ENVIRONMENTAL AND GENETIC FACTORS INFLUENCING THE DEVELOPMENT OF BELLY NOSING IN THE EARLY-WEANED PIG

A Thesis Submitted to the College of
Graduate Studies and Research
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in the Department of Animal and Poultry Science
University of Saskatchewan
Saskatoon

by
Clover Joy Bench

© Copyright Clover Joy Bench, July 2005. All rights reserved.

PERMISSION TO USE STATEMENT

In presenting this thesis in partial fulfillment of the requirements for a Postgraduate Degree from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis work or, in their absence, by the Head of Department or Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any material in my thesis.

Requests for permission to copy or to make other use of material in this thesis in whole of part should be addressed to:

Head of the Department of Animal and Poultry Science
University of Saskatchewan
Saskatoon, Saskatchewan S7N 5A8

ABSTRACT

This study investigated environmental and genetic factors influencing the development of belly nosing in the early-weaned pig. The first experiment investigated the effects of gender, duration of liquid milk replacer supplementation, breed line and environmental enrichment designed to simulate components of a sow's udder, on the incidence of belly nosing and its associated behaviours in pigs weaned at 7 days-of-age. Both breed line and environmental enrichment were found to affect the incidence of oral-nasal behavioural vices related to belly nosing. Differences between breed lines were found in the types of behavioural vices performed and whether these vices were generally focused or directed at specific regions of the body of penmates. Enrichment devices, designed for nosing, rooting, sucking, and biting were also found to be specific in the types of behavioural vices they effectively alleviated. Significant breed line by environmental enrichment interactions were found, with Yorkshire pigs more responsive to environmental enrichment than Duroc pigs.

The second study documented the ontogeny of belly nosing from weaning into the grow-finish period in pigs weaned at 12-14 days-of-age and determined whether early belly nosing correlated with behavioural vices observed during the grow-finish period. The results of the study suggest that after belly nosing subsides, a number of other oral-nasal behaviours take its place. Pigs that progressed from belly nosing to belly sucking, tended to continue to perform belly sucking behaviour into the grow-finish phase. In contrast, piglets which exhibited generalized nosing and sucking behaviours during the grow-finish period were more likely to tail bite and to engage in generalized biting of penmates. A direct correlation between belly nosing during the nursery phase and tail biting during the grow-finish period was not found.

The third study investigated the effects of sire breed and individual sires within breed on belly nosing. Breed of sire affected whether nosing and sucking behaviours were generally focused or directed towards the belly of penmates. Specifically, Large White-sired pigs performed more belly nosing and belly sucking behaviour, while Duroc-sired pigs performed more generally directed nosing and sucking behaviours.

The fourth study investigated the use of 'relevant' environmental enrichment devices to further clarify the underlying motivation for belly nosing. A second objective was to investigate the provision of such enrichment at two different developmental stages to determine whether a sensitive period exists for the introduction of environmental enrichment. While providing any type of environmental enrichment during the nursery phase reduced belly nosing, providing nosing enrichment in particular had the most significant effect, despite it being the least utilized. The sensitive period for providing environmental enrichment to reduce belly nosing was found to be during the early nursery phase, within the first two weeks following weaning.

The final study investigated the thermal preference of early-weaned pigs as it relates to activity levels, huddling and belly nosing. Early-weaned pigs preferred cooler temperatures during the night, when they huddled to keep warm, and warmer temperatures during the day. Activity levels and belly nosing also demonstrated a diurnal pattern, with the highest incidence of belly nosing occurring during the transition from piglets being more active during the day to spending more time lying at night.

Belly nosing is influenced by both environmental and genetic factors. Recognizing the circumstances in which belly nosing occurs will help in designing strategies to reduce the incidence of the behaviour , while still keeping the practice of early weaning as a viable option in disease eradication programs.

ACKNOWLEDGEMENTS

To my husband, Matt Oryschak, thank you for your support and not allowing me to give up, for giving my life balance and purpose, and for sharing my belief that anything worth anything at all is worth working hard for.

With great appreciation for his patience, trust and generosity, I wish to thank my PhD advisor, Harold Gonyou. You have given me perspective in the field of animal behaviour and welfare that I have come to value very much.

I wish to thank the members of the Ethology group at the Prairie Swine Centre, both past and present, which helped with countless hours of observations, weigh days, and treatment set-ups. In particular, I extend a special thanks to Tammy Done, Yuzhi Li, Stephanie Hayne, and Thusith Samarakone.

Thank you to the Prairie Swine Centre barn staff that took all of my research in stride and provided many helpful suggestions. I especially wish to thank the barn manager, Brian Andries, and the farrowing technicians, Karen Wurtz, Marc Damant and Tatjana Ometlic.

I owe a great deal of thanks to the members of my PhD committee: Drs. Bernard Laarveld, Joe Stookey, Iain Christison, Dianne Winkleman-Sim, Phil Thacker, and Tina Widowski. I have appreciated our many in-depth discussions and thank you for all of your valuable input.

To my family back home in sunny California and to the Oryschak family, you have my eternal gratitude for your incredible love and support. Thank you for trusting my abilities, supporting my dreams, and encouraging me forward.

DEDICATION

With eternal love, I dedicate this work to my daughter, Hannah Mary Kathryn Oryschak, who was born during the final stages of writing my thesis. Hannah, you are a gift from God.

And to my mom, Sue Barling-Frye, who always believed I'd do great things in life. Your inspiration and support have carried me through many adventures, and I thank you from the bottom of my heart.

Table of Contents

LIST OF TABLES

LISTOF FIGURES

LIST OF ABBREVIATIONS

WENR	Manipulating (interacting with) environmental enrichment
Other	Other nosing and sucking behaviour
Nose	Foam rubber matting enrichment
Suck	Rubber nipple enrichment
Bite	Bite-Rite Tail Chew™ enrichment
Root	Soil-filled tray enrichment
$Variable_1$	Variable weight category (heat-controlling pen)
$Variable_2$	Variable weight category (non-heat-controlling pen)
Own	Piglets who remained with their own dam until weaning
Cross	Piglets crossfostered at 24 hours-of-age

1.0 INTRODUCTION

> The existence of individual variation in the behaviour of piglets...will arise through a combination of both innate and environmental influences. Further, environmental influences will have both immediate and chronic effects.
>
> (Webster and Jones, 1997a)

The ability to adapt to a given environment is essential to an animal's well-being. Raising pigs in a captive environment presents many challenges to the animal as well as to the caretaker. It is presumed that the wild pig taken from the natural environment, would have great difficulty coping with the challenges of the intensive environment, while the domesticated animal would fair much better. However, while breeders have artificially selected for leaner and faster growing animals, the altered genotype of these animals may have changed their ability to cope and adapt to the intensive environment in more subtle ways. The result may be that not all genotypes are equally equipped to deal with the many challenges of the intensive rearing environment. In the swine industry, some of these challenges include re-grouping with non-littermates, crowding, diet change, lack of environmental stimuli, and overall fluctuations in the environment such as temperature.

The practice of early weaning in pigs has received a considerable amount of attention over the past decade as age at weaning has steadily decreased to less than 21 days-of-age (Gonyou et al., 1998; Robert et al., 1999). In disease eradication situations, weaning age has been dropped even further to as young as 7 days-of-age in order to reduce or eliminate infection of offspring (Robert et al., 1999). In studies such as Worobec et al. (1999), it has been found that the earlier weaning occurs, the higher the incidence of behavioural vices such as belly nosing and belly sucking. Furthermore, pigs on the receiving end of such behaviour have been found to gain less weight in the grow-finish period, than their instigating counterparts (Gonyou et al., 1998). However, research investigating the behavioural consequences of belly nosing during later stages of development has not been done. Due to the oral-nasal characteristics of belly nosing, it is reasonable to investigate whether belly nosing is related to the development of other oral-nasal vices, such as belly sucking and tail biting.

The underlying motivation to perform belly nosing is not clear. The time course for belly nosing reflects a right-skewed bell-shaped curve in which the behaviour commences 3-4 days following weaning, peaks 2-3 weeks later, and then gradually declines (Gonyou et al., 1998; Worobec et al., 1999). Li and Gonyou (2002) found that piglets weaned at 12-14 days-of-age would spend an average of 2.4% of their daily time budget involved in belly nosing penmates and approximately 2.2% being belly nosed. Furthermore, 81 % of piglets early-weaned at 12-14 days-of-age will demonstrate the behaviour, with 5% of those animals showing very high levels of belly nosing in which they spend more than 8% of their total time involved in belly nosing penmates (Li and Gonyou, 2002). As a further concern, as the incidence of belly nosing increases, the incidence of belly sucking also increases, which may lead to the formation of umbilical hernias and lesions (Leibbrandt et al., 1975).

Evidence that pigs exhibit more anomalous behaviours when weaned early raises concerns about their welfare (Robert et al., 1999; Weary et al., 1999; Worobec et al., 1999). The abnormal behavioural characteristics seen in belly nosing, belly sucking and tail biting provide indirect evidence of suffering through the gradual impairment of an animal's ability to interact with its environment. However, while belly nosing and its associated behaviours may have negative consequences, such as increased maintenance energy costs or harmful physical effects, performance of the behaviour may have some benefits or may at least be reinforcing in nature. It has been suggested that belly nosing may be a substitute for the normal behaviour pattern from which it has arisen, such as a substitute for nursing at the sow's teat (Fraser, 1978; Dybkjær, 1992; Gonyou et al., 1998; Weary et al., 1999; Worobec et al., 1999). On the other hand, it may play a more general role in helping an animal to cope (Weary et al., 1999; Worobec et al., 1999).

The study of farm animal behaviour has frequently emphasized only the causal mechanisms of anomalous and commercially important behaviours seen in animals intensively raised in confined feeding operations. Fraser et al. (1995) argued that more emphasis should be given to the function or evolutionary nature of such behaviours. Many behavioural studies tend to focus more on reducing the incidence of a behaviour that has already exhibited itself, rather than preventing the aberrant behaviour from developing in the first place (Fraser et al., 1995). In order to improve the welfare of the animals under our care, it is important, if not essential, to determine what triggers the development of behavioural vices, such as belly nosing in early-weaned pigs, in addition to finding symptomatic solutions for such problems. Such behavioural investigations lend themselves to not only unraveling the complexity and multi-factorial nature of individual behaviours, but are also practical for the producer who is challenged to raise animals in a welfare friendly fashion while also being efficient and financially profitable.

The relevant literature on early weaning in pigs and belly nosing is surveyed in Chapter 2 of this thesis. The following five chapters (Chapters 3 to 7) describe studies designed to increase our limited understanding of the development and motivation to perform belly nosing in the early-weaned pig. Chapter 3 is a preliminary examination of the interaction between genetics and the environment as it affects nosing and sucking behaviours in piglets weaned at 7 days-of-age. Chapter 4 is the first detailed examination of the ontogeny of belly nosing and its related oral-nasal vices in pigs weaned at 14 days-of-age and observed until 13 weeks-of-age. Chapter 5 examines the role of genetics on the incidence of belly nosing, while Chapters 6 and 7 examine the roles of both environmental enrichment during the pre- and post-weaning stages of development and the thermal environment on the incidence of belly nosing in piglets weaned at 14 days-of-age. The eighth chapter comprises a general discussion.

1.1 Objectives

The overall objective of this series of studies was to increase our present understanding of the underlying motivation of early-weaned piglets to perform belly nosing. Within this broad purpose, the studies had several more specific objectives that included the investigation of the role of environmental as well as genetic factors on the incidence of belly nosing and its development in the early-weaned pig. It is the hypothesis of this thesis that belly nosing in the early-weaned pig has both environmental and genetic components. Specific objectives were:

i) To determine the ontogeny of belly nosing in early-weaned pigs reared in confinement as they mature from weaning to 13 weeks-of-age in a longitudinal study;
ii) To test the effect of breed of sire and sire within breed on the incidence of belly nosing in early-weaned pigs;
iii) To test the effect of environmental enrichment pre- and post-weaning on the incidence of belly nosing in early-weaned pigs;
iv) To test the effect of control over the thermal environment and sorting by weight in the early-weaned pig on huddling behaviour, activity levels, and belly nosing;
v) To determine the thermal preference of early-weaned pigs in the nursery environment and its effect on belly nosing.

2.0 LITERATURE REVIEW

2.1 Introduction

> Under modern housing conditions, farm animals frequently perform behaviours that an ethologist is inclined to describe as abnormal...these behaviours are called abnormal, because...they are virtually absent if conditions are less confined, adequate substrate is present or normal social contacts are possible.
>
> (Wiepkema, 1985)

2.1.1 Behavioural vices as a welfare concern

From an ethological perspective, the welfare of an animal is considered to be good if each of the New Five Freedoms (Webster, 1993) have been met for the environment in which an animal lives. These five freedoms include: (1) freedom from hunger, thirst or malnutrition, (2) freedom from pain, injury or disease, (3) freedom from fear and distress, (4) freedom from discomfort, and (5) freedom to express normal behaviour. Accordingly, as these freedoms become infringed upon, the development of behavioural vices can occur. For the most part, aberrant behaviours do not just “appear”, but develop over time. Due to the fact that behavioural vices are not normally observed in either a natural environment or in captive environments in which most of the five freedoms are met, they are considered abnormal and constitute a welfare concern for the animal. Furthermore, it can be argued that the abnormal and/or disintegrated characteristics of behavioural vices provide direct evidence of suffering through the gradual impairment of an animal’s ability to interact with the environment. However, it is largely unknown what motivates the performance of many behavioural vices in intensively raised livestock species, and this lack of knowledge has made it difficult to control outbreaks of these behaviours or to prevent them from occurring altogether. Furthermore, social experience may be influential, if it involves conspecifics performing behavioural vices or stereotypies. Such circumstances may act to accelerate the development of aberrant behaviours through social learning. For example, Terlouw et al. (1991) found that excessive drinking in sows developed as a result of learning the behaviour pattern of drinker pressing from neighbouring sows performing the behaviour.

Once a vice becomes more established in the behaviour repertoire of an animal, its nature can change through the emotional uncoupling of the performance of a given behaviour from its original eliciting factors (Groothuis, 1989). Behavioural vices have also been described as being 'incomplete' (van Putten, 1982; Broom, 1983) as original elements of the behaviour pattern are lost over time. The loss of specific elements may be responsible for the transition from environment-directed behaviours such as bar biting, to self-directed behaviours such as sham-chewing in tethered sows (Dantzer, 1986).

While aberrant behaviours may have negative consequences such as high maintenance energy costs or specific harmful physical effects, they may also have some benefits, or at least be reinforcing. Behavioural vices may act as substitutes for normal behaviour patterns from which they have arisen, or they may have more general roles in helping the animal to cope with its environment. The reinforcement of such behaviours may be affected by endogenous opiates, the hypothalamic pituitary adrenocortical axis, autonomic nervous system, or physiological systems responding to stress (Lawrence and Rushen, 1993).

Behavioural vices tend to occur in environments containing high levels of stress and arousal (Dybkjær, 1992). It has been suggested that the performance of such behaviours may be a way of reducing the impact of these conditions on the animal's psychological or physiological state. A change in the activity of the hypothalamo-pituitary-adrenocortical axis during the performance of behavioural vices would, therefore, be a logical consequence. However, data on the relationship between performance of stereotypies and hypothalamic pituitary adrenocortical axis activity has been inconsistent, with examples of both positive and negative effects (ex: Cronin and Barnett, 1987; von Borrell and Hurnik, 1991).

2.2 Natural Weaning

Under natural conditions, a sow and her litter will remain in or close to the nesting site from birth until about 9 days after farrowing (Jensen, 1986). In the weeks following farrowing, piglets make the transition from hiders to followers and the sow and her litter will suddenly abandon the nest site to rejoin the rest of the herd (Jensen, 1986). Piglets do not cease suckling until approximately 9-20 weeks-of-age, and continue to live in social contact with the sow for some time afterward (Newberry and Wood-Gush, 1985; Jensen, 1986; Jensen and Recén, 1989; Stolba and Wood-Gush, 1989; Gonyou, 2001). Bøe (1991) found that when sows and piglets are provided with ample bedding material in enriched pens, weaning occurs at about 11-12 weeks. In these populations, weaning is a prolonged process in which it is often difficult to determine exactly when milk transfer from sow to her offspring definitely ceases. While some authors use weaning as a term to denote the sudden break in the mother-offspring relationship, the term may be better used to describe the process leading up to the termination of lactation. Since not only milk transfer, but maternal care also declines gradually during the process, Martin (1984) suggested that weaning be defined as the period where the drop in parental investment per unit time is the largest. Furthermore, since lactation represents a significant part of the sow's care for her offspring, the termination of such care can be expected to cause the young to make considerable efforts to obtain more than the parent is prepared to provide. As a result, weaning might be expected to be a process signified by overt conflicts, such as intense begging efforts from the young, aggressive rejection from the mother, and competition for remaining milk resources by the young (as described by Trivers, 1974). However, in free-range and wild conditions, there is very little conflict behaviour, such as aggression, that is obvious during the weaning process (Jensen and Recén, 1989). Under these more or less natural conditions, there is a gradual and slow decline in maternal care and suckling with few attempts by the mother to forcefully reject her young or to show aggressive behaviour towards them (Jensen and Recén, 1989). Instead, the mother usually initiates fewer nursings, terminates more, and generally makes suckling more tedious to the young so they have to work harder to acquire the milk (Jensen and Recén, 1989; Jensen, 1995a). This is accompanied by a general decrease of milk production and milk quality as lactation continues.

Udder massage by the piglets outside of sucklings and prior to milk ejection increases during the gradual weaning process (Jensen et al., 1991). The result is an increase in the energy cost to the piglet in obtaining milk from the sow as lactation goes on. Due to the added costs, suckling behaviour initiated by piglets drops from 80-100% of the time to 40-55% (Jensen et al., 1991). As such, it can be concluded that weaning is controlled by the mother, only to the extent that she affects the energetic costs and benefits, which the young obtain from continued sucking (Jensen and Recén, 1989).

The decreased stress associated with a gradual weaning process is further aided by the environmental complexity surrounding sows and piglets reared free-range or in semi-enclosed structures in which straw and other bedding is provided (Cox and Copper, 2001). This is in stark contrast to the concrete and barren environment that is common in cases where pigs are intensively reared. Newberry (1995) has argued that the value of environmental enrichment provided to an animal should be based on the biological endpoint or outcome for the animal. Specifically, whether it increases an animal's lifetime reproductive success or inclusive fitness, or a correlate of these such as improved health. Examples of such enrichment would be providing perches or dust bathing sites to cage-reared chickens. In pigs, the provision of "biologically relevant" stimuli during lactation, reduces the proportion of suckling terminations by the sow, increases suckling duration (Herskin et al., 1999) and favours piglet survival (Herskin et al., 1998).

Weary et al. (1999) found that allowing piglets from different litters to mingle prior to weaning, provides some welfare advantages. This type of early mixing of pigs involves little conflict, provides piglets with a socially enriched pre-weaning environment, allows sows to nurse less frequently, avoids fights between piglets mixed at weaning, and results in better post-weaning weight gain and feed consumption (Weary et al., 1999). Access to environmental stimuli also has important benefits in strengthening the bond between mother and offspring. Latency to recognition of her piglets, which is an essential component of maternal bonding and responsiveness, is reduced in sows that live in more complex environments (Herskin et al., 1998).

2.3 Early Weaning

> Early weaning causes significant behavioural differences over a prolonged period...the disruptive effects of early weaning last long beyond the initial period of adaptation.
>
> (Worobec et al., 1999)

Age at weaning has steadily decreased on commercial pig farms in North America (Gonyou et al., 1998). While sows in natural or semi-natural environments will gradually wean their piglets at 9-20 weeks-of-age (Newberry and Wood-Gush, 1985; Jensen and Recén, 1989), the average weaning age of pigs in North America ranges from 21-28 days following farrowing (Robert et al., 1999). The abrupt nature of weaning in commercial pig practices can be a traumatic event due to sudden changes in diet and in the social and physical environments (Fraser et al., 1997). In early weaning, pigs are separated from the sow at even younger ages coinciding with the peak phase of the sow's lactational output. In recent years, the practice of early weaning has been combined with segregation from the sow herd in segregated early weaning (SEW; Robert et al., 1999). SEW was a practice introduced with the intent of improving disease status through colostrum immunity received by piglets at birth, as a means of avoiding vertical contamination (Robert et al., 1999). The principle behind the management practice involves removing piglets from the sow while they have passive immunity from the sow's colostrum and before the piglets themselves are infected by the pathogens from the sow (CARC, 2003). Weaning age would thereby be determined by the age corresponding to the loss of maternal immunity for a specific pathogen of concern. In offsite nursery production systems, moving piglets to another location at weaning also avoids horizontal contamination (Robert et al., 1999). Since the practice has shown promise in reducing the incidence of disease and increasing performance in the newly weaned pig, the practice of weaning pigs at less than 21 days-of-age had become more common in North America (Pettigrew et al., 1995; Robert et al., 1999; Worobec et al., 1999). However, recent research is encouraging producers to move back to older weaning ages as a means of improving wean-to-finish performance (Main et al., 2004).

It is well established that the sow's lactation curve peaks at 3-4 weeks following farrowing (Gill and Thomson, 1956), during which time piglets are highly dependent on sow milk. Therefore, abrupt weaning during this time would, in effect, be a great interference upon the behaviour and nutritional development of the young pig (Metz and Gonyou, 1990) and can be considered biologically early compared with the time that domestic pigs reared under semi-natural conditions stop suckling (Newberry and Wood-Gush, 1985; Jensen, 1988). Despite this, early weaning has become economically feasible through the use of highly palatable nursery diets, such as those containing spray-dried porcine plasma, (Ermer et al., 1994; Dritz et al., 1996) and precise thermal environmental control, which increases feed intake and provides an optimum thermal environment during the week following weaning. However, despite the potential benefits of the practice, early weaning was identified as a welfare issue when early weaning meant weaning at 28 days-of-age. In fact, the practice of weaning at less than 21 days-of-age is illegal in European Union countries due to the welfare implications (Robert et al., 1999) and is not recommended in the Canadian Code of Practice for the Care and Handling of Pigs (Ag Canada, 1993) due to the high level of management and specialized facilities required for such animals. Furthermore, the later addendum regarding the Codes of Practice for Early-Weaned Pigs has noted the practice is not without shortcomings and potential welfare risks (CARC, 2003).

Experimental evidence has shown that piglets exhibit a strong behavioural response to weaning. In particular, piglets weaned at 4 weeks-of-age or less are usually more active (Fraser, 1978; Metz and Gonyou, 1990; Bøe, 1993) and aggressive (Fraser, 1978), spend more time playing and fighting (Hohenshell et al., 2000), have difficulty lying together comfortably (Fraser, 1978), vocalize at a higher rate (Weary et al., 1999), have increased disease susceptibility (Blecha et al., 1983; Metz and Gonyou, 1990), and engage in higher levels of behavioural vices such as belly nosing (van Putten and Dammers, 1976; Fraser, 1978; Blackshaw, 1981; Bøe, 1993; Robert et al., 1999) which can lead to skin lacerations (Fraser, 1978). Furthermore, the change in the activity pattern of piglets, as a result of the abrupt changes that occur at weaning, do not stabilize for several days (Gonyou, 1987). The younger the age at weaning, the more piglets exhibit indicators of behavioural stress, such as high frequency (> 500 Hz) vocalizations (Weary and Fraser, 1997; Weary et al., 1999). Piglets weaned at less than 4 weeks-of-age engage in frequent belly massaging (nosing) and suckling of penmates (Metz and Gonyou, 1990; Bøe, 1993), and general manipulation of conspecifics (Hohenshell et al., 2000), which has been shown to persist for several weeks or longer (Bøe, 1993). Furthermore, Bøe (1993) found that pigs weaned at younger ages demonstrated increased levels of sniffing, rooting, chewing, and nibbling penmates, which resulted in lesions in both the belly and tail regions. Piglets weaned at 4 weeks had a higher frequency of massaging and sucking penmates, while piglets weaned at 6 weeks-of-age spent more time lying.

Gonyou et al. (1998) demonstrated that piglets weaned at 12 versus 21 days-of-age showed a longer delay to consumption of solid feed and had a higher incidence of anomalous behaviours. Worobec et al. (1999) also found piglets weaned at 7 days-of-age exhibited more escape attempts immediately following weaning, lower levels of exploratory behaviour, and spent less than 1% of their time at the feeder 2 days post-weaning. In contrast, piglets weaned at 3-4 weeks-of-age usually begin eating solid food within 24 hours of weaning (Metz and Gonyou, 1990). Providing early-weaned piglets with higher quality and more palatable diets (Ermer et al., 1994; Dritz et al., 1996) has helped to increase feed intake in these young pigs, which eventually surpass the weight gain of non-early-weaned contemporaries. Blecha et al., (1983) found that weaning piglets at less than 5 weeks-of-age causes physiological changes, which are detrimental to cellular immune reactivity and could alter the disease susceptibility in such young pigs. Medicated early weaner diets containing antibiotics have aided in overcoming disease susceptibility. However, the cause of the decreased immune response has remained unchanged despite the dietary improvements.

Similar to the incidence of anomalous behaviours in early-weaned mink pups (Jeppesen et al., 2000), the incidence of belly nosing in pigs is known to increase as weaning age is decreased (Metz and Gonyou, 1990; Bøe, 1993; Gonyou et al., 1998; Worobec et al., 1999). Metz and Gonyou (1990) weaned piglets at 2 and 4 weeks-of-age and found that piglets weaned at 2 weeks tended to be more active and more likely to belly nose penmates during the 7 days after weaning. This trend in the effect of age at weaning on belly nosing is supported by the findings of Bøe (1993). Despite the advances made in diets designed for early-weaned piglets (Tokach et al., 1994), studies looking at the effects of diet on indicators of behavioural stress have found that these more complex diets do not serve to reduce the incidence of belly nosing (Weary et al., 1999). Furthermore, Gonyou et al. (1998) found that piglets weaned at 12 days-of-age continued to nose and chew other piglets to a greater extent during the grow-finish period than did those weaned at 21 days-of-age. These results are supported by the findings of Worobec et al (1999), which suggest that early weaning has a significant and prolonged effect on behaviour in pigs, just as they do in other farmed species (Jeppesen et al., 2000). Algers (1984), Bøe (1993), and Worobec et al. (1999) demonstrated that these problems are exacerbated when piglets are weaned at even younger ages, becoming further aggravated when weaning conditions are unsuitable or otherwise stressful (Dybkjær, 1992). Such evidence that early-weaned pigs exhibit more anomalous behaviours raises concerns about their welfare (Robert et al., 1999; Weary et al., 1999; Worobec et al., 1999).

The piglet's pre-weaning experiences are likely to be important factors in their ability to adapt to the post-weaning environment (Cox and Copper, 2001). Piglets reared outdoors appear to have fewer problems after weaning than indoor reared piglets, exhibiting less fighting and more rooting and exploitation of solid food (Webster and Jones, 1997b; Horrell and Ness, 1998; Cox and Copper, 2001). In particular, Horrell and Ness (1998) reported a lower incidence of tail biting and belly nosing in outdoor-reared piglets. Cox and Copper (2001) found similar trends both before and after weaning, although the results were not statistically significant. In an earlier study involving only a single cohort of pigs, Cooper et al. (2000) found that indoor reared piglets exhibited belly nosing 0.32% of the time versus outdoor reared piglets that exhibited the same behaviour 0.14% of the time in the 3 weeks following weaning and mixing. The authors suggest that the difference in incidence of these behavioural vices between indoor and outdoor reared animals may be due to the effect of environmental enrichment on what piglets do while they are active.

Although there are many welfare concerns regarding the practice of early weaning in the pig (Robert et al., 1999), early weaning also involves features that may offset the negative effects already mentioned. While early-weaned pigs once experienced a growth check immediately following weaning due to decreased feed intake, improvements in diet have meant early-weaned pigs actually grow faster and eat more throughout the nursery phase than piglets reared in conventional systems (Robert et al., 1999). Likewise, the reduced exposure to infectious diseases in SEW pigs promotes an animal's well-being. This should lead us to try to find ways of maximizing the benefits of early weaning in pigs, while also reducing the harmful effects of the practice. Of major concern however, is the increased incidence of belly nosing exhibited by piglets weaned at very young ages (Gonyou et al., 1998; Worobec et al., 1999), which leads us to question whether the early-weaned pig can cope without its mother. Ethologically, we are challenged to understand what leads to an individual becoming a belly noser in order to reduce or eliminate the negative consequences associated with the behaviour. Until such solutions are found, the practice of early weaning in pigs will continue to require an extremely high level of management and specialized facilities, which have already led to standards of care practices in some countries recommending that weaning at less than three weeks-of-age not be utilized (Ag Canada, 1993).

2.4 Belly nosing

2.4.1 What is belly nosing?

> Belly nosing, like the navel-sucking performed by some early-weaned calves and lambs, closely resembles a principle component of normal suckling behaviour.
>
> (Fraser, 1978)

Belly nosing appears similar to the udder massage that occurs during the appetitive and post-consumatory phases of nursing behaviour (described by Fraser, 1980). During bouts of belly nosing, piglets frantically nose the bellies of penmates between the front and rear flanks. Metz and Gonyou (1990) have suggested that the greater total time spent belly nosing after weaning compared with the time spent massaging the sow's udder prior to weaning is possibly due to the lower incentive value of belly nosing.

The time course for the development of belly nosing in the post-weaning period has been well established, with multiple studies reporting that the behaviour commences 3-4 days after weaning, peaking approximately two weeks later, and then gradually decreasing in incidence (Gonyou et al., 1998; Worobec et al., 1999). Gardner et al. (2001a) found that belly nosing did not begin until 7 days after weaning, and Fraser (1978) found large differences in the variation of the incidence of belly nosing within and between litters in the number of days post-weaning that the vice first appeared. However, the time course laid out by Gonyou et al. (1998) and Worobec et al. (1999) is generally found to be accurate.

Due to the onset of the behaviour occurring just a few days after weaning, belly nosing is believed to be indicative of a separation problem (Gonyou, 2001). Specifically, in the absence of the sow, piglets begin directing nosing behaviour towards the belly of their littermates approximately 4 days following weaning (Blackshaw, 1981; Metz and Gonyou, 1990). Blackshaw (1981) and Gonyou et al. (1998) have also observed that not all piglets engage in belly nosing, and some pigs are more likely to be nosed than to nose others.

While the motivation for belly nosing remains unclear, Li and Gonyou (2002) recently sought to determine the temporal association of belly nosing with other behaviours in an attempt to elucidate its proximate causation. The objectives of the study were to determine the variation in belly nosing among pigs weaned at 12-14 days-of-age, and to examine the motivation for belly nosing by means of a sequential analysis of associated behaviours. The authors found that on day 7 post-weaning, piglets spent an average of 2.4% of their total time belly nosing and about the same proportion of time being nosed (2.2%). Eighty-one percent of the piglets were observed belly nosing during the study. Approximately 60% of the pigs spent 0.1-4.0% of their total time belly nosing and 19% did not show any belly nosing. About 5% of the pigs showed very high levels of belly nosing, spending more than 8% of their total time performing the activity. This suggests that there is a high level of individual variation in belly nosing, including a significant proportion of pigs that do not engage in the behaviour. Li and Gonyou (2002) also reported that bouts of belly nosing tended to last an average of 60 seconds and were often abruptly ended by the recipient of the nosing escaping or, in some cases personally observed by this author, by a third individual stepping between the initiator and the recipient.

> Belly nosing may also exert an undesirable influence on the recipient animal or on the litter as a whole...
>
> (Fraser, 1978)

Studies have not been conducted to determine how or whether individuals are specifically targeted to be victims of belly nosing. What is known is that the recipients of the behaviour sometimes grow less well (Fraser, 1978; Gonyou et al., 1998) and piglets that are subjected to belly nosing may be injured (Waran and Broom, 1993). Gonyou et al. (1998) investigated the impact of belly nosing, during the nursery phase, on the growth rates of pigs in the grow-finish phase and found that pigs which were belly nosed in the nursery phase showed slower growth rates in the grow-finish phase. Such results suggest that belly nosing in the nursery has a negative effect on performance in the later stages of development. Due to the oral-nasal characteristics of belly nosing, it is reasonable to investigate whether belly nosing is related to the development of other oral-nasal vices, such as belly sucking and tail biting.

Li and Gonyou (2002) also found belly nosing to be negatively correlated with eating and lying behaviour and positively correlated with standing, active and low-feed-intake pigs. This same type of effect is seen in other farmed species in which age at weaning strongly corresponds with the development and incidence of aberrant behaviours (Jeppesen et al., 2000).

The younger piglets are at weaning, the higher the incidence of belly nosing (Gonyou et al., 1998; Worobec et al., 1999). When piglets are weaned at 12-14 days-of-age, belly nosing may occur at two or three times the level of that of pigs weaned at 21-28 days-of-age (Gonyou et al., 1998; Worobec et al., 1999). Metz and Gonyou (1990) found that 2 week old piglets spent more time suckling than 4 week old piglets, which they attributed to the greater amount of time spent in post-massage by the younger piglets. It was hypothesized by Mees and Metz (1984) that the motivation for post-massage in these young piglets was endogenously determined since the behaviour continued despite there being no momentary milk reward.

2.4.2 Does belly nosing develop into other behavioural vices?

Whether belly nosing develops into other behavioural vices is not definitively known. However, we know from studies of the development of aberrant behaviours such as stereotypies that environmental factors that initially determine the development of an abnormal behaviour may be different from the factors that trigger or maintain already developed behavioural abnormalities later in life (Fentress, 1976; Ödberg, 1978; Mason, 1991). Studies in pigs have hypothesized there may be a link between belly nosing in the nursery and tail biting behaviour or anal massage in growing-finishing animals (Gonyou et al., 1998; Cox and Copper, 2001). An association between belly nosing with other oral-nasal behavioural vices (Breuer et al., 2001) has also been reported. These associated behavioural vices include the nosing of penmates, ear biting, and genital-anal nosing. Gonyou et al. (1998) reported that piglets weaned at 12 days-of-age continued to nose and chew other piglets to a greater extent during the grow-finish period than did those weaned at 21 days-of-age. Similar behaviour problems have been found in farmed mink, which develop more self-directed tail biting when weaned early (Mason, 1994). Similar to early-weaned piglets, early-weaned mink also exhibit a number of other long-lasting oral behaviour patterns, which are believed to be an indication of chronic stress (Mason, 1994).

It has been suggested that belly nosing has what appears to be a "socially contagious" component similar to tail biting in grow-finish pigs, which has led to the need for further investigations into whether belly nosing is related to tail biting. Tail biting behaviour, which is often seen during the grow-finish phase of development, is thought to occur in two stages (McIntyre and Edwards, 2002). Initially, the tail is held in the mouth (tail-in-mouth behaviour) without hurting the recipient. After a certain length of time, the tail may be accidentally bitten and the wound may start to bleed. This wound irritates the bitten animal causing it to move its tail, and thereby encourages further biting. Several animals may then start to chase the wounded pig intensively.

While there are many environmental and nutritional factors that have been cited as possible causes of tail biting (Gadd, 1967; Ewbank, 1973; Larson, 1983; Denton, 1984; Fraser, 1987a), the reason why some pigs develop a greater predisposition to tail bite is not as simple as it would appear. McIntyre and Edwards (2002) suggest that although factors such as reduced weight gain and inadequate protein in the diet (Fraser et al., 1991) seem to contribute to causing tail biting behaviour in a pen of pigs, there must also be other external or internal factors influencing the development of the behaviour. Some studies have suggested that when young pigs are placed into a barren environment, they quickly become restless and look for something to play with or bite at such as a penmate's tail (van Putten, 1969). Specifically, van Putten (1969) argues that the persistent, destructive tail biting seen in an outbreak of the behaviour is actually derived from the "quiet", low-intensity chewing and rooting on penmates that is observed almost universally among pigs in groups. Because pigs have a natural tendency to chew on objects in their environment, some of this behaviour is directed at other pigs. Ears and tails are the easiest to chew, but because ear chewing is likely to provoke an attack by the recipient, considerable chewing is directed toward the tails of penmates. However, a recent study by Jankevicius et al. (2004) argues that although aspects of the environment may cause animals to become restless, it does not necessarily lead to an increase in tail biting.

Overcrowding is generally recognized as a causative factor of tail biting, and group size has also been implicated in the behaviour. However, evidence for this causative link is limited and the association may be unfounded (Gonyou, 2001). To prevent tail biting, many producers clip pigs' tails soon after birth. However, this practice is widely seen as a way of masking, not rectifying, the underlying problem (Fraser, 1987a).

Studies in mink have found that individuals early-weaned at 7 weeks-of-age develop more tail biting than those left with their mothers until 6 months of age (de Jonge, 1988, 1989; Mason, 1994). This trend was seen in both male and female animals (Mason, 1994). Abnormal behaviour may to some extent be prevented and reduced by environmental enrichment (van Hoek and ten Cate, 1998). Mason (1994) suggested that young animals predisposed to tail biting might be diverted by the provision of other objects to chew, or the problem could be avoided altogether by later weaning.

A behavioural vice that has been less studied is belly sucking, which greatly resembles sheath sucking in dairy calves. Belly sucking occurs when one pig sucks on the navel area of another pig. In calves, the provision of milk replacer, particularly at higher concentrations has been found to increase the incidence of non-nutritive sucking behaviour (de Passille et al., 1997).

2.5 Motivation to Belly Nose

> Despite the clear association with early weaning, the immediate causes of belly nosing are obscure.
>
> (Fraser, 1978)

While belly nosing has become one of the primary welfare concerns regarding the practice of early weaning, the underlying motivation for belly nosing in the early-weaned piglet is not fully understood.

2.5.1 Is belly nosing motivated by hunger?

A number of hypotheses have been tested regarding the motivation to perform belly nosing. One theory suggests that belly nosing is hunger-driven due to the similarities between belly nosing and massaging the udder and suckling during nursing bouts (Fraser, 1978; Dybkjær, 1992; Gonyou et al., 1998; Weary et al., 1999; Worobec et al., 1999). Metz and Gonyou (1990) suggested that nosing littermates in younger piglets acts as a substitute for teat contact with the sow, but it is unknown whether this need for teat contact is due to hunger or desire for the comfort of the sow's udder. Interestingly, belly nosing occurs infrequently within the first few days after weaning, when the intake of solid feed is very low, but peaks at 2-3 weeks post-weaning (Gonyou et al., 1998; Worobec et al., 1999). However, evidence that hunger is not the motivating factor behind belly nosing can be found in the fact that the behaviour begins after the restoration of normal feed intake in the 1-3 days following weaning (Metz and Gonyou, 1990; Gonyou, 2001). This finding is also supported by the findings of Weary et al. (1999) who investigated the effects of diet on vocalization rate and belly nosing in early-weaned piglets. Their results showed that while piglets fed a more complex diet produced lower frequency calls (< 500 Hz) than those fed a standard diet, there was no effect of diet on the incidence of belly nosing.

In fact, the hunger hypothesis has gone largely unsubstantiated since belly nosing will occur despite feeding improved diet formulations (Tokach et al., 1994; Weary et al., 1999) and the presence of milk in the diet (Gardner et al., 2001a). While it is clear that belly nosing is of an oral-nasal nature and is similar to nursing behaviour in the pre-weaning phase of development, Gardner et al. (2001a) were unable to substantiate hunger as the underlying motivation to perform the behaviour. However, Bruni and Widowski (2004) have reported inducing belly nosing in piglets through feed restriction in pigs weaned at 18-22 days-of-age. Thus, hunger, as a possible causal factor of belly nosing, may be more complex than previously thought.

2.5.2 Is belly nosing motivated by a need for udder massage?

Belly nosing is very much like the udder massage directed towards the sow and may have some relationship to suckling behaviour (Gonyou, 2001). Fraser (1978) proposed that some of the variation in belly nosing observed within litters might possibly be associated with the animal's teat choice and suckling habits before weaning. Metz and Gonyou (1990) suggested that nosing littermates in younger piglets acts as a substitute for teat contact with the sow. Accordingly, a second hypothesis is that belly nosing reflects a motivation to massage the udder, independent of feeding and hunger, and that the delay in its development represents a learning period (Weary et al., 1999). Under this hypothesis, the proximate motivation for udder massage may be one of several factors, such as one for social contact that has been lost through the removal of the sow. While it can be argued that species such as pigs, in which the young hide in the nest during early development, would be expected to show a low response to separation of their mother, Newberry and Swanson (2001) point out that cases of prolonged separation or removal from the nest can cause great distress. As a species that bonds through affiliative behaviour, piglets derive comfort from the presence of the sow in addition to the milk and warmth that she provides. This bond between sow and offspring is stronger in younger piglets as well as in smaller litters (Newberry and Swanson, 2001).

