethology in Livestock, Germany, pp109-120.

Rivier, S. and Rivest, S. (1991). Effect of stress on the activity of the hypothalamic-pituitary-gonadal axis: peripheral and central mechanisms. *Biological reproduction*, 45:523-532.

Schnurrbusch, U. and Elze, K. (1981). Pre- and perinatal piglet mortality. *Monatshefte für veterinar medizin*, 36:706-711.

Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Lawrence, A.B. and Simmins, P.H. (1999). Social recognition in gilts mixed into a dynamic group of 30 sows. *Animal science*, 62:630.

Stephens, D.B. (1980). Stress and its measurement in domestic animals: a review of behavioural and physiological studies under fields and laboratory situations. *Advances in veterinary science and comparative medicine*, 24:179-210

Toplis, P. Ginesi, M.F.J. Wrathall, A.E. (1983). The influence of high food levels in early pregnancy on embryo survival in multiparous sows. *Animal Production*. 37: 45-48.

Van Putten, G. and Van de Burgwal, J.A. (1990). Vulva biting in group-housed sows: a preliminary report. *Applied animal behaviour science*, 26:181-186.

Varley, M.A. (1991). Stress and reproduction. *Pig news and information*, 12:567-571.

Wood-Gush, D.G.M. (1983). Elements of ethology. Chapman and Hall, London, United Kingdom.