2.5.3 Is belly nosing socially motivated?

Li and Gonyou (2002) agree with the findings of Gardner et al. (2001a) that belly nosing is not motivated by eating, but suggest that belly nosing may be socially motivated. In a study investigating the sequential analysis of belly nosing, they found that belly nosing and eating did not frequently occur in sequence, which they concluded was indicative that the motivation for belly nosing is different from that for eating. Sequential analysis of behavioural time budgets found that only social interaction led to belly nosing more often than expected. Furthermore, belly nosing frequently led to 'other' behaviour and social interaction. 'Other' served as a transitional behaviour connecting eating, drinking, and belly nosing, but was not well defined. Li and Gonyou (2002) also reported that, within pens, belly nosing was negatively correlated with lying and eating, but positively correlated with standing. This suggests that pigs that spend more time lying and eating spend less time belly nosing. However, the authors caution that the motivation for belly nosing may be different from that for eating since the two behaviours did not occur frequently in sequence. Social interaction and belly nosing frequently occurred in sequence, suggesting that these two behaviours may share common motivational factors. When only active behaviours were considered in the study, belly nosing appeared to substitute for other social behaviours during the nosing segment of bouts of belly nosing. Li and Gonyou (2002) concluded that belly nosing is more closely associated with social interaction than with eating or drinking behaviours.

Similar to the findings of Li and Gonyou (2002), Fraser (1978) also reported that behavioural problems observed among early-weaned pigs include unusually high levels of general activity and restlessness. Fraser (1978) concluded that the sudden post-weaning increase in general activity, coupled with restless behaviour when the animals lay down together, gave the impression that the piglets were uncomfortable during the first day or more after weaning. In chickens, hens that exhibit feather pecking and cannibalism have also been found to have higher activity levels (Keeling and Jensen, 1995). Due to the social nature of pigs, the social motivation theory is plausible in that social contact with other pigs, especially at very young ages, when piglets spend a majority of their daily time budget nursing and sleeping as a concerted group, may provide comfort. This may be particularly true in times of transition such as when pigs are moved from the farrowing environment to the nursery.

Another means in which the social environment may play a role in the development of behavioural vices, such as belly nosing, may be through social learning. Lewis (1999) suggested that pigs acquire expectations of their environment through the learning process. Specifically, when expectations of the environment are not met, frustration itself becomes adaptive in that it induces problem-solving behaviour to develop. Lewis (1999) also suggested that it is when these responses are unsuccessful, other behaviours, reflecting general frustration, are elicited. In her study involving grower pigs, Lewis (1999) investigated the effect of pairing pigs on their problem solving abilities and level of frustration. While she found that frustration increased general oral activity, she also found that pigs housed alone, rather than housed with another individual, divided their time differently when housed in a social setting. Lewis (1999) also found evidence that oral manipulation is transferred almost intact from feeding to oral manipulation of objects in the environment, the feeder and other pigs, which further suggests that such behavioural vices are socially transmitted.

Like other behaviour abnormalities such as feather pecking in poultry and tail-biting in growing-finishing pigs, Fraser (1978) suggested belly nosing could be socially 'contagious', thus explaining the near synchronous onset of the behaviour by members of the same litter. If so, the social transmission of belly nosing may be carried out in two ways. First, one piglet may observe the belly nosing of another individual and copy this behaviour. Social transmission has been documented in cases of feather pecking behaviour in chickens (Zeltner et al., 2000). In such situations, if the behaviour is found to be of value to that individual, then it will continue to perform the behaviour and, in turn, could provide a model for the behaviour for other individuals. Pigs that have observed demonstrators in operant activities have been shown to learn different types of behaviours (Nicol and Pope, 1994). Thus, there is the ability in pigs to acquire information from others in the transmission of new behaviour patterns within a population. Some of the practical applications of such findings include a greater understanding of the role of social learning in the spread of stereotypic (Cooper and Nicol, 1994) and other re-directed behaviours. However, Nicol (1995) noted that while it is frequently asserted that behaviour patterns such as tail biting may be copied, and despite the rapid spread of outbreaks of re-directed behaviour, there is no direct evidence that transmission is social. Instead, animals may rapidly, but individually, learn the behaviour under specific environmental conditions. Second, even a few of these belly nosing piglets could disrupt the other individuals within a nursery pen, and this disturbance may trigger an outbreak of abnormal behaviour, such as belly nosing, that disturbs the group even more, and so the cycle becomes self-perpetuating. In either case, when an offending individual targets another, the recipient may then become an attractive target for other animals in the pen to target as well (McAdie and Keeling, 2002).

2.5.4 Is belly nosing a means of coping with a stressful environment?

> An animal is said to be in a state of *stress* if it is required to make abnormal or extreme adjustments in its physiology or behaviour in order to cope with adverse aspects of its environment and management.
>
> (Fraser et al., 1975)

It has also been argued that stress can be defined by how much an animal has to work to cope with its environment:

> 'the welfare of an individual is its state as regards its attempt to cope with its environment. This state includes how much it is having to do to cope, the extent to which it is succeeding in or failing to cope, and its associated feelings.'
>
> (Broom, 1996)

Broom (1993) also proposed that based on such a definition of animal welfare, a continuum exists from very good to very poor welfare based on the incidence of an animal's attempts to cope with its environment. An example might be an animal under a condition of chronic stress, an environmental effect on an individual that overtaxes its control systems and reduces its fitness or appears likely to do so. Individuals will vary in their coping methods (Broom, 1988). Each individual animal has several alternative methods of trying to cope with adversity and individuals differ in the methods which they favour (Broom, 1988). Hessing et al. (1993) reported evidence for an active/passive coping strategy in pigs. While this classification has been criticized by some authors (Forkman et al., 1995; Jensen , 1995b), Giroux et al. (2000a) found that a passive reaction to stress in early-weaned pigs was associated with better weight gain during the first week post-weaning. The authors suggested that reacting passively to stress could facilitate adaptation to weaning based on these findings. While pigs that adopt the passive coping strategy would dissipate less energy than piglets reacting actively to stress, and thereby gain more weight, the suggestion given by Giroux et al. (2000a) does not explain why, if it is more advantageous to cope passively with the stress of weaning, piglets weaned at younger ages demonstrate more behavioural vices, an indication of an active coping strategy. Such active coping is known to be energy-expensive, which necessarily means some aspect of the performance of such behaviour must be reinforcing. However, when animals show that they are willing to work to improve their environment or adopt an active coping strategy, it is reasonable to conclude that their welfare is improved (Broom, 1988). When animals encounter stressful situations, they show a range of behavioural and physiological changes, which have the general effect of helping them to survive. Although the changes may be biologically adaptive in some situations, they do not always have beneficial effects.

Sharman et al. (1982) found that early-weaned piglets showing stereotyped snout-rubbing behaviour had a reduction in the metabolism of dopamine in parts of the brain receiving a dopaminergic neuronal input. As a result of these findings, the authors suggested that the change in the metabolism of dopamine might be associated with the separation of the piglets from the sow and may provide evidence for biochemical changes in the brain occurring as a result of early weaning. Moberg (1985) suggested that displaced behaviours, such as nibbling on a chain or other behavioural vices, appear to help the animals to cope with the psychological aspects of the stressor, and in turn alleviate some of the physiological responses. Behaviour, therefore, offers the animal an opportunity to either alleviate the stressor by removing itself from the stimulus, or to ameliorate the impact of the stressor by engaging in displacement activities. However, once an animal enters into a pre-pathological state, an animal's well-being is threatened (Moberg, 1987; 1996).

Algers (1984) investigated the hypothesis that since sucking behaviour persisted in the absence of hunger in early-weaned pigs, the sucking of penmates was due to increased concentrations of plasma corticoids as a result of frustration arising from the lack of reward in the form of mother's milk (based on work by Dantzer et al., 1978). To test this hypothesis, Algers (1984) created environments that were known to induce stress responses as a result of a lack of adequate stimuli to determine if such environments contributed to an increased motivation to perform injurious behaviour towards penmates and pen fittings. The findings of Algers (1984) agreed with those of van Putten and Dammers (1976) who observed a higher frequency of 'abnormal' behaviour and a lower frequency of 'normal' behaviour among pigs weaned at three weeks-of-age and placed in cages compared with unweaned pigs placed in boxes with bedding material. Other studies on belly nosing in early-weaned piglets have hypothesized that the behaviour is a result of trying to cope with a stressful environment (Weary et al., 1999; Gonyou et al., 1998; Worobec et al., 1999; Hohenshell et al., 2000).

Dybkjær (1992) observed that belly nosing occurred at significantly higher rates in piglets weaned with unfamiliar conspecifics in more crowded, barren environments compared with piglets weaned and grouped with littermates in pens enriched with straw. Dybkjær (1992) also reported that piglets in a barren environment are left with an unsatisfied need to explore and that penmates do not serve as a satisfactory substitute for an enriched environment. Using the 'stress' definition of Fraser et al. (1975), Dybkjær (1992) defined stress as when an animal 'is required to make abnormal or extreme adjustments in its physiology or behaviour in order to cope with adverse aspects of its environment and management'. Accordingly, Dybkjær (1992) identified belly nosing, manipulating other piglets, chewing on items in the pen, and sitting passively as behavioural indicators of stress in early-weaned pigs; behaviours she noted were exacerbated by a lack of enrichment such as bedding material. Other studies have also identified belly nosing as a key behavioural indicator of stress related to the absence of the sow in early-weaned pigs (Fraser, 1978; Dybkjær, 1992; Gonyou et al., 1998; Weary et al., 1999; Worobec et al., 1999).

However, Gardner et al. (2001b) tested whether early-weaned piglets that perform belly nosing were doing so as a means of coping with a stressful environment, and concluded that stress was not a motivating factor. More specifically, Gardner et al. (2001b) concluded that belly nosing was not a 'general' behavioural indicator of stress. However, the authors also added in their discussion that the ways in which they attempted to create varying degrees of stress (mixed litters versus littermates and high versus low density housing of pigs) may not have been effective, and therefore, piglets may not have been truly 'stressed', which led to no differences in belly nosing for any of the treatments.

The coping hypothesis found its roots in studies of stereotypic behaviour and was initially supported by three lines of evidence (reviewed by Rushen, 1993) suggesting that performance of such behavioural vices may reduce physiological responses associated with stress: (a) animals showing these types of behaviours have fewer physiological signs of stress, (b) performance of related vices appears to reduce pituitary-adrenocortical activity, and (c) opioid antagonists, such as naloxone, reduce the frequency of stereotypic behaviour, which has led to suggestions that the behaviour acted to increase endogenous opiod activity and induce a degree of analgesia in animals that performed them. However, as convincing as the arguments for the stress hypothesis theory are, some argue that it is a mistake to assume that all abnormal behaviours are a response to stress (Rushen, 1993). Citing numerous studies that do not support the coping hypothesis, Rushen (1993) concludes that there is an element of 'wishful thinking' in the evidence supporting the coping hypothesis.

One possible reason for the conflicting findings in stress motivation studies may be due to the early experience of the animal. Price (1985) proposed that the suffering or stress experienced by an animal in response to any given set of environmental circumstances may be determined directly or indirectly by some combination of factors relating to its evolutionary and ontogenic or developmental past. That is, the characteristics that an animal inherits from its ancestors and the experiences it acquires during its lifetime may have a profound effect on its ability to adapt to any existing set of environmental circumstances. Such differences in results require further studies to be conducted to investigate whether belly nosing in early-weaned piglets is motivated by stress.

2.5.5 Is belly nosing inherited?

> ...an animal will inherit from its parents a genetic potential to perform certain behaviours and a genetic predisposition for the manner in which they will be performed.
>
> (Hohenboken, 1987)

A final hypothesis that has not yet been investigated is that the motivation to perform belly nosing is heritable. While Fraser (1978) noted the large differences in the time to onset of belly nosing seen between litters, it is possible that this is the result of genetic factors. If this theory is true, then genes inherited from the parents are involved in determining the potential of an individual to develop behavioural vices such as belly nosing in environmental conditions unsuitable for that individual. If the genetic potential to perform a behaviour trait were high, then little change in the social or physical environment would cause aberrant behaviours to develop. If the genetic potential is low, it would require more environmental stimulation to invoke the development of the behavioural vice. As a general practice, early and abrupt weaning would contribute to the environmental stressors, thus making early-weaned piglets more susceptible to the development of aberrant behaviours such as belly nosing. In his review of behaviour genetics, Hohenboken (1987) reported that during the course of development, the environment in which an animal is raised often modifies or influences the behavioural expression such that the final observed behaviour usually has both a genetic and an environmental component. In a few cases, behavioural traits may be influenced entirely by genetics or entirely by the environment or early experience of an animal. If a behaviour trait can be easily measured, is heritable to some extent, and is phenotypically variable, selection can be used to reduce or eliminate the incidence of unacceptable behaviours and thereby enhance animal welfare. Belly nosing in the early-weaned pig can be easily measured through scan sampling observations and is known to be phenotypically variable (Fraser, 1978). Thus, genetic selection may be one way of successfully reducing the incidence of behaviours such as belly nosing in early weaning operations. However, the extent to which belly nosing is heritable has not been studied.

Similar to behavioural vices encountered in the swine industry, like belly nosing, feather pecking behaviour is a behavioural disorder which raises welfare concerns for domestic laying hens. Unlike belly nosing, feather pecking has been explained as the redirection of foraging behaviour (Klein et al., 2000), and strain differences in the tendency to feather peck are known to exist (Kjær, 1995; van Hierdan et al., 2002). Klein and coworkers (2000) found genetic differences in the foraging behaviour and in the way hybrid birds cope with changes from an enriched to an environment in which they were restricted from foraging possibilities. These results suggested that it was the inheritance of foraging behaviour that led to the strain differences in feather pecking behaviour, rather than the inheritance of feather pecking itself (Klein et al., 2000). Testing the general assumption that feather pecking is a heritable trait, Kjær et al. (2001) conducted a selection experiment for and against feather pecking in order to produce both high and low feather pecking lines of birds. The results were dramatic with feather pecking behaviour in adult hens being significantly higher in the high feather pecking line versus the low feather pecking line. A later study found that when high feather pecking and low feather pecking lines of birds were compared, a difference existed in the underlying motivational system controlling its development (van Hierdan et al., 2002). Furthermore, these differences in feather pecking behaviour between the high and low feather pecking lines were observed at very young ages (van Hierdan et al., 2002).

Evidence exists that some breeds of pigs are more fearful than others (Shea-Moore, 1998). Due to the similarities between behavioural vices in the nursery and behaviours observed in the pre-weaning environment, it is possible that line differences in behaviour exhibited in the early-weaned pig are apparent in the pre-weaning environment as well. In comparisons of piglets born to either Upton-Meishan or Large White sows, Farmer et al. (2001) found that Large White piglets spent more time being active at the udder at 5 and 20 days of lactation than Meishan pigs, despite Meishan sows showing better overall maternal behaviour towards their piglets than Large White sows.

Producer magazines have also cited breed or line differences in behaviour, based on observations at packing plants. Some of these citations have reported that lines with some Duroc genetics tend to be calmer, while lines with Hampshire or Peitrain genetics tend to be more nervous (Grandin, 2002). In a study investigating the use of environmental enrichment devices designed to encourage stimulus directed activities (straw rack, logs suspended in chains, and a 12 kg stone placed on the floor), Danish Landrace were found to engage in more stimulus directed activities and were more aggressive than Duroc pigs (Lund and Simonsen, 1995). Thus, the Duroc pigs were found to be calmer and less aggressive than their Landrace contemporaries. Earlier studies in extinction and avoidance responses in pigs found similar results when comparing Hampshire and Duroc pigs (Willham et al., 1964). In contrast, at least one recent study comparing Large White x Landrace and part-Meishan or part-Duroc pigs reared in either indoor or outdoor housing systems, found that a genotype by housing system interaction did not occur (Guy et al., 2002). In fact, relatively few differences in behaviour were found among the genotypes.

In addition to breed differences in pig behaviour, sire line has also been found to influence behaviour traits such as feeding behaviour (Augspurger et al., 2002). In a study comparing purebred versus a synthetic line of Peitrain grow-finish pigs, pigs sired by boars from synthetic breeds exhibited higher feed intake and lower feeder occupation times per day than those sired by the purebred boars. The results of the study highlighted the influence of genetic ancestry on the feeding patterns of grow-finish pigs that influence performance. Estimated heritabilities of learning ability were determined to be 0.45 and 0.52, and estimated narrow sense heritability for emotionality in an open field test at seven weeks-of-age was 0.16 (Willham et al., 1963; 1964). A high correlation among full-siblings (0.46) suggested that a common litter environment may have caused some similarities in the emotional behaviour among littermates (Willham et al., 1963; 1964).

2.5.6 Effects of the environment

In the absence of enriching stimuli, pigs will spend 20% of their daily activity nosing concrete and metal (Beattie et al., 1995), manipulate penmates for long periods of time (Fraser et al., 1991; Schouten, 1991), spend more time sham chewing (Haskell et al., 1995; Petersen et al., 1995), rooting (Haskell et al., 1995), interacting with the feeder, floor and pen fittings (Haskell et al., 1995; Petersen et al., 1995), and nudging and tail biting littermates (Fraser et al., 1991; Schouten, 1991; Petersen et al., 1995). It was suggested by van Putten and Dammers (1976) that this latter manipulation of penmates may be redirected rooting behaviour. Day et al. (1996) found that grower pigs gather nutritional information in their environment through chewing behaviour, which may explain the significant amount of time spent "mouthing" the pen and penmates, especially in more barren environments. However, it is unclear whether chewing behaviour reflects feeding motivation, exploratory motivation, or a combination of both (Day et al., 1995).

Barren environments have long been implicated in the development of adverse behaviours, and this has led to many studies focusing on the provision of environmental enrichment. According to Newberry (1995), appropriate environmental enrichment is defined as 'an improvement in the biological functioning of captive animals resulting from modifications to their environment'. A fundamental problem with many studies involving environmental enrichment is that they mistake environmental complexity for environmental enrichment. It has been argued that increasing the complexity of the environment presents animals with many conflicting choices (Newberry and Estevez, 1997). In contrast, biologically 'relevant' environmental enrichment fulfills the animal's motivation to perform behaviours, and can thereby reduce the incidence of vices more effectively (Newberry, 1995; Morrow-Tesch and McGlone, 1997). Even very simple means of environmental enrichment have been found to reduce the development of abnormal oral behavioural vices (Wûrbel et al., 1998), and in some cases are preferred to more complex ones (Jones et al., 2000).

Bøe (1993) found that the unenriched post-weaning environment has a major influence on the frequency of abnormal behaviours in weaned piglets. In studies of tail biting behaviour, it has been demonstrated that while the underlying motivation is still not understood, enriching the environment with destructible objects has proved successful in reducing tail biting in the grow-finish phase (Feddes and Fraser, 1994). In some cases, providing substrates such as straw (Bure et al., 1983), branches (Peterson et al., 1995), peat (Beattie et al., 1995), and mushroom compost (Beattie et al., 2001) has also worked well. Stolba and Wood-Gush (1981) found that pigs in these types of enriched environments spent approximately 33% of daylight hours performing rooting behaviour. Petersen et al. (1995) also found that pigs housed in pens enriched with straw, logs and branches spent more time rooting, biting and chewing the provided material, while pigs housed in barren environments spent more time rooting, biting and chewing the floors and walls of their pen. These findings suggest that environmental enrichment that promotes exploration and is an "outlet" for oral activities may be the most effective means of re-directing oral vices away from pen fittings and penmates in order to improve animal well-being. Kelly et al. (2000) found that pigs housed in systems incorporating straw, such as the Straw-Flow™ system, showed behaviour patterns associated with increased welfare relative to those housed in barren pens. Specifically, pigs provided with straw demonstrated more straw-directed behaviour and less pig-directed and pen-directed behaviour. Cox and Cooper (2001) found that early-weaned pigs raised outdoors, in a rich and complex environment, fought less, were more likely to consume solid food, and spent less time exhibiting belly nosing than pigs reared indoors in a barren pen environment.

Some studies have concluded that the provision of an enrichment device such as a soft, pliable, rubber dog toy can reduce the expression of aggressive and stereotypic behaviours commonly associated with confinement (Apple and Craig, 1992). However, the effectiveness and success of such enrichment relies upon its ability to reinforce a motivated behaviour. In the case of oral vices such as tail biting, the provision of chains is unlikely to have any long-term effect on the behaviour because pigs quickly habituate to their presence. Rau and Duncan (1999) found that the provision of trough-anchored blind teats (nipples) did not have an effect on feed intake, water use, and growth in piglets weaned at 14 days-of-age. In contrast, Day et al. (2002a) found that destructible objects will remain the subject of exploratory behaviour for longer durations as they remain novel when the pig interacts with such types of enrichment. Reixach et al. (2001) provided newly weaned pigs with trace mineral salt blocks to determine whether oral-nasal behaviours directed at penmates were motivated by both behavioural and nutritional influences. They concluded that the use of mineral salt blocks might reduce the predisposition to perform some types of harmful social behaviours and promote ingestive behaviour. However, the findings related to ear biting, tail biting, and belly nosing were found not to be significant. It is possible that any differences in the performance of such behaviours in animals provided with the mineral blocks may have been more the result of the destructibility of the blocks, thereby keeping them novel, than anything else. Even simple devices or very small changes to the environment can have a significant impact on the development of behavioural vices.

Furthermore, the thermal environment is known to have large effects on the health and productivity of growing swine. This is especially critical in the case of newly weaned piglets, which require warmer temperatures in the nursery environment (this is due to a lack of subcutaneous fat and a higher surface area to body weight ratio). Recommendations for ambient temperatures in the pig barn are based on experiments and calculations, which give single values for each class of pigs, but do not consider special management techniques or programs such as early weaning (Brumm et al., 1985; Christison, 1988).

In the recently weaned piglet, behavioural patterns facilitate the pig's thermoregulatory capacity (Curtis and Morris, 1982). Huddling behaviour and the selection of a comfortable environment are two known strategies for animals in cooler temperatures to find the warmth needed. However, today's confined pigs are often prevented from selecting their optimal temperature. During cold weather, nursery temperatures are frequently kept relatively uniform over space and constant over time. This approach deprives young pigs of the chance to select an environment more comfortable than the one chosen by the swine manager. However, the barn manager must minimize fuel use in pork production in order to increase profit. As a result, the need to conserve fuel costs is often in direct conflict with increased animal welfare due to thermal comfort.

When kept in a thermal environment that is chronically too cool for the pig's preference, physiological and behavioural consequences begin to take effect. Growth and meat quality decrease (Lambooy, 1988) while huddling behaviour increases (Boon, 1981; 1982) as a means of coping with the thermally stressful environment. Likewise, animals kept at constant high temperatures do not grow as well as a result of reduced feed intake (Le Dividich et al., 1982). Heat stressed pigs decrease feed intake in order to reduce metabolic heat production and maintain homeothermy, and this results in slower growth (Kouba et al., 2001). Furthermore, chronic exposure of growing pigs to a high ambient temperature has been found to enhance lipid metabolism in both the liver and the adipose tissue which facilitates plasma triglyceride uptake and storage in the adipose tissue which results in heat stressed pigs being fatter (Kouba et al., 2001). When ambient temperatures are either too high or too low, studies have found that the maximal growth of early-weaned pigs fed milk replacer cannot be supported due to average daily gain, average daily feed intake, and gain to feed ratios being affected (Heo et al., 1999).

Baldwin and Ingram (1968) demonstrated that pigs could learn through operant conditioning to adjust their thermal environment during cold periods by performing a task in which heat serves as the reward. Specifically, it was reported that individually reared pigs showed a frequency of operant responses for a 3-second burst of infrared heat that was inversely proportional to environmental temperature. Balsbaugh and Curtis (1979) found similar results for pigs treated differently in two respects, the pigs were reared in groups, instead of housed alone, and they were given much longer infrared heat rewards of 1, 3, or 6 minutes. These results suggest that operantly controlled supplemental heat might be feasible in swine production systems. Curtis and Morris (1982) conducted two experiments to test such feasibility and found that group-reared 4 week old pigs (in a large nursery situation) learned to operate a switch in order to obtain a 10-minute reward of heat from 4 supplemental infrared heat lamps, which also turned on a natural gas-fired unit heater for 8 minutes. The heat lamps suspended above an operant switch were used to ensure immediate reward so the conditional response would be reinforced psychologically. The results showed that the performance and general health of these pigs were comparable to those of animals produced in commercial nurseries. Standard housed pigs gained an average of 0.38 kg per day, while those in the operantly controlled environment gained 0.39 kg per day. The gain to feed ratio was 0.50 for both treatments. These results are in agreement with later work by Morrison et al. (1987, 1989a). In addition, the pigs proved to be much more efficient in fuel usage than conventionally housed pigs. A 53% saving in fuel was found in the operant-controlled environment over all trials. Furthermore, the fuel savings increased as the outside air temperature decreased. For the trial conducted during the coldest weather, there was a 73% saving of fuel.

Baldwin and Ingram (1968), Balsbaugh and Curtis (1979), and Curtis and Morris (1982), and Morrison et al. (1989a) all found that pigs preferred to have a lower temperature at night and chose to huddle to keep warm (Baldwin and Ingram, 1968). Increases in general activity in the barn during the day may help to explain some of the difference in the amount of heat demanded between day and night periods. These diurnal temperature preferences may, in fact, reflect the maintenance of diurnal cycles of activity and metabolism as pigs evolved in outdoor thermally fluctuating environments (Christison, 1988).

An increasing number of scientists have claimed that control over events in the environment is important to animals (Mineka et al., 1986; Wiepkema, 1990; Markowitz and Line, 1991). However, in intensive farming systems, animals have little or no control over important elements in their environments, such as temperature. As a result of such low levels of environmental control over important events, it has been argued that welfare is reduced in the intensively farmed animal by increasing its passivity and stress (Taylor et al., 2001). This has led to suggestions that the welfare of farm animals could be improved by allowing them control over certain environmental stimuli (Wiepkema, 1990; Appleby and Hughes, 1993; Farm Animal Welfare Council, 1993). Animals allowed to work for feed and other rewards are reported to be physically and psychologically healthier than animals maintained under standard husbandry conditions, where opportunities to control the environment are limited (Markowitz and Woodworth, 1978; Mineka et al., 1986). Jones and Nicol (1998) studied the effect of control of the thermal environment on the well-being of growing pigs 4 - 6 weeks-of-age. Pigs with operant control over their thermal environment were less active and showed a tendency to lie more than pigs in the yoked or standard husbandry treatments. Furthermore, the proportion of lying time that pairs spent huddling together was significantly greater in the operant control group than the yoked group. The standard housed pigs spent the least amount of time huddled together of the three groups, suggesting they enjoyed the greatest thermal comfort.

Wiepkema (1987) argued that increased stress associated with uncontrollable and/or unpredictable stimulation may increase the likelihood of redirected behaviour, which may function in stress reduction and coping. Evidence for this view remains controversial, but Wiepkema's argument would predict a lower incidence of redirected behaviours such as belly nosing and tail biting in pigs with the ability to control their environment either through operant conditioning or otherwise. However, Jones and Nicol (1998) did not find this to be the case concerning the thermal environment of growing pigs. They concede it is possible that beneficial effects may exist when pigs have a greater total duration of exposure to control or when they have exposure to control at some critical age. Because the period of treatment imposition was only two weeks in the Jones and Nicol (1998) study, it may have been insufficient or have been provided at the wrong stage of development for differences to become apparent. Some have argued that the most beneficial effects of control occur during the acquisition of control rather than during repeated execution of acquired control (Sambrook and Buchanan-Smith, 1997). If this is the case, then the period of treatment imposition in the Jones and Nicol (1998) study was too long. The final possibility is that there are no general effects of control, but rather effects of control over specific reinforcers. Authors involved in the various studies agree that more research needs to be conducted on the benefits achieved by providing control over aspects of the environment.

In conclusion, the abundance of speculation about the potential causes of belly nosing in the early-weaned pig, combined with relatively few studies investigating specific motivating factors influencing the behaviour, suggests more possible avenues for research into the area of belly nosing in pigs than it is possible to practically include in a single doctoral program. While some major recurring themes about causation have been investigated, and are apparent from the preceding literature review, others have been largely neglected, such as the role of genetics and some specific aspects of the environment, including sensitive periods for enrichment and the role of temperature preference and thermal control. The following chapters were designed to examine these areas in more detail.

3.0 EFFECT OF ENVIRONMENTAL ENRICHMENT AND BREED LINE ON THE INCIDENCE OF BELLY NOSING IN PIGLETS WEANED AT 7 DAYS-OF-AGE: A PRELIMINARY STUDY

3.1 ABSTRACT

The incidence of nosing and sucking behaviour was studied in 291 piglets weaned at 7 days-of-age. Pigs ranged from 17-30 days-of-age at the time of observation. Piglets were fed a liquid milk replacer diet for either 7 or 14 days following weaning, at which time they were switched to a dry pelleted diet. Pen environment was enriched by providing either an air-filled inner tube (Tube), rubber nipples in the feed trough (Nipple), or neither (Control). Pens were segregated by sex with 14-16 pigs per pen. Within pens, there were both Duroc and Yorkshire pigs. Instantaneous scan sampling by two observers, at 5-min intervals, was used to determine the mean percentage of time piglets spent belly nosing and belly sucking, as well as nosing and sucking other parts of the body for 8-hours (ie. 192 scans per observation day) on two consecutive days. An analysis of variance was performed with diet, environmental treatment and sex in the main plot, and breed line as a sub-plot. Neither length of liquid milk replacer nor gender affected any of the behaviours. Nipple enrichment reduced the percentage of time spent belly sucking (1.10%) compared with Tube enrichment (3.12%) and the Control (4.12%) treatment ($P=0.027$). Nipple enrichment also reduced the total amount of sucking (1.57%) compared with Tube enrichment (3.46%) and the Control treatment (4.75%; $P<0.01$). Yorkshire line pigs engaged in more belly sucking (3.97 vs. 1.59%; $P<0.01$), total sucking (4.30 vs. 2.21%; $P=0.017$), and belly-directed behaviour (9.2 vs. 6.21%; $P=0.089$) than did the Duroc line pigs. Significant breed line by environmental enrichment interactions were present for several variables. Nipple enrichment effectively reduced the level of belly sucking, overall sucking and belly-directed behaviours in the Yorkshire line pigs, while Tube enrichment reduced other nosing and oral-nasal vices directed away from the belly in the Duroc line pigs. It was concluded that breed line differences may affect the incidence of nosing and sucking behaviours in early-weaned

pigs, which may be reduced through the use of environmental enrichment tailored to the specific behavioural vices being performed.

3.2 INTRODUCTION

Studies have repeatedly shown that belly nosing is the most common behavioural vice exhibited by early-weaned pigs, and as weaning age decreases, the incidence of belly nosing increases (Gonyou et al., 1998; Worobec et al., 1999). Furthermore, the effect of early weaning on behaviour persists well into the grow-finish phase of development (Gonyou et al., 1998; Worobec et al., 1999).

Similar to the naval sucking observed in calves and lambs, belly nosing resembles a principle element of normal suckling behaviour (Fraser, 1978). Specifically, belly nosing appears similar to the massage of the sow's udder that occurs during the appetitive and post-consumatory phases of nursing behaviour (described by Fraser, 1980) prior to weaning. As a result of these apparent similarities, some researchers have hypothesized that the behaviour results from premature separation from the sow (Weary et al., 1999; Worobec et al., 1999). While the underlying motivation to perform belly nosing is not clear, the similarity of belly nosing to the udder massage phases of suckling suggests that the motivation to perform belly nosing is related to hunger. However, belly nosing does not commence until a few days after weaning, by which time the piglets are eating adequate amounts of solid feed, and nosing reaches its highest incidence 2-3 weeks later (Gonyou et al., 1998; Worobec et al., 1999). Gardener et al. (2001a) also provided evidence disputing hunger as the root cause of belly nosing in the early-weaned pig. However, in calves, de Passillé et al. (1997) reported that the provision of milk replacer, particularly at higher concentrations, actually increased the incidence of non-nutritive suckling behaviour.

One possible explanation for the delay in the development of belly nosing is provided by Weary et al. (1999) who suggested that belly nosing reflects a motivation to massage the udder, independent of feeding and hunger, and that the delay in its development represents a learning period. Under this hypothesis, the proximate motivation for udder massage may include the need for social contact that has been lost through the removal of the sow. Dybkjær (1992) observed that belly nosing occurred at significantly higher rates in piglets weaned with unfamiliar conspecifics in more crowded, barren environments compared with piglets weaned in littermate groups in pens enriched with straw.

Among members of the same litter and between litters, there is considerable variation in the incidence of belly nosing as well as in the amount of time it takes for the behaviour to commence following weaning (Fraser, 1978; Li and Gonyou, 2002). Li and Gonyou (2002) studied the temporal association of belly nosing with other behaviours in an attempt to identify the proximate cause of the behaviour. The authors found that the social environment can have a profound effect on the incidence of belly nosing, possibly explaining some of the variation in belly nosing observed between litters. However, while a majority of the research has investigated the role of the environment on belly nosing, breed as a source of variation has not been investigated.

The objectives of this study were to determine the influence of breed line and environmental enrichment, simulating components of the sow's udder, on the incidence of belly nosing and its associated behaviours in pigs early-weaned at 7 days-of-age, and to further examine the effect of milk replacer supplementation and gender on these behaviours. Specifically, it is hypothesized that the interaction between breed line and environmental enrichment influences belly nosing in the early-weaned pig.

3.3 MATERIALS AND METHODS

3.3.1 Facilities and Animals

The study was conducted in a nursery room at BioSearch in St. Andrew, Manitoba on October 30th and 31st of 1999. The room was ventilated using a negative pressure system and heated to 32-34°C with a natural gas heater. Fans and heaters for the room were controlled by thermostat in order to maintain a comfortable thermal environment for the pigs. All pens were made of durable plastic penning and tribar flooring. Lighting was provided on a 12-hour cycle, turned on at 07:00 and turned off at 19:00h.

The incidence of belly nosing and belly sucking, as well as other nosing and sucking behaviours were observed in 291 piglets, weaned at 7 days-of-age, sorted according to gender (males: n=9, female: n=10), and housed in 24 pens. Five pens had to be removed from the study due to health. Each pen of 14-16 pigs contained pigs of both Yorkshire and Duroc lines. The numbers of Yorkshire and Duroc piglets per pen were approximately equal. At the time of observation, pigs ranged from 17-30 days-of-age (10-23 days following weaning). Prior to the study, piglets had been kept with their mother in a single sow farrowing crate, without environmental enrichment.

Upon weaning, pen environment was modified by providing either an air-filled black rubber inner-tube (Tube; n = 6; Figure 3.1), eight rubber baby bottle nipples anchored vertically in the feed trough (Nipple; n = 6; Figure 3.2; based on work by Rau, 2002), or neither (Control; n = 7). Enrichment was placed in the center of each pen. Piglets in each enrichment treatment group received commercial liquid milk replacer for either 7 (n = 9) or 14 (n = 10) days following weaning, and were then switched to a standard pelleted diet for early-weaned piglets. Piglets receiving Nipple enrichment, continued to have nipples anchored vertically in the pellet feeder, once on solid feed. Thus, the study included 12 treatment combinations (each with an n = 1 or 2), with all treatment combinations distributed evenly across the wide age range at the time of observations.

3.3.2 Observation Techniques

Instantaneous scan sampling by two observers, at 5-min intervals, was used to determine the mean percentage of time piglets spent belly nosing and belly sucking, as well as other nosing and sucking for 8-hours (from 08:00 to 16:00h; ie. 192 scans per observation day) for two consecutive days. Prior to the scan sampling, both observers determined the definitions of belly nosing and belly sucking, as well as other nosing and sucking through a series of practice sessions conducted at the Prairie Swine Centre, Inc., Saskatoon, SK in order to avoid observer bias during the two-day experimental observations (Table 3.1). The observers recorded the number of piglets in each breed

Figure 3.1. Diagram of Tube enrichment used to simulate the smooth surface of the sow's mammary area.

Figure 3.2. Diagram of the Nipple enrichment used to simulate the nipples of the sow (based on work by Rau, 2002).

Table 3.1. Behaviours observed during the two-day preliminary study.

Observed behaviour	Definition
Belly nosing	Nose of one piglet actively rooting at the belly region, between the front and rear flanks, of another piglet.
Other nosing	Nose of one piglet actively rooting at a region other than the belly of another piglet.
Belly sucking	Mouth of one piglet actively sucking on the belly region, between the front and rear flanks, of another piglet. This behaviour involves the instigator taking the skin of the belly of the recipient into its own mouth as part of the sucking behaviour.
Other sucking	Mouth of one piglet sucking at a region other than the belly of another piglet. This behaviour involves the instigator taking the skin of the region other than the belly into its own mouth as part of the sucking behaviour.
Total nosing	Includes both belly nosing and other nosing behaviours
Total sucking	Includes both belly sucking and other sucking behaviours
Total belly	Includes both belly nosing and belly sucking behaviours,
Total other	Includes both other nosing and other sucking behaviours.

engaged in each of the mutually exclusive behaviours within each pen. The breed of the recipients was not recorded.

3.3.3 Statistical Analysis

A Kolmogorov-Smirnov test was conducted using the Univariate procedure of SAS (SAS Institute Inc., 2000) to test for normality of the data. All data were found to be normally distributed.

The effects of breed line (Yorkshire or Duroc), gender (barrow or gilt), duration of liquid milk replacer supplementation (7 vs. 14 days), and type of environmental enrichment (Tube, Nipple, or Control) were tested using the General Linear Model (GLM) procedure of SAS with duration of liquid milk replacer, environmental enrichment and gender in the main plot, and breed line as the sub-plot (Appendix A). For all analyses, the experimental unit for the main plot was the pen. A Bonferroni means separation test was also performed. Belly nosing, belly sucking and other nosing and sucking were expressed as the total percentage of time spent performing the behaviour. The total percentage of time spent nosing was defined as the sum time spent belly nosing and other nosing. Total percentage of time spent sucking was defined as the sum time spent belly sucking and other sucking. Total percentage of time spent engaged in behaviour directed at the belly was defined as total percentage of time spent belly nosing and belly sucking, while total percentage of time spent engaged in behaviour directed at regions other than the belly was defined as the total percentage of time spent conducting other nosing and sucking (Table 3.1).

3.4 RESULTS

3.4.1 Effect of gender and milk replacer

Gender (Table 3.2) and duration of liquid milk replacer (7 vs 14 days; Table 3.3) did not have any significant effect on any of the behaviours observed. Likewise, no significant interaction was found between these two parameters.

Table 3.2. Effect of gender on the mean percentage of time (± SE) spent performing nosing and sucking behaviours directed at the belly and other regions of penmates.

	Barrow	Gilt	SE	P-value
Belly nosing	4.15	5.09	0.75	P>0.10
Belly sucking	2.01	3.39	0.56	P>0.10
Other nosing	2.69	3.03	0.29	P>0.10
Other sucking	0.565	0.667	0.097	P>0.10
Total nosing	7.19	7.78	0.93	P>0.10
Total sucking	2.57	4.06	0.56	P>0.10
Total belly	6.16	8.48	1.24	P>0.10
Total other	3.36	3.60	0.27	P>0.10

Table 3.3. Effect of duration of liquid milk replacer diet (7 versus 14 days) on the mean percentage of time (± SE) spent performing nosing and sucking behaviours directed at the belly and other regions of penmates.

	7 days	14 days	SE	P-value
Belly nosing	4.43	4.93	0.78	P>0.10
Belly sucking	2.94	2.63	0.58	P>0.10
Other nosing	2.72	2.96	0.30	P>0.10
Other sucking	0.63	0.62	0.10	P>0.10
Total nosing	7.15	7.89	0.97	P>0.10
Total sucking	3.57	3.25	0.58	P>0.10
Total belly	7.37	7.56	1.30	P>0.10
Total other	3.35	3.58	0.28	P>0.10

3.4.2 Effect of breed line

Breed line was found to have a significant effect on a number of the behaviours which were observed (Table 3.4). Specifically, while breed line did not significantly affect belly nosing (P>0.10) or total nosing (P>0.10) behaviours, it was found to significantly affect other nosing (P<0.01) with Duroc piglets observed performing nosing behaviour 3.64% of the time compared with 1.83% in Yorkshire pigs. Similarly, Duroc pigs also had a higher incidence of other sucking behaviour (0.626%) compared with Yorkshires (0.33%; P=0.042). As a result, Duroc pigs also exhibited higher overall levels of total other behaviours (4.27%) in contrast to Yorkshire pigs that only spent 2.16% of their time performing generalized behaviours (P<0.001). Yorkshires tended to exhibit more total belly-directed behaviours (9.2%; P=0.089) and engaged in significantly higher levels of total sucking (4.30%; P=0.017) behaviours than Duroc pigs (6.21% and 2.21%, respectively). Likewise, Yorkshire pigs also spent more time engaged in belly sucking behaviour (3.97%) than Durocs (1.59%; P<0.01).

3.4.3 Effect of environmental enrichment

Environmental enrichment devices (Nipple vs. Tube) used to simulate components of the sow's udder environment were also found to have a significant effect on a number of the behaviours observed (Table 3.5). Providing some type of environmental enrichment did not significantly reduce the incidence of belly nosing (P>0.10), other sucking (P>0.10), or total nosing (P>0.10) behaviours. Piglets not provided with any enrichment (Control) had the highest incidence of belly sucking (4.12%), other nosing (3.18%), total sucking (4.75%), total belly (9.7%), and total other (3.81%) behaviours compared with pens which received either the Nipple or Tube enrichments. Providing Tube enrichment significantly reduced the incidence of other nosing (2.00%; P=0.027) and total other behaviours (2.34%; P=0.021) compared with Nipple enrichment (3.02% and 3.49%, respectively). However, Nipple enrichment had a significant effect on reducing the incidence of belly sucking (1.10%; P=0.014) and total sucking (1.57%; P<0.01) behaviours compared with Tube enrichment (3.12% and 3.46%,

Table 3.4. Effect of breed line on the mean percentage of time (± SE) spent performing nosing and sucking behaviours directed at the belly and other regions of penmates.

	Yorkshire	Duroc	P-value
Belly nosing	5.25 ± 0.81	4.62 ± 0.54	P>0.10
Belly sucking	3.97 ± 0.60	1.59 ± 0.40	P<0.01
Other nosing	1.83 ± 0.31	3.64 ± 0.21	P<0.01
Other sucking	0.33 ± 0.11	0.626 ± 0.071	P=0.042
Total nosing	7.1 ± 1.0	8.26 ± 0.67	P>0.10
Total sucking	4.30 ± 0.60	2.21 ± 0.40	P=0.017
Total belly	9.2 ± 1.3	6.21 ± 0.90	P=0.089
Total other	2.16 ± 0.29	4.27 ± 0.20	P<0.001

Table 3.5. Effect of environmental enrichment consisting of Nipple or Tube on the mean percentage of time (± SE) spent performing nosing and sucking behaviours directed at the belly and other regions of penmates.

	Nipples	Tube	Control	P-value
Belly nosing	3.49 ± 0.89	5.71 ± 0.98	5.59 ± 0.67	P>0.10
Belly sucking	1.10 ± 0.66^{b}	$3.12 \pm 0.73^{a,b}$	4.12 ± 0.50^{a}	P=0.01
Other nosing	3.02 ± 0.35^{a}	2.00 ± 0.38^{b}	3.18 ± 0.26^{a}	P=0.027
Other sucking	0.47 ± 0.12	0.34 ± 0.13	0.63 ± 0.88	P>0.10
Total nosing	6.5 ± 1.1	7.7 ± 1.2	8.78 ± 0.84	P>0.10
Total sucking	1.57 ± 0.66^{b}	$3.46 \pm 0.73^{a,b}$	4.75 ± 0.50^{b}	P<0.01
Total belly	4.6 ± 1.5^{b}	8.8 ± 1.6^{a}	9.7 ± 1.1^{a}	P=0.072
Total other	3.49 ± 0.32^{a}	2.34 ± 0.35^{b}	3.81 ± 0.24^{a}	P=0.021

Includes Bonferroni means separation results (means with same letter superscript along same row are not significantly different).

respectively). Providing Nipple enrichment also tended to reduce the incidence of total belly-directed (4.6%; P=0.072) behaviours compared with Tube enrichment (8.8%).

3.4.4 Breed line and environmental enrichment interactions

Significant breed line by environmental enrichment treatment interactions were observed for several variables. While Yorkshire pigs were found to exhibit a higher incidence of belly sucking (6.5%) behaviour compared with Duroc pigs (1.7%) under Control conditions, providing Yorkshire pigs with Nipple enrichment significantly reduced the incidence of the behaviour (1.0%; P=0.033) compared with Tube enrichment (4.4%; Figure 3.3a) in the Yorkshire line. Similarly, Yorkshire pigs were also found to engage in more total sucking (7.0%; Figure 3.3b) and belly-directed behaviours (13.7%; Figure 3.3c) compared with Duroc pigs (2.5% and 5.8%, respectively) under Control conditions. Providing Nipple enrichment was effective in reducing the incidence of total sucking to 1.3% (P=0.036) and total belly to 3.6% (P=0.054) in Yorkshire pigs, levels similar to those observed in the Duroc pigs (1.8% and 5.6%, respectively).

In contrast, for other nosing (Figure 3.3d) and total other behaviours (Figure3.3e), in which Durocs (3.5% and 4.3%, respectively) and Yorkshires (2.8% and 3.3%, respectively) did not differ under Control conditions, providing either Tube or Nipple enrichment tended to be effective in reducing the incidence of these behaviours in Yorkshire pigs. However, Yorkshire line pigs given Tube enrichment tended to spend less time performing other nosing (0.5%; P=0.099) and total other (0.7%; P=0.071) behaviours, compared with Yorkshires provided with Nipple enrichment (2.1% and 2.5%, respectively).

However, for total nosing behaviour (Figure 3.3f), in which Durocs and Yorkshires did not differ under Control conditions (7.6% and 10.0%, respectively), providing either Tube or Nipple enrichment tended to be effective in reducing the incidence of generalized nosing behaviour in Yorkshire pigs. Providing Nipple enrichment had the greatest effect of reducing overall nosing behaviour (4.7%; P=0.097) compared with Tube enrichment (6.5%).

Figure 3.3. Interaction between breed line and pen enrichment on the mean percentage of time (± SE) spent performing nosing and sucking behaviours directed at the belly and other regions of penmates.

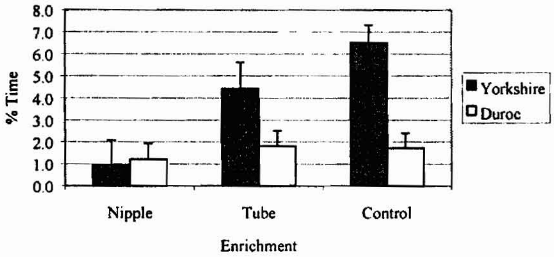

Figure 3.3a. Belly sucking behaviour (P=0.033).

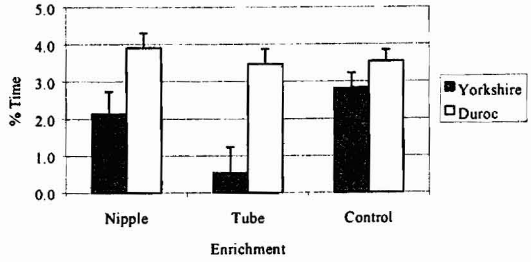

Figure 3.3d. Other nosing behaviour (P=0.099).

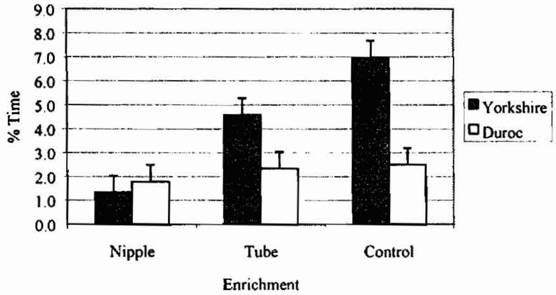

Figure 3.3b. Total sucking behaviour (P=0.036).

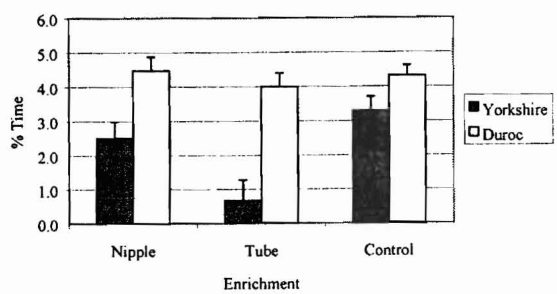

Figure 3.3e. Total other behaviour (P=0.071).

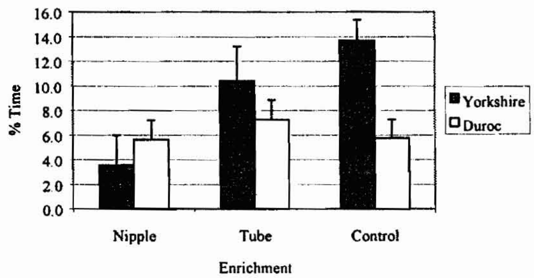

Figure 3.3c. Total belly behaviour (P=0.054).

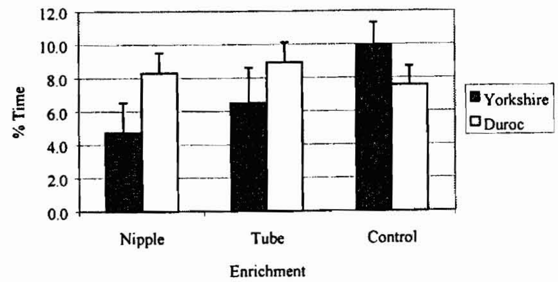

Figure 3.3f. Total nosing behaviour (P=0.097).

3.4.5 Other interactions

Aside from interactions between breed line and environmental enrichment, interactions between gender and environmental enrichment as well as duration of liquid milk replacer supplementation and breed line were found. The interaction between gender and environmental enrichment was found to have a significant effect on other sucking behaviour (Figure 3.4; P=0.016). Specifically, males were found to exhibit a higher incidence of other sucking behaviour in both the Control (0.3%) and Tube (0.6%) enrichments compared with females (0.1% and 0.1%, respectively). However, the incidence of other sucking behaviour was almost equally as high in both genders when provided with Nipple enrichment (male = 0.4%; female = 0.5%). Similarly, the interaction between duration of liquid milk replacer supplementation and breed line also tended to have an effect on other sucking behaviour (Figure 3.5). In this case, both Duroc and Yorkshire pigs exhibited equally high levels of other sucking behaviour when milk replacer was provided for seven days following weaning (0.6% for both breed lines). However, providing milk replacer for an additional seven days significantly reduced the incidence of other sucking behaviour in Yorkshire pigs (0.1%) compared with Duroc pigs (0.7%; P=0.064). No other significant interactions were found.

3.5 DISCUSSION

Duration of milk replacer supplementation was not found to be a significant contributor to the development of nosing and sucking behaviours in the early-weaned pig. These findings agree with Gardner et al. (2001a) who concluded that belly nosing was not hunger motivated. Gender was also found not to have a significant influence on the development of oral-nasal behavioural vices in the early-weaned pig.

In general, piglets of the Yorkshire line spent more time performing sucking and belly directed behaviours, including belly sucking, than did Duroc pigs. In contrast, Duroc pigs exhibited higher levels of nosing and sucking behaviours directed away from the belly of penmates. While the immediate reasons for the significant difference in behavioural

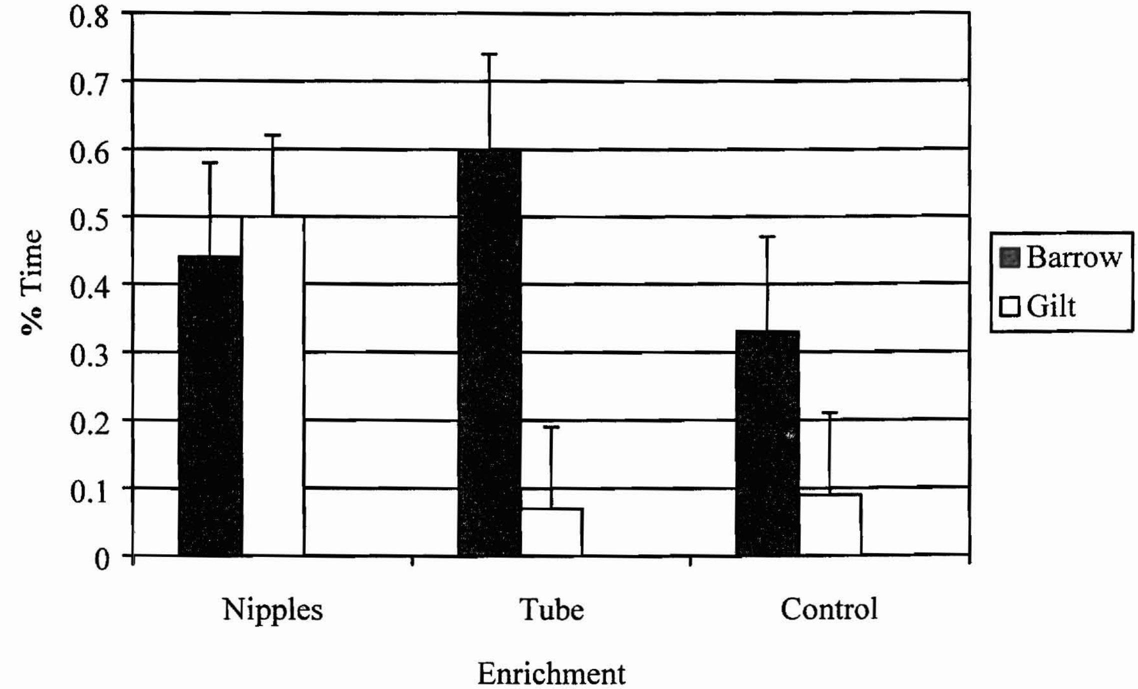

Figure 3.4. Interaction between gender and type of environmental enrichment on mean percentage of time (± SE) spent performing other sucking behaviours directed at regions other than the belly of penmates (P=0.016). For all gender by enrichment treatments, n=3, with exception of gilts in the control enrichment treatment, which had n=4.

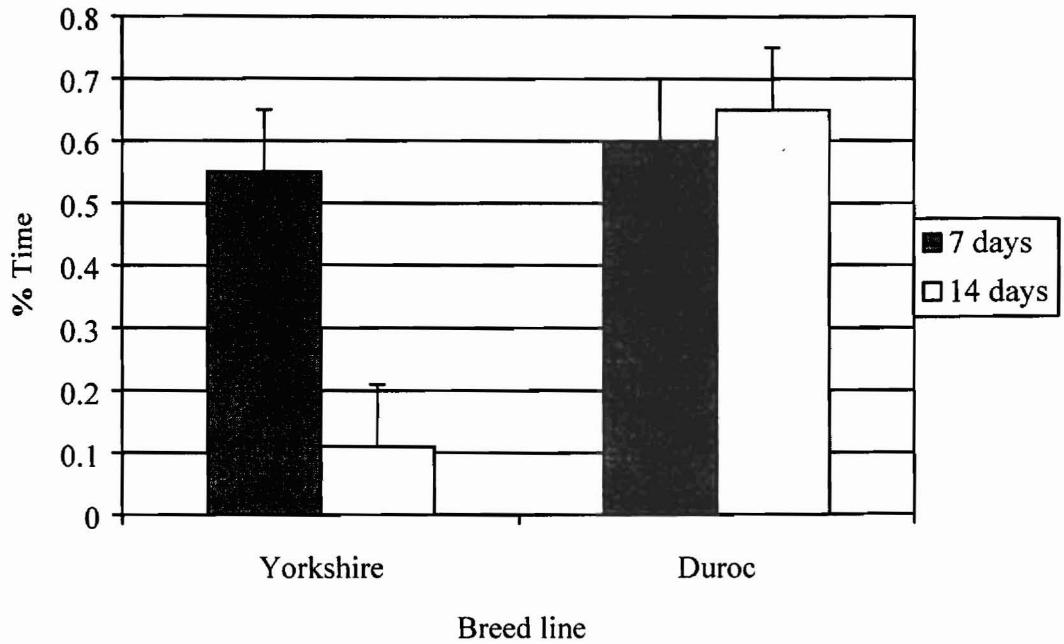

Figure 3.5. Interaction between duration of liquid milk replacer (7 vs. 14 days) and breed line on mean percentage of time (± SE) spent performing other sucking behaviours directed at regions other than the belly of penmates (P=0.064).

vices observed in these two breed lines are not apparent, it may be due in part to genetic selection. The Yorkshire breed, similar to the Large White, is popular for use as a maternal line in commercial herds due to its prolificacy and excellent maternal instincts (Briggs, 1983). In contrast, the Duroc breed was selected for its heavy carcass production and makes particularly good sires, although Duroc males have been known to be aggressive (Briggs and Briggs, 1980). In selecting for these varying qualities in these two breeds, behavioural vices or the tolerance for them may have been inadvertently selected for as well.

Many studies have supported the provision of environmental enrichment to pigs as a means of reducing and/or eliminating behavioural vices, including tail biting in the grow-finish phase of development. The results of this study support such findings. The results revealed that providing environmental enrichments, which simulate the nipples and smooth surface of the sow's mammary area, were effective in reducing the incidence of oral-nasal behavioural vices associated with belly nosing. In this case, providing nipples, anchored in milk replacer troughs and dry feeders, was effective in reducing sucking and belly-directed behaviours, including belly sucking, while providing air-filled inner tubes was effective in reducing more generally focused behaviours, such as nosing behaviour directed away from the belly of penmates. While the pigs may have been motivated to seek manipulative objects, these findings may also support the hypothesis of Weary et al. (1999) that the underlying motivation to perform belly nosing in the early-weaned pig is to seek comfort. In this case, if piglets seek comfort from the belly region specifically, the presence of nipples may be the determining factor in whether that need is met. Likewise, if piglets seek comfort in general, then the provision of an inner tube may meet this need better than providing nipples, since it allows the piglets to pile up with one another in the center of the tube. As such, those pigs that seek comfort in general may be more socially motivated than piglets that seek comfort from the belly region specifically.

The most interesting finding in the study involves the interaction between breed line and environmental enrichment. Both breed lines differed little under Control conditions when it came to other nosing, total nosing, and total other behaviours.

However, Yorkshire pigs were much more responsive to the provision of either Nipple or Tube enrichment than the Duroc pigs when it came to these specific behaviours. In contrast, Yorkshires exhibited higher levels of belly sucking, total belly and total sucking behaviours compared with Duroc pigs under Control conditions, but were again found to be very responsive to enrichment. In comparison with Yorkshire pigs, Duroc pigs consistently demonstrated lower levels of these same behaviours, despite the enrichment treatment. As such, it appears that breed line not only affects the types and incidence of oral-nasal behavioural vices performed, but also how responsive animals are to the provision of environmental enrichment. Furthermore, the types of environmental enrichments that work in one breed line may not necessarily work in another breed line. The findings also suggest that not all behavioural vices observed in early-weaned piglets respond to Nipple and Tube enrichment.

Of particular interest is how tailored an environmental enrichment treatment needs to be to reduce a specific behavioural vice. In this study, the Nipple treatment was found to reduce the incidence of behavioural vices that involved sucking behaviour and were belly-directed. This makes sense, since the sow's teats are located at her belly and stimulate sucking behaviour. In contrast, the Tube treatment was found to reduce the incidence of behaviours directed away from the belly. In this case, such types of generalized behaviours may be effectively reduced through the provision of a large surface that provides some sort of resistance suitable for redirected nosing behaviour or huddling in groups. Again, this would make sense, given that piglets are commonly observed sleeping next to the sow's udder, particularly after a nursing bout, as well as next to one another, thigmotactically.

In addition to breed by environmental enrichment interactions, two other interactions were found. Both interactions were found to be significant for generalized sucking behaviour only. The first interaction occurred between gender and type of environmental enrichment. Females of both breeds demonstrated lower levels of other sucking behaviour than did males. However, when provided with Nipple enrichment, the incidence of other sucking behaviour significantly increased among females. This leads to the question of whether some types of enrichment actually encourage the development of behavioural vices in some populations. In this case, does providing Nipple enrichment to females stimulate sucking behaviour? Another interesting observation was made regarding the interaction between the duration of liquid milk replacer supplementation and breed line. Both the Yorkshire and Duroc lines exhibited similar levels of other sucking behaviour when given liquid milk replacer for one week following weaning. However, when given milk replacer for an additional week, Yorkshire piglets showed a greater reduction in the incidence of the behaviour than piglets of the Duroc line. One possible explanation for this may be that piglets within the Duroc breed have a higher genetic predisposition to exhibit other sucking behaviour than piglets in the Yorkshire breed, and this predisposition cannot be easily overcome through the provision of milk replacer alone. Interestingly, providing Duroc pigs with Tube enrichment was also ineffective at reducing the incidence of other sucking behaviour.

3.6 CONCLUSIONS

Both breed line and providing environmental enrichment to piglets weaned at 7 days-of-age were found to affect the incidence of oral-nasal behavioural vices related to belly nosing. Differences between breed lines were found in the types of behavioural vice performed and whether these vices were generally focused or directed at specific regions of the body of penmates. Specifically, Yorkshire pigs performed more belly-directed and sucking behaviours, including belly sucking behaviour, while Duroc pigs performed more generally directed nosing and sucking behaviours.

Providing environmental enrichment simulating the sow's udder was effective in reducing the incidence of oral-nasal vices compared with early-weaned piglets that received no enrichment (Control). However, enrichment devices were specific in the types of behavioural vices they effectively alleviated. Providing piglets with Tube enrichment reduced the incidence of behaviours directed away from the belly of penmates, including general nosing behaviour, while providing piglets with Nipple enrichment was effective in reducing the incidence of sucking and belly-directed behaviours, including belly sucking. Significant breed line by environmental enrichment interactions were found, with Yorkshire pigs being much more responsive to environmental enrichment than Duroc pigs.

These findings suggest that breed line differences may affect the incidence of nosing and sucking behaviours in early-weaned pigs, which may be reduced through the use of environmental enrichment tailored to the specific behavioural vices being performed. Based on the results of this preliminary study, a larger and more comprehensive examination of the incidence of nosing and sucking behaviours in early-weaned pigs of different genetic lines and various environmental settings is warranted.

4.0 ONTOGENY OF BELLY NOSING IN PIGS WEANED AT 14 DAYS-OF-AGE: A STUDY FROM WEANING TO 13 WEEKS-OF-AGE

4.1 ABSTRACT

As age at weaning decreases, belly nosing and other oral-nasal behaviours, such as nosing, chewing and sucking on penmates, are known to increase. Furthermore, belly nosing in the nursery has been found to have lasting effects on growth as well as the frequency of nosing and chewing penmates into the grow-finish phase of development. The objective of this study was to investigate the incidence and frequency of belly nosing and belly sucking behaviour in early-weaned pigs as these behaviours relate to other oral-nasal behaviours, including tail biting, in both the nursery and grow-finish phases. Piglets sired by Duroc (n = 120) and Large White (n = 122) boars were weaned at 14 days-of-age and observed at 18, 23, 28 and 50 days-of-age for belly nosing, belly sucking, other nosing and other sucking behaviours during the nursery phase of development using instantaneous scan sampling. Additionally, pigs were observed during the grow-finish phase at 63 and 91 days-of-age for belly nosing, belly sucking, other nosing, other sucking, tail biting and other biting behaviours, also using scan sampling. Continuous observations done live at 21 and 35 days-of-age were used to determine mean belly nosing and belly sucking bout lengths. Belly nosing was found to commence within four days of weaning, peak in incidence at 23-28 days-of-age and gradually decrease thereafter ($P<0.001$). Belly sucking behaviour was found to increase with age ($P<0.001$) with the highest incidence of the behaviour occurring during the grow-finish phase. Belly nosing and belly sucking bout durations were also found to increase with age ($P<0.01$ and $P<0.001$, respectively), with belly nosing bouts lasting an average of 17.5 (21d) to 27.3 (35d) seconds compared with mean belly sucking bouts of 22.6 (21d) to 58.1 (35d) seconds. While belly nosing is a vice commonly thought of as a nursery phase problem, the results of this study suggest that its associated oral-nasal vices continue to rise in incidence into the latter stages of development, which raises welfare concerns for early-weaned pigs into the grow-finish period.

4.2 INTRODUCTION

In the past twenty years, various studies have reported that piglets show a strong behavioural response to weaning (Weary and Fraser, 1997; Gonyou et al., 1998; Worobec et al., 1999). Specifically, studies found that piglets become more active, exhibit a higher rate of vocalizing, and begin to engage in behavioural vices, such as belly nosing, upon weaning (Fraser, 1978; Blackshaw, 1981; Robert et al., 1999). The current practice of weaning before three weeks-of-age was developed to exploit the health benefits from the passive disease resistance acquired by piglets from suckling colostrum (Robert et al., 1999). However, the practice of early weaning involves the abrupt severance of the mother-young bond, an abrupt change in diet, and depriving the offspring of the opportunity to perform suckling behaviour at an age when they are highly motivated to perform this comforting behaviour (Newberry and Swanson, 2001). Furthermore, Gonyou et al. (1998) reported that piglets early-weaned at 12 versus 21 days-of-age show a longer delay to consumption of solid feed, and exhibit a higher incidence of anomalous behaviours. Gonyou et al. (1998) also found that piglets weaned at 12 days-of-age continue to nose and chew other piglets to a greater extent during the grow-finish period compared with piglets weaned at 21 days-of-age. Various studies have reported that the incidence of behavioural vices, such as belly nosing, increase as the age at weaning decreases (Metz and Gonyou, 1990; Gonyou et al., 1998; Worobec et al., 1999), and are further aggravated when weaning conditions are unsuitable or stressful (McKinnon et al., 1989; Dybkjær, 1992). Similar behaviour problems have been found in farmed mink, which develop more tail biting when weaned early (Mason, 1994). Similar to early-weaned piglets, early-weaned mink also exhibit a number of other long-lasting oral behaviour patterns, which are believed to be an indication of chronic stress (Mason, 1994).

The time course for the development of belly nosing in the post-weaning period has been well established, with multiple studies finding that the onset of the behaviour occurs 3-4 days after weaning, peaks approximately two weeks later, and then gradually decreases in incidence (Gonyou et al., 1998; Worobec et al., 1999). Due to the onset of the behaviour occurring just a few days after weaning, belly nosing is believed to be indicative of a separation problem (Gonyou, 2001). Specifically, in the absence of the sow, piglets begin directing nosing behaviour towards the belly of their littermates approximately four days following weaning (Blackshaw, 1981; Metz and Gonyou, 1990). Blackshaw (1981) and Li and Gonyou (2002) have also observed that not all piglets engage in belly nosing, and some pigs are more likely to be nosed than to nose others. Gonyou et al. (1998) investigated the impact of belly nosing during the nursery phase on the growth of pigs in the grow-finish phase and found that pigs, which were belly nosed in the nursery phase, showed slower growth in the grow-finish phase. Such results demonstrate that belly nosing in the nursery has a negative effect on performance in the later stages of development. However, research investigating the behavioural consequences of belly nosing into the grow-finish phase of development has not been done. Due to the oral-nasal characteristics of belly nosing, it is reasonable to investigate whether belly nosing is related to the development of other oral-nasal vices, such as belly sucking and tail biting. Belly sucking and tail biting are often observed during the grow-finish phase of development and are well-documented welfare concerns encountered by swine producers (Fraser, 1978).

Fraser (1978) observed that, like other behaviour abnormalities such as tail biting in growing pigs, belly nosing may be 'contagious', thus explaining the near synchronous onset of the behaviour by members of the same litter. However, Nicol (1995) noted that while it is frequently asserted that behaviour patterns such as tail biting may be copied, and despite the rapid spread of outbreaks of redirected behaviour, there is no direct evidence that transmission is social. Instead, animals may rapidly, but individually, learn the behaviour under specific environmental conditions. The earlier findings of studies associating belly nosing with other oral-nasal behavioural vices (Breuer et al., 2001) such as nosing penmates, ear biting, genital-anal nosing, and belly nosing, in addition to suggestions that belly nosing has what appears to be a "socially contagious" component similar to tail biting, lead to the need for further investigations into whether belly nosing is correlated with other behavioural vices, including tail biting behaviour.

The first objective of this study was to investigate the ontogeny of belly nosing, and its associated oral-nasal behavioural vices, in piglets early-weaned at 14 days-of-age, through behaviour observations carried out during the nursery and grow-finish phases of development. A second objective of this study was to determine whether belly nosing is correlated to other oral-nasal behavioural vices that develop at later stages of development, such as tail biting.

4.3 MATERIALS AND METHODS

4.3.1 Facilities and Animals

The study was conducted at the Prairie Swine Centre, Inc., Saskatoon, SK, between May, 2001 and March, 2002. Twenty-four litters were observed (over 2 blocks of 12 litters per block), with an average of 10-11 piglets per litter. Blocks were composed of two farrowing groups, each farrowing a week apart from one another. A total of 242 piglets from the 24 litters were the focus of behaviour observations from weaning to 13 weeks-of-age. All animals were fed nutritionally balanced diets *ad libitum* and kept in a climate appropriate for the age and weight of the pigs throughout the study.

All piglets used in the study were born to PIC-Camborough 15 strain sows with 120 of the piglets born to purebred Duroc (PIC line 3) and 122 piglets born to purebred Large White (PIC line 280) sires. Three sires from each breed line were used. Fresh semen from each sire was obtained from Carlo Genetics (Ste. Anne, Manitoba), tested for transmittable diseases, shipped via air to the Prairie Swine Centre, and stored at 15-17°C until use. To minimize the age spread of piglets, five ml of PG600® (Intervet, Millsboro, Delaware) was administered intramuscularly four days prior to the first breeding of each sow in order to synchronize estrus. Each sow was bred to the same boar on two consecutive days corresponding with behavioural estrus.

Two to three days prior to farrowing, sows were washed and moved into tubular steel farrowing crates (2.0 m x 0.8 m). Farrowing pen floors were plastic-coated expanded metal (Tenderfoot®, Tandem Products Ltd., Blooming Prairie, MN). In both blocks, sows were housed in one of four rooms. Each farrowing room had a capacity of seven sows and their litters. To further control for the age spread of piglets, two ml Planate™ (Schering-Plough Animal Health) was administered intramuscularly to sows the day before expected farrowing in order to insure that all sows farrowed within a 12-hour window.

Within 24-36 hours of birth, piglets were crossfostered between litters within their own sire (Price et al., 1994). Five piglets from each litter were randomly selected and kept with their own sow, while the remaining 5-6 piglets in each litter were crossfostered from another sow. The average size of these resultant litters was 10-11 pigs per litter. Crossfostering was used as a means of controlling for maternal effects on piglet behaviour and performance. No milk replacer or creep feed was provided at any point during the pre-weaning phase.

At 14 days-of-age, all piglets were weaned and moved as intact litter groups into the nursery. Two identical nursery rooms of six pens, each (1.5 m x 1.5 m) equipped with Tenderfoot® flooring and durable plastic side paneling, were used for each block. Each nursery pen was equipped with a trough feeder large enough for four piglets to eat simultaneously. Two nipple drinkers were provided at the rear of each pen. Piglets remained in the nursery for six weeks, at which time they were again moved as intact groups to four identical grow-finish rooms. Within each grow-finish room, six litter groups were housed in pens (3.6 m x 4.8 m) with fully slatted concrete flooring and solid plastic side paneling. Within each grow-finish pen, two single space dry feeders were placed in the right and left front corners. Two nipple drinkers were located along the rear wall of the pen.

4.3.2 Observation Techniques

For all observations, piglets were individually identified through back markings (nursery phase) and ear tags (grow-finish phase) and observed within each pen. During the nursery phase of development, both instantaneous scan sampling and continuous observations were used. Instantaneous scan sampling of individual pigs in a pen, by four observers at 5-min intervals, was used to determine the mean percentage of time spent belly nosing, belly sucking, other nosing, and other sucking (Table 4.1) for 8-hours (ie. 96 scans per observation day) at 18, 23, 28, and 50 days-of-age (4, 9, 14, and 36 days following weaning). Continuous observations by three observers (one per two pens) were also conducted at 21 and 35 days-of-age (7 and 21 days following weaning), for 4-hours each observation day, to determine the mean time (in seconds) spent per belly nosing and belly sucking bout.

Table 4.1. Behaviours observed during the nursery and grow-finish phases.

Observed behaviour	Definition
Belly nosing	Nose of one piglet actively rooting at the belly region, between the front and rear flanks, of another piglet.
Other nosing	Nose of one piglet actively rooting at a region other than the belly of another piglet.
Belly sucking	Mouth of one piglet actively sucking on the belly region, between the front and rear flanks, of another piglet. This behaviour involves the instigator taking the skin of the belly of the recipient into its own mouth as part of the sucking behaviour.
Other sucking	Mouth of one piglet actively sucking at a region other than the belly of another piglet. This behaviour involves the instigator taking the skin of the region other than the belly into its own mouth as part of the sucking behaviour.
Tail biting	Mouth of one piglet actively chewing on or having the tail of another piglet in its mouth.
Other biting	Mouth of one piglet actively chewing on or having a part of the body other than the tail of another piglet in its mouth.

During the grow-finish phase, instantaneous scan sampling, at 5-minute intervals, was used to determine the percentage of time spent belly nosing, belly sucking, other nosing, other sucking, tail biting, and other biting (Table 4.1) for 8-hours (ie. 96 scans per observation day) at 63 and 91 days-of-age (7 and 11 weeks following weaning). Continuous observations were not utilized during the grow-finish phase.

4.3.3 Statistical Analysis

A Kolmogorov-Smirnov test was conducted using the Univariate procedure of SAS (SAS Institute Inc., 2000) to test for normality of the behaviour data. Behaviour data for belly sucking, other nosing, other sucking, and other biting were square root transformed and tail biting behaviour data were transformed using square root plus one, to obtain a normal distribution, prior to statistical analysis. For clarity purposes, data provided in tables has not been transformed.

Belly nosing, belly sucking, other nosing, other sucking, tail biting and other biting behaviours were compared using the pen as the experimental unit (Appendix B.1). Behaviour data were first analyzed using the covariance feature provided with the GLM analysis in SAS, in order to obtain a pooled estimate of regression based on the 24 pens observed in the study. Data were tested to determine if changes with age were the same for all pens. No interaction between age and pens was found.

Behaviour data, using the pen as the experimental unit, were then analyzed as a split-plot over time model provided with the GLM and MIXED analyses for repeated measures (Appendix B.2) in SAS, with pen in the main plot and age in the sub-plot. Age was defined as days-of-age. For the MIXED procedure in SAS, age was used as the fixed variable, while pen was used as the random variable. A Bonferroni means separation test was performed for age.

Using the individual as the experimental unit, partial correlations between behaviour data at different ages were examined to determine whether belly nosing in the nursery was correlated to other behavioural vices during the nursery or grow-finish period, using the residuals from the GLM analysis of variance, with the MANOVA procedure of GLM (Appendix B.3).

Bout length and mean number of bouts for belly nosing and belly sucking behaviour at 21 and 35 days-of-age, using the pen as the experimental unit, were analyzed as a split-plot over time model provided with the GLM analysis for repeated measures in SAS, with pen in the main plot and age in the sub-plot (Appendix B.4). A Bonferroni means separation test was performed for age.

4.4 RESULTS

4.4.1 Ontogeny of belly nosing

The normal time course for belly nosing was observed with the behaviour presenting itself at approximately four days following weaning (at 18 days-of-age), peaking by 28 days-of-age, and gradually decreasing as animals spent a smaller percentage of their daily time budget engaged in the behavioural vice (Table 4.2; $P<0.001$). At its peak, at 28 days-of-age, piglets spent an average of 5.42% of their daily time budget belly nosing penmates. While the mean number of bouts did not significantly differ between 21 and 35 days-of-age, mean belly nosing bout duration was significantly higher at 35 d (27.3 ± 2.4 seconds) versus 21 d (17.5 ± 2.4 seconds) of age ($P<0.01$; Table 4.3). While belly nosing was never observed to disappear completely, the mean percentage of time spent engaged in the behaviour dropped off significantly into the grow-finish phase, with pigs spending an average of 0.86% of their daily time budget belly nosing at approximately 91 days-of-age.

4.4.2 Ontogeny of belly sucking behaviour

Piglets were found to spend less than 1.0% of their daily time budget involved in belly sucking behaviour (Table 4.2). While the behaviour was observed at four days after weaning (at 18 days-of-age), piglets only performed the behaviour an average of 0.10% of their daily time budget. However, as the piglets grew older, the incidence of the behavioural vice was found to increase into the grow-finish phase ($P<0.001$), with piglets exhibiting belly sucking behaviour an average of 0.95% of their daily time budget by 91 days-of-age. Mean belly sucking bout length increased between 21 (22.6 ± 6.6 seconds) and 35 days-of-age (58.1 ± 6.6 seconds; $P<0.001$; Table 4.3). Likewise, the mean number

Table 4.2. Mean percentage of daily time budget per pig spent performing belly nosing, belly sucking, tail biting, other nosing, other sucking, and other biting at 18, 23, 28, 50, 63, and 91 days-of-age.

	Age (days)							
	18	23	28	50	63	91	SE	P -value
Belly nosing	1.52^{b}	4.12^{a}	5.42^{a}	1.76^{b}	1.35^{b}	0.86^{b}	0.35	P < 0.001
Belly sucking	0.10^{c}	0.30 ^{b,c}	0.30 ^{b,c}	0.70 ^{a,b}	0.76 ^{a,b}	0.95^{a}	0.13	P < 0.001
Tail biting	-	-	-	-	0.352	0.549	0.083	P>0.10
Other nosing	2.29^{b}	2.99 ^{a,b}	3.10 ^{a,b}	2.40^{b}	4.23^{a}	4.30^{a}	0.38	P < 0.001
Other biting	1.59 ^{a,b}	1.81^{a}	1.47 ^{a,b}	0.91^{b}	1.53 ^{a,b}	1.89^{a}	0.19	P < 0.01
Other sucking	0.0	0.0	0.1	0.6	0.4	4.3	1.3	P>0.10

Includes Bonferroni means separation results (means with same letter superscript along same row are not significantly different). Statistical analysis performed on transformed data, while data in table reflects non-transformed values. Tail biting was not measured days 18 through 50 (denoted as --).

Table 4.3. Mean bout durations and mean number of bouts of belly nosing and belly sucking behaviour observed at 21 and 35 days-of-age.

	Age (days)			
	21	35	SE	P -value
Belly nosing bout duration (sec)	17.5	27.3	2.4	P < 0.01
Belly sucking bout duration (sec)	22.6	58.1	6.6	P<0.001
Belly nosing bouts (#/4 hr.)	100	70	14	P>0.10
Belly sucking bouts (#/4 hr.)	2.9	7.1	1.2	P=0.024

Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

of belly sucking bouts per pen also increased from 21 (2.9 bouts) to 35 (7.1 bouts) days-of-age (P=0.024; Table 4.3).

4.4.3 Tail biting behaviour during grow-finish phase

Tail biting behaviour was observed only during the grow-finish phase of development. By the first week in grow-finish (at 63 days-of-age), pigs were already found to be involved in tail-in-mouth behaviour, and spending an average of 0.352% of their daily time budget chewing on the tails of penmates (Table 4.2). Mid-way through the grow-finish period (at 91 days-of-age), the incidence of tail biting behaviour had risen, although not significantly, to an average of 0.549% of the daily time budget per pig (P>0.10). Interestingly, while tail biting is believed to be a common problem during the grow-finish phase, pigs were observed to spend the lowest percentage of time per day engaged in the behaviour, compared with the other behavioural vices also observed. No pigs were taken off-test due to tail bites during the course of this study.

4.4.4 Ontogeny of generalized behaviours

Four days following weaning, when pigs were 18 days-of-age, other nosing and other biting behaviours were observed at higher incidences than belly nosing, with piglets spending an average of 2.29% of their daily time budget on other nosing behaviour, and 1.59% on other biting behaviour (Table 4.2). Piglets were found to consistently spend 2-3% of their day engaged in other nosing behaviour during the nursery phase of development and 4.23 – 4.30% during the grow-finish period (P<0.001). In contrast, while other biting behaviour varied in incidence from day to day, the mean percentage of time spent performing the behaviour remained between 0.91 – 1.89% of the daily time budget per pig (P<0.01).

4.4.5 Correlation of behaviours

Tables 4.4 through 4.8 show the results of the partial correlation matrix used to determine whether belly nosing in the nursery was correlated to other

Table 4.4. Residuals correlation matrix (r-value and significance level) for belly nosing (BN) and belly sucking (BS) behaviours at 18, 23, 28, 50, 63, and 91 days-of-age.

	Belly nosing						Belly sucking					
	BN18	BN23	BN28	BN50	BN63	BN91	BS18	BS23	BS28	BS50	BS63	BS91
BN18	1.000	0.196**	0.056	-0.043	0.141*	-0.037	0.284***	0.190**	0.127†	-0.118	0.108	0.016
BN23		1.000	0.219**	0.053	0.005	0.038	0.128†	0.168*	0.089	0.019	0.106	0.019
BN28			1.000	0.188**	0.188**	0.253***	0.002	0.128†	0.196**	0.143*	0.121†	0.137*
BN50				1.000	0.275***	0.252***	-0.059	0.006	-0.043	0.195**	0.253***	0.236***
BN63					1.000	0.243***	0.044	-0.008	-0.011	0.104	0.370***	0.201**
BN91						1.000	-0.072	0.007	0.024	-0.035	0.126†	0.231***
BS18							1.000	0.275***	0.291***	0.107	0.185**	0.009
BS23								1.000	0.195**	-0.015	0.122†	0.141*
BS28									1.000	0.128†	0.166*	0.023
BS50										1.000	0.290***	0.249***
BS63											1.000	0.303***
BS91												1.000

(† = 0.10 < P < 0.05; * = P < 0.05; ** = P < 0.01; *** = P < 0.001)

Table 4.5. Residuals correlation matrix (r-value and significance level) for other nosing (ON) behaviour compared to belly nosing (BN) and belly sucking (BS) behaviours at 18, 23, 28, 50, 63, and 91 days-of-age.

	Other nosing					
	ON18	ON23	ON28	ON50	ON63	ON91
BN18	0.076	0.009	-0.021	0.059	0.083	0.040
BN23	0.074	0.166*	0.035	-0.017	-0.033	-0.102
BN28	-0.062	0.072	0.054	-0.057	-0.201**	-0.003
BN50	0.078	-0.105	-0.045	0.131†	-0.080	-0.073
BN63	0.027	-0.027	-0.143*	0.030	0.103	-0.035
BN91	-0.014	-0.034	0.027	0.003	0.044	0.084
BS18	-0.006	0.024	-0.134*	-0.111†	0.010	-0.021
BS23	-0.007	-0.027	-0.028	-0.059	-0.100	-0.056
BS28	0.059	0.096	-0.027	-0.066	-0.143*	0.006
BS50	-0.009	0.003	0.042	0.059	-0.075	0.007
BS63	-0.099	-0.008	-0.170*	0.021	-0.085	0.011
BS91	0.010	-0.066	0.013	0.019	-0.052	0.053
ON18	1.000	0.049	0.197**	0.009	0.001	0.037
ON23		1.000	0.028	0.035	0.052	0.059
ON28			1.000	0.027	-0.007	0.036
ON50				1.000	0.101	0.092
ON63					1.000	0.254***
ON91						1.000

(† = 0.10 < P < 0.05; * = P < 0.05; ** = P < 0.01; *** = P < 0.001)

Table 4.6. Residuals correlation matrix (r-value and significance level) for other sucking (OS) behaviour compared to belly nosing (BN), belly sucking (BS), and other nosing (ON) behaviours at 18, 23, 28, 50, 63, and 91 days-of-age.

	Other sucking					
	OS18	OS23	OS28	OS50	OS63	OS91
BN18	-0.124†	0.029	0.007	0.000	-0.098	0.002
BN23	0.134*	0.069	-0.124	-0.174**	-0.013	-0.045
BN28	0.074	0.040	-0.045	0.047	-0.138*	0.077
BN50	-0.072	-0.071	0.044	-0.005	-0.094	-0.034
BN63	-0.034	-0.033	0.018	0.027	-0.067	0.014
BN91	0.015	0.020	0.030	-0.003	-0.049	0.030
BS18	-0.092	0.000	0.103	-0.054	-0.003	-0.031
BS23	-0.038	-0.027	0.138*	-0.003	-0.028	-0.057
BS28	-0.009	-0.006	0.057	-0.106	-0.104	0.108
BS50	-0.000	0.000	0.073	-0.066	-0.007	-0.091
BS63	-0.027	0.017	-0.045	-0.014	-0.080	0.034
BS91	-0.043	0.114†	0.169*	0.007	-0.083	0.009
ON18	-0.130†	-0.018	0.014	0.006	0.022	0.079
ON23	0.062	0.149*	-0.039	-0.076	0.012	0.079
ON28	0.005	0.023	-0.028	-0.053	-0.010	0.031
ON50	-0.076	0.056	0.068	0.113†	0.069	0.059
ON63	-0.044	0.034	0.104	0.047	0.204**	0.070
ON91	-0.145*	-0.042	0.035	0.036	0.035	0.182**
OS18	1.000	0.000	0.000	0.008	0.033	-0.093
OS23		1.000	0.132*	-0.023	-0.059	-0.093
OS28			1.000	0.081	0.008	0.174**
OS50				1.000	0.037	0.085
OS63					1.000	0.230***
OS91						1.000

(† = 0.10 < P < 0.05; * = P < 0.05; ** = P < 0.01; *** = P < 0.001)

Table 4.7. Residuals correlation matrix (r-value and significance level) for tail biting (TB) behaviour compared to belly nosing (BN), belly sucking (BS), other nosing (ON), and other sucking (OS) behaviours at 18, 23, 28, 50, 63, and 91 days-of-age.

	Tail biting	
	TB63	TB91
BN18	0.023	-0.082
BN23	-0.023	-0.066
BN28	-0.008	-0.105
BN50	-0.039	0.058
BN63	-0.045	0.046
BN91	-0.024	0.077
BS18	0.105	-0.143*
BS23	0.060	-0.171*
BS28	0.073	-0.021
BS50	0.056	-0.002
BS63	0.050	0.0123
BS91	0.043	0.007
ON18	0.046	0.010
ON23	0.195**	0.073
ON28	-0.113†	-0.026
ON50	-0.017	-0.027
ON63	-0.010	0.059
ON91	0.120†	0.067
OS18	-0.079	-0.042
OS23	-0.048	-0.053
OS28	-0.002	-0.033
OS50	-0.043	0.005
OS63	0.084	-0.037
OS91	0.155*	0.072
TB63	1.000	0.012
TB91		1.000

(† = 0.10 < P < 0.05; * = P < 0.05; ** = P < 0.01; *** = P < 0.001)

Table 4.8. Residuals correlation matrix (r-value and significance level) for other biting (OB) behaviour compared to belly nosing (BN), belly sucking (BS), other nosing (ON), other sucking (OS), and tail biting (TB) behaviours at 18, 23, 28, 50, 63, and 91 days-of age.

	Other biting					
	OB18	OB23	OB28	OB50	OB63	OB91
BN18	-0.020	-0.034	0.043	-0.043	0.165	0.033
BN23	-0.112†	0.097	0.063	-0.015	-0.032	0.044
BN28	-0.014	0.080	-0.124†	-0.030	-0.016	-0.055
BN50	-0.037	-0.049	-0.024	-0.074	-0.084	-0.063
BN63	0.008	-0.074	-0.059	0.027	0.086	0.035
BN91	0.011	0.000	-0.045	0.081	-0.090	-0.009
BS18	-0.073	0.097	-0.047	0.007	0.078	-0.039
BS23	-0.040	0.052	0.025	-0.136*	-0.044	-0.060
BS28	-0.104	-0.005	-0.008	-0.010	0.009	0.126†
BS50	0.052	0.119†	-0.069	-0.006	0.025	-0.087
BS63	-0.093	-0.026	0.006	-0.066	-0.064	0.031
BS91	-0.017	-0.040	0.026	0.039	-0.045	0.022
ON18	0.196**	-0.038	0.048	0.044	0.052	0.137*
ON23	-0.053	0.086	0.024	-0.030	0.027	0.022
ON28	0.118†	0.093	0.181**	-0.038	-0.101	-0.016
ON50	-0.024	-0.044	0.001	0.149*	0.005	-0.030
ON63	-0.022	-0.071	0.073	0.024	0.136*	0.023
ON91	-0.013	-0.167*	0.045	-0.060	-0.072	0.129†
OS18	0.021	0.120	-0.077	-0.016	0.003	-0.079
OS23	0.014	0.020	0.010	0.023	-0.094	-0.027
OS28	0.028	-0.032	-0.116†	0.008	0.073	-0.044
OS50	0.054	0.080	-0.058	0.007	0.078	0.078
OS63	0.063	-0.003	0.016	-0.014	0.068	0.040
OS91	-0.064	-0.086	0.047	0.016	0.015	-0.001
TB63	0.093	-0.061	0.043	0.088	-0.107	0.033
TB91	-0.046	-0.034	0.069	-0.050	-0.021	0.086
OB18	1.000	-0.020	-0.082	0.060	-0.080	-0.043
OB23		1.000	0.075	-0.006	0.014	-0.101
OB28			1.000	-0.009	0.024	0.076
OB50				1.000	0.210**	0.080
OB61					1.000	0.038
OB91						1.000

(† = 0.10 < P < 0.05; * = P < 0.05; ** = P < 0.01; *** = P < 0.001)

behavioural vices during the nursery or grow-finish phases. Belly nosing was positively correlated with belly sucking, other nosing, and other sucking behaviours during the nursery period. Belly nosing that occurred during the grow-finish period and belly sucking behaviour performed in the nursery were both positively correlated with belly sucking behaviour being performed during the grow-finish period. However, piglets that belly sucked during the nursery phase, were less likely to perform tail biting behaviour in the grow-finish phase. In contrast, piglets that demonstrated other nosing behaviour in the nursery, while they were less likely to also engage in other biting behaviour while in nursery, they were more likely to perform tail biting in the grow-finish phase of development. Piglets that engaged in other sucking behaviour in the grow-finish phase were also more likely to be tail biters during grow-finish as well. Other nosing behaviour was positively correlated to other sucking and other biting behaviour during the grow-finish period.

4.5 DISCUSSION

The results of this study indicate that belly nosing is associated with other oral-nasal behaviours, involving nosing and sucking. van Putten (1969) suggested that this is due to the natural tendency to chew and root on penmates that is observed almost universally among pigs in groups. In piglets, chewing on penmates, including the tails of penmates, has been suggested as being derived from suckling behaviour (Newberry and Swanson, 2001), which has been re-directed (Mason et al., 2003). This may further explain why some studies found correlations between tail biting and other harmful social behaviours, including nosing penmates, ear biting, genital anal nosing and belly nosing (Breuer et al., 2001). It was casually observed during this study that pens with higher activity levels also exhibited higher incidences of all behavioural vices investigated. These observations are also supported by previous findings, which found activity levels to correlate to higher levels of oral-nasal behavioural vices (van Putten, 1969; Fraser, 1978; Keeling and Jensen, 1995; Lewis, 1999; Li and Gonyou, 2002). In this study, belly nosing was found to commence within four days of weaning and peak at 23-28 days-of-age, after which time the behavioural vice decreased in incidence. Thus, the pigs in this study demonstrated the well-documented time course for belly nosing found in previous studies (Gonyou et al., 1998; Worobec et al., 1999). However, after belly nosing decreased dramatically (although never disappearing completely), generalized nosing, sucking and biting behaviours were found to increase as the pigs matured, with almost all of the behaviours observed reaching their highest levels at 13 weeks-of-age during the grow-finish period.

While tail biting is commonly noted as a welfare concern in grow-finish operations, the results of this study found that the mean percentage of time spent tail biting per day per pig was actually lower than the mean percentage of time spent belly sucking during the grow-finish period. Personal observations noted a tendency for "belly suckers" to target specific "favourite" pigs, while "tail-biters" directed the behavioural vice at any penmate. However, this was not statistically tested. Thus, it would appear that after belly nosing subsides in the early-weaned pig, a number of other oral-nasal behaviours take its place.

Thus, while belly nosing was positively correlated to belly sucking behaviour, belly sucking behaviour was negatively correlated to tail biting behaviour, thereby ruling out a link between belly nosing and tail biting. Such results may suggest that belly nosing and tail biting originate from two different motivational systems. Similar to the development of stereotypies, the development of belly sucking from belly nosing may be one of an increase in intensity and time spent performing the behaviour, which gradually becomes disconnected from the function of the original behaviour pattern, in this case nosing the belly of a penmate. This change in intensity of the behaviour is demonstrated as the behaviour changes from nosing to sucking, while the increase in mean bout length, number of bouts, and mean percentage of time spent performing belly sucking demonstrate the further focusing of the behaviour, particularly if pigs that belly suck into the grow-finish phase have a "favourite" target individual for the behaviour. With tail biting behaviour, the same increase in intensity is not seen. In fact, while the behaviour does seem to be a more mature oral behavioural vice, many factors have been suggested as contributing to the development of the behaviour, including overcrowding (Gonyou, 2001), the presence of blood (Fraser, 1987a; Fraser, 1987b; Fraser et al., 1991) and diet (Ewbank, 1973; Denton, 1984; McIntyre and Edwards, 2002). Furthermore, the results of this study show that generalized nosing and sucking behaviour during the grow-finish phase is a better predictor of tail biting behaviour during the same period than the incidence of belly nosing during the nursery phase. However, what has not been investigated with any of these oral-nasal vices is the contribution of genetic background, including breed and sire, on the development of these behaviours.

The keys to the development of belly nosing and its associated behavioural vices may be found in the complex interplay between genetic and environmental factors. The genetic background of an individual may affect how it perceives its environment as well as the extent to which early experiences can influence adult behaviour, and the capacity of an animal to modify its behaviour to meet environmental demands (Price, 1985). As such, genetics may play a substantial role in determining which individuals become belly suckers and which become tail biters as adults. Data from this study were later analyzed (Chapter 5) for genetic effects. Furthermore, the role of enrichment during the pre-wean and nursery phases of development may be possible ways to prevent the onset of behavioural vices such as belly nosing from occurring. If this proves to be the case, then it may be possible to eliminate many of these behavioural vices from occurring throughout production.

4.6 CONCLUSIONS

The onset of belly nosing in the early-weaned pigs occurs around 3-4 days following weaning and peaks in incidence approximately two weeks later, after which time the percentage of time spent belly nosing per day decreases. However, as belly nosing decreases, the incidence of generalized nosing, sucking, and biting behaviours increase in incidence with the highest levels of these behaviours occurring during the grow-finish phase of development. Thus, as belly nosing subsides in the early-weaned pig, a number of other oral-nasal behaviours take its place. While nosing, sucking and biting penmates in general were the most prevalent of these behavioural vices to develop after belly nosing, pigs that progressed from belly nosing to belly sucking, tended to continue to perform belly sucking behaviour into the grow-finish phase. In contrast, piglets exhibiting generalized nosing and sucking behaviours during the grow-finish period were more likely to be tail biters and to engage in generalized biting of penmates. Thus, pigs that performed tail biting exhibited a wider range of behavioural vices in the grow-finish period, and tended to be more active in general. However, no correlation was found between belly nosing in the nursery and tail biting behaviour during the grow-finish period.

5.0 EFFECT OF BREED OF SIRE AND SIRE WITHIN BREED ON BELLY NOSING IN EARLY-WEANED PIGS

5.1 ABSTRACT

The objective of this study was to investigate the effect of sire breed and sire within breed on the proportion of time that early-weaned pigs spent belly nosing and belly sucking. Two hundred forty-two crossbred pigs sired by Duroc (PIC line 3; n = 120) and Large White (PIC line 280; n = 122) boars were observed at 3 and 10 days-of-age to determine teat consistency score, nursing bout duration, and nursing cycle duration during the pre-weaning phase of development using instantaneous scan sampling. Piglets were weaned at 14 days-of-age and observed at 18, 23, 28, and 50 days-of-age for belly nosing, belly sucking, and other nosing and sucking behaviours during the nursery phase of development using instantaneous scan sampling. Additionally, pigs were observed during the grow-finish phase at 63 and 91 days-of-age for belly nosing, belly sucking, other nosing and sucking, tail biting, and other biting behaviours, also using scan sampling. Continuous observations done live at 21 and 35 days-of-age were used to determine mean belly nosing and belly sucking bout durations. During the pre-weaning phase, neither the sire breed nor the individual sires were found to significantly affect teat consistency score, nursing bout duration or nursing cycle duration. Belly nosing, belly sucking, other nosing, and other sucking behaviours were significantly affected by breed of sire. Pigs sired by Large White boars spent a greater proportion of time belly nosing (2.040%; $P<0.01$) and belly sucking (0.440%; $P<0.01$) compared with pigs sired by Duroc boars (1.597% and 0.308%, respectively). In contrast, Duroc-sired pigs spent a greater proportion of time conducting other nosing (0.356%; $P<0.01$) and other sucking (2.496%; $P<0.001$) behaviours compared with Large White-sired pigs (0.173% and 2.063%, respectively). Individual sire also had a significant effect on belly nosing ($P<0.001$), belly sucking ($P<0.001$) and other sucking ($P<0.01$) behaviours post-weaning.

5.2 INTRODUCTION

The practice of early weaning in pigs was introduced as a potential means of eradicating and/or controlling disease, as well as a means to possibly improve sow performance (Robert et al., 1999). While early weaning has been useful in reducing disease, it has not been found to improve sow performance, and has been found to increase the incidence of belly nosing in the nursery environment (Robert et al., 1999). Gonyou et al. (1998) reported that piglets weaned at 12 versus 21 days-of-age showed a longer delay to eating and had a higher incidence of anomalous behaviours. Worobec et al. (1999) demonstrated that these problems are exacerbated when piglets are weaned at even younger ages, becoming further aggravated when weaning conditions are unsuitable (Dybkjær, 1992).

As a result of recent advances in feed technology, the significant growth check and digestive problems (Fraser, 1978; Algers, 1984; Metz and Gonyou, 1990) once seen in piglets weaned at less than four weeks-of-age have decreased due to improved diet formulations (Ermer et al., 1994; Dritz et al., 1996) and made weaning at 10-21 days-of-age more common in some areas of North America (Robert et al., 1999). However, the incidence of behavioural vices such as belly nosing in these early-weaned pigs has remained largely unchanged. If left unresolved, this trend may mean the progression of behavioural problems well into the grow-finish period. Gonyou et al. (1998) found that early-weaned piglets continued to display greater levels of nosing and chewing on pen mates throughout the grow-finish phase representing a possible compromise of welfare and potentially higher morbidity rates. Although, specialized diets may allow early-weaned piglets to achieve satisfactory growth rates, it does not necessarily address the animal welfare concern that earlier separation is a cause of distress for piglets (Weary and Fraser, 1997; Robert et al., 1999). Welfare concerns regarding the incidence of belly nosing in early-weaned pigs have reflected the environmental contribution to the development of the aberrant behaviour while the genetic component has not been researched beyond preliminary findings (Chapter 3).

If heritability is high, genetic selection may become a way of reducing belly nosing and its deleterious side effects. Thus, the welfare of early weaning pigs improves substantially while maintaining the disease reduction advantages of early weaning. If belly nosing is moderately or highly heritable in a given breed, then it may be plausible to use that information as a means of reducing the behaviour through the genetic selection of pigs to be used in early weaning systems. The objective of this study was to compare the incidence of belly nosing (and its associated behavioural vices), teat order consistency, and nursing behaviour between three sires within two common breed lines of pigs: one of Duroc and one of Large White origin. Data from this study were previously analyzed (Chapter 4) to determine the ontogeny of belly nosing.

5.3 MATERIALS AND METHODS

5.3.1 Facilities and Animals

The study was conducted at the Prairie Swine Centre, Inc., Saskatoon, SK, between May, 2001 and March, 2002. Animals used in this study were the same as those used in the previous Ontogeny study (Chapter 4). Twenty-four litters were observed with an average of 10-11 piglets per litter. A total of 242 piglets from the 24 litters were the focus of behavioural observations from birth to 13 weeks-of-age. All animals were fed nutritionally balanced diets *ad libitum* and kept in a climate appropriate for the age and weight of the pigs throughout the study.

All piglets used in the study were born to PIC-Camborough 15 strain sows with 120 of the piglets sired by three purebred Duroc boars (PIC line 3) and 122 piglets sired by three purebred Large White (PIC line 280) boars. Three boars of each genetic strain (Denoted as DB1, DB2, DB3 and LW1, LW2, and LW3) were bred to 48 sows over the course of the study. Fresh semen from each sire was obtained from Carlo Genetics (Ste. Anne, Manitoba), tested for transmittable diseases, shipped via air to the Prairie Swine Centre, and stored at 15-17°C until use. To minimize age spread of piglets, five ml of PG600® (Intervet, Millsboro, Delaware) was administered intramuscularly four days prior to the first breeding of each sow in order to synchronize estrus. Each sow was bred to the same boar on two consecutive days corresponding with behavioural estrus. All sires were unrelated to one another with the exception of DB1 and DB2 which were half-siblings. Of the 48 litters born, the 24 most viable litters (4 from each sire) with more than 12 piglets per litter were selected for the study. This ensured a minimum number of 240 animals for the duration of the study, including the expected loss of a small percentage of animals due to mortality and morbidity.

Two to three days prior to farrowing, sows were washed and moved into tubular steel farrowing crates (2.0 m x 0.8 m). Farrowing pen floors were plastic-coated expanded metal (Tenderfoot®, Tandem Products Ltd., Blooming Prairie, MN). Sows were housed in one of four rooms. Each farrowing room had a capacity of up to seven sows and their litters. To further control for the age spread of piglets, two ml Planate™ (Schering-Plough Animal Health) was administered intramuscularly to sows the day before expected farrowing in order to insure that all sows farrowed within a 12-hour window.

Within 24-36 hours of birth, piglets were crossfostered between litters within sire (Price et al., 1994). Five piglets from each litter were randomly selected and kept on their own sow (Own), while 5-6 piglets in each litter were crossfostered (Cross) from another sow. The average size of the resultant litters was 10-11 pigs per litter. Thereafter, 'litter' referred to piglets nursed by the same sow. Crossfostering was used as a means of controlling for maternal effects on piglet behaviour and performance. No milk replacer supplementation or creep feed was provided at any point during the pre-weaning phase.

At 14 days-of-age, all piglets were weaned and moved as intact litters into the nursery. Two identical nursery rooms of six pens, each (1.5 m x 1.5 m) equipped with Tenderfoot® flooring and durable plastic side paneling were used. Each nursery pen was equipped with a trough feeder large enough for four piglets to eat simultaneously. Two nipple drinkers were provided at the rear of each pen. Piglets remained in the nursery for six weeks, at which time they were again moved as intact litters to four identical grow-finish rooms. Within each grow-finish room, six litters were housed in pens (3.6 m x 4.8 m) with fully slated concrete flooring and solid plastic side paneling. Within each grow-finish pen, two single-spaced dry feeders were placed in the right and left front corners. Two nipple drinkers were located along the rear wall of the pen.

5.3.2 Observation Techniques

For all observations, piglets were individually identified through back markings (nursery phase) and ear tags (grow-finish phase) and observed within each pen. During the pre-weaning phase, teat order, nursing bout length and nursing cycle length for each litter were recorded. Teat order was determined through live continuous observations done in two 2-hour blocks at 4 and 12 days-of-age. Nursing bout and cycle lengths were obtained through continuous observations made via 24-hour videotaping at 7-8 days-of-age. A nursing bout was defined (in minutes) as the start of more than half the pigs in a litter suckling from the sow's teats until more than half the litter had stopped suckling. A nursing cycle was defined as the time (in minutes) from the beginning of one nursing bout to the start of the next nursing bout.

During the nursery phase of development, both instantaneous scan sampling and continuous observations were used. Instantaneous scan sampling, at 5-minute intervals, was used to determine the mean percentage of time spent belly nosing, belly sucking, other nosing, and other sucking (Table 5.1) for 8-hours (ie. 96 scans per observation day) at 18, 23, 28, and 50 days-of-age (4, 9, 14, and 36 days following weaning). Continuous observations were also conducted at 21 and 35 days-of-age (7 and 21 days following weaning), for 4-hours each observation day, to determine the mean time (in seconds) spent per belly nosing and belly sucking bout as well as the total time spent belly nosing and belly sucking. Bout length was defined as the length of time (in seconds) between the start of nosing or sucking the belly of a penmate until the behaviour ceased to continue for more than 5 seconds. Total time spent belly nosing and belly sucking was calculated as the sum of all bouts.

During the grow-finish phase of development, instantaneous scan sampling, at 5-minute intervals, was used to determine the mean percentage of time spent belly nosing, belly sucking, other nosing, other sucking, tail biting, and other biting (Table 5.1) for 8-hours (ie. 96 scans per observation day) at 63 and 91 days-of-age (7 and 11 weeks following weaning). Continuous observations were not utilized during the grow-finish phase.

5.3.3 Calculation of Teat Order Consistency

Teat order consistency was calculated using piglet teat preference data acquired through live continuous observations conducted during the pre-weaning phase of the study. Teat preference per piglet in a litter was determined in two 2-hour time blocks at both 4 and 12 days-of-age. As a result of these observations, all piglets were assigned a preferred teat within their litter, based on which teat pair and side (right or left) of the

Table 5.1. Behaviours observed during the nursery and/or grow-finish phases.

Observed behaviour	Definition
Belly nosing	Nose of one piglet actively rooting at the belly region, between the front and rear flanks, of another piglet.
Other nosing	Nose of one piglet actively rotting at a region other than the belly of another piglet.
Belly sucking	Mouth of one piglet actively sucking on the belly region, between the front and rear flanks, of another piglet. This behaviour involves the instigator taking the skin of the belly of the recipient into its own mouth as part of the sucking behaviour.
Other sucking	Mouth of one piglet actively sucking at a region other than the belly of another piglet. This behaviour involves the instigator taking the skin of the region other than the belly into its own mouth as part of the sucking behaviour.
Tail biting	Mouth of one piglet actively chewing on or having the tail of another piglet in its mouth.
Other biting	Mouth of one piglet actively chewing on or having a part of the body other than the tail of another piglet in its mouth.

sow they spent nursing the most during the observation periods. Teat consistency score calculations were based on earlier work by Hemsworth et al. (1976), and were formulated (per pig per litter) as:

$$\text{Teat Consistency Score} = \frac{\text{Number of observations at the preferred teat}}{\text{Total number of nursing observations}}$$

Teat order consistency was calculated as the mean teat consistency score for each litter.

5.3.4 Statistical Analysis

A Kolmogorov-Smirnov test was conducted using the Univariate procedure of SAS to test for normality of the behaviour data. Behaviour data for belly sucking, other nosing, other sucking, and other biting were square root transformed and tail biting behaviour data were transformed using square root plus one, prior to statistical analysis. For clarity purposes, data provided in tables has not been transformed.

Teat consistency scores, nursing bout length, and nursing cycle duration during the pre-weaning phase (Appendix C.1), belly nosing, belly sucking, other nosing, and other sucking behaviours during the nursery phase, and belly nosing, belly sucking, other nosing, other sucking, tail biting, and other biting behaviours during the grow-finish phase were all compared using the pen as the experimental unit as a split-plot over time model provided within the GLM analyses for repeated measures (Appendix C.2) in SAS, with sire breed (Duroc PIC line 3 and Large White PIC line 280) and sire within breed (ex: DB1 vs DB2 vs DB3) in the main plot and age in the sub-plot. Age was defined as days-of-age. Subsequently, the effect of crossfostering piglets at 24 hours-of-age was analyzed as a split-split-plot over time model provided with the GLM analyses for repeated measures in SAS, with sire breed and sire within breed in the main plot, age in the sub-plot and crossfostering in the sub-sub plot (Appendix C.3). Durations of behaviours were expressed as the mean percentage of time spent performing the behaviour. Total time spent performing belly nosing and belly sucking behaviour at 21 and 35 days-of-age was also compared. A Bonferroni means separation test was performed using sire breed, sire within breed and age.

5.4 RESULTS

5.4.1 Nursing behaviour and teat order consistency

During the pre-weaning phase of development, the total number of nursing bouts and nursing cycles, along with the mean time spent per nursing bout and per nursing cycle were found not to differ significantly when breed lines or sires within lines were compared (Table 5.2). Likewise, teat consistency scores were not significantly different (Table 5.2).

5.4.2 Belly nosing and belly sucking bout and cycle lengths

Mean total time spent belly nosing per litter did not significantly differ by age. However, a significant age by breed of sire interaction was found (Table 5.3). Duroc-sired pigs spent the least amount of time per litter involved in belly nosing at 21 days-of-age (1107 secs/4 hrs.), while the highest incidence of the behaviour occurred in Large White-sired pigs at the same age (2777 secs/4 hrs.). In contrast, the relationship was reversed at 35 days-of-age when the mean time spent belly nosing per Duroc-sired litter increased to 2072 secs/4 hrs. and dropped in Large White-sired litters to 1791 secs/4 hrs. ($P=0.045$). Table 5.4 shows the effect of sire within breed line on mean time spent belly nosing per litter.

5.4.3 Observed behavioural vices

All nosing and sucking behaviours observed, both directed at the belly as well as directed to other regions of the body, were significantly affected by sire breed (Table 5.5). However, incidence of tail biting and other biting behaviours did not differ significantly between sire breed lines. Pigs sired by Large White boars exhibited a greater proportion of their mean daily time budget per litter in belly nosing (2.040%) and belly sucking (0.440%) behaviour compared with Duroc-sired pigs (1.597% and 0.308%; $P<0.01$ and $P<0.01$, respectively; Table 5.5). However, Duroc-sired pigs were observed spending a greater proportion of their time performing generalized nosing (other nosing=0.356%) and sucking (other sucking =2.496%) behaviours compared with Large White-sired pigs

Table 5.2. Effect of sire breed on mean nursing bout and cycle durations, number of nursing bouts and cycles (over 24 hours at 7-8 days-of-age), and teat consistency scores.

	Duroc	Large White	SE	P-value
Nursing bout duration (in minutes)	8.32	7.96	0.57	P>0.10
Nursing cycle duration (in minutes)	41.62	42.26	1.81	P>0.10
Number nursing bouts (over 24 hours)	31.25	31.30	1.43	P>0.10
Number nursing cycles (over 24 hours)	30.58	30.25	1.49	P>0.10
Teat consistency score	0.819	0.749	0.031	P>0.10

Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

Table 5.3. Effect of sire breed and age interaction on mean belly nosing bout duration, mean belly sucking bout duration, mean total time spent belly nosing, and mean total time spent belly sucking per litter at 21 and 35 days-of-age (4 hours/observation day).

	Age (days)					
	21		35			
	Duroc	Large White	Duroc	Large White	SE	P-value
Belly nosing bout duration (s)	15.6	19.4	29.5	25.1	2.0	P>0.10
Belly sucking bout duration (s)	18.6	26.6	65.7	50.4	3.8	P>0.10
Total time spent belly nosing (s)	1107	2777	2072	1791	789	P=0.045
Total time spent belly sucking (s)	92	141	703	456	53	P>0.10

Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

Table 5.4. Effect of sire within breed line on mean belly nosing bout duration, mean belly sucking bout duration, mean total time spent belly nosing, and mean total time spent belly sucking per litter. Data averaged for 21 and 35 days-of-age.

	Sire breed							
	Duroc			Large White				
	Boar 1	Boar 2	Boar 3	Boar 1	Boar 2	Boar 3	SE	P-value
Belly nosing bout duration (s)	20.2	27.8	19.5	21.1	23.2	22.4	2.5	P>0.10
Belly sucking bout duration (s)	21.7	46.4	58.3	25.7	46.3	43.6	4.6	P>0.10
Total time spent belly nosing (s/4h)	1358	2258	1152	1863	1644	3345	966	P=0.060
Total time spent belly sucking (s/4h)	303	556	335	175	487	234	65	P>0.10

Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

Table 5.5. Effect of sire breed on mean percentage of time spent belly nosing, belly sucking, other nosing, other sucking, tail biting, and other biting per litter. Data averaged for all observations days post-weaning.

	Sire breed			
	Duroc (% time)	Large White (% time)	SE	P-value
Belly nosing	1.597	2.040	0.097	P<0.01
Belly sucking	0.308	0.440	0.033	P<0.01
Other nosing	0.356	0.173	0.041	P<0.01
Other sucking	2.496	2.063	0.079	P<0.001
Tail biting	0.335	0.299	0.057	P>0.10
Other biting	1.101	1.029	0.040	P>0.10

Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

($P<0.01$ and $P<0.001$, respectively; Table 5.5). Figures 5.1a and 5.1b provide a more detailed account of the breakdown of mean percentage of time spent per litter performing belly nosing and its related vices by both breed line and age. Significant breed of sire and age interactions were found for belly nosing ($P<0.01$) and other sucking ($P=0.021$) behaviours. It should be noted that breeds of sire did not significantly differ in weaning weight.

Sire within breed line was found to have a significant affect on the incidence of belly nosing ($P<0.001$), belly sucking ($P<0.001$), and other sucking ($P<0.01$) behaviours in the post-weaning environment (Table 5.6). While offspring from Duroc boars consistently spent more than 2.0% of their daily time budget performing other sucking behaviour compared with offspring of Large White boars, only piglets from one Large White line boar were found to outperform the others in both belly nosing (Large White Boar #3) and belly sucking (Large White Boar #1) behaviour. Significant boar and age interactions were also found in belly nosing ($P<0.01$), belly sucking ($P<0.001$), and other sucking ($P<0.01$) behaviours in addition to other biting behaviour ($P<0.01$).

5.4.4 Crossfostering

Crossfostering piglets at 24-36 hours-of-age was not found to have any statistically significant effect on any of the observed behaviours, during either the pre- or post-weaning phases of the study (Table 5.7).

5.5 DISCUSSION

The results of this study indicate that belly nosing, and some of its associated behavioural vices, particularly those involving nosing and sucking, are influenced by breed line and sire within a breed to a degree. Specifically, Large White-sired pigs were found to exhibit more nosing and sucking behaviours directed toward the belly region of penmates (belly nosing and belly sucking behaviours), while Duroc-sired pigs performed more generalized behaviours (nosing and sucking behaviours directed towards regions other than the belly of penmates, such as other nosing and other sucking behaviours).

Figure 5.1. Effect of sire breed and age interaction on mean percentage of time spent belly nosing (P<0.01) and other sucking (P=0.021) per litter at 18, 23, 28, 50, 63 and 91 days-of-age.

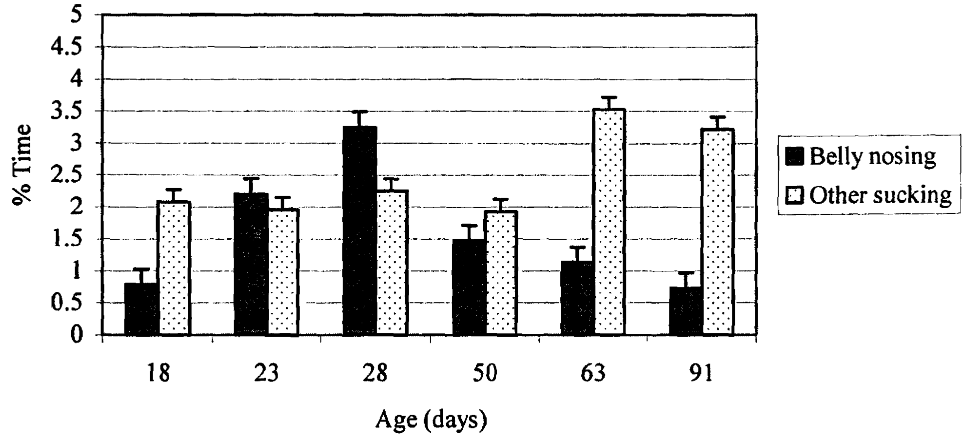

Figure 5.1a. Duroc (PIC line 3)

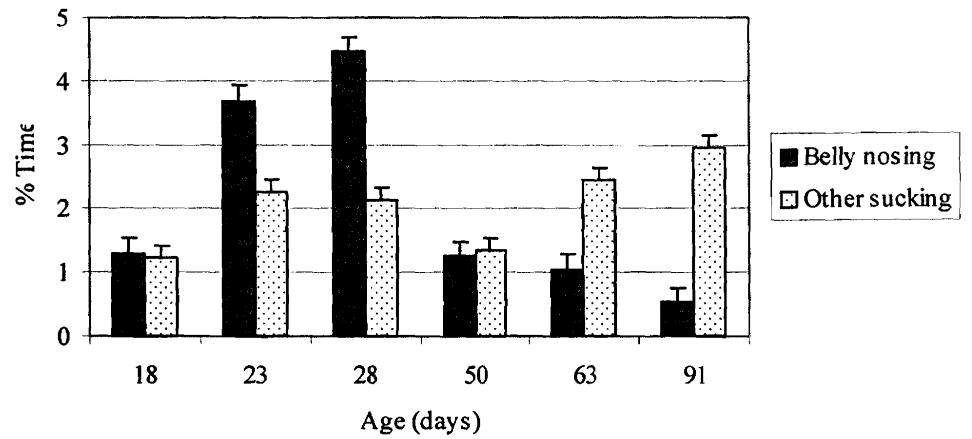

Figure 5.1b. Large White.(PIC line 280)

grow-finish period, and tended to be more active in general. However, no correlation was found between belly nosing in the nursery and tail biting behaviour during the grow-finish period.

Table 5.6. Effect of sire within breed line on mean percentage of time spent belly nosing, belly sucking, other nosing, other sucking, tail biting, and other biting per litter.

	Sire breed							
	Duroc			Large White				
	Boar 1 (% time)	Boar 2 (% time)	Boar 3 (% time)	Boar 1 (% time)	Boar 2 (% time)	Boar 3 (% time)	SE	P-value[2]
Belly nosing[1]	1.83^b	1.52^b	1.43^b	1.90^b	1.16^c	3.05^a	0.17	P<0.001
Belly sucking[1]	0.338^b	0.199^c	0.385^b	0.799^a	0.292^b	0.239^b	0.058	P<0.001
Other nosing[1]	0.363	0.448	0.207	0.233	0.123	0.156	0.071	P>0.10
Other sucking[1]	2.60^a	2.50^a	2.38^a	2.04^b	1.59^c	2.55^a	0.14	P<0.01
Tail biting	0.372	0.372	0.267	0.244	0.359	0.294	0.098	P>0.10
Other biting	1.075	1.124	1.123	0.936	0.945	1.207	0.069	P>0.10

[1] Variables include a significant Sire breed effect (see Table 5.4)
[2] P-value reflects Boar (Sire breed) with 4 degrees of freedom. Effect of sire breed has not been removed (see Appendix C).
Letters represent means separation of 6 boars used in the study (means with same letter superscript along same row are not significantly different). Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

Table 5.7. Effect of crossfostering on mean percentage of time spent on post-weaning behaviour.

	Own	Cross	SE	P-value
Belly nosing	1.73	1.90	0.26	P>0.10
Belly sucking	0.361	0.385	0.070	P>0.10
Other nosing	0.221	0.302	0.064	P>0.10
Other sucking	2.33	2.22	0.16	P>0.10
Tail biting	0.356	0.277	0.057	P>0.10
Other biting	1.112	1.011	0.069	P>0.10

Statistical analysis performed on transformed data, while data in table reflects non-transformed values.

These results agree with findings in the preliminary study (Chapter 3) of this thesis, in which Duroc pigs exhibited higher levels of nosing and sucking behaviours directed away from the belly of penmates, compared with Yorkshires. The Yorkshire breed, similar to the Large White, is popular for use as a maternal line in commercial herds due to its prolificacy and excellent maternal instincts (Briggs, 1983). The Duroc breed was selected for its heavy carcass production despite Duroc males being slightly more aggressive (Briggs and Briggs, 1980). The difference in the proportion of time spent performing behavioural vices between the two breeds may be the result of either genetic selection for maternal versus carcass characteristics, in which the behavioural vices or tolerance to them may have been inadvertently selected along with the desired production characteristics, or due to genetic drift.

In addition to breed of sire, sire within breed line also had a significant effect on the percentage of time pigs spent performing belly nosing, belly sucking, and other sucking behaviour during the nursery and grow-finish periods. Combined with the influence of breed line, these results suggest that males within a particular breed line may need to be observed for indications of behavioural vices prior to use in a breeding program, or conversely, using males from breeds or sires with a low incidence of behavioural vices, such as belly nosing, may be a useful means of helping to reduce such behaviours in an early weaning management system. However, further large-scale investigations into the effect of breed line and sire on behavioural vices in pigs are needed, particularly those that extend over multiple generations.

Tail biting and generalized biting (other biting) were not significantly affected by the two breed lines used in this study or by sire, thereby indicating that these behaviours, which are more closely associated with the grow-finish phase of development, may be largely due to environmental factors. However, given the limited number of breed lines and sires in the current study, further investigations are warranted. In piglets, chewing on penmates, including the tails of penmates has been suggested as being derived from suckling behaviour (Newberry and Swanson, 2001), which has been re-directed (Mason et al., 2003). Furthermore, many environmental factors have been found to contribute to the development of tail biting behaviour, including overcrowding (Gonyou, 2001), the presence of blood (Fraser, 1987a; Fraser, 1987b; Fraser et al., 1991) and diet (Ewbank, 1973; Denton, 1984; McIntyre and Edwards, 2002). It has also been found that generalized nosing and sucking behaviours are a better predictor for tail biting in the grow-finish period than the incidence of belly nosing (Chapter 4). Therefore, while genetics may affect the incidence of belly nosing and belly sucking behaviours, tail biting behaviour seems to have more to do with the environment than either breed line or sire.

5.6 CONCLUSIONS

Both breed of sire and sire within breed line were found to affect the incidence of oral-nasal behavioural vices related to belly nosing. Sire breeds differed in whether nosing and sucking behaviour were generally focused or directed towards the belly of penmates. Specifically, Large White-sired pigs performed more belly nosing and belly sucking behaviour, while Duroc-sired pigs performed more generally directed nosing and sucking behaviours. Sire breed differences in belly nosing and its related vices may be the result of inadvertently selecting for such behaviours secondary to desirable production traits. Furthermore, within each breed line, individual sires were also found to have an affect on the proportion of time spent nosing and sucking penmates. Combined with the influence of breed line, the effect of sire on such behavioural vices indicates the potential for selection within breed for sires that exhibit less belly nosing or other behavioural vices in an early weaning operation.

Compared with nosing and sucking behaviours in the early-weaned pig, tail biting and generalized biting associated with the grow-finish phase of development were not significantly affected by either sire breed or sire within breed, which may suggest that biting behaviour is more the result of environmental factors.

6.0 EFFECT OF ENVIRONMENTAL ENRICHMENT AT TWO STAGES OF DEVELOPMENT ON BELLY NOSING IN PIGLETS WEANED AT 14 DAYS-OF-AGE

6.1 ABSTRACT

The incidence of belly nosing related behaviours were studied in 480 piglets, weaned at 14 days-of-age, provided with environmental enrichment during either or both pre- and post-weaning. Pen enrichment was achieved by providing either a foam rubber mat on the pen wall (Nose), rubber nipples (Suck), a Bite-Rite Tail Chew ™ (Bite), a soil-filled tray (Root), or no enrichment (Control). Instantaneous scan sampling observations, at 5-min intervals, were conducted for 8-hours (ie. 96 scans per observation day) at 3, 10, 19, 26, and 33 days-of-age. Observations during the pre-weaning phase were made to determine the number of piglets lying, standing, nursing, and interacting with environmental enrichment. During the post-weaning phase, observations were made to determine the number of piglets belly nosing, belly sucking, other nosing and sucking (Other), biting, eating, drinking, and interacting with enrichment. The time course for belly nosing was again confirmed with the behaviour rising gradually by 19 d (4.50%), peaking by 26 d (7.36%) and decreasing by 33 days-of-age (4.28%; $P<0.001$). While providing any type of environmental enrichment reduced the proportion of time pigs spent performing belly nosing, providing Nose enrichment was the most effective means of reducing the behaviour (3.8%) compared with Control animals (6.6%; $P<0.001$). In contrast, Suck enrichment increased the incidence of belly sucking behaviour (1.42%) compared with the Control treatment (1.36%; $P<0.001$). Pigs provided Root or Bite enrichment spent more time manipulating their enrichment devices (30.2% and 9.3%, respectively) compared with Nose and Suck enrichment groups (1.3% and 2.7%, respectively; $P<0.001$). Providing enrichment relevant to a particular behavioural vice as it commences, or shortly afterward, was found to have the greatest effect on reducing the incidence of such behaviours during the nursery period.

6.2 INTRODUCTION

Piglets weaned at less than four weeks-of-age engage in frequent belly massaging (nosing) and sucking of penmates (Metz and Gonyou, 1990; Bøe, 1993; Gonyou et al., 1998; Worobec et al., 1999), and general manipulation of conspecifics (Hohenshell et al., 2000), which has been shown to persist for several weeks or longer (Bøe, 1993).

Studies such as Gonyou et al. (1998) and Worobec et al. (1999) have established the time course for belly nosing in the early-weaned piglet. Specifically, both studies found the behavioural vice to commence approximately four days after weaning, peak 14-21 days later, and then gradually decrease in frequency. While it is clear that the behaviour is of an oral-nasal nature and is similar to nursing behaviour in the pre-weaning phase of development, Gardener et al. (2001a) were unable to substantiate hunger as the underlying motivation to perform the behaviour. Specifically, they found neither poor-quality diet nor the presence of milk in the diet had an effect on belly nosing or other oral-nasal behaviours. Similar findings were found by this author in a preliminary study (Chapter 3) investigating the interaction between breed lines and environmental enrichment on the percentage of time spent belly nosing (Bench et al., 2000). The results of the study showed that provision of liquid milk replacer for either 7 d or 14 d following weaning neither reduced belly nosing nor its related behaviours, in piglets weaned at 7 d of age. However, enriching pens with blind nipples anchored to milk replacer troughs and dry feeders was found to be effective in reducing the time spent belly nosing, in a high belly nosing line. The findings of Li and Gonyou (2002) also agreed with those of Gardner et al. (2001a) that belly nosing is not motivated by hunger, but suggest that belly nosing is related to social interaction. In a study investigating the sequential analysis of belly nosing, they found that belly nosing and eating did not occur in sequence frequently, which they concluded was indicative that the motivation for belly nosing may be different from eating. Li and Gonyou (2002) reported that social activity most often preceded the belly nosing of penmates and concluded that belly nosing is more closely associated with social interaction than with eating or drinking behaviours. Their findings also agree with preliminary findings by this author (Bench et al., 2000; Chapter 3) in which belly nosing is suggested to be motivated by a need for comfort through general social interaction and reduced through interaction with specific stimuli such as a simulated sow udder or blind nipples in the days and weeks following weaning.

Bøe (1993) reported that the un-enriched post-weaning environment has a major influence on the frequency of abnormal behaviours being exhibited by weaned piglets. While it has been argued that increasing the complexity of the environment presents animals with many conflicting choices (Newberry and Estevez, 1997), biologically 'relevant' environmental enrichment fulfills the animal's motivation to perform behaviours, which manifest themselves as vices, and can thereby reduce their incidence more effectively (Newberry, 1995; Morrow-Tesch and McGlone, 1997). In some cases, providing substrates such as straw (Bure et al., 1983), branches (Peterson et al., 1995), peat (Beattie et al., 1995), and mushroom compost (Beattie et al., 2001) has worked well. These findings suggest environmental enrichment, that promotes exploration and is an "outlet" for oral activities, may be the most effective means of re-directing oral vices away from pen fittings and penmates in order to improve animal well-being.

Some studies have concluded that the provision of an enrichment device such as a soft, pliable, rubber dog toy can reduce the expression of aggressive and stereotypic behaviours commonly associated with confinement (Apple and Craig, 1992). Moreover, Day et al. (2002b) reported that destructible objects remain the subject of exploratory behaviour for longer than when non-destructible objects are provided to growing pigs. Horell and Ness (1995) found chewing behaviour can be reduced through the provision of 'toys' such as tires, balls and chains. However, the greatest reduction in behavioural vices was achieved through housing early-weaned piglets in 'ethologically enriched' environments, such as those equipped with a peat-filled rooting tray and carpeted board with protruding tubes to simulate an udder. Together, these findings suggest that not only does an appropriate and early environmental enrichment experience seem to be important in reducing the incidence of behavioural vices, but may also serve to stop these vices from progressing once they begin. In studies involving mice, even simple devices or very small changes to the environment have had a significant impact on the development of behavioural vices (Wûrbel et al., 1998).

Few studies have investigated the effect of age of exposure to biologically 'relevant' environmental enrichment on the incidence of behavioural vices. In most cases, environmental enrichment is used as a means of reducing the incidence of an already existing behaviour problem, rather than as a preventive measure. This study aimed to investigate not only the underlying behavioural motivation to perform belly nosing in the early-weaned piglet, using environmental enrichment relevant to the need to perform nosing, sucking, rooting, and chewing behaviours, but the study also aimed to investigate the role of sensitive periods in the development of such behaviours.

This study had two main objectives: which were to investigate the use of 'relevant' environmental enrichment to further clarify the underlying motivation for belly nosing in the early-weaned piglet, and to investigate the provision of such enrichment at two different developmental stages (pre- or post-weaning) to determine whether a sensitive period exists in which environmental enrichment works to reduce the incidence of belly nosing in the early-weaned piglet. The hypothesis was that environmental enrichment is not equivalent to environmental complexity, and must specifically fulfill the underlying motivation for the behavioural vice itself. In addition, the stage of development at which such enrichment is provided to the animal is of critical importance, especially in the case of a behavioural vice exhibited at such an early age, and which shows behavioural consequences well into the grow-finish phase.

6.3 MATERIALS AND METHODS

6.3.1 Facilities and Animals

The study was conducted at Prairie Swine Centre, Inc., Saskatoon, Saskatchewan, between April and July 2002. Subjects were born to Camborough 22 strain sows and observed during both the pre- and post-weaning phases.

During the two-week pre-weaning phase, piglets remained with their original sows and litters (n = 66), with an average of 11 piglets per litter (no cross-fostering occurred at birth). Farrowing crates measured 2.0 m long x 0.8 m wide, and were constructed of tubular steel. Farrowing crate floors were plastic-coated expanded metal (Tenderfoot®, Tandem Products Ltd., Blooming Prairie, MN). Each farrowing crate was equipped with one 175-watt infrared heat lamp, situated towards the front of the pen. Heat lamps were switched on approximately one day before the sows were due to farrow and remained on continuously until the piglets were weaned at two weeks-of-age. No milk replacer or creep feed supplementation was provided at any point during the pre-weaning phase. All piglets were early-weaned at 14 days-of-age.

Upon weaning, two pairs of pigs were selected randomly from enrichment treatments in the pre-weaning phase and placed into corresponding enrichment treatment pens of four pigs per pen in each of five nursery rooms of 24 pens per room. As a result, 480 piglets became the subjects of the post-weaning phase of the study. Lights were programmed to turn on and off on a 12-hour cycle at 07:00 and 19:00. Nursery pens measuring approximately 1 m x 1 m, were constructed of tubular steel tri-bar flooring with durable plastic side paneling and were equipped with a nipple drinker at the rear of each pen.

6.3.2 Enrichment Treatments

During the pre-weaning (farrowing crate) phase of the study, each litter was randomly assigned to one of five environmental enrichment treatments, which were placed at the rear of the farrowing crate on the wider of the two sides. Each of the environmental enrichments was designed to encourage a specific behavioural component of belly nosing or one of its related behavioural vices. Based on the results of an ontogenic study of belly nosing (Chapter 4), nosing, sucking, biting, and rooting behaviour patterns were identified and became the focus of each of the four enrichment devices to determine their effects on the incidence of belly nosing and its related vices. Enrichment devices designed to attach to the farrowing crate were placed at the pigs' nose-level and were secured by bolting the apparatus to the crate wall and through the flooring as needed. Enrichment suspended from the ceiling was situated such that the device hung at the back of the crate also at nose-level.

The nosing (Nose; n=10; Figure 6.1) enrichment device consisted of black foam rubber matting 30 cm x 30 cm x 2.5 cm bolted to the back of the pen with a spacer wedged behind it to create a flexible nosing surface. Four baby-bottle rubber nipples were screwed onto a 2.5 cm x 8 cm x 16 cm piece of plywood and bolted to the pen wall for the sucking (Suck; n=10; Figure 6.2; based on Rau, 2002) enrichment treatment. Rooting (Root; n=10; Figure 6.3) enrichment consisted of filling 30 cm x 30 cm x 5 cm cake pans

Figure 6.1. Diagram of Nose environmental enrichment device used during the pre- and post-weaning phases.

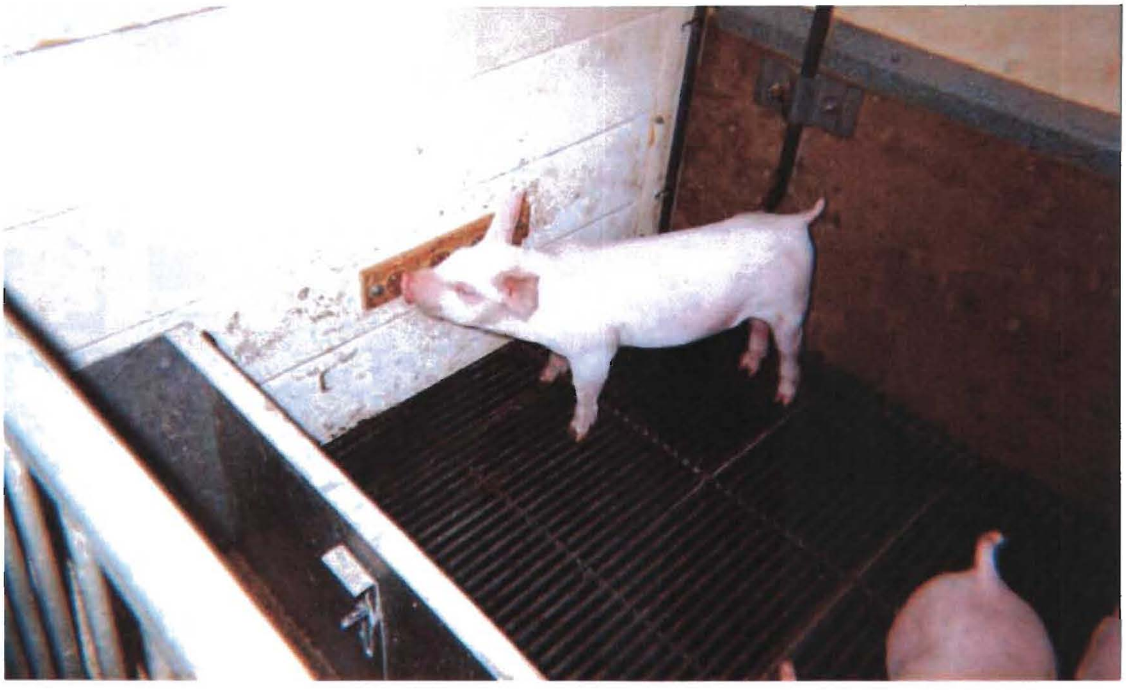

Figure 6.2. Diagram of the Suck environmental enrichment device used during the pre- and post-weaning phases. Enrichment based on Rau (2002).

with an autoclaved potting soil mixture with mushroom compost and securing the apparatus to the floor and pen wall. Rooting trays were filled to a depth of approximately 3 cm and refilled as needed. For the biting (Bite; n=10; Figure 6.4) enrichment, Bite-Rite Tail Chews™ (Ikadan, Denmark) were assembled and suspended from the ceiling at piglet nose height. Those litters that received no type of environmental enrichment acted as the control (Control; n=26) treatment. Once enrichment devices were in place, they remained in the pen until weaning at 14 days-of-age.

During the post-weaning (nursery) phase of the study, piglets exposed to Nose, Suck, Bite, and Root treatments in the pre-weaning phase either continued to experience the same enrichment or received no enrichment after weaning. Enrichment, which was designed to attach to the penning, was placed at nose-level and secured by bolting the apparatus to the pen wall and through the flooring as needed. Enrichment suspended from the ceiling was situated such that the device hung at the center of the back of the pen also at nose level. Based on the enrichment treatment assigned to each pen in the nursery, piglets were randomly selected, two at a time, from their litters representing one of the five enrichment treatments, and regrouped with two other piglets from a different litter and same pre-weaning enrichment experience. Piglets receiving the Control treatment in the pre-weaning phase of the study either continued to receive no treatment, or were given one of the four enrichment devices following weaning. As a result of the experimental design, 13 different phase treatments (Control treatment replicated for each phase treatment) were investigated with those that received no enrichment in either phase of the study acting as the study controls (n = 12) compared with all other treatments in which environmental enrichment was provided during at least one of the two developmental phases (n = 9 for each phase treatment; Table 6.1).

6.3.3 Observation Techniques

Instantaneous scan sampling of each pen, at 5-min intervals, was used to determine the number of pigs standing, lying, and nursing for 8-hours (ie. 96 scans per observation day) during the pre-weaning phase and interacting with environmental enrichment (Table 6.2) at 3 and 10 days-of-age. During the post-weaning phase (Table 6.3) at 19, 26, and 33 days-of-age, observations were made for the number of pigs belly

Figure 6.4. Diagram of the Bite environmental enrichment device (Bite Rite Tail Chew™, Ikaden, Denmark) used during the pre- and post-weaning phases.

Table 6.1. Breakdown of numbers of pigs per environmental enrichment and phase treatments observed during the post-weaning (nursery) phase of development.

Phase Treatment	Number of Pens	Number of Pigs
Control	12	48
Control-Nose	9	36
Nose-Control	9	36
Nose-Nose	9	36
Control-Root	9	36
Root-Control	9	36
Root-Root	9	36
Control-Suck	9	36
Suck-Control	9	36
Suck-Suck	9	36
Control-Bite	9	36
Bite-Control	9	36
Bite-Bite	9	36
Total	120	480

Table 6.2. Behaviours observed during the pre-weaning phase of development.

Observed behaviour	Definition
Lying	Piglets lying down either laterally or ventrally with no weight on any of their four legs.
Standing	Piglets standing on at least two feet (includes sitting behaviour).
Nursing	Piglets at the sow's udder either actively nosing or sucking at the teats.
Interacting with enrichment	Piglets manipulating the enrichment device placed in their pen in some manner, including nosing, sniffing, rooting, sucking, pawing, biting, or lying in the apparatus.

Table 6.3. Behaviours observed during the nursery phase of development.

Observed behaviour	Definition
Belly nosing	Nose of one piglet actively rooting at the belly region, between the front and rear flanks, of another piglet.
Belly sucking	Mouth of one piglet actively sucking on the belly region, between the front and rear flanks, of another piglet. This behaviour involves the instigator taking the skin of the belly of the recipient into its own mouth as part of the sucking behaviour.
Other nosing and sucking (Other)	Nose of one piglet actively rooting at a region other than the belly of another piglet OR mouth of one piglet sucking at a region other than the belly of another piglet. Sucking behaviour involves taking the skin of the region other than the belly into its own mouth as part of the sucking behaviour.
Biting	Mouth of one piglet open with the body part of another piglet in its mouth, including chewing on the body part.
Eating	Piglet manipulating the feed in the feed trough.
Drinking	Piglet manipulating the nipple drinker.
Interacting with enrichment	Piglets manipulating the enrichment device placed in their pen in some manner, including nosing, sniffing, rooting, sucking, pawing, biting, or lying in the apparatus.

nosing, belly sucking, other nosing and sucking (Other), biting, eating, and drinking. The number of piglets interacting with environmental enrichment per crate (pre-weaning) and per pen (post-weaning) were observed during both developmental phases of the study. Data were summarized within pen and age as the proportion (%) of observations spent performing each observed behaviour:

$$\frac{\text{Total number of pigs performing a behaviour}}{\text{Number of observations by Total number of pigs}}$$

6.3.4 Statistical Analysis

A Kolmogorov-Smirnov test was conducted using the Univariate procedure of SAS (SAS Institute Inc., 2000) to test for normality of the data. All data were found to be normally distributed.

During the pre-weaning phase, standing, lying, nursing behaviours and interacting with environmental enrichment in each enrichment treatment group were compared using the crate as the experimental unit. The relationship between type of enrichment and behaviour was examined using the split-plot over time model provided within the GLM analysis for repeated measures (SAS Institute Inc., 2000). Environmental enrichment was used as the main plot and age as the subplot (Appendix D.1). A Bonferroni means separation test was performed using environmental enrichment, age and enrichment by age interactions.

During the post-weaning phase, belly nosing, belly sucking, other, biting, eating, drinking behaviours and interacting with environmental enrichment were compared using the pen as the experimental unit. The interactions between type of environmental enrichment and phase treatment at time of enrichment placement (phase treatment) were analyzed using the split-plot over time model provided with the GLM analysis for repeated measures (SAS Institute Inc., 2000), with both environmental enrichment type and phase treatment in the main plot and age as the subplot (Appendix D.2). A Bonferroni means separation test was performed using environmental enrichment, phase treatment, age, and interactions between factors. In addition, data was analyzed as a split-plot over time model provided with the GLM analysis for repeated measures, comparing enrichment provided during both pre- and post-weaning phases with study controls (those pens of animals that received no enrichment in either phase of the study).

6.4 RESULTS

6.4.1 Effect of environmental enrichment

During the pre-weaning phase, amount of time spent lying, standing, and nursing were not found to be significantly different among the different enrichment treatments (Table 6.4). However, pigs provided with Root (0.753%) and Bite (0.319%) enrichment spent significantly more time interacting with their enrichment devices compared with those animals provided with Nose (0.030%) and Suck (0.121%) enrichment ($P<0.001$).

During the post-weaning phase, providing pigs with Nose enrichment significantly reduced the proportion of time spent belly nosing (3.8%) compared with Control pigs (6.6%; $P<0.001$; Table 6.5). In contrast, pigs provided with Suck enrichment spent a greater proportion of time exhibiting belly sucking behaviour (1.42%) compared with animals in the Nose enrichment treatment. Pigs provided with Root enrichment spent less time eating (21.4%) compared with pigs in the Control treatment ($P<0.01$). However, pigs given Root and Bite enrichment also spent more time manipulating the enrichment devices provided to them (30.2% and 9.3%, respectively) when compared with the Nose enrichment groups (1.3%; $P<0.001$).

6.4.2 Effect of phase treatment

Tables 6.6a – 6.6d show the effect of Nose, Suck, Root, and Bite enrichment during the pre- and post-weaning phases of development on the proportion of time pigs spent belly nosing, belly sucking, other, biting, eating, drinking, and interacting with environmental enrichment during the post-wean phase. Pigs in both the Nose (Table 6.6a) and Suck (Table 6.6b) enrichment treatments interacted with their enrichment devices to a greater extent during the nursery phase if they had not been given enrichment during the pre-weaning phase ($P<0.01$ and $P<0.001$, respectively). Providing Suck enrichment during the pre-weaning phase (Suck-Control = 7.67% and Suck-Suck = 6.41%) tended to

Table 6.4. Effect of environmental enrichment on mean percentage of time spent lying, standing, nursing, and interacting with enrichment device (WENR) during the pre-weaning phase of development.

	Nose	Suck	Root	Bite	Control	SE	P-value
Lying	27.71	27.38	30.39	30.37	28.38	1.05	P>0.10
Standing	7.86	7.92	7.05	7.24	7.46	0.74	P>0.10
Nursing	10.09	8.40	10.34	9.59	9.15	0.83	P>0.10
WENR	$0.030^{b,c}$	$0.121^{b,c}$	0.753^{a}	0.319^{b}	0.000^{c}	0.072	P<0.001

Includes Bonferroni means separation results (means with same letter superscript along same row are not significantly different).

Table 6.5. Mean percentage of time spent belly nosing, belly sucking, other nosing and sucking (Other), eating, drinking, and interacting with environmental enrichment (WENR), during the nursery phase of development, according to enrichment treatment (provided only post-weaning, ex: -N and NN resulting in n=18 for each enrichment device).

	Nose	Suck	Root	Bite	Control	SE	P-value
Belly nosing	3.8 ^{b}	6.4 ^{a}	6.2 ^{a}	5.1 ^{a,b}	6.6 ^{a}	1.1	P<0.001
Belly sucking	0.41 ^{c}	1.42 ^{a}	0.88 ^{a,b,c}	0.51 ^{b,c}	1.36 ^{a,b}	0.30	P<0.001
Other	8.83	7.52	6.22	7.41	8.83	0.55	P>0.10
Biting	4.04 ^{a}	4.94 ^{a,b}	3.57 ^{a}	3.89 ^{a,b}	4.53 ^{a}	0.54	P=0.077
Eating	29.2 ^{a}	28.3 ^{a,b}	21.4 ^{b}	25.8 ^{a}	27.6 ^{a}	1.3	P<0.01
Drinking	2.80	2.94	2.51	2.35	2.72	0.42	P>0.10
WENR	1.3 ^{c}	2.7 ^{b,c}	30.2 ^{a}	9.3 ^{b}	0.0 ^{c}	1.7	P<0.001

Includes Bonferroni means separation results (means with same letter superscript along same row are not significantly different).

Table 6.6. Effect of enrichment treatments (N=Nose, S=Suck, R=Root, and B=Bite) at two different phases of development (pre- and post-weaning; 2 x 2 interaction) on mean percentage of time spent belly nosing, belly sucking, other nosing and sucking (Other), eating, drinking, and interacting with environmental enrichment (WENR) during the nursery phase for early-weaned pigs. Control (n=12) compared to the phase treatments (n=9 for each phase treatment) for each enrichment device.

Table. 6.6a. Nose Enrichment.

	Control-Control	Nose-Control	Control-Nose	Nose-Nose	SE	P-value[1]
Belly nosing	6.3	3.2	4.5	3.9	1.1	P>0.10
Belly sucking	1.36	0.57	0.41	0.22	0.55	P>0.10
Other	8.4	7.3	7.5	8.5	1.5	P>0.10
Biting	4.4	4.8	3.3	4.0	1.0	P>0.10
Eating	27.8	26.7	28.4	29.0	2.3	P>0.10
Drinking	2.72	2.43	3.15	2.85	0.55	P>0.10
WENR	--	--	1.70	1.30	0.29	P<0.01

Dashed line indicates that no enrichment was provided during the nursery phase of development.

[1] P-value refers to the interaction between environmental enrichment treatment and phase of development.

Table 6.6b. Suck Enrichment.

	Control-Control	Suck-Control	Control-Suck	Suck-Suck	SE	P-value[1]
Belly nosing	6.28	7.67	3.52	6.41	0.97	P=0.068
Belly sucking	1.36	2.67	1.00	0.59	0.89	P>0.10
Other	8.4	6.9	8.7	6.7	1.2	P>0.10
Biting	4.4	5.7	4.2	4.5	1.0	P>0.10
Eating	27.8	25.7	27.2	27.5	2.5	P>0.10
Drinking	2.72	2.15	2.78	3.89	0.69	P>0.10
WENR	--	--	4.33	2.74	0.71	P<0.001

Dashed line indicates that no enrichment was provided during the nursery phase of development.

[1] P-value refers to the interaction between environmental enrichment treatment and phase of development.

increase belly nosing in the nursery compared with Control animals (6.28%, P=0.068). However, pigs provided with Suck enrichment during only the nursery phase spent a greater proportion of their time interacting with environmental enrichment (4.33%; P<0.001), which tended to result in less time being spent belly nosing (3.52%) compared with Control animals (6.28%; P=0.068). Providing pigs with Root enrichment (Table 6.6c) during the post-weaning phase resulted in less time spent performing other behaviours (Control-Root = 4.5% and Root-Root = 5.1%, respectively) compared with Control animals (8.4%; P=0.011). Pigs receiving Root enrichment during only the pre-wean phase (Root-Control) spent slightly more time (8.5%) involved in other behaviour compared with Control, and tended to exhibit more belly nosing as well (8.7%; P=0.082). Moreover, pigs receiving Root enrichment during the nursery phase tended to exhibit less belly nosing (Control-Root = 4.4% and Root-Root = 5.8%, respectively) than Control animals (6.2%).

6.4.3 Effect of Age

During the pre-weaning phase of development, the proportion of time piglets spent lying (Table 6.7) decreased with age from 29.99% at 3 days-of-age to 27.70% at 10 days-of-age (P=0.013). As activity levels increased with age, the proportion of time piglets spent interacting with environmental enrichment also increased from 0.160% of the daily time budget at 3 days-of-age to 0.329% at 10 days-of-age (P<0.01).

The time course for belly nosing (Table 6.8) was again confirmed with the behaviour rising gradually, peaking by 26 days-of-age (7.36%) and decreasing by 33 days-of-age (4.28%; P<0.001). Similarly, belly sucking (P<0.01), other (P<0.001), biting (P<0.001), eating (P<0.001), drinking (P<0.01), and interacting with environmental enrichment (P=0.014) also exhibited significant peaks at 26 days-of-age.

Table 6.9 shows the proportion of time spent belly nosing at each observed age during the nursery phase, based on the type of enrichment received during the post-wean phase compared with those animals receiving no enrichment during the study (Control). Overall, providing enrichment during the post-wean phase of development was found to

Table 6.6c. Root Enrichment.

	Control-Control	Root-Control	Control-Root	Root-Root	SE	P-value[1]
Belly nosing	6.2	8.7	4.4	5.8	1.1	P=0.082
Belly sucking	1.36	1.37	0.63	0.67	0.67	P>0.10
Other	8.4	8.5	4.5	5.1	1.1	P=0.011
Biting	4.37	5.03	2.63	2.40	0.98	P>0.10
Eating	27.8	28.2	22.8	20.8	2.8	P>0.10
Drinking	2.72	3.41	2.11	2.11	0.67	P>0.10
WENR	--	--	29.6	30.4	2.9	P>0.10

Dashed line indicates that no enrichment was provided during the nursery phase of development.

[1] P-value refers to the interaction between environmental enrichment treatment and phase of development.

Table 6.6d. Bite Enrichment.

	Control-Control	Bite-Control	Control-Bite	Bite-Bite	SE	P-value[1]
Belly nosing	6.2	5.7	6.0	4.8	1.2	P>0.10
Belly sucking	1.36	0.58	0.37	0.59	0.57	P>0.10
Other	8.4	10.4	6.1	7.1	1.5	P>0.10
Biting	4.37	3.71	4.67	3.26	0.85	P>0.10
Eating	27.8	26.7	31.2	24.9	2.5	P>0.10
Drinking	2.72	2.42	2.11	2.52	0.57	P>0.10
WENR	--	--	8.1	10.4	1.7	P>0.10

Dashed line indicates that no enrichment was provided during the nursery phase of development.

[1] P-value refers to the interaction between environmental enrichment treatment and phase of development.

Table 6.7. Mean percentage of time spent lying, standing, nursing, and interacting with environmental enrichment (WENR) during the pre-weaning phase of development at 3 and 10 days-of-age.

	Age (days)			
	3	10	SE	P-value
Lying	29.99	27.70	0.63	P=0.013
Standing	7.26	7.75	0.44	P>0.10
Nursing	9.16	9.87	0.49	P>0.10
WENR	0.160	0.329	0.043	P<0.01

Table 6.8. Mean percentage of time spent belly nosing, belly sucking, other nosing and sucking (Other), eating, drinking, and interacting with environmental enrichment (WENR) at 19, 26, and 33 days-of-age during the nursery phase of development.

	Age (days)				
	19	26	33	SE	P-value
Belly nosing	4.50^{b}	7.36^{a}	4.28^{b}	0.44	P<0.001
Belly sucking	0.45^{b}	1.14^{a}	$0.98^{a,b}$	0.19	P<0.01
Other	7.71^{b}	9.90^{a}	4.61^{c}	0.44	P<0.001
Biting	4.03^{b}	5.68^{a}	2.74^{c}	0.34	P<0.001
Eating	24.30^{b}	31.25^{a}	24.32^{b}	0.87	P<0.001
Drinking	2.50^{b}	3.33^{a}	2.15^{b}	0.23	P<0.01
WENR	$6.5^{a,b}$	8.3^{a}	4.9^{b}	1.2	P=0.014

Includes Bonferroni means separation results (means with same letter superscript are not significantly different).

Table 6.9. Effect of environmental enrichment provided during the post-weaning phase of development on mean percent time spent belly nosing at 19, 26, and 33 days-of-age.

	Age (days)				
	19	26	33	SE	P-value
Control	5.77	8.13	4.70		
Nose	4.80	4.65	3.15	0.96	P>0.10
Suck	4.4	7.2	3.2	1.0	P=0.083
Root	3.8	7.9	4.5	1.3	P=0.052
Bite	3.3	8.1	4.0	1.2	P=0.035

Within age, each environmental enrichment type (n=9 pens for each type of enrichment device) compared to Control animals (n=12 pens) receiving no enrichment in either phase of development.

decrease belly nosing at each of the ages observed, when compared with the Control. Specifically, providing Bite enrichment resulted in the most significant difference from Control (5.77%), particularly at 19 d (3.33%; $P<0.05$). However, Root and Suck enrichment also tended to decrease belly nosing ($P=0.05$ and $P=0.08$, respectively) when compared with those pigs receiving no enrichment during the nursery phase. While providing Nose enrichment resulted in the lowest incidence of belly nosing at 26 d and 33 days-of-age, these findings were not statistically significant.

6.5 DISCUSSION

While belly nosing has become one of the primary welfare concerns regarding the practice of early weaning, the underlying motivation for belly nosing in the early-weaned piglet is not fully understood. Similar to results found in other studies, animals housed in a barren (Control) environment exhibited the highest levels of behavioural vices (Fraser et al., 1991; Schouten, 1991; Beattie et al., 1995; Haskell et al., 1995; Petersen et al., 1995; Lewis et al., 2001), perhaps due to a lack of environmental challenge (Wemelsfelder and Birke, 1997). Specifically, Petersen et al. (1995) reported that pigs housed in pens enriched with straw, logs, and branches spent more time rooting, biting and chewing the provided materials, while pigs housed in barren environments spent more time rooting biting and chewing the floors and walls of their pen. These findings suggest that any environmental enrichment that promotes exploration and is an "outlet" for oral activities may be the most effective means of re- directing oral vices away from pen fittings and penmates in order to improve animal well-being.

According to Newberry (1995), appropriate environmental enrichment is defined as 'an improvement in the biological functioning of captive animals resulting from modifications to their environment'. A fundamental problem with many studies involving environmental enrichment is that environmental complexity is mistaken for environmental enrichment (Newberry and Estevez, 1997). It has been argued that increasing the complexity of the environment presents animals with many conflicting choices (Newberry and Estevez, 1997). The enrichment devices used in the current study were carefully designed to provide an outlet for specific oral-nasal behaviours associated with belly nosing, most notably rooting, nosing, biting and sucking. During the pre-weaning phase, piglets spent little of their time budget interacting with any of the environmental enrichment devices provided. While the rooting trays for the Root treatment were visited considerably more than any of the other enrichments (combined), the overall lack of interest in the presence of the environmental enrichment is probably best explained by the priorities of the piglet to keep warm through lying huddled together and maintaining good nourishment through nursing at regular intervals. As the piglets grew older, play periods increased, which led to a decrease in the amount of time spent lying and an increase in the proportion of time spent interacting with the provided enrichment devices. Interestingly, piglets in the Root and Bite enrichment groups spent more time lying than pigs in the Nose and Suck enrichment treatment groups.

As piglets were weaned and moved into the nursery, piglets gradually increased their interactions with the enrichment provided to them, with Root enrichment having the highest incidence of visits, followed by Bite, Suck, and Nose enrichment, respectively. During this post-weaning phase of development, the incidence of behavioural vices, such as belly nosing, belly sucking, other, and biting were relatively low compared with the time spent eating. Eating behaviour composed the greatest percentage of the daily activity time budget for almost all pigs in the study, with the exception of Root enrichment pigs, which spent the greatest proportion of their time rooting. It should be noted, however, that eating behaviour was measured as the percentage of time spent manipulating the feed, and not necessarily ingesting the feed. Given that piglets performed belly nosing despite piglets in all enrichment treatments continuing to spend a large portion of their time involved in Eating behaviour, these findings would support those of Bench et al. (2000), Chapter 3, and Gardner et al. (2001a) that hunger is not the underlying motivation to perform belly nosing. However, providing any type of enrichment was found to decrease the amount of time spent performing belly nosing, which may suggest that belly nosing is driven by more than the motivation to merely nose. Further research also needs to focus on how the environment influences the behaviour of the recipient animal.

Studies such as Beattie et al. (2001) have provided evidence that pigs will work for access to rooting substrates such as spent mushroom compost. In addition, pigs with access to such substrate exhibited less nosing, biting and chewing behaviours directed towards penmates, and resulted in fewer animals needing to be removed due to tail biting.

It was further found that pigs will re-direct rooting behaviour towards penmates and the feeder in the absence of any rooting substrate. Thus, the authors concluded that adding substrate, such as mushroom compost, to commercial finishing pens reduces the re-direction of such behaviours and improves welfare by minimizing injury through tail biting. Pigs provided with a soil-filled root tray consistently spent a greater proportion of their time interacting with their pen enrichment which may have effectively directed their attention away from most other objects within the pen, including the feed trough. The large amount of time piglets spent rooting in the soil-filled trays was similar to findings by Stolba and Wood-Gush (1981), Haskell et al. (1995), and Horrell and Ness (1995). Studnitz and Jensen (2002) did not find evidence that rooting is a behavioural need in their sow study, but there is support that rooting behaviour is reinforcing (Day et al., 1996) due to the high degree of preference that pigs show for it.

Similar to the findings of Beattie et al. (2001) that pigs with access to rooting substrate demonstrate less generalized nosing and biting behaviour, the current study also found a decrease in the amount of belly sucking, other, and biting behaviours. However, the Root treatment was not found to be effective in decreasing the incidence of belly nosing compared with Control animals. Li and Gonyou (2002) found social interaction immediately preceded behavioural vices such as belly nosing. Pigs in the Root treatment not only exhibited more activity than the other treatment groups, but they also had one of the higher incidences of belly nosing, compared with the other enrichment treatments, particularly by 33 days-of-age. The only other treatment group to match the high level of belly nosing was the Control group. Li and Gonyou (2002) agreed with the findings of Gardner et al. (2001a) that belly nosing was not likely to be motivated by hunger, but suggested that the behavioural vice may be more socially motivated. Therefore, the increase in behavioural vices exhibited in the Root group may have been due to the increase in social interaction and activity in the pen as a result of the rooting trays.

Piglets provided with a foam rubber matting anchored to the pen wall with a spacer for adequate nosing (Nose) interacted significantly less with the pen enrichment. However, Nose enrichment pigs also exhibited belly nosing and belly sucking behaviours the least amongst all enrichment groups. If the expectation theory of Lewis (1999) is correct, it may be that providing nosing mats, to re-direct the strong nosing behaviour need during the nursery phase, best meets the piglet's nosing expectations of the environment. Study into the ontogeny of belly nosing (Chapter 4) would suggest that piglets are in a "nosing" phase of development during the nursery period. The question remains, did even a little interaction with the nosing mats reduce the performance of belly nosing and belly sucking behaviour? Interestingly, providing Nose enrichment reduced the proportion of time pigs spent in belly-directed nosing and sucking, but failed to reduce the incidence of generalized nosing and sucking behaviour (Other) compared with animals under Control conditions. These findings further suggest that belly nosing is not performed for the sole sake of nosing, and needs to be investigated further.

It has been suggested by many ethologists that since survival of the young mammal depends on sucking success, it is assumed that sucking motivation must be strong and sucking deprivation would result in frustration, which could have a negative impact on a young mammal's welfare (de Passillé, 2001). However, providing newly weaned animals with a non-nutritive artificial teat has been found to reduce the occurrence of cross-sucking in some cases (de Passillé, 2001). Similar to the piglets in the Nose enrichment, piglets provided with blind nipples for sucking (Suck), had a low level of interacting with environmental enrichment. While, piglets in this group appeared to spend more time at the drinker than any other group, these findings were not significant. However, providing Suck enrichment led to a slight increase in the incidence of belly sucking behaviour, compared with Control animals. It is difficult to determine from such findings whether providing Suck enrichment actually encouraged the higher levels of belly sucking behaviour observed. The same results were not found in the previous preliminary study (Chapter 3). However, the study into the ontogeny of belly nosing (Chapter 4) would suggest that sucking behaviour develops after nosing behaviour. This raises the question of whether providing sucking enrichment too early during the nursery phase leads to increased levels of belly sucking behaviour by encouraging it prematurely. Providing sucking enrichment was not found to decrease the incidence of belly nosing compared with animals housed in an un-enriched environment. Algers (1984) suggested that sucking was due to increased concentrations of plasma corticoids as a result of frustration arising from a lack of reward, which then leads animals to continue to attempt to 'cope' with a stressful environment (Weary and Fraser, 1997; Gonyou et al., 1998;

Worobec et al., 1999). If the presence of the nipples encouraged sucking behaviour, it may have been that the nipple drinkers provided positive reinforcement due to the consumption of water, versus the dry nipples. While the incidence of both eating and drinking behaviours were higher amongst Suck treatments, Rau and Duncan (1999) found that providing blind nipples to piglets of the same age as those used in this study had no effect on feed intake, water use, or growth, however the authors did find a reduction in belly nosing.

After piglets in the Root group, piglets provided with Bite Rite™ Tail Chews spent a considerable amount of time engaged in activities involving the enrichment provided to them. Furthermore, Bite pigs tended to exhibit lower levels of biting behaviour compared with pigs in Nose, Suck and Control treatments, which may be explained by the novel aspect of the device. Only Root pigs exhibited a lower incidence of biting behaviour. The tail chews allowed for four animals to interact with the device at once, which facilitated social interactions. Similar results were found with Horrell and Ness' (1995) using a hanging rope. Day et al. (1996) suggested that grower pigs gather nutritional information in their environment through chewing behaviour, which may explain the oral nature of the vices exhibited by the Bite pigs.

The increase in overall activity levels, compared with the amount of time spent lying during the pre-weaning phase were expected findings as animal became more independent and explored their environment more, including interacting with the various enrichments provided. While previous studies found belly nosing to commence around 3-4 days following weaning, peak incidence occurred two weeks later, and then gradually declined, it was interesting to find that this type of peaking and waning was not particular to belly nosing alone. All of the behaviours observed during the post-weaning period followed a similar trend with an increase in duration until approximately two weeks following weaning (26 days-of-age), and then decreasing by 33 days-of-age. These results differ from those found in the previous ontogeny study (Chapter 4). The overall persistence of general manipulation found throughout the nursery period, agrees with previous work by Metz and Gonyou (1990), Bøe (1993) and Worobec et al. (1999).

Day et al. (2002a) studied the effects of experience with straw on the behaviour of growing pigs and found that if pigs are provided with straw, which doesn't continue into the grow-finish phase of development, the result can be an increase in the occurrence of adverse penmate-directed behaviour. However, even a small amount of straw in the grow-finish environment may serve to ameliorate the negative effects of the change in housing environment. Together, these findings suggest that not only does early environmental enrichment experience seem to be important in reducing the incidence of behavioural vices, but may also serve to stop these vices from progressing once they begin. In the current study, providing environmental enrichment prior to weaning did not seem to have any effect on the incidence of behavioural vices in the nursery phase. However, providing enrichment in general during the post-weaning phase lead to lower incidences of belly nosing, belly sucking, other and biting behaviours. These findings suggest that a sensitive period for providing enrichment to piglets as a means of reducing oral-nasal behaviours occurs during the nursery phase when the behaviours are likely to develop, rather than during the pre-weaning phase when the piglets spend most of their time budget keeping warm and nursing. These findings agree with those of Vandenheede and Bouissou (1995) that enrichment prior to weaning had no effect. Nicol et al. (2001) also found that the current enrichment is of great importance to animals, regardless of prior experience. They suggest that this was due to a secondary 'sensitive period' resulting in adult behaviour being generally flexible and strongly influenced by the current environmental conditions. The effect of this sensitive period on the behaviour of early-weaned pigs during the grow-finish period was not investigated.

6.6 CONCLUSIONS

Similar to findings in other studies, pigs housed in a barren environment demonstrated the highest incidence of behavioural vices, which emphasizes the need to provide enrichment during the nursery phase of development. While environmental enrichment devices that facilitated social interaction were used the most, they were not found to be the most effective in reducing belly nosing in the early-weaned pig. However, providing any type of environmental enrichment reduced the amount of time spent performing belly nosing. Generalized nosing and sucking (other) behaviour directed toward penmates was the most prominent behavioural vice observed during the nursery phase, followed by belly nosing. This may indicate that providing Nose enrichment is most appropriate during this phase of development, due to the obvious need for piglets of this age to nose. In fact, providing nosing enrichment significantly decreased the proportion of time piglets spent belly nosing. However, belly nosing may not be performed for the sole sake of nosing. The finding that pigs performed belly nosing despite high levels of eating agrees with earlier studies that hunger does not seem to be the underlying motivation to perform belly nosing.

A sensitive period for belly nosing was not found to exist during the pre-weaning environment. Overall, providing environmental enrichment relevant to a particular behavioural vice as it commences, or shortly afterward, was found to have the greatest effect in reducing the incidence of such behaviours during the nursery phase of development. As such, the window of opportunity for providing effective environmental enrichment for the early-weaned pig may be in the transition between one type of behavioural vice and the next.

The findings of this study suggest that providing environmental enrichment during the early nursery phase is important to piglets, and can reduce the incidence of behavioural vices. While Root and Bite enrichments were most frequently used by piglets, Nose and Suck enrichments also had some significant effects on the behaviour of early-weaned piglets. As a result, the use of environmental enrichments at the appropriate phase of development may serve to stop oral-nasal vices from progressing or reduce their incidence once they begin, thereby having positive effects on welfare into the grow-finish phase of development.

7.0 TEMPERATURE PREFERENCE AND THE INCIDENCE OF BELLY NOSING AND HUDDLING BEHAVIOUR IN PIGLETS WEANED AT 12-14 DAYS-OF-AGE

7.1 ABSTRACT

The thermal environment is known to have large effects on the health, productivity, and behaviour of growing swine. The thermal environment is especially critical in the case of early-weaned piglets, which require warmer temperatures in the nursery environment, and show increased levels of behavioural vices such as belly nosing. Little is known about the thermal preferences of piglets weaned at 12-14 days-of-age. Likewise, studies on the incidence of belly nosing in early-weaned piglets in relation to thermal environment have not been conducted.

Piglets were weaned at 12-14 days-of-age and observed for 21 days post-weaning in a study to determine the thermal preference in early-weaned pigs through the use of operant conditioning. Hourly temperatures were averaged at three, four and five weeks-of-age to determine weekly thermal preference. To determine the effect of time of day, age, sorting by weight at weaning, and provision of control over the thermal environment on activity, lying, belly nosing, and huddling behaviour, 240 piglets were observed over 5 replicates. In each replicate, pigs were sorted by weight into six pens of eight pigs each: heavy, medium-heavy, medium-light, light, and two variable weight ($Variable_1$ and $Variable_2$) pens. Each pen was videotaped for 48-hours at 15 and 16, 22 and 23, and 29 and 30 days-of-age, and behaviour data were obtained through instantaneous scan sampling of the tapes every 10-mins (ie. 288 scans per pen per 48-hour observation period.)

Overall, the mean preferred temperature was found to decrease during the night and early morning, and increase during the day. While piglets spent most of their overall activity budget lying, activity levels were the highest from 08:00-16:00 (30.5 - 33.4%). This peak in activity levels was found to coincide with higher preferred temperatures of 25-27°C during the day. Piglets were found to huddle most from 00:00-08:00 (Huddling Index = 42.1 - 47.8% of lying) during which time they preferred cooler temperatures of 23-25°C. The percentage of time piglets spent belly nosing per pen was found to be

highest between 16:00-00:00 (5.48 – 5.51%) when temperature and activity levels still remained relatively high. While the huddling index tended to decrease with age (44.2% at 15-16 d compared with 21.0% at 29-30 d), the percentage of time piglets spent belly nosing per pen peaked at 22-23 days-of-age (7.56%), decreasing by 29-30 days-of-age (6.68%; $P<0.001$). The present study indicates that periods of highest preferred temperature, coincided with belly nosing and activity in these early-weaned pigs.

7.2 INTRODUCTION

The thermal environment is known to have large effects on the health and productivity of growing swine (Noblet et al., 2001). This is likely to be most critical in the case of newly weaned piglets, which require warmer temperatures in the nursery environment (Christison, 1988). Recommendations for ambient temperatures in the pig barn are based on experiments and calculations, which give single values for each phase, age, and/or weight category of a pig during it's life, but do not consider special management techniques or programs such as early weaning. Christison (1988) cautioned that it is prudent to manage the environment to suit the weakest, not the average pig and concluded temperatures should remain at a constant temperature of 26–28°C, for pigs 3-4 weeks-of-age, with minimal temperature fluctuations.

In the newly weaned piglet, behavioural patterns determine the pig's thermal status (Curtis and Morris, 1982). Huddling behavior and the selection of a comfortable environment are two known strategies for animals in cooler temperatures to find the warmth needed. However, today's confined pigs are often prevented from selecting their optimal temperature. During cold weather, nursery temperatures are frequently kept relatively uniform over space and constant over time. This approach deprives young pigs of the chance to select an environment more comfortable than the one chosen by the swine herdsman.

Operant conditioning has been used as an accepted means of determining not only an animal's environmental preferences, but also how much an animal is willing to work for a given reward. Baldwin and Ingram (1968) demonstrated that pigs can learn to adjust their thermal environment during cold periods by becoming conditioned to perform an operant task for which heat serves as the reward. Specifically, it was reported that individually reared pigs showed a frequency of operant responses for a 3-second burst of infrared heat that was inversely proportional to environmental temperature. Balsbaugh and Curtis (1979) found similar results for pigs treated differently in two respects: the pigs were reared in groups, instead of housed alone, and they were given much longer infrared heat rewards of 1, 3, or 6 minutes. These results suggest that operantly controlled supplemental heat might be feasible in swine production systems. Curtis and Morris (1982) tested this possibility and found group reared 4-week old pigs learned to operate a switch in order to obtain a 10-minute reward of heat from four supplemental infrared heat lamps which also turned on a natural gas-fired unit heater for 8-minutes. The results showed the performance and general health of these pigs were comparable to those of animals produced in commercial nurseries. Later work by Morrison et al. (1987, 1989b) is in agreement with these results. In addition, the pigs proved to be much more efficient in fuel usage than the more conventionally housed pigs. A 53% savings in fuel was found in the operant-controlled environment over all replicates. For the replicate conducted during the coldest weather, there was a 73% savings in fuel.

Curtis and Morris (1982) found the temperature in the operant control group peaked for a period each day at a temperature similar to that recommended for pigs of that age. This suggests that the environmental temperature agriculturalists have selected as the optimum is the peak temperature preferred during mid-day, and the temperature can be reduced at other times of day without a negative effect on productivity. Studies by Baldwin and Ingram (1968), Balsbaugh and Curtis (1979), and Curtis and Morris (1982), all agree that pigs prefer to have a lower temperature at night, and choose to huddle to keep warm (Baldwin and Ingram, 1968). General activity in the barn during the day may help to explain some of the difference in the amount of heat demanded between day and night periods. These diurnal temperature preferences may, in fact, reflect the maintenance of diurnal cycles of activity and metabolism as pigs have evolved in outdoor thermally fluctuating environments (Christison, 1988). Furthermore, a number of studies have found similar pig performance when nursery room temperatures were reduced at night (Brumm et al., 1985; Brumm and Shelton, 1988; Neinaber and Hahn, 1989).

An increasing number of studies have suggested that control over events in the environment is important to animals (Markowitz and Line, 1991; Mineka et al., 1986;

Wiepkema, 1990). However, in intensive farming systems, animals have little or no control over important elements in their environments, such as temperature. As a result of such low levels of environmental control, it has been argued that welfare is reduced in the intensively farmed animal by increasing its passivity and stress (Taylor et al., 2001). This has led to suggestions that the welfare of farm animals could be improved by allowing them control over certain environmental stimuli (Wiepkema, 1990; Appleby and Hughes, 1993; Farm Animal Welfare Council, 1993). Animals allowed to work for food and other rewards are reported to be physically and psychologically healthier than animals maintained under standard husbandry conditions, where opportunities to control the environment are limited (Markowitz and Woodworth, 1978; Mineka et al., 1986). Jones and Nicol (1998) studied the effect that control of the thermal environment had on the well-being of growing pigs 4-6 weeks-of-age. Pigs with operant control over their thermal environment were found to behave differently than pigs housed in control conditions. Wiepkema (1987) argued that increased stress associated with uncontrollable and/or unpredictable stimulation may increase the likelihood of re-directed behaviour, which may function in stress reduction and coping.

Few studies have investigated the effect of the thermal environment on the development of re-directed behaviours, such as belly nosing, in the early-weaned piglet. In a sequential analysis study of belly nosing in the early-weaned pigs, Li and Gonyou (2002) found social activity most often preceded the behavioural vice. Since it is known that temperature affects activity levels in animals (Boon, 1981; 1982), the logical question is whether temperature affects the proportion of time early-weaned piglets spend belly nosing in the nursery environment.

The objectives of this study were twofold. The first part of the study was to determine the preferred temperature of piglets early-weaned at 12-14 days-of-age during the first three weeks following weaning, when the incidence of behavioural vices, such as belly nosing, are known to be a problem. The second objective was to determine the relationship between belly nosing, activity levels and huddling behaviour in the early-weaned piglet. This second part of the study also investigated the effect of control over the thermal environment on the incidence of belly nosing. Both objectives also included investigating the effects of age as well as time of day on temperature preference, the activity time budget, and the incidence of belly nosing of early-weaned piglets.

7.3 MATERIALS AND METHODS

7.3.1 Facilities and Animals

Conducted at the Prairie Swine Centre in Floral, Saskatchewan, 240 piglets in five replicates of 48 piglets each were studied during the winter of 2000. Within each replicate, pigs were housed in a nursery room with six pens of eight piglets per pen. Pens measured approximately 1.5 m x 1.5 m and were constructed of durable plastic paneling and Tenderfoot® (Tandem Products Ltd., Blooming Prairie, MN) flooring. Each pen was equipped with one nipple drinker mounted at the back of the pen just above piglet nose height, and one trough feeder located towards the front of each pen. Each trough feeder allowed enough space for up to four piglets to feed at one time. Lights were turned off and on a 12-hour cycle from 07:00 to 19:00h. Of the six nursery pens, the pen furthest from the gas heater in the room was designated as the "heat-controlling" pen (pen with operational lever) and was equipped with a 2-lever box (Figure 7.1), over which hung an infrared heat lamp. Of the two levers, one (the operational lever) turned on the infrared heat lamp for 60-seconds and the room's gas heater for 90-seconds, while the other was a "non-operating" lever. The pen closest to the gas heater in the room was designated as a non-operating pen (Figure 7.2) and was also equipped with a lever box with one non-operational lever. All levers were easily activated by pushing on them.

Thermocouples were placed in the room's inlet duct, at the centre of the nursery room, and over the centre of each pen about 1.5 m from the pen floor. A relative humidity sensor was also hung from the centre of the room to verify constant humidity throughout each replicate, since humidity is known to affect perceived temperature.

All piglets in the study were of Camborough 22 lineage, weaned at 12-14 days-of-age, and assigned to pens without regard to sex. Piglets were monitored and observed for 21 days post-weaning per replicate. Within each replicate, piglets were sorted into one of five weight categories: light (2.5-3.5 kgs), medium-light (3.6-4.5 kgs), medium-heavy

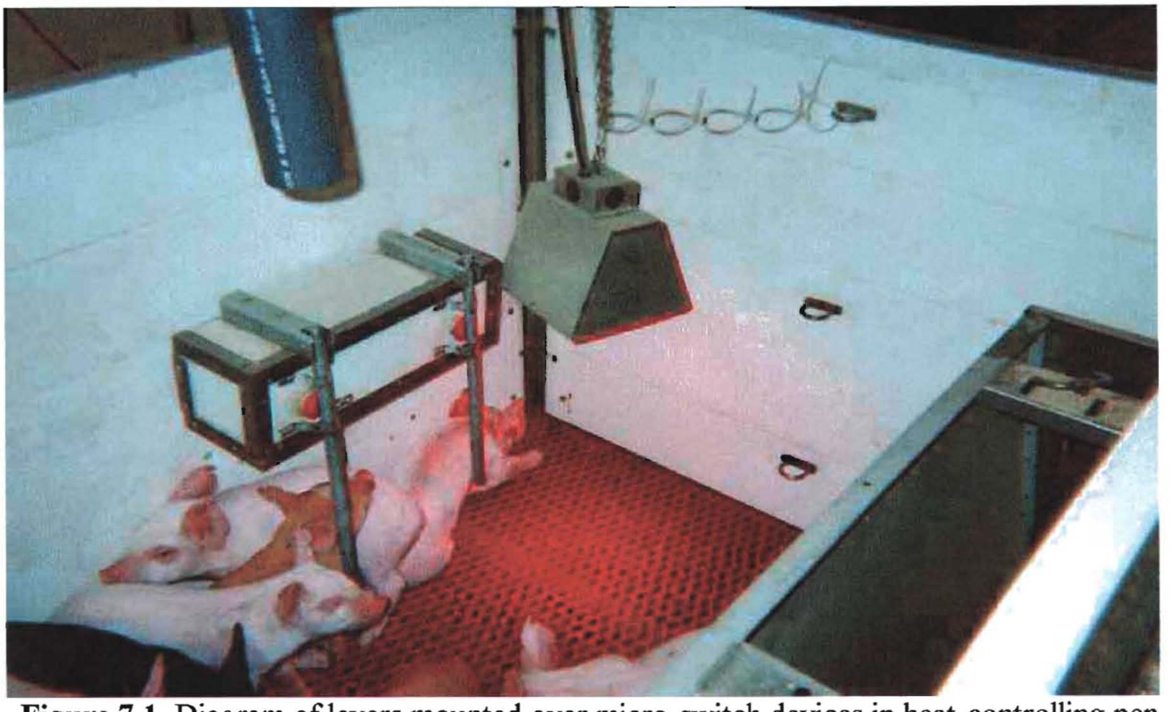

Figure 7.1. Diagram of levers mounted over micro-switch devices in heat-controlling pen (infrared heat lamp located over the heat-controlling (operating) lever).

Figure 7.2. Diagram of lever mounted over micro-switch device in non-heat-controlling pen.

(4.6-5.5 kgs), heavy (5.5-7.0 kgs), and variable (two pens ($Variable_1$ and $Variable_2$) within the nursery room). The heat-controlling pen was always assigned a variable weight group ($Variable_1$), which consisted of two light, two medium-light, two medium-heavy and two heavy piglets. With the exception of the heat-controlling pen, each of the five remaining pens were randomly assigned a weight category each replicate, so that weight groupings were rotated throughout the room by the end of the fifth replicate.

7.3.2 Data Collection

7.3.2.1 Datalogger

A datalogger (Datataker DT 100, Data Electronics (Aust.) Pty. LTD Australia) was used to control temperature safety settings, ventilation rates and relays as well as to record all temperature preference data and lever hits. The thermocouples in the nursery room were connected to the datalogger, which recorded temperature every 5-min for the entire 21 days of each replicate. Temperature for the heat-controlling pen was also recorded whenever an operational lever hit occurred. Temperature and lever data were downloaded from the datalogger once every 24-hours throughout the study.

As a safety feature, the minimum temperature for the nursery room was set to 19°C at which point the gas heater in the room would turn on to maintain at least the minimum temperature. The maximum temperature for each room was set to 35°C at which point the fans would increase to maximum speed in order to reduce the room to 30°C or cooler. To control for outside air temperature and its impact on the output of the furnace heater, air from the outer hallway was pre-heated to 9°C and supplied to the nursery with a minimum ventilation rate of 0.2 m^3/s. The minimum and maximum temperature safety features as well as control for the ventilation rate in the room, were all controlled through the datalogger as it regularly collected temperature information through each replicate. When a high or low temperature safety setting was reached, the relays from the datalogger were programmed to adjust the speed of the nursery fans and the output of the gas heater.

Through the use of relays, hits to each of the three levers (operational lever and two non-operational levers) were recorded by the datalogger. For each hit of the operational lever, the datalogger recorded the temperature in the heat-controlling pen.

Once the operational lever was hit, the infrared heat lamp and gas heater were turned on, increasing the temperature in the room by approximately 0.5°C with each hit to the lever. Hits to the operational lever and temperature readings continued to be recorded, however, time of gas heater output was not cumulative. The infrared heat lamp and gas heater could only be reactivated once the previous 90-sec of gas heater output had been completed.

The datalogger also recorded the relative humidity of the room every 5-min in order to verify that humidity did not fluctuate within the room throughout each replicate. As a further precaution, washing was prohibited during each replicate so relative humidity was not artificially increased.

7.3.3 Observation Techniques

Behaviour observations for belly nosing, huddling, and general activity (Table 7.1) were conducted via video recording (Panasonic S-VHS AG-6730 Time Lapse Video Cassette Recorder) using a sequential switcher (Panasonic WJ-521), which rotated through each pen every 30 seconds, for 48 consecutive hours at 15-16 (2-3 days following weaning), 22-23, and 29-30 days-of-age. Video cameras (Panasonic Black and White WV-BL200) were set up approximately 2.5 m over the central front of each pen so the entire pen could be recorded. Using instantaneous scan sampling on a 10-min cycle (ie. 288 scans per pen per 48-hour observation period), video recordings were observed and behaviourally coded for: 1) the number of piglets engaged in belly nosing, 2) huddling behaviour, and 3) general activity. Huddling scores, adapted from Boon (1981; 1982), were assigned on the degree of huddling for the majority of pigs in a pen:

0 –majority of pigs standing

1 –majority of pigs lying, but not in contact with each other

2 –majority of pigs lying, with most pigs in contact with each other

3 - majority of pigs huddled together, with piglets piled atop one another

7.3.4 Calculation of the Huddling Index

Using the huddling scores, a huddling index (Boon, 1981; 1982) was calculated for each hour. This huddling index was calculated as the percentage of time spent

Table 7.1. Behaviours observed at 15-16, 22-23, and 29-30 days-of-age. Belly nosing, activity, and lying behaviours were reported as the percent time spent performing the behaviours.

Observed behaviour	Definition
Belly nosing	Nose of one piglet actively rooting at the belly region, between the front and rear flanks, of another piglet.
Activity	Majority of pigs in a pen standing on at least two feet (includes sitting behaviour).
Lying	Majority of pigs in a pen lying down either laterally or ventrally with no weight on any of their four legs.
Huddling	Piglets lying together to varying degrees: lying but not touching, lying and touching, and lying piled on top of one another. Huddling observations were based on what the majority of pigs in a pen were exhibiting.

huddling (based on a huddling score of 3) divided by the percentage of time spent lying (score 1-3). A mean huddling index was calculated for each of six 4-hour time periods during the day. Thus, giving a measure of the proportion of time the piglets spent huddling while lying in a given pen at a given time of day.

7.3.5 Statistical Analysis

A Kolmogorov-Smirnov test was conducted using the Univariate procedure of SAS (SAS Institute Inc., 2000) to test for normality of the data. All data was found to be normally distributed, with the exception of outliers present for the percentage of time spent active versus lying in the medium-heavy weight category in pen 6 of replicate 4.

The mean, minimum, and maximum preferred temperatures for each hour, along with temperature range, were calculated using data obtained from the heat-controlling pen thermocouple. To test the effects of replicate, age, and time of day (hour), temperature preference data were analysed using GLM ANOVA for repeated measures (Appendix E.1). A Bonferroni means separation test was performed using age and time of day.

The mean number of hits per replicate to the operating, control pen non-operating, and non-control pen non-operating levers were analysed using GLM ANOVA. A Bonferroni means separation test was performed for number of hits to each lever.

Behaviour data (belly nosing, huddling behaviour, and activity) were collected from the 48-hr videotapes collected at 15-16, 22-23, and 29-30 days-of-age. Behaviour data were analysed using the split-split plot model provided with the GLM analysis for repeated measures, using the pen as the experimental unit, age as the split-plot and time of day (period) as the split-split plot (Appendix E.2). Time of day was broken down into six time periods of 4-hours each:

1 - 00:00 to 04:00
2 - 04:00 to 08:00
3 - 08:00 to 12:00
4 - 12:00 to 16:00
5 - 16:00 to 20:00
6 - 20:00 to 00:00

Behaviour data per time period were calculated using the mean percent time spent active, lying, huddling while lying (huddling index), and belly nosing for the HC pen ($Variable_1$) and the non-controlling pen ($Variable_2$) 30-minutes prior to and following each time period. A Bonferroni means separation test was performed using age and time period.

To determine the effects of weight category on behaviour, data were analyzed as a 5 x 5 Latin Square. Behaviour data (belly nosing, huddling behaviour, and activity) for each of the five weight categories in each of the five non-controlling pens for each of the five replicates of the study were compared. Data were analysed as a 5 x 5 Latin Square split- split-plot, using the pen as the experimental unit, weight category in the main plot, age as the split-plot and time of day as the split-split plot (Appendix E.3). A Bonferroni means separation test was performed for weight category.

7.4 RESULTS

7.4.1 Temperature preference

As age increased, the mean preferred temperature for piglets early-weaned at 12-14 days-of-age decreased by approximately 0.5-0.6°C per week (Table 7.2). Mean temperature preferences were 26.31°C, 25.69°C, and 25.27°C for 3, 4, and 5 weeks-of-age, respectively ($P<0.001$). While the mean and maximum preferred temperatures, as well as the temperature range, did not differ significantly each week, the mean minimum temperature was highest at 3 weeks-of-age ($P=0.051$; Table 7.2). Furthermore, it is important to note, the minimum temperature in the room did not drop below 19°C, which was the lower temperature safety setting. The mean minimum temperatures were consistently between 22-23°C, while thermal preference ranged between 22-29°C at each age.

Thermal preference in the early-weaned pig reflected a circadian (diurnal) pattern in which the piglets preferred the highest temperatures during the day and the lowest temperatures during the night ($P<0.001$; Figure 7.3). These results agree with trends found in studies done in grow-finish hogs (Baldwin and Ingram, 1968; Balsbaugh and

Table 7.2. Average preferred temperatures with minimums, maximums, and range at 3, 4, and 5 weeks-of-age for piglets early-weaned at 12–14 days-of-age.

	Age				
	Week 3	Week 4	Week 5	SE	P-value
Average Minimum	23.17°C	22.06°C	21.98°C	0.32	P=0.051
Average Preferred	26.31°C [a]	25.69°C [b]	25.27°C [b]	0.13	P<0.001
Average Maximum	30.14°C	29.61°C	29.65°C	0.46	P>0.10
Range	6.97°C	7.55°C	7.67°C	0.32	P>0.10

Averages based on all temperatures collected each week for all replicates. Includes Bonferroni means separation results (means with same letter superscript along same row are not significantly different).

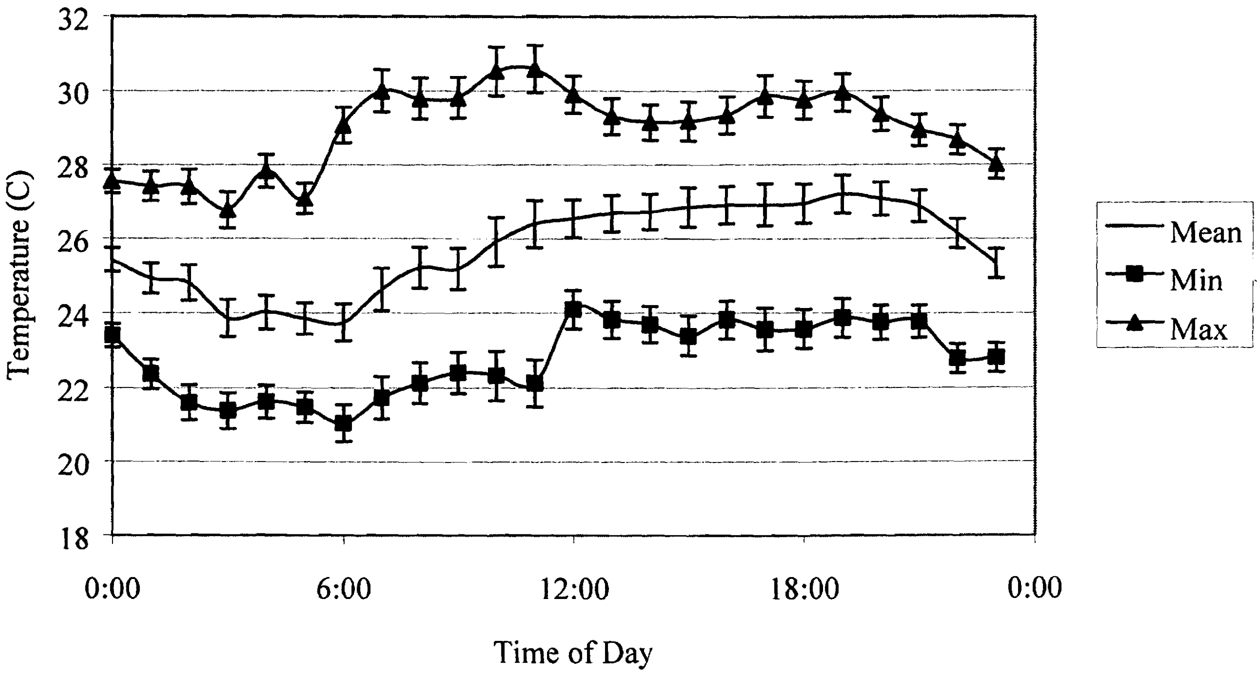

Figure 7.3. Mean preferred temperatures (± SE), selected by pigs weaned at 12-14 days-of-age, for a 24-hour circadian cycle (averaged for all replicates; P<0.001). P-value represents differences in mean temperature data per hour of the day.

Curtis, 1979; Curtis and Morris, 1982; Morrison et al., 1989a). In this case, the piglets preferred to let the temperature drop to its lowest in the very early morning hours from 03:00 to 06:00 (23.9°C to 23.8°C), and preferred the highest temperatures in the mid-evening around 19:00 to 20:00 (27.2°C to 27.1°C).

Using the mean number of hits per replicate to each of the levers provided during the study, the results show that most hits were made with the operational lever (8486), while the non-heat-controlling pen non-operational lever was used the least (1388; $P<0.001$). Most likely due to its proximity to the operational lever, the non-operational lever (5355) in the heat-controlling pen showed a higher amount of use than the dummy lever in the non-heat-controlling pen.

7.4.2 Behaviour

7.4.2.1 Effect of control

Mean percent time spent active, lying, or belly nosing between pigs in the non-heat-controlling ($Variable_2$ weight category) pen did not differ significantly from those able to control the thermal environment (heat-controlling pen). Furthermore, huddling index scores were also not found to differ significantly between the heat-controlling and non-heat-controlling pens ($P>0.10$).

7.4.2.2 Effect of age

Figure 7.4a shows the mean percentage of time spent active throughout the day at each age. Similar to the results in Table 7.3, piglets were most active during the middle of the day and least active into the evening and early morning hours ($P<0.01$). These results were particularly true for piglets of 15-16 days-of-age (Figure 7.4a). However, as the piglets grew older, piglets were more active in the later evening ($P<0.001$). While piglets were generally more active during the day, piglets consistently spent most of their overall time budget lying and resting (Tables 7.3 and 7.4). As the weeks following weaning progressed, differences in the percentage of time spent lying were observed (Figure 7.4b; $P<0.01$). Figure 7.4c and Table 7.3 show the percentage of lying time spent huddling (huddling index) decreased as the piglets grew ($P<0.001$). At 15-16 days-of-age, piglets spent a large percentage of their lying time huddling with one another (44.2%; Table 7.4;

Figure 7.4. Mean percentage of time spent engaged in (a) activity (± SE = 0.040; P<0.01) and (b) lying (± SE = 0.040; P<0.01) and the incidence of (c) huddling (± SE = 0.052; P=0.012) and (d) belly nosing (± SE = 0.74; P>0.10) behaviours for 15-16, 22-23, and 29-30 days-of-age, including breakdown by time period.

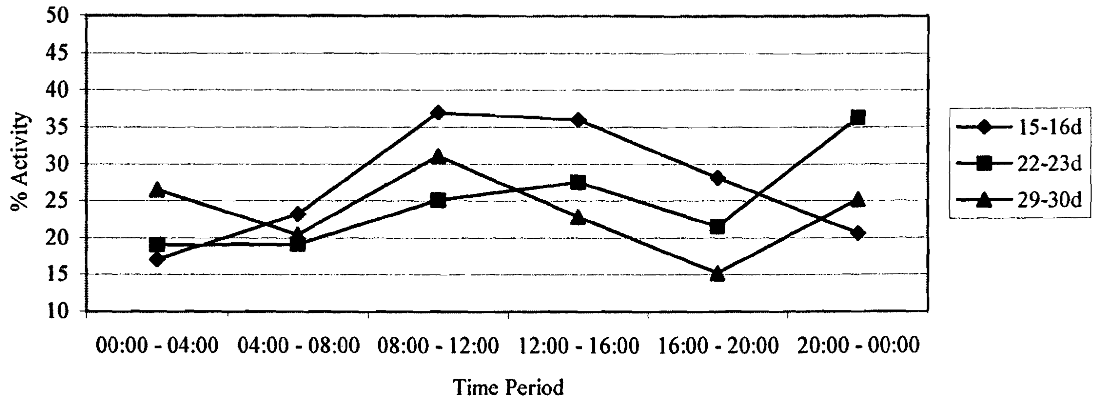

Figure 7.4a. Activity behaviour

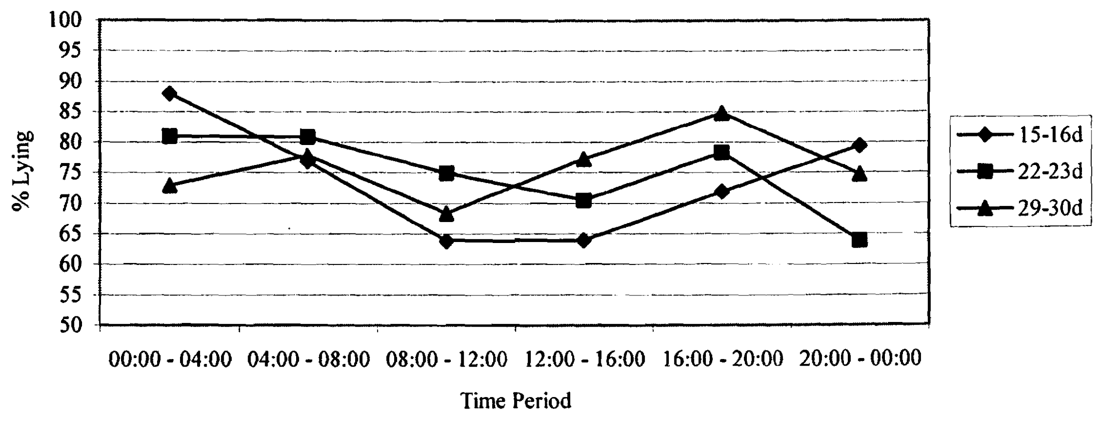

Figure 7.4b. Lying behaviour

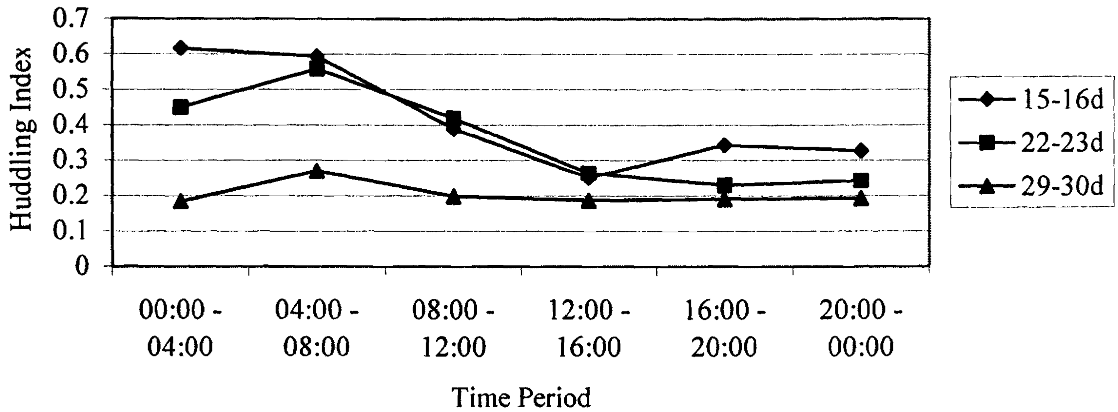

Figure 7.4c. Huddling behaviour

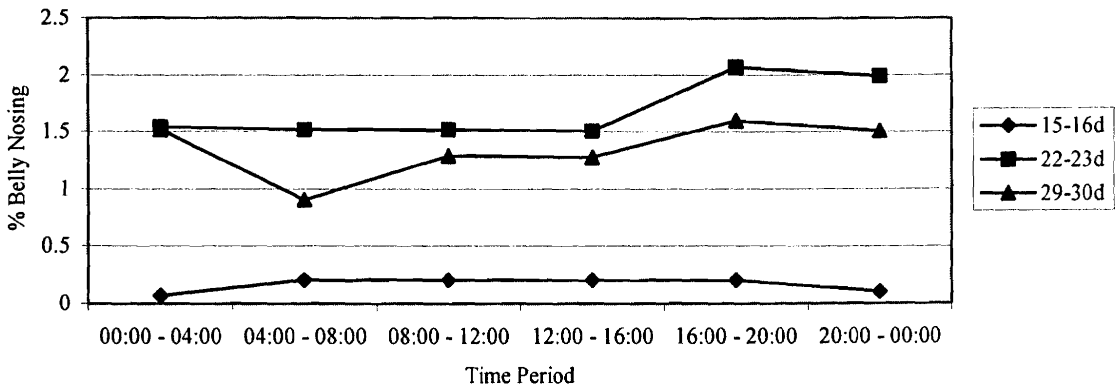

Figure 7.4d. Belly nosing

Table 7.3. Mean percentage of time spent active, lying and belly nosing and mean huddling index scores for each age.

	Age (days)				
	15-16	22-23	29-30	SE	P-value
Active (% time)	27.1	26.5	23.9	1.6	P>0.10
Lying (% time)	73.0	73.6	76.2	1.6	P>0.10
Huddling Index	0.442 [a]	0.328 [b]	0.210 [c]	0.021	P<0.001
Belly Nosing (% time)	0.61 [b]	7.56 [a]	6.68 [a]	0.30	P<0.001

Includes Bonferroni means separation results (means with same letter superscript along same row are not significantly different).

Table 7.4. Mean percentage of time spent active, lying and belly nosing and mean huddling index scores for each time period.

Time Class	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-00:00	SE	P-value
Active (% time)	19.0 ^{c}	20.5 ^{b,c}	33.4 ^{a}	30.5 ^{a,b}	23.2 ^{a,b,c}	27.9 ^{a,b,c}	3.8	P<0.001
Lying (% time)	81.1 ^{a}	79.6 ^{a,b}	66.6 ^{c}	69.6 ^{b,c}	76.8 ^{a,b,c}	72.1 ^{a,b,c}	3.8	P<0.001
Huddling Index	0.421 ^{a,b}	0.478 ^{a}	0.326 ^{b,c}	0.235 ^{c}	0.241 ^{c}	0.260 ^{c}	0.043	P<0.001
Belly Nosing (% time)	4.76	3.74	4.57	4.53	5.48	5.51	0.74	P=0.056

Includes Bonferroni means separation results (means with same superscript along same row are not significantly different).

P<0.001). In contrast, by 29-30 days-of-age, piglets were only spending an average of 20% of their lying time huddled together. Additionally, while the younger piglets showed a definite pattern of huddling more at night (60% of lying time) and less during the day (25%), the older piglets consistently spent the same percentage of lying time huddled together throughout the day (20%; Figure 7.4c; P=0.012). Table 7.4 shows most belly nosing was observed during the late evening from 16:00 to 00:00 (5.48 – 5.51%), while belly nosing was observed the least in the early morning hours (3.74%; P=0.056). At 15-16 days-of-age, the incidence of belly nosing was very low (Figure 7.4d and Table 7.3), with the highest incidence of the behaviour occurring at 22 - 23 days-of-age, then gradually dropping off by 29-30 days-of-age (P<0.001). At these latter two ages, the increase in belly nosing in the later evening is evident.

7.4.2.3 Effect of time period

Table 7.4 shows the comparison between the percentage of time spent active, lying and engaged in belly nosing, as well as the mean huddling index for each time period. Piglets spent the overall majority of their time lying, with most lying behaviour occurring from 00:00-04:00 (81.1%) and spent the least amount of time lying from 08:00-12:00 (66.6%; P<0.001). The most active period of the day occurred between 08:00 and 16:00 (30.5 – 33.4%; P<0.001), which coincided with the time of day in which piglets spent the least amount of time lying. Piglets spent the greatest proportion of their lying time huddled together during the very early morning hours of 00:00-08:00 (42.1 – 47.8 % of lying time; P<0.001), which correlates with when piglets spent the greatest proportion of their time lying. As piglets became more active during the day, the huddling index decreased, with the least huddling occurring between 12:00-16:00 (23.5% of lying time). However, during this same time period, piglets were becoming less active and were spending more of their time lying. In fact, during the transition from activity to lying, in the latter half of the day (12:00-00:00), the huddling index was consistently at its lowest (23.5 – 26.0% of lying time).

Percentage time spent belly nosing was at its lowest 04:00-08:00 (P=0.056), when huddling index was highest (3.74%) and activity levels remained low (Table 7.4). As piglets became more active and huddled less during the day, belly nosing was found to increase. However, the period with the largest proportion of time spent belly nosing occurred from 16:00-00:00 (5.48 – 5.51%) despite the gradual drop in activity levels in the pen. Interestingly, in the transition from piglets being active to spending more time lying, the huddling index remains quite low (23.5 – 26. 0% of lying time). Furthermore, as huddling index was found to increase, the incidence of belly nosing was found to decrease and vice-versa. Piglets were found to belly nose most in the evening (16:00-00:00) when temperatures were warmer and the need to huddle was not as great.

7.4.3 Effects of sorting by weight

Tables 7.5 and 7.6 show the mean percentages of time spent active, lying, or engaged in belly nosing in addition to the mean huddling index for each weight category. No significant difference was found among weight categories for mean percentage of time spent active or lying (due to outlier data present in pen 6 of replicate 4; Tables 7.5 and 7.6). Piglets in the different weight categories also did not significantly differ in the mean percentage of time spent belly nosing or in huddling index scores. This is even while pigs in the lightest group spent the largest proportion of lying time huddled (36.3% of lying time) than any other group. In comparison, the heavy weight group did the least huddling (26.0% of lying time).

7.5 DISCUSSION

The results demonstrate that piglets weaned at 12-14 days-of-age are able to learn to control their environment successfully through the use of operant conditioning. In fact, piglets in this study were observed readily controlling their thermal environment within 24 hours of weaning. Furthermore, early-weaned piglets prefer to have warmer temperatures during the day, when activity levels are higher, and lower temperatures through the night, when piglets exhibited more lying and huddling behaviour. While it may be speculated that the increased activity in the pen resulted in preferred temperature during the day being higher, the results of the study by Balsbaugh and Curtis (1979) found a similar preference for higher thermal temperatures during the day when pigs were required to work to cool down the thermal environment. The authors found that

Table 7.5. Mean percentage of time spent active, lying and belly nosing and mean huddling index scores for each weight category.

Weight Category	Heavy	Medium-Heavy	Medium-Light	Light	Variable$_2$	SE	P-value
Active (% time)	24.0	30.6*	25.0	25.7	23.7	1.7	P=0.077*
Lying (% time)	76.0	69.4*	75.0	74.3	76.3	1.7	P=0.077*
Huddling Index	0.260	0.299	0.289	0.363	0.370	0.041	P>0.10
Belly Nosing (% time)	2.22	2.07	2.16	2.00	2.23	0.34	P>0.10

(* indicates presence of known outlier data in pen 6 of replicate 4 in medium-heavy weight category). Data averaged over 6 days of observation.

able 7.6. Mean percentage of time spent active, lying and belly nosing and mean ıddling index scores for each weight category (means without outlier data).

Veight ategory	Heavy	Medium-Heavy	Medium-Light	Light	Variable$_2$	SE	P-value
Active ⁄o time)	24.0	27.7	25.0	25.7	23.7	1.8	P>0.10
Lying ⁄o time)	76.0	72.3	75.0	74.3	76.3	1.8	P>0.10
uddling Index	0.260	0.299	0.289	0.363	0.370	0.041	P>0.10
Belly Nosing ⁄o time)	2.22	2.07	2.16	2.00	2.23	0.74	P>0.10

ata averaged over 6 days of observation.

despite being more active during the day, pigs manipulated the thermal control device less during the day than they did during the night hours. In fact, during the night, when the piglets were more likely to be sleeping and resting, the piglets in the Balsbaugh and Curtis (1979) study worked the operant device the most in order to keep the environment cooler. Further evidence supporting the findings in this study reflecting the true temperature preference, rather than an activity curve, is provided by findings that most lever hits occurred to the operational lever in the heat-controlling pen compared to the two non- operational levers. Furthermore, the minimum and maximum temperature safety settings of 19°C and 30°C, respectively, were never reached during the duration of the five replicate study. Even as young as two weeks-of-age, piglets were able to not only maintain temperatures above the lower temperature safety setting, but the youngest pigs demanded the highest mean temperature, compared to three and four week old piglets.

While many commercial swine operations currently house early-weaned pigs in temperatures that are consistent over space and uniform over time, the mean preferred temperatures found in this study, along with those previously found in other studies (Curtis and Morris, 1982; Morrison et al., 1987; Morrison et al., 1989a) suggest that temperatures consistent over age and time of day are not preferred by early-weaned piglets. Instead, early-weaned pigs prefer a thermal environment with higher temperatures during the day and reduced nocturnal temperatures, reflecting a diurnal pattern. Furthermore, studies such as Brumm and Shelton (1991) have found that a diurnal temperature regime results in growth comparable to those animals housed under standard conditions.

Interestingly, the activity patterns of early-weaned piglets were found to correspond to the thermal environment, with piglets becoming more active as temperature increased, and less active as temperature gradually decreased. Likewise, as piglets became more active during warmer periods, the huddling index also decreased. However, during the latter half of the day when piglets made the transition from being more active to spending more time lying, the huddling index was consistently lowest. This may go to show that lying time does not necessarily reflect time spent huddling. Temperature data has already shown that piglets prefer warmer temperatures during the latter part of the day, which would not require them to huddle for warmth while entering into the least active periods of the day. Boon (1981; 1982) determined that the huddling index varied with the departure from the theoretical lower critical temperature. As such, it is only as temperature cools in the early morning hours, that piglets spend the greatest percent of time huddling.

A number of studies have documented the time course for belly nosing (Gonyou et al., 1998; Worobec et al., 1999) as commencing 3-4 days following weaning, peaking around two weeks later, and then gradually decreasing. The findings of this study found similar results. Belly nosing occurred most during transition periods when pigs were becoming less active, yet huddling remained low due to higher temperatures. This results in many piglets in the pen lying with their bellies "exposed", while a proportion of the pigs in the pen are still quite active. These periods coincided with the latter evening (16:00-00:00), when about half the pigs in a pen were settling down for the night, and the other half was still quite active, perhaps even restless. Combined with higher preferred temperatures during this same time period, piglets lying and resting during this time may have been easy targets of belly nosing by those piglets that were still active. However, as nursery temperature dropped (and piglets huddled more) to its lowest levels in the very early morning, belly nosing also dropped to its lowest levels.

The negative correlation between belly nosing and huddling behaviour was also observed between different weight classes of piglets, although these findings were not statistically significant. Pigs in the heaviest weight group were found to huddle least and belly nose most. In contrast, piglets in the lightest group showed higher levels of huddling behaviour and spent less time engaged in belly nosing. These results may be due to the fact that as piglets grow, they become more thermally insulated and thereby have less of a need to huddle to keep warm and, as a result, are more active in general. On the other hand, smaller piglets have less mass to keep them warm and need to huddle more to conserve body heat. Since lighter pigs are least active, they tend to belly nose the least. Interestingly, piglets in the variable weight group were found to belly nose the least of any of the weight treatments.

7.6 CONCLUSIONS

While it is known that early-weaned piglets need warmer temperatures in the nursery, these data suggest that keeping the thermal environment uniform over space and constant over time is not preferred by piglets. In addition to a reduction of 0.5 – 0.6°C each week following weaning, temperature preference in piglets early-weaned at 12-14 days-of-age followed a diurnal pattern, with warmer temperatures preferred during the day and cooler temperatures preferred at night, when piglets prefer to huddle together to keep warm. As such, temperature settings for the nursery should be based on age of the animal and time of day. This challenges hog producers to consider more fuel-efficient (and welfare friendly!) ways of managing the thermal environment of the early-weaned piglet.

Similarly, activity levels and belly nosing also demonstrated a diurnal pattern, with the highest incidence of belly nosing occurring during the transition from piglets being more active during the day to spending more time lying at night. Most importantly, warmer temperatures during this transition period result in piglets huddling little, despite the increase in lying behaviour. This combination of factors may explain the result in a higher incidence of belly nosing during this transition period.

Control over the thermal environment and sorting by weight at weaning were not found to significantly affect belly nosing in this study. However, more studies investigating the effect of weight variation in a pen and control over aspects of the environment, on belly nosing in the early-weaned pig, may be warranted.

8.0 GENERAL DISCUSSION

The behavioural repertoire of the domesticated pig is primarily composed of behaviours that are either oral or nasal in nature. Combined with the fact that pigs are also social creatures, one could conclude that it would take only a matter of time before these two important aspects of the pig's environment should collide. Whether or not such a combination becomes a welfare concern is a matter of context. Evidence that pigs exhibit more anomalous behaviours when weaned early raises concerns about their welfare (Robert et al., 1999; Weary et al., 1999; Worobec et al., 1999). The abnormal behavioural characteristics seen in belly nosing and similar oral-nasal behavioural vices, such as belly sucking and tail biting, provide indirect evidence of suffering through the gradual impairment of an animal's ability to interact with their environment. However, while belly nosing, and its associated behaviours, may have negative consequences, such as increased energy costs or harmful physical effects, performance of the behaviour may have some benefits, or at least be reinforcing in nature.

The primary objective of the studies described within this thesis was to add to our understanding of the underlying motivation of early-weaned piglets to perform belly nosing. The five experimental studies took different approaches to examine the contexts under which belly nosing and its related behavioural vices occur and its relationship to possible causative factors. Diverse themes were addressed in the pursuit of evidence about the basic nature of belly nosing in pigs, and in an attempt to explain why it happens, this evidence was combined with the findings of previous studies. Within this broad purpose, the studies had several more specific objectives that included the investigation of the role of environmental as well as genetic factors on the incidence of belly nosing and its development in the early-weaned pig.

The time course for belly nosing has been substantiated by a number of studies (Gonyou et al., 1998; Worobec et al., 1999; Chapters 4 and 5) as a right-skewed bell-shaped curve in which the behaviour commences 3-4 days following weaning, peaks 2-3 weeks later, and then gradually declines. Li and Gonyou (2002) found that, at its peak, nursery piglets will spend an average of 2.4% of their daily time budget involved in belly nosing penmates and approximately 2.2% being belly nosed. Additionally, 81% of piglets early-weaned at 12-14 days-of-age will perform the behaviour with 5% of those animals showing very high levels of belly nosing in which they spend more than 8% of their total time involved in belly nosing penmates (Li and Gonyou, 2002). Approximately 60% of the pigs spent 0.1-4.0% of their total time on belly nosing and 19% did not show any belly nosing. The percentage of time spent belly nosing was found to be a bit higher than the mean time spent belly nosing in the work by Li and Gonyou (2002). As a further concern, as the incidence of belly nosing increases, the incidence of belly sucking behaviour also increases (Chapters 4 and 5), which may lead to the formation of umbilical hernias and lesions or other further injury (Waran and Broom, 1993). In addition, recipients of the behaviour may grow slower (Fraser, 1978; Gonyou et al., 1998).

We know from studies of the development of aberrant behaviours such as stereotypies that factors that initially trigger the development of an abnormal behaviour may be different from the factors that maintain already developed behavioural abnormalities later in life (Fentress, 1976; Ödberg, 1978; Mason, 1991). Studies in pigs have hypothesized that there may be a link between belly nosing in the nursery and tail biting behaviour in growing-finishing animals (Gonyou et al., 1998; Cox and Copper, 2001). However, that was not found to be the case (Chapter 4).

An association between belly nosing behaviour with other oral-nasal behavioural vices (Breuer et al., 2001) has also been reported. These associated behavioural vices include the nosing of penmates, ear biting, and genital-anal nosing. The suggestion that belly nosing is associated with other oral-nasal behavioural vices agrees with the findings of Chapter 4, which found that as belly nosing decreases, the incidence of generalized nosing, sucking, and biting behaviours increase in incidence with the highest levels of these behaviours occurring during the grow-finish phase of development. Thus, it would appear that after belly nosing subsides in the early-weaned pig, a number of other oral-nasal behaviours take its place. While nosing, sucking and biting penmates in general were the most prevalent of these behaviours to develop after belly nosing, it seems that some pigs develop into either "suckers" or "biters". For example, pigs that progressed from belly nosing to belly sucking tended to continue to perform the belly sucking behaviour into the grow-finish phase. Similar to the development of stereotypies, the development of belly sucking behaviour from belly nosing may be one of an increase in intensity and time spent performing the behaviour, which gradually becomes disconnected from the original function of the original behaviour pattern, in this case nosing the belly of a penmate. This change in intensity of the behaviour is demonstrated as the behaviour changes from nosing to sucking, while the increase in mean bout length and mean percentage of time spent performing belly sucking (Chapters 4 and 5) demonstrate the further focusing of the behaviour, particularly given that pigs that belly suck into the grow-finish phase tend to have a "favourite" target individual for the behaviour. With tail biting behaviour, the same increase in intensity is not seen. Moreover, piglets exhibiting generalized nosing and sucking behaviours during the grow-finish period were more likely to be tail biters and to engage in generalized biting of penmates (Chapter 4). Thus, pigs that performed tail biting exhibited a wider range of behavioural vices in the grow-finish phase, and tended to be more active in general. However, no correlation was found between belly nosing in the nursery and tail biting behaviour during the grow-finish period. The results of the present study show that generalized nosing and sucking behaviours were a better predictor for tail biting in the grow-finish period than the incidence of belly nosing. The association between belly nosing and other behavioural vices may be due to the natural tendency of the pig to chew and root on penmates, which is observed almost universally amongst pigs housed in groups (van Putten, 1969). In piglets, chewing on penmates, including the tails of penmates, has been suggested as being derived from suckling behaviour (Newberry and Swanson, 2001), which has been re-directed (Mason et al., 2003).

Li and Gonyou (2002) recently sought to determine the temporal association of belly nosing with other behaviours in an attempt to elucidate its proximate causation. In their study, they conducted a sequential analysis of behaviour and found that only social interaction led to 'other' behaviour and social interaction. 'Other' served as a transitional behaviour connecting eating, drinking, and belly nosing, but was not well defined. Li and Gonyou (2002) also reported that, within pens, belly nosing was negatively correlated with lying and eating, but positively correlated with standing. Social interaction and belly nosing frequently occurred in sequence, suggesting that these two behaviours may share common motivational factors. When only active behaviours were considered in the study, belly nosing appeared to substitute for other behaviours during the nosing segment of bouts of belly nosing. The authors concluded that belly nosing is more closely associated with social interaction than with eating or drinking behaviours. Chapter 4 also found that pens with higher activity levels exhibited higher incidences of all behavioural vices investigated. These findings are also supported by previous studies, which found activity levels to correlate to higher levels of oral-nasal behavioural vices (van Putten, 1969; Fraser, 1978; Keeling and Jensen, 1995; Lewis, 1999; Li and Gonyou, 2002; Keeling et al., 2004). Additional studies have found that pigs that are lower weight-for-age perform more nosing behaviour when compared with heavier groups of pigs weaned at the same age (Gardner et al., 2001a), which may be due to faster growing individuals tending to be less active and less likely to nose and chew other pigs (Gonyou et al., 1998; Brooks et al., 2001). However, while such results suggest that weight and belly nosing are somehow related, weaning weights of individual piglets have not been found to relate to the performance of belly nosing (Straw and Bartlett, 2001; Chapter 7).

It has been suggested that the motivation to perform belly nosing is hunger-driven due to the similarities between belly nosing and massaging the udder and suckling during nursing bouts (Fraser, 1978; Dybkjær, 1992; Gonyou et al., 1998, Weary et al., 1999; Worobec et al., 1999) and represents the perseverance or re-direction of sucking behaviour in piglets that have been removed from the sow (Newberry and Wood-Gush, 1985; Dybkjær, 1992). Metz and Gonyou (1990) suggested that nosing littermates in younger piglets acts as a substitute for teat contact with the sow, but it was unknown whether this need for teat contact was due to hunger or comfort of the sow's udder. However, evidence that hunger is not the motivating factor behind belly nosing can be found in a number of places, including the fact that belly nosing begins after the restoration of normal feed intake in the 1-3 days following weaning (Metz and Gonyou, 1990; Gonyou, 2001). This finding is also supported by the findings of Weary et al. (1999) who investigated the effects of diet on vocalization rate and belly nosing and found that while piglets fed a more complex diet produced lower frequency calls (< 500 Hz) than those fed a standard diet, there was no effect of diet on the incidence of belly nosing. In fact, the hunger hypothesis has gone largely unsubstantiated since belly nosing occurs despite feeding improved diet formulations (Tokach et al., 1994; Weary et al.,

1999) and the presence of milk in the diet (Gardner et al., 2001a). Results from Chapter 3 further found that even when liquid milk replacer was provided to piglets weaned at 7 days-of-age for an extended period of time, there was no reduction in the incidence of belly nosing. Further results in Chapter 6 found that pigs engaged in belly nosing despite piglets in all enrichment treatments continuing to spend most of their daily activity budget involved in eating behaviour. Moreover, Bruni and Widowski (2004) reported that pigs fed a restricted diet did not perform belly nosing significantly more than pigs fed *ad libitum* during the three weeks following weaning. As a result of their findings, the authors suggested that hunger stimulates nosing and rooting behaviour directed at the pen floor, indicative of foraging behaviour, rather than directed at penmates.

Fraser (1978) proposed that some of the observed variation in belly nosing within litters might possibly be associated with the animal's teat choice and suckling habits before weaning. However, results from Chapter 5 suggest that there is no correlation between teat order consistency, nursing bout lengths, or nursing cycle lengths and the performance of belly nosing or its related vices in either the nursery or grow-finish periods. Torrey and Widowski (2004b) has reported similar findings of belly nosing being negatively correlated to time spent nosing and sucking during nursing bouts. These findings are further supported by previous studies by Petrie and Gonyou (1988) and Gardner et al. (2001a) which found no effect of offering diets formulated with milk (an important cue known to stimulate sucking in mammalian species) on the incidence of belly nosing, feed intake or feeding behaviour. Likewise, other sensory cues associated with suckling behaviour, such as nursing vocalizations (Cronin et al., 2001; Torrey and Widowski, 2004b) have not been found to have an effect on belly nosing. Providing early-weaned piglets with non-nutritive sucking enrichment, such as blind nipples or 'soothers', has been found to significantly reduce the performance of belly nosing in some studies (Rau, 2002; Gonyou and Bench, 2003; Chapter 3). However, these findings were not replicated in Chapter 6 of this thesis, which found that providing nosing enrichment most effectively reduced belly nosing, while providing blind nipples led to a higher incidence of belly sucking behaviour during the nursery period. This may have been due, in part, to the difference in presentation of the nipple enrichment treatments in Chapters 3 and 6. In Chapter 3, the nipple enrichment treatment was provided in conjunction with liquid milk replacer and solid feed, while in Chapter 6 nipples were mounted to the pen wall. Furthermore, while Rau (2002) found that accommodating non-nutritive sucking reduced both drinking and belly nosing, other studies have found drinking and belly nosings follow the same temporal pattern in the early-weaned pig (Gonyou et al., 1998; Chapter 6). Torrey and Widowski (2004a) provide a possible explanation for such findings in a more recent study on the effect of nipple and bowl drinkers on belly nosing. The authors found belly nosing to be significantly greater in pigs using a nipple drinker than those using a bowl drinker, which may be due to bowl drinkers better accommodating sucking behaviour (Thexton et al., 1998; Torrey and Widowski, 2004a).

Another hypothesis is that belly nosing reflects a motivation to massage the udder, independent of feeding and hunger, and that the delay in its development represents a learning period (Weary et al., 1999). Under this hypothesis, the proximate motivation for udder massage may be one of several factors, such as the need for social contact that has been lost through the removal of the sow. Newberry and Swanson (2001) point out that cases of prolonged separation between a sow and her piglets can cause great distress since piglets derive comfort from the presence of the sow in addition to the milk she provides. This is true in the case of cows and calves as well, and is the major argument for a two-step weaning process (Haley et al., 2004). However, while providing environmental enrichment simulating the sow's udder is an effective way to reduce the incidence of oral-nasal behaviours associated with belly nosing, type of enrichment affects very specific behaviours (Chapter 3). In particular, providing nipples anchored in milk replacer troughs and dry feeders were effective in reducing sucking and belly-directed behaviours, including belly sucking, while providing air-filled inner tubes were effective in reducing more generally focused behaviours, such as nosing behaviour directed away from the belly of penmates. These findings support the hypothesis of Weary et al., (1999) that the underlying motivation to perform belly nosing in the early-weaned pig is to seek comfort. Based on the findings of Chapter 3, if piglets seek comfort from the belly region specifically, the presence of nipples may be the determining factor in whether that need is met. Likewise, if piglets seek comfort in general, then the provision of an inner tube may meet this need better than providing nipples, since it allows the piglets to pile up with one another in the center of the tube. As such, those pigs that seek comfort in general may be more socially motivated than piglets that seek comfort from the belly region specifically.

Behaviour, therefore, offers the animal an opportunity to either alleviate a stressor by removing itself from the stimulus, or to buffer the impact of a stressor by engaging in displacement activities. Based on work by Dantzer et al. (1978), Algers (1984) investigated the hypothesis that the sucking of penmates was due to increased plasma corticoid concentrations as a result of frustration arising from the lack of reward in the form of mother's milk. Other studies on belly nosing in early-weaned pigs have hypothesized that the behaviour is the result of trying to cope with a stressful environment (Weary et al., 1999; Gonyou et al., 1998; Worobec et al., 1999; Hohenshell et al., 2000). Support for this theory comes from observations that belly nosing occurs at significantly higher rates in piglets weaned with unfamiliar conspecifics in more crowded, barren environments compared with piglets weaned in littermate groups in pens enriched with straw (Dybkjær, 1992). Using the 'stress' definition of Fraser et al. (1975), Dybkjær (1992) defined stress as when an animal 'is required to make abnormal or extreme adjustments in its physiology or behaviour in order to cope with adverse aspects of its environment and management'. Accordingly, Dybkjær (1992) identified belly nosing as a behavioural indicator of stress in early-weaned pigs (behaviours she noted were exacerbated by a lack of enrichment such as bedding material). Other studies have also identified belly nosing as a key indicator of stress related to the absence of the sow in early-weaned pigs (Fraser, 1978; Gonyou et al., 1998; Weary et al., 1999; Worobec et al., 1999).

Gardner et al. (2001b) tested whether early-weaned piglets that perform belly nosing were doing so as a means of coping with a stressful environment and concluded that stress was not a motivating factor. More specifically, Gardner et al. (2001b) concluded that belly nosing was not a 'general' behavioural indicator of stress. However, the authors also added in their discussion that the ways in which they attempted to create varying degrees of stress may not have been effective, and therefore, piglets may not have been truly 'stressed' which led to no differences in belly nosing for any of the treatments. The coping hypothesis found its roots in studies of stereotypic behaviour. However, as convincing as the arguments for the stress hypothesis theory are, some argue that it is a mistake to assume that all abnormal behaviours are a response to stress (Rushen, 1993). Price (1985) proposed that the suffering or stress experienced by an animal in response to any given set of environmental circumstances may be determined directly or indirectly by some combination of factors relating to its evolutionary and ontogenic or developmental past. That is, the characteristics that an animal inherits from its ancestors and the experiences it acquires during its lifetime may have a profound effect on its ability to adapt to any existing set of environmental circumstances.

One of the factors investigated in this thesis was whether belly nosing, at least in part, is heritable. The large differences in the time to onset of belly nosing between litters observed by Fraser (1978) may have been the result of genetic factors. Both Chapters 3 and 5 found that breed line has an effect on the proportion of time spent performing specific behavioural vices related to belly nosing. In general, piglets of the Yorkshire line spent more time performing sucking and belly directed behaviours, including belly sucking, than Duroc pigs (Chapter 3). This higher incidence of belly-directed behavioural vices in the Yorkshire is not unexpected. Discussions with many producers, although anecdotal in nature, have indicated similar observations in the field. However, producer magazines have also cited breed or line difference in behaviour, based on observations at packing plants. Some of these citations have reported that lines with some Duroc genetics tend to be calmer, while lines with Hampshire, Pietrain, or Landrace genetics tend to be more nervous (Willham et al., 1964; Lund and Simonsen, 1995; Grandin, 2002). In contrast, Duroc pigs exhibited higher levels of nosing and sucking behaviours directed away from the belly of penmates (Chapters 3 and 5). In Chapter 5, Large White pigs were found to exhibit more nosing and sucking behaviours directed toward the belly of penmates, while Duroc pigs performed more generalized behaviours directed away from the belly of penmates. While the immediate reasons for the significant difference in behavioural vices observed in the Yorkshire and Duroc lines of pigs may not be apparent, it may be due in part to genetic selection. As a result of selecting for varying qualities, behavioural vices may have been inadvertently selected as well.

In addition to breed line, the results of Chapter 5 indicate that sire within breed line has a significant effect on the percentage of time pigs spend performing belly nosing, belly and general-directed sucking behaviours during both the nursery and grow-finish periods. Combined with the influence of breed line, these results suggest that males within a particular breed line may need to be observed for indications of behavioural vices prior to use in a breeding program, or conversely, using males from breeds or sires with a low incidence of behavioural vices, such as belly nosing, may be a useful means of helping to reduce such behaviours in an early weaning management system. Interestingly, tail biting and generalized biting during grow-finish are not significantly affected by either breed line or sire (Chapter 5), which suggests that these behaviours are primarily due to environmental factors. However, further large-scale investigations into the role of genetics on belly nosing and its associated vices in pigs is needed, particularly those that extend over multiple generations. Further research may indicate whether genetics plays a role in whether an individual becomes a “sucker” or a “biter” such as that casually observed in Chapter 4.

In his review of behavioural genetics, Hohenboken (1987) suggested that during the course of development, the environment in which an animal is raised often modifies or influences the behavioural expression such that the final observed behaviour usually has both a genetic and environmental component. More recently, O’Connell et al. (2004) discussed the importance of both genetic and early environmental factors in determining a piglet’s response to weaning. Chapter 3 investigated this interaction between genetics and the environment to determine the effect it had on belly nosing. Under control conditions in which no environmental enrichment was provided, Yorkshire and Duroc line pigs differed little when it came to generalized and overall nosing behaviours. However, Yorkshire pigs were much more responsive to the provision of either nipples or inner-tube enrichment than Duroc pigs when it came to these specific behaviours. In contrast, Yorkshire pigs exhibited higher levels of belly-directed and overall sucking behaviours compared with Duroc pigs under control conditions, but were again found to be very responsive to enrichment. In comparison with Yorkshire pigs, Duroc pigs consistently demonstrated lower levels of these same behaviours, despite the enrichment treatment. As such, it appears that breed line not only affects the types and incidence of oral-nasal behavioural vices performed, but how responsive animals are to the provision of a particular environmental enrichment treatment. Furthermore, types of enrichment that work in one breed line may not necessarily work in another breed line. The findings also suggest that not all behavioural vices observed in early-weaned pigs respond to nipple and tube enrichment.

In a few cases, behavioural traits may be influenced entirely by genetics or entirely by the environment or early experience of an animal. Many studies have supported the provision of environmental enrichment to pigs as a means of reducing and/or eliminating behavioural vices. The results of Chapters 3 and 6 further support these findings. Specifically, providing environmental enrichment, which simulates the sow's udder, is effective in reducing the incidence of oral-nasal behavioural vices associated with belly nosing. Furthermore, the type of enrichment affects very specific behaviours. In Chapter 3, providing nipples anchored in milk replacer troughs and dry feeders was effective in reducing sucking and belly-directed behaviours, including belly sucking, while providing air-filled inner tubes was effective in reducing more generally focused behaviours, such as nosing behaviour directed away from the belly of penmates. Similar to results found in other studies (Lewis et al., 2001; Haskell et al., 1995; Petersen et al., 1995; Fraser et al., 1991; Schouten, 1991; Beattie et al., 1995), the findings of Chapter 6 concluded that animals housed in barren environments exhibit the highest levels of behavioural vices. These findings suggest that environmental enrichment that promotes exploration and is an "outlet" for oral activities may be the most effective means of re-directing oral vices away from pen fittings and penmates in order to improve animal well-being.

According to Newberry (1995) and Sherwin (2004), appropriate environmental enrichment should improve the biological functioning of captive animals resulting from modifications to their environment that take into account the motivations and senses of a species. The enrichment devices used in Chapter 6 were carefully designed to provide an outlet for specific oral-nasal behaviours associated with belly nosing, most notably rooting, nosing, biting and sucking. Providing any type of enrichment was found to decrease the incidence of biting and general nosing and sucking behaviours during the nursery period, suggesting the enormous impact of a barren environment on the propensity of belly nosing in early weaning management systems. It is clear from these results that the best and easiest means of reducing behavioural vices during the nursery phase of development is to provide some type of environmental enrichment that acts as an outlet for oral-nasal behaviour in the young pig. Beyond this basic need for enrichment in the nursery, it is important to consider that even while pigs may spend a great deal of time manipulating a given enrichment, it does not mean the enrichment is effective at reducing the incidence of an undesirable behavioural vice. Pigs provided with rooting trays filled with mushroom and peat compost consistently spent the greatest proportion of time interacting with the provided enrichment. However, pigs provided with rooting enrichment also exhibited a higher level of belly nosing in the nursery period compared with pigs provided with nosing enrichment (Chapter 6). The only other treatment group to match these high levels of belly nosing and belly sucking behaviour was the Control group provided with no environmental enrichment. It is possible that the lack of decrease in behavioural vices exhibited by pigs given rooting enrichment may have been due to the increase in social interaction and activity in the pen, such as that suggested by Li and Gonyou (2002). Piglets provided with rubber matting anchored to the pen wall with a spacer for adequate nosing consistently interacted significantly less with the pen enrichment. However, the incidence of belly nosing and belly sucking behaviour in those pens was also the least amongst all enrichment groups. If the expectation theory of Lewis (1999) is correct, it may be that providing nosing mats to re-direct the strong nosing behavioural need during the nursery phase best meets the piglet's nosing expectations of the environment. Study into the ontogeny of belly nosing (Chapter 4) would suggest that piglets are in a "nosing" phase of development during the nursery period.

Day et al. (2002a) found that even a small amount of straw in a pen may serve to ameliorate the negative effects of a change in housing environment. These findings suggest that not only does an early environmental enrichment experience seem to be important in reducing the incidence of behavioural vices, but may also serve to stop these vices once they begin. Providing enrichment prior to weaning did not seem to have any effect on the incidence of behavioural vices in the nursery phase (Chapter 6). However, providing enrichment in general during the post-weaning phase led to lower incidences of belly nosing, belly sucking, generalized nosing, sucking and biting behaviours. These findings suggest that a sensitive period for providing enrichment to piglets as a means of reducing oral-nasal behaviours occurs during the nursery phase when the behaviours are likely to develop, rather than during the pre-weaning phase when piglets spend most of their time budget keeping warm and nursing. These findings agree with those of Vandenheede and Bouissou (1995) that enrichment prior to weaning is not beneficial. Nichol et al. (2001) also found that the current enrichment environment is of great importance to animals, regardless of prior experience. They suggest that this is due to a secondary 'sensitive period' resulting in adult behaviour being generally flexible and strongly influenced by the current environmental conditions. As such, the window of opportunity for providing effective environmental enrichment for the early-weaned pig may be in the transition between one type of behavioural vice and the next. One question raised by the study is whether providing enrichment for a vice before it has developed on its own, actually stimulates the early development of a more mature behavioural vice.

In addition to providing environmental enrichment, other aspects of the environment can also impact the incidence of behavioural vices. Temperature is a particularly important part of how an animal perceives its environment and is especially critical in the case of early-weaned piglets, which require warmer temperatures in the nursery and show increased levels of belly nosing. In the recently weaned piglet, behavioural patterns facilitate the pig's thermoregulatory capacity (Curtis and Morris, 1982). During cold weather, nursery temperatures are frequently kept relatively uniform over space and constant over time. This approach deprives young pigs of the chance to select an environment more comfortable than the one chosen by the swine manager. Furthermore, the need to conserve fuel costs is often in direct conflict with increased animal welfare due to thermal comfort.

After first determining that early-weaned piglets prefer decreased temperatures during the night and early morning, and increased temperatures during the day (Chapter 7), the belly nosing, activity, and huddling behaviour of pigs weaned at 12-14 days-of-age in their preferred thermal environment was investigated. Given that temperature has been cited as a possible cause of other behavioural vices, such as tail biting in the grow-finish period, observing the incidence of behavioural vices in a controlled temperature setting is very important. In this case, the control over the thermal environment was given to the pigs themselves to determine the effect of control over the thermal environment on the behaviour of early-weaned pigs. Previous studies have argued that control over events in the environment is important (Markowitz and Line, 1991; Mineka et al., 1986; Wiepkema, 1990) and that welfare is reduced and stress increased in animals that lack control over their surroundings (Taylor et al., 2001). Similar to thermal preferences, activity and belly nosing demonstrated a diurnal pattern, with the highest incidence of the behaviour occurring during the transition from piglets being more active during the day to spending more time lying at night (Chapter 7). Most importantly, warmer temperatures during this transition period resulted in piglets huddling little, despite the increase in lying behaviour. This results in many piglets in the pen lying with their bellies "exposed", while a proportion of the pigs in the pen are still quite active. This combination of factors may explain the observed increase in belly nosing during this transition period. Control over the thermal environment and sorting piglets by weight were not found to significantly affect belly nosing.

9.0 GENERAL CONCLUSIONS

If we go back and look at the list of original factors investigated, we now know that gender, additional liquid milk replacer, sorting by weight at weaning, pre-weaning teat order, control over the thermal environment, and providing environmental enrichment during the pre-weaning phase do not have a significant effect on the incidence of belly nosing.

However, breed lines differed in whether nosing and sucking behaviours were generally focused of directed towards the belly of penmates. Combined with the influence of breed line, the effect of sire on such behaviours indicates the potential for selection within breed for sires whose piglets exhibit less belly nosing or other behavioural vices.

The type of enrichment provided to piglets during the nursery phase is also very important. For example, some types of enrichment, such as those tailored to more mature vices, such as belly sucking, may actually encourage the behavioural vice to develop pre-maturely. Also, while enrichment devices that facilitate social interaction may be used the most, they were not found to be the most effective in reducing belly nosing. Thus, use does not equal effectiveness.

Belly nosing may also be an issue of context. Specifically, it was found that in the later evening, while temperature is still relatively high, and at least half the pigs are still quite active (and huddling behaviour is still at a minimum), the opportunity for increased levels of belly nosing may present itself.

The results of these studies give us some potential to prevent belly nosing before it begins in addition to ways to reduce or possibly eliminate the behaviour after it commences. Ultimately, the importance of examining belly nosing may be in increasing our knowledge about what motivates early-weaned pigs to perform the behaviour at higher rates than pigs weaned at later ages. While the studies presented in this thesis do not present a complete explanation of belly nosing, they do clarify several aspects of it, and suggest further avenues for future research. Based on what is known about belly nosing to date, however, one must conclude that the behaviour has both environmental and genetic components reflecting a thwarted motivation to receive comfort through either social contact or otherwise.

10.0 REFERENCES

Ag Canada, 1993. Recommended Code of Practice for Care and Handling of Pigs. Agriculture Canada Publication 1771/E. Communications Branch, Ag Canada, Ottawa. 55 pp.

Algers, B., 1984. Early weaning and cage rearing of piglets: Influence on behavior. Zentralb. Vet. Riehe A. 31, 14-24.

Apple, J.K. and Craig, J.V., 1992. The influence of pen size on toy preference of growing pigs. Appl. Anim. Behav. Sci. 35, 149-155.

Appleby, M.C. and Hughes, B.O., 1993. The future of applied ethology. Appl. Anim. Behav. Sci. 35, 389-395.

Augspurger, N.R., Ellis, M., Hamilton, D.N., Wolter, B.F., Beverly, J.L., and Wilson, E.R., 2002. The effects of sire line on the feeding patterns of grow-finish pigs. Appl. Anim. Behav. Sci. 75, 103-114.

Baldwin, B.A. and Ingram, D.L. 1968. Factors influencing behavioural thermoregulation in the pig. Physiol. Behav. 3, 409-415.

Balsbaugh, R.K. and Curtis, S.E., 1979. Operant supplemental heat by pigs in groups; Further observations. In: 71st Annual Meeting of Amer. Soc. Anim. Sci. pp. 181 (Abstract).

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

Beattie, V.E., Sneddon, I.A., Walker, N., and Weatherup, R.N., 2001. Environmental enrichment of intensive pig housing using spent mushroom compost. Anim. Sci. 72, 35-42.

Bench, C.J., Hayne, S.M., Froese, C.F., and Gonyou, H.W., 2000. Factors affecting the incidence of belly nosing in early weaned piglets: A preliminary study. In: Proc. North Amer. Regional Meeting of the Int. Soc. for Appl. Ethol., June 10-11. pp. 26 (Abstract).

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

Blecha, F., Pollmann, D.S., and Nichols, D.A., 1983. Weaning pigs at an early age decreases cellular immunity. J. Anim. Sci. 56, 396-400.

Bøe, K., 1991. The process of weaning in pigs: When the sow decides. Appl. Anim. Behav. Sci. 30, 47-59.

Bøe, K., 1993. The effect of age at weaning and post-weaning environment on the behavior of pigs. Acta Agr. Scand. A-AN. 43, 173-180.

Boon, C.R., 1981. The effect of departures from lower critical temperature on the group postural behaviour of pigs. Anim. Prod. 33, 71-79.

Boon, C.R., 1982. The effect of air speed changes on the group postural behaviour of pigs. J. Agr. Eng. Res. 27, 71-79.

Breuer, K.B., Beattie, V.E., Dunne, L.M., Slade, E.C., Davies, Z., Mercer, J.T., Rance, K.A., Sneddon, I.A., Sutcliffe, M.E.M., and Edwards, S.A., 2001. Validation and development of a behavioural test to predict the predisposition of growing pigs to perform harmful social behaviour such as tail-biting. In: Proc. Brit. Soc. Anim. Sci., April 23, Scarborough.

Briggs, H.M. and Briggs, D.M., 1980. Modern Breeds of Livestock. 4th Edition. MacMillan Publishing Company Inc. New York. pp. 736.

Briggs, H.M., 1983. International Pig Breed Encyclopedia. Elanco Animal Health. pp. 65.

Brooks, P.H., Moran, C.A., Beal, J.D., Demeckova, V., and Campbell, A., 2001. Liquid feeding for the young pig. In: Varley, M.A. and Wiseman, J. (Eds), The Weaner Pig: Nutrition and Management. CAB International, Wallingford, Oxon, UK. 153-178.

Broom, D.M., 1983. Stereotypies as animal welfare indicators. In: Smidt, D. (Ed), Indicators Relevant to Farm Animal Welfare. Martinus Nijhoff, The Hague. pp. 81-87.

Broom, D.M., 1988. The scientific assessment of animal welfare. Appl. Anim. Behav. Sci. 20, 5-19.

Broom, D.M., 1993. A usable definition of animal welfare. J. Agric. Envir. Ethics. 6 (Suppl. 2), 15-25.

Broom, D.M., 1996. Animal welfare defined in terms of attempts to cope with the environment. Acta Agr. Scand. A-AN. Suppl. 27, 22-28.

Brumm, M.C. and Shelton, D.P., 1988. A modified reduced nocturnal temperature regimen for early-weaned pigs. J. Anim. Sci. 66, 1067 (Abstract).

Brumm, M.C. and Shelton, D.P., 1991. Two reduced nocturnal temperature regimens for early-weaned pigs. J. Anim. Sci. 69, 1379-1388.

Brumm, M.C., Shelton, D.P., and Johnson, R.K., 1985. Reduced nocturnal temperatures for early weaned pigs. J. Anim. Sci. 61, 552 (Abstract).

Bruni, A. and Widowski, T.M., 2004. The effect of feed restriction on behavior of piglets weaned at 18-22 days of age. 7th Int. Soc. Appl. Ethol. North Amer. Regional Meeting. Purdue University. West Lafayette, Indiana. June 18-19. (Poster).

Bure, R.G., van de Krek, P., and Koomans, P., 1983. The supply of straw, compost and garden mould to fattening pigs. Publikatie, Instituiet voor Mechanisatie, Arbeid en Gebouven No. 190. pp. 23.

Canadian Agri-Food Research Council (CARC), 2003. Recommended Code of Practice for the Care and Handling of Farm Animals: Pigs. Addendum Early Weaned Pigs. Canadian Agri-Food Research Council, Ottawa. 16 pp.

Christison, G.I., 1988. Effects of fluctuating temperatures and of humidity on growing pigs: An outline. In: Livestock Environment III, Proc. 3rd Int. Livestock Env. Symp. Amer. Soc. Agr. Eng. Toronto, Canada. pp. 101-108.

Cooper, J.J., Cox, L.N., and Whitworth, C. 2000. Early environmental experience and transferable skills in the weaned piglet. In: UFAW Symposium on consciousness, cognition, and animal welfare. pp.31 (Abstract).

Cooper, J.J. and Nicol, C.J., 1994. Neighbour effects on the development of stereotypies in bank voles Clethrionomys glareolus. Anim. Behav. 47, 214-216.

Cox, L.N. and Cooper, J.J., 2001. Observations on the pre- and post-weaning behaviour of piglets reared in commercial indoor and outdoor environments. Anim. Sci. 72, 75-86.

Cronin, G.M. and Barnett, J.L., 1987. An association between plasma corticosteroids and performance of stereotypic behaviour in tethered sows. In: Barnett, J.L. (Ed), Manipulating Pig Production. Australian Pig Science Association. Werribee, Australia. pp. 26.

Cronin, G.M., Leeson, E., Cronin, J.G., and Bartlett, J.L., 2001. The effect of broadcasting sow suckling grunts in the lactation shed on pig growth. Asian-Aust. J. Anim. Sci. 14, 1019-1023.

Curtis, S.E. and Morris, G.L., 1982. Operant supplemental heat in swine nurseries. In: Proc. 2nd Int. Livestock Environ. Symp. Amer. Society of Agric. Eng., St. Joseph, MI. pp. 295-297.

Dantzer, R., Arnone, R., and Mormede, P., 1978. Effects of frustration on behaviour and plasma corticosteroid levels in pigs. In: 1st World Congress on Ethol. Appl. To Zootech. Symposia. October 23-27.

Day, J.E.L., Burfoot, A., Docking, C.M., Whittaker, X., Spoolder, H.A.M., and Edwards, S.A., 2002a. The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 76, 189-202.

Day, J.E.L., Kyriazakis, I., and Lawrence, A.B., 1995. The effect of food deprivation on the expression of foraging and exploratory behaviour in the growing pig. Appl. Anim. Behav. Sci. 42, 193-206.

Day, J.E.L., Kyriazakis, I., and Lawrence, A.B., 1996. An investigation into the causation of chewing behaviour in growing pigs: The role of exploration and feeding motivation. Appl. Anim. Behav. Sci. 48, 47-59.

Day, J.E.L., Spoolder, H.A.M., Burfoot, A., Chamberlain, H.L., and Edwards, S.A., 2002b. The separate and interactive effects of handling and environmental enrichment on the behaviour and welfare of growing pigs. Appl. Anim. Behav. Sci. 75, 177-192.

de Jonge, G., 1988. Genetics and evolution of tail biting by mink. In: Murphy, D.B. and Hunter, D.B. (Eds), Biology, Pathology and Genetics of Fur-Bearing animals. Proc. IVth Int. Soc. Cong. Of Furbearing Anim. Toronto. pp. 503-505.

de Jonge, G., 1989. Genetics and evolution of tail biting by mink. Fur Rancher. 69, 5-6.

Denton, D., 1984. Hunger for Salt. Springer, New York. pp. 650.

de Passille, A.M., 2001. Sucking motivation and related problems in calves. Appl. Anim. Behav. Sci. 72, 175-187.

de Passille, A.M.B., Rushen, J., and Janzen, M., 1997. Some aspects of milk that elicit non-nutritive sucking in the calf. Appl. Anim. Behav. Sci. 53, 167-173.

Dritz, S.S., Owen, K.Q., Nelssen, J.L., Goodband, R.D., and Tokach, M.D., 1996. Influence of weaning age and nursery diet complexity on growth performance and carcass characteristics and composition of high-health status pigs from weaning to 109 kilograms. J. Anim. Sci. 74, 2975-2984.

Dybkjær, L., 1992. The identification of behavioural indicators of 'stress' in early weaned piglets. Appl. Anim. Behav. Sci. 35, 135-147.

Ermer, P.M., Miller, P.S., and Lewis, A.J., 1994. Diet preference and meal patterns of weanling pigs offered diets containing either spray-dried porcine plasma or dried skim milk. J. Anim. Sci. 72, 1548-1554.

Ewbank, R., 1973. Abnormal behaviour and pig nutrition: An unsuccessful attempt to induce tail biting by feeding a high energy, low fibre vegetable protein ration. Brit. Vet. J. 129, 366-369.

Farm Animal Welfare Council, 1993. Report on Priorities for Animal Welfare Research and Development. F.A.W.C., Surrey, UK. pp. 17.

Farmer, C., Palin, M.F., Sorensen, M.T., and Robert, S., 2001. Lactational performance, nursing and maternal behavior of Upton-Meishan and Large White sows. Can. J. Anim. Sci. 81, 487-493.

Feddes, J.J.R and Fraser, D., 1994. Nonnutritive chewing by pigs – Implications for tail-biting and behavioral enrichment. Trans. ASAE. 37, 947-950.

Fentress, J.C., 1976. Dynamic boundaries of patterned behaviour: Interaction and self-organisation. In: Bateson, P.P.G. and Hinde, R.A. (Eds), Growing Points in Ethology. Cambridge University Press, Cambridge. pp. 135-167.

Forkman, B., Furuhaug, I.L., and Jensen, P., 1995. Personality, coping patterns, and aggression in piglets. Appl. Anim. Behav. Sci. 45, 31-42.

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

Fraser, D., 1980. A review of the behavioural mechanisms of milk ejection of the domestic pig. Appl. Anim. Ethol. 6, 247-255.

Fraser, D., 1987a. Attraction to blood as a factor in tail biting by pigs. Appl. Anim. Behav. Sci. 17, 61-68.

Fraser, D., 1987b. Mineral-deficient diets and the pigs' attraction to blood: Implications for tail-biting. Can. J. Anim. Sci. 67, 909-918.

Fraser, D., Phillips, P.A., Thompson, B.K., Pajor, E.A., Weary, D.M., and Braithwaite, L.A., 1995. Behavioural aspects of piglet survival and growth. In: Varley, M.A. (Ed) The Neonatal Pig: Development and Survival. CAB International, Wallingford, UK. pp. 287-312.

Fraser, D., Ritchie, J.S.D., and Fraser, A.F., 1975. The term "stress" in a veterinary context. Brit. Vet J. 131, 653-662.

Fraser, D., Weary, D.M., Pajor, E.A., and Milligan, B.N., 1997. A scientific conception of animal welfare that reflects ethical concerns. Anim. Welfare. 6, 187-205.

Gadd, J., 1967. Tail biting. Pig Farming. 15, 57-59.

Gardner, J.M., de Lange, C.F.M., and Widowski, T.M., 2001a. Belly nosing in early weaned piglets is not influenced by diet quality or the presence of milk in the diet. J. Anim. Sci. 79, 73-80.

Gardner, J.M., Duncan, I.J.H., and Widowski, T.M., 2001b. Effects of social 'stressors' on belly nosing behaviur in early-weaned piglets: Is belly nosing an indicator of stress? Appl. Anim. Behav. Sci. 74, 135-152.

Gill, J.C. and Thomson, W., 1956. Observation on the behaviour of suckling pigs. Brit. J. Anim. Behav. 4, 46 (Abstract).

Giroux, S., Martineau, G.-P., and Robert, S., 2000. Relationship between individual behavioural traits and post-weaning growth in segregated early-weaned piglets. Appl. Anim. Behav. Sci. 70, 41-48.

Gonyou, H.W., 1987. Auditory and social stimulation of newly weaned pigs. Appl. Anim. Behav. Sci. 17, 366 (Abstract).

Gonyou, H.W., 2001. The social behaviour of pigs. In: Keeling, L.J. and Gonyou, H.W. (Eds), Social Behaviour in Farm Animals. CAB International. pp. 147-176.

Gonyou, H.W. and Bench, C.J., 2003. Effects of environmental enrichment at two phases of development on the incidence of belly nosing behaviour in early weaned pigs. Proc. 37th Cong. Int. Soc. Appl. Ethol., Abano Terme, Italy. pp. 114.

Gonyou, H.W., Beltranena, E., Whittington, D.L., and Patience, J.F., 1998. The behaviour of pigs weaned at 12 and 21 days of age from weaning to market. Can. J. Anim. Sci. 78, 517-523.

Grandin, T., 2002. Handling pigs for optimum performance on the farm and in the slaughter plant. Western Hog J. Spring. pp. 29-33.

Groothuis, T., 1989. On the ontogeny of display behaviour in the black-headed gull: I. The gradual emergence of the adult forms. Behav. 109, 76-124.

Guy, J.H., Rowlinson, P., Chadwick, J.P., and Ellis, M., 2002. Behaviour of two genotypes of growing-finishing pig in three different housing systems. Appl. Anim. Behav. Sci. 75, 193-206.

Haley, D.B., Stookey, J.M., Weary, D.M., and Baily, D.W., 2004. A new way to wean minimizes the behavioural response of cattle over traditional weaning methods. Proc. 38th Cong. Int. Soc. Appl. Ethol. Helsinki, Finland. pp. 58 (Abstract).

Haskell, M., Wemelsfelder, F., Mendl, M., Calvert, S., and Lawrence, A.B., 1995. The effect of barren and enriched housing environments on the interactive behaviour of pigs. Appl. Anim. Behav. Sci. 44, 257-281.

Hemsworth, P.H., Winfield, C.G., and Mullaney, P.D., 1976. A study of the development of the teat order in piglets. Appl. Anim. Ethol. 2, 225-233.

Heo, K.N., Odle, J., Oliver, W., Kim, J.H., Han, I.K., and Jones, E., 1999. Effects of milk replacer and ambient temperature on growth performance of 14-day-old early-weaned pigs. Asian-Aust. J. Anim. Sci. 12, 908-913.

Herskin, M.S., Jensen, K.H., and Thodberg, K., 1998. Influence of environmental stimuli on maternal behaviour related to bonding, reactivity and crushing of piglets in domestic sows. Appl. Anim. Behav. Sci. 58, 241-254.

Herskin, M.S., Jensen, K.H., and Thodberg, K., 1999. Influence of environmental stimuli on nursing and suckling behaviour in domestic sows and piglets. Anim. Sci. 68, 27-34.

Hessing, M.J.C., Hagelso, A.M., van Beek, J.A.M., Wiepkema, P.R., Schouten, W.G.P., and Kurkow, R., 1993. Individual behavioural characteristics in pigs. Appl. Anim. Behav. Sci. 37, 285-295.

Hohenboken, W.D., 1987. Behavioral genetics. Vet. Clin. N Am-Food A. 3, 217-229.

Hohenshell, L.M., Cunnick, J.E., Ford, S.P., Kattesh, H.G., Zimmermann, D.R., Wilson, M.E., Matteri, R.L., Carroll, J.A., and Lay Jr., D.C., 2000. Few differences found between early- and late-weaned pigs raised in the same environment. J. Anim. Sci. 78, 38-49.

Horrell, R.I. and A'Ness, P.J., 1995. Enrichment satisfying specific behavioural needs in early-weaned pigs. Appl. Anim. Behav. Sci. 44, 264 (Abstract).

Horrell, R.I. and A'Ness, P.J., 1998. The skills to cope with early-weaning in pigs: A comparison of indoor and outdoor. In: Vessier, I. and Boissy, A. (Eds), Proc. 32nd Cong. Int. Soc. Appl. Ethol. Institut National de la Recherche Agronomique, France. pp. 216.

Jankevicius, M., Scott, L., Tippin, L., Urban, L., MacDonald, R., and Widowski, T.M. 2004. The effect of increased air velocity and chewing behavior directed at rope tail models in growing pigs. Proc. 7th Int. Soc. Appl. Ethol. North Amer. Regional Meeting. Purdue University. West Lafayette, Indiana. June 18-19. (Poster).

Jensen, P., 1986. Observations on the maternal behaviour of free-ranging domestic pigs. Appl. Anim. Behav. Sci. 23, 49-60.

Jensen, P., 1988. Maternal behaviour and mother-young interactions during lactation in free-ranging domestic pigs. Appl. Anim. Behav. Sci. 20, 297-308.

Jensen, P., 1995a. The weaning process of free-ranging domestic pigs: Within- and between-litter variations. Ethol. 100, 14-25.

Jensen, P., 1995b. Individual variation in the behaviour of pigs-noise or functional coping srategies? Appl. Anim. Behav. Sci. 44, 245-255.

Jensen, P. and Recén, B., 1989. When to wean: Observations from free-ranging domestic pigs. Appl. Anim. Behav. Sci. 23, 49-60.

Jensen, P., Stangel, G., and Algers, B., 1991. Nursing and suckling behaviour of semi-naturally kept pigs during the first 10 days postpartum. Appl. Anim. Behav. Sci. 31, 195-209.

Jeppesen, L.L., Heller, K.E., and Dalsgaard, T., 2000. Effects of early weaning and housing conditions on the development of stereotypies in farmed mink. Appl. Anim. Behav. Sci. 68, 85-92.

Jones, B.R., Carmichael, N.L., and Rayner, E., 2000. Pecking preferences and pre-dispositions in domestic chicks: Implications for the development of environmental enrichment devices. Appl. Anim. Behav. Sci. 69, 291-312.

Jones, R.B. and Nicol, C.J., 1998. A note on the effect of control of the thermal environment on the well-being of growing pigs. Appl. Anim. Behav. Sci. 60, 1-9.

Keeling, L. and Jensen, P., 1995. Do feather pecking and cannibalistic hens have different personalities? Appl. Anim. Behav. Sci. 44, 265 (Abstract).

Keeling, L.J., Bracke, M.B.M., and Larsen, A., 2004. Who tail bites and who doesn't in groups of fattening pigs? In: Hänninen, L. and Valros, A. (Eds), Proc. 38th Cong. Int. Soc. Appl. Ethol. Helsinki, Finland, Aug. 3-7. pp. 70 (Abstract).

Kelly, H.R.C., Bruce, J.M., English, P.R., Fowler, V.R., and Edwards, S.A., 2000. Behaviour of 3-week weaned pigs in Straw-Flow® deep straw and flatdeck housing systems. Appl. Anim. Behav. Sci. 68, 269-280.

Kjær, J.B., 1995. Genetic variation in feather pecking behaviour in chickens. Appl. Anim. Behav. Sci. 44, 266 (Abstract).

Kjær, J.B., Sørensen, P., and Su, G., 2001. Divergent selection on feather pecking behaviour in laying hens (*Gallus gallus domesticus*). Appl. Anim. Behav. Sci. 71, 229-239.

Klein, T., Zeltner, E., and Huber-Eicher, B., 2000. Are genetic differences in foraging behaviour of laying hen chicks paralleled by hybrid-specific differences in feather pecking? Appl. Anim. Behav. Sci. 70, 143-155.

Kouba, M., Hermier, D., and Le Dividich, J., 2001. Influence of a high ambient temperature on lipid metabolism in the growing pig. J. Anim. Sci. 79, 81-87.

Lambooy, E., 1988. Road transport of pigs over a long distance: Some aspects of behaviour, temperature and humidity during transport and some effects of the last two factors. Anim. Prod. 46, 257-263.

Larson, C., 1983. Tail biting in pigs. New Zeal. Vet. J. 31, 105-106.

Lawrence, A.B. and Rushen, J., 1993. Stereotypic Animal Behaviour: Fundamentals and Applications to Welfare. CAB International, Wallingford, UK. 212 pp.

Le Dividich, J., Noblet, J., and Aumaître, A., 1982. Environmental requirements of early-weaned intensively reared piglets. In: Livestock Environment II Proc. 2rd Int. Livestock Env. Symp. Amer. Soc. Agric. Eng .pp. 353-361.

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

Lewis, L., Cooper, J.J., and Mason, G.J., 2001. The behavioural responses of mink (*Mustela vison*) to deprivation of highly valued resources. In: Proc. Int. Soc. of Appl. Ethol., University of York, UK, April 10-11.

Lewis, N.J., 1999. Frustration of goal-directed behaviour in swine. Appl. Anim. Behav. Sci. 64, 19-29.

Li, Y.Z. and Gonyou, H.W., 2002. Analysis of belly nosing and associated behaviour among pigs weaned at 12-14 days of age. Appl. Anim. Behav. Sci. 77, 285-294.

Lund, A. and Simonsen, H.B., 1995. Stimulus directed activities and aggression in two breeds of slaughter pigs. Appl. Anim. Behav. Sci. 44, 268 (Abstract).

Main, R.G., Dritz, S.S., Tokach, M.D., Goodband, R.D., Nelssen, J.L. 2004. Increasing weaning age improves pig performance in a multisite production system. Proc. 4th Annual London Swine Conf. April 1-2. London, ON. (Abstract).

Markowitz, H. and Line, S.W., 1991. The need for responsive environments. In: Rollins, B.E. and Kesel, M.C. (Eds), The Experimental Animal Biomedical Research. CRC Press, Boca Raton, FL, USA. pp. 153-170.

Markowitz, H. and Woodworth, G., 1978. Experimental analysis and control of group behaviour. In: Markowitz, H. and Stevens, V.J. (Eds), Behaviour in Captive Wild Animals. Nelson Hall, Chicago.

Martin, P., 1984. The meaning of weaning. Anim. Behav. 32, 1257-1259.

Mason, G., 1991. Stereotypies: A critical review. Anim. Behav. 41, 1015-1037.

Mason, G.J., 1994. Tail biting in mink (*Mustela vison*) is influenced by age at removal from the mother. Anim. Welfare. 3, 305-311.

Mason, S.P., Jarvis, S., and Lawrence, A., 2003. Individual differences in responses of piglets to weaning at different ages. Appl. Anim. Behav. Sci. 80, 117-132.

McAdie, T.M. and Keeling, L.J., 2002. The social transmission of feather pecking in laying hens: Effects of environment and age. Appl. Anim. Behav. Sci. 75, 147-159.

McBride, G., 1963. The 'teat order' and communication in young pigs. Anim. Behav. 11, 53-56.

McGlone, J.J. and Anderson, D.L., 2002. Synthetic maternal pheromone stimulates feeding behaviour and weight gain in weaned pigs. J. Anim. Sci. 80, 3179-3183.

McIntyre, J. and Edwards, S.A., 2002. An investigation into the effect of different protein and energy intakes on model tail chewing behaviour of growing pigs. Appl. Anim. Behav. Sci. 77, 93-104.

McKinnon, A.J., Edwards, S.A., Stephens, D.B., and Walters, D.E., 1989. Behaviour of groups of weaner pigs in three different housing systems. Brit. Vet. J. 145, 367-372.

Mees, A.M.F. and Metz, J.H.M., 1984. Saughverhalten von Kälbern- Bedürfnis und Befriedigung bie verschiedene tränk-esystemen. KTBL-Schrift 299, 82-93.

Metz, J.H.M. and Gonyou, H.W., 1990. Effect of age and housing conditions on the behavioural and haemolytic reaction of piglets to weaning. Appl. Anim. Behav. Sci. 27, 299-309.

Mineka, S., Gunnar, M., and Champoux, M., 1986. Control and early sociomotional development in infant Rhesus monkeys reared in controllable versus uncontrollable environments. Child Dev. 57, 1241-1256.

Moberg, G.P., 1985. Biological responses to stress: Key to assessment of animal well-being? In: Moberg, G.P. (Ed), Animal Stress. Am. Physiol. Soc., Bethesda, Maryland. pp. 27-49.

Moberg, G. P., 1987. A model for assessing the impact of behavioural stress on domestic animals. J. Anim. Sci. 65, 1228-1235.

Moberg, G.P., 1996. Suffering from stress: An approach for evaluating the welfare of an animal. Acta Agr. Scand. A-AN Suppl. 27, 46-49.

Morrison, W.D., Amyot, E., McMillan, I., Otten, L., and Pei, D.C.T., 1987. Effect of duration of reward upon operant heat demand of piglets receiving microwave or infrared heat. Can. J. Anim. Sci. 67, 903-907.

Morrison, W.D., Laforest, K.L., and McMillan, I., 1989a. Effect of group size on operant heat demand of piglets. Can. J. Anim. Sci. 69, 23-26.

Morrision, W.D., Laforest, K.L., McMillan, I., and Pei, D.C.T., 1989b. Growth and reproductive performance of gilts raised under supplementary infrared or microwave heat. Can. J. Anim. Sci. 69, 27-31.

Morrow-Tesch, J. and McGlone, J.J., 1997. Environmental enrichment and well-being in cattle and swine production systems. In: Livestock Environment V, Vol. I. Proc. 5th Int. Symp. Amer. Soc. Agric. Eng. Bloomington, Minnesota, May 29-31. pp. 287-294.

Newberry, R., 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Appl. Anim. Behav. Sci. 44, 229-243.

Newberry, R.C. and Estevez, I., 1997. A dynamic approach to the study of environmental enrichment and animal welfare. Appl. Anim. Behav. Sci. 54, 53-57.

Newberry, R. and Swanson, J., 2001. Breaking social bonds. In: Keeling, L.J. and Gonyou, H.W. (Eds), Social Behaviour in Farm Animals. CAB International. pp. 307-331.

Newberry, R.C. and Wood-Gush, D.G.M., 1985. The suckling behaviour of domestic pigs in a semi-natural environment. Behav. 95, 11-25.

Nicol, C.J., 1995. The social transmission of information and behaviour. Appl. Anim. Behav. Sci. 44, 79-98.

Nicol, C.J. and Pope, S.J., 1994. Social learning in sibling pigs. Appl. Anim. Behav. Sci. 40, 31-43.

Nicol, C.J., Lindberg, A.C., Phillips, A.J., Pope, S.J., Wilkins, L.J., and Green, L.E., 2001. Influence of prior exposure to wood shavings on feather pecking, dustbathing and foraging in adult laying hens. Appl. Anim. Behav. Sci. 73, 141-155.

Nienaber, J.A. and Hahn, G.L., 1989. Cool nighttime and weaning age effects on 3 to 10 week old pigs. Trans ASAE. 32(2), 691 (Abstract).

Noblet, J., Le Dividich, J., and Van Milgen, J., 2001. Thermal environment and swine nutrition. In: Lewis, A.J. and Southern, L.L. (Eds), Swine Nutrition, 2nd Edition. CRC Press, Boca Raton. pp. 519-544.

O'Connell, N.E., Beattie, V.E., Sneddon, I.A., Breuer, K., Mercer, J.T., Rance, K.A., Sutcliffe, M.E.M., and Edwards, S.A., 2004. Influence of individual predisposition, material experience and lactation environment on the responses of pigs to weaning at two different ages. In: Hänninen, L. and Valros, A. (Eds), Proc. 38th Cong. Int. Soc. Appl. Ethol. Helsinki, Finland, Aug. 3-7. pp. 125 (Abstract).

Ödberg, F., 1978. Abnormal behaviours (stereotypies), Introduction to the round table. In: Proc. 1st World Cong. Ethol. Appl. to Zootechnics, Madrid. Editorial Garsi, Industrias Grafices Espana, Madrid. pp. 475-480.

Petersen, V., Simonsen, H.B., and Lawson, L.G., 1995. The effect of environmental stimulation on the development of behaviour in pigs. Appl. Anim. Behav. Sci. 45, 215-224.

Petrie, C.L. and Gonyou, H.W., 1988. Effects of auditory, visual and chemical stimuli on the ingestive behaviour of newly weaned piglets. J. Anim. Sci. 66, 661-668.

Pettigrew, J.E., Walker, R.D., and White, M.E., 1995. The early-weaned pig: The role of age at weaning, health status, and diet. In: Ivan, M. (Ed), Animal Science Research and Development: Moving Toward a New Century. Centre for Food and Animal Research, Agriculture and Agri-Food Canada, Ottawa, Canada. pp. 329-337.

Price, E.O., 1985. Evolutionary and ontogenetic determinants of animal suffering and well-being. In: Moberg, G.P. (Ed), Animal Stress. Am. Physiol. Soc., Bethesda, Maryland. pp. 15-26.

Price, E.O., Hutson, G.D., Price, M.I., and Borgwardt, R., 1994. Fostering in swine as affected by age of offspring. J. Anim. Sci. 72, 1697-1701.

Rau, J.A., 2002. Behaviour and performance of early-weaned piglets: Effects of trough-anchored blind teats and liquid food. M.Sc. Thesis, University of Guelph, Guelph, Ontario.

Rau, J.A. and Duncan, I.J.H., 1999. Effect of trough-anchored blind teats on food intake, water use, and growth of piglets weaned at 14 days, fed a liquid or pelleted diet. Can. J. Anim. Sci. 79, 585-586 (Abstract).

Reixach, G.M., Felius, S., Coonan, C., English, P.R., and Edwards, S.A., 2001. The influence of mineral blocks on the behaviour of newly weaned pigs. In: Proc. Brit. Soc. Anim. Sci., Scarborough Annual Meeting, March. pp. 180.

Robert, S., Weary, D.M., and Gonyou, H.W., 1999. Segregated early weaning and the welfare of piglets. J. Appl. Anim. Welfare Sci. 2, 31-40.

Rushen, J., 1993. The 'coping' hypothesis of stereotypic behaviour. Anim. Behav. 45, 613-615.

Sambrook, T.D. and Buchanan-Smith, H.M., 1997. Control and complexity in novel object enrichment. Anim. Welfare. 6, 207-216.

SAS Institute, Inc., 2000. SAS/STAT Users Guide: Statistics, Volume I-III. Version 8 SAS Institute Inc., Cary, NC. 3810 pp.

Schouten, W., 1991. Effect of rearing on subsequent performance of pigs. Pig News Inform. 12, 245-247.

Sharman, D.F., Mann, S.P., Fry, J.P., Banns, H., and Stephens, D.B., 1982. Cerebral dopamine metabolism and stereotyped behaviour in early-weaned piglets. Neuroscience. 7, 1937-1944.

Shea-Moore, M., 1998. The effect of genotype on behaviour in segregated early-weaned pigs tested in an open field. J. Anim. Sci. 76, (Suppl. 1) 100 (Abstract).

Sherwin, C.M., 2004. $E^2 = 3R + 2Q$: Calculating species-appropriate environmental enrichment. In: Hänninen, L. and Valros, A. (Eds), Proc. 38th Cong. Int. Soc. Appl. Ethol. Helsinki, Finland, Aug. 3-7. pp. 132 (Abstract).

Stolba, A. and Wood-Gush, D.G.M., 1981. The assessment of behavioural needs of pigs under free-range and confined conditions. Appl. Anim. Ethol. 7, 388-389.

Stolba, A. and Wood-Gush, D.G.M., 1989. The behaviour of pigs in a semi-natural environment. Anim. Prod. 48, 419-425.

Straw, B.E. and Bartlett, P., 2001. Flank or belly nosing in weaned pigs. J. Swine Health Prod. 9, 19-23.

Studnitz, M. and Jensen, K.H., 2002. Expression of rooting motivation in gilts following different lengths of deprivation. Appl. Anim. Behav. Sci. 76, 203-213.

Taylor, P.E., Coerse, N.C.A., and Haskell, M., 2001. The effects of operant control over food and light on the behaviour of domestic chickens. Appl. Anim. Behav. Sci. 71, 319-333.

Terlouw, E.M.C., Lawrence, A.B., and Illius, A.W., 1991. Influences of feeding level and physical restraint on the development of stereotypies in sows. Anim. Behav. 42, 981-992.

Thexton, A.J., Compton, A.W., and German, R.Z., 1998. Transition from suckling to drinking at weaning: A kinematic and electromyographic study in miniature pigs. J. Exp. Zoo. 280, 327-343.

Tokach, M.D., Goodband, R.D., and Nelsson, J.L., 1994. Recent developments in nutrition for the early weaned pig. Comp. Cont. Educ. Pract. 16, 407-419 and 432.

Torrey, S. and Widowski, T.M., 2004a. Effect of drinker type and sound stimuli on early-weaned pig performace and behaviour. J. Anim. Sci. 82, 2105-2114.

Torrey, S. and Widowski, T.M., 2004b. Relationships among pre- and post-weaning oral/nasal behavior and growth rates in newly weaned pigs. In: Proc. Amer. Soc. Anim. Sci. St. Louis, Mo, July. pp. 277 (Abstract).

Trivers, R.L., 1974. Parent-offspring conflict. Am. Zool. 14, 249-264.

Vandenheede, M. and Bouissou, M.F., 1995. Effects of enriched environment on subsequent fear reactions of lambs and their mothers. Appl. Anim. Behav. Sci. 44, 257-281.

van Hierden, Y.M., Korte, S.M., Ruesink, E.W., van Reenen, C.G., Engel, B., Koolhaas, J.M., and Blokhuis, H.J., 2002. The development of feather pecking behaviour and targeting of pecking in chicks from a high and low feather pecking line of laying hens. Appl. Anim. Behav. Sci. 77, 183-196.

van Hoek, C.S. and ten Cate, C., 1998. Abnormal behavior in caged birds kept as pets. J. Appl. Anim. Welfare Sci. 1, 51-64.

van Putten, G., 1969. An investigation into tail biting among fattening pigs. Brit. Vet. J. 125, 511-516.

van Putten, G., 1982. Discussion of Session III. In: Bessei, W. (Ed), Disturbed Behaviour in Farm Animals. Eugen Ulmer, Hohenheimer Arbeiten, Stuttgart. pp. 129.

van Putten, G. and Dammers, J., 1976. A comparative study of the well-being of piglets reared conventionally and in cages. Appl. Anim. Ethol. 2, 339-356.

von Borrell, E. and Hurnik, J.F., 1991. Stereotypic behavior, adrenocortical function, and open field behavior of individually confined gestating sows. Physiol. Behav. 49, 709-713.

Waran, N.K. and Broom, D.M., 1993. The influence of a barrier on the behaviour and growth of early-weaned piglets. Anim. Prod. 56, 115-119.

Weary, D.M. and Fraser, D., 1997. Vocal response of piglets to weaning: Effect of piglet age. Appl. Anim. Behav. Sci. 54, 153-160.

Weary, D.M., Appleby, M.C., and Fraser, D., 1999. Responses of piglets to early separation from the sow. Appl. Anim, Behav. Sci. 63, 289-300.

Webster, A.J.F., 1993. The challenge of animal welfare. In: 7th Proc. World Conf. Anim. Prod. June 28-July 2, Edmonton, Alberta. pp. 513-524.

Webster, A.J.F. and Jones, A.R., 1997a. The behaviour of piglets between birth and twelve days old; Evidence against stable differences. In: Hemsworth, P.H., Spinka, M., Kostal, L. (Eds), Proc. 31st Int. Cong. Int. Soc. Appl. Ethol. August 13-16, Prague, Czech Republic. pp. 235.

Webster, A.J.F. and Jones, A.R., 1997b. The behaviour of piglets within indoor and outdoor farrowing systems. In: Hemsworth, P.H., Spnka, M. and Kostal, L. (Eds), Proc. 31st Int. Cong. Int. Soc. Appl. Ethol. August 13-16, Prague, Czech Republic. pp. 236.

Wemelsfelder, F. and Birke, L., 1997. Environmental challenge. In: Appleby, M.C. and Hughes, B.O. (Eds), Animal Welfare. CAB International. pp. 35-47.

Wiepkema, P.R., 1985. Abnormal behaviour in farm animals: Ethological implications. Neth. J. Zool. 35, 279-289.

Wiepkema, P.R., 1987. Behavioural aspects of stress. In: Wiepkema, P.R. and Adrichchen, P.W. M. (Eds), Biology of Stress in Farm Animals: An Integrative Approach. Martinus Nijhoff, The Hague. pp. 113-133.

Wiepkema, P.R., 1990. Stress: Ethological implications. In: Puglisi-Allegra, S. and Oliverio, A. (Eds), Psychology of Stress. Kluwer Academic Publishers, Netherlands. pp. 1-13.

Willham, R.L., Cox, D.F., and Karas, G.G., 1963. Genetic variation in a measure of avoidance learning in swine. J. Comp. Physiol. Psychol. 56, 294 (Abstract).

Willham, R.L., Cox, D.F., and Karas, G.G., 1964. Partial acquisition and extinction of an avoidance response in two breeds of swine. J.Comp. Physiol. Psychol. 57, 117 (Abstract).

Worobec, E., Duncan, I.J.H., and Widowski, T.M., 1999. The effects of weaning at 7, 14 and 28 days on piglet behaviour. Appl. Anim. Behav. Sci. 62, 173-182.

Wŭrbel, H., Chapman, R., and Rutland, C., 1998. Effect of feed and environmental enrichment on development of stereotypic wire-gnawing in laboratory mice. Appl. Anim. Behav. Sci. 60, 69-81.

Zeltner, E., Klien, T., and Huber-Eicher, B., 2000. Is there social transmission of feather pecking in groups of laying hen chicks? Anim. Behav. 60, 211-216.

APPENDIX A STATISTICAL ANALYSIS FOR PRELIMINARY STUDY (CHAPTER 3)

Split-plot model used to analyze preliminary study behaviour data.

Source	Degrees of freedom
Gender	1
Duration of supplementation	1
Environmental enrichment type	2
Gender * Duration of supplementation	1
Gender * Environmental enrichment type	2
Duration of supplementation * Environmental enrichment type	2
Pen (Gender * Duration of supplementation * Environmental enrichment type) [a]	9
Breed line	1
Gender * Breed line	1
Duration of supplementation * Breed line	1
Environmental enrichment type * Breed line	2
Pen (Breed line * Gender * Duration of supplementation * Environmental enrichment type) [b]	14

[a] Main plot error
[b] Sub-plot error
ANOVA and error terms and degrees of freedom, used to test the effects of gender, duration of milk replacer supplementation, environmental enrichment type, and breed line, are shown.

APPENDIX B STATISTICAL ANALYSIS FOR ONTOGENY STUDY (CHAPTER 4)

Appendix B.1. Pooled estimate of regression model used to analyze study data on belly nosing, belly sucking, other nosing, other sucking, other biting, and tail biting behaviours at 18, 23, 28, 50, 63, and 91 days-of-age.

Source	Degrees of freedom
Pen	23
Age	1
Residual error	119

ANOVA and error terms and degrees of freedom, used to test the effect of pen and the linear effect of age, are shown. Pen represents the experimental unit (replication), while age represents time.

Appendix B.2. Split-plot over time model used to analyze study data on belly nosing, belly sucking, other nosing, other sucking, other biting, and tail biting behaviours at 18, 23, 28, 50 , 63, and 91 days-of-age.

Source	Degrees of freedom
Pen	23
Age	5
Error	115

ANOVA and error terms and degrees of freedom, used to test the effect of pen and age as a categorical variable, are shown. Pen represents the experimental unit (replication), while age represents time. Data shown in table 4.2.

Appendix B.3. Partial correlation matrix model used to analyze study data on belly nosing, belly sucking, other nosing, other sucking, other biting, and tail biting behaviours at 18, 23, 28, 50, 63, and 91 days-of-age.

Source	Degrees of freedom
Pen	23
Individual (Pen)[a]	118

[a] Error

ANOVA and error terms and degrees of freedom, used to test the effect of pen, are shown. Pen represents experimental unit (replication). Data shown in tables 4.4 to 4.8.

Appendix B.4. Split-plot over time model used to analyze study data on mean belly nosing and belly sucking bout length and mean number of bouts at 21 and 35 days-of-age.

Source	Degrees of freedom
Pen	23
Age	1
Error	23

ANOVA and error terms and degrees of freedom, used to test the effect of pen and age, are shown. Pen represents experimental unit (replication), while age represents time. Data shown in table 4.3.

APPENDIX C STATISTICAL ANALYSIS FOR BREED OF SIRE AND SIRE WITHIN BREED STUDY (CHAPTER 5)

Appendix C.1. Split-plot over time model used to analyze pre-weaning behaviour data.

Source	Degrees of freedom
Sire breed	1
Boar (Sire breed)	4
Litter (Boar * Sire breed)[a]	18
Age	1
Sire breed * Age	1
Boar * Sire breed * Age	4
Litter (Sire breed * Boar * Age)[b]	18

[a] Main plot error term
[b] Sub-plot error term
ANOVA and error terms and degrees of freedom, used to test the effects of sire breed, boar, and age on pre-weaning teat consistency score, nursing cycle duration, nursing bout duration, total number of nursing bouts, and total number of nursing cycles, are shown.

Appendix C.2. Split-plot over time model used to analyze post-weaning behaviour data.

Source	Degrees of freedom
Sire breed	1
Boar (Sire breed)	4
Litter (Boar * Sire breed)[a]	18
Age	5
Sire breed * Age	5
Boar * Sire breed * Age	20
Litter (Sire breed * Boar * Age)[b]	90

[a] Main plot error term
[b] Sub-plot error term
ANOVA and error terms and degrees of freedom, used to test the effects of sire breed, boar, and age on post-weaning belly nosing, belly sucking, other nosing, other sucking, tail biting, and other biting, are shown.

Appendix C.3. Split-split-plot model used to analyze post-weaning behaviour data.

Source	Degrees of freedom
Sire breed	1
Boar (Sire breed)	4
Litter (Boar * Sire breed)[a]	18
Age	5
Sire breed * Age	5
Boar * Sire breed * Age	20
Litter (Sire breed * Boar * Age)[b]	90
Cross	1
Cross * Sire breed * Boar	4
Age * Cross	5
Litter (Cross * Sire breed * Boar * Age)[c]	134

[a] Main plot error term
[b] Sub-plot error term
[c] Sub-sub plot error term
ANOVA and error terms and degrees of freedom, used to test the effect of crossfostering (Cross) on belly nosing and belly sucking, are shown.

APPENDIX D STATISTICAL ANALYSIS FOR ENVIRONMENTAL ENRICHMENT STUDY (CHAPTER 6)

Appendix D.1. Split-plot over time model used to analyze study data on behaviour during the pre-weaning phase of development.

Source	Degrees of freedom
Environmental enrichment	4
Crate (Environmental enrichment)[a]	61
Age	1
Environmental enrichment * Age	4
Crate (Environmental enrichment * Age)[b]	62

[a] Main plot error term
[b] Sub-plot error term
ANOVA and error and degrees of freedom, used to test the effects of environmental enrichment and age, are shown.

Appendix D.2. Split-plot over time model used to analyze study data on behaviour during the nursery phase of development.

Source	Degrees of freedom
Environmental enrichment	4
Phase treatment	2
Environmental enrichment * Phase treatment	6
Pen (Environmental enrichment * Phase treatment)[a]	107
Age	2
Environmental enrichment * Age	8
Phase treatment * Age	4
Environmental enrichment * Phase treatment * Age	12
Pen (Environmental enrichment * Phase treatment * Age)[b]	214

[a] Main plot error term
[b] Sub-plot error term
ANOVA and error and degrees of freedom, used to test the effects of environmental enrichment, phase treatment, and age, are shown.

APPENDIX E STATISTICAL ANALYSIS FOR THERMOREGULATION STUDY (CHAPTER 7)

Appendix E.1. Repeated measures model used to analyze study data on temperature preference.

Source	Degrees of freedom
Replicate	4
Age	2
Replicate (Age)[a]	8
Hour	23
Age * Hour	46
Replicate (Age * Hour)[b]	276

[a] Main plot error term
[b] Sub-plot error term
ANOVA and error terms and degrees of freedom, used to test the effects of replicate, age, and time of day (hour), are shown.

Appendix E.2. Split-split plot over time model used to analyze study data on behaviour.

Source	Degrees of freedom
Replicate	4
Lever	1
Replicate * Lever [a]	4
Age	2
Lever * Age	2
Replicate (Lever * Age)[b]	14
Period	5
Lever * Period	5
Age * Period	10
Lever * Age * Period	10
Replicate (Lever * Age * Period)[c]	122

[a] Main plot error term
[b] Sub-plot error term
[c] Sub-sub-plot error term
ANOVA and error terms and degrees of freedom, used to test the effects of replicate, lever (operational and heat-controlling pen non-operational levers), age, and time period, are shown.

Appendix E.3. 5 x 5 Latin Square split-split plot model used to analyze weight and behaviour data.

Source	Degrees of freedom
Replicate	4
Pen	4
Weight	4
Replicate * Pen* Weight [a]	12
Age	2
Pen * Age	8
Weight * Age	8
Age * Replicate * Pen* Weight [b]	32
Period	5
Pen * Period	20
Weight * Period	20
Period * Age	10
Period * Age * Replicate * Pen * Weight [c]	320

[a] Main error term
[b] Sub-plot error term
[c] Sub-sub plot error term
ANOVA and error terms and degrees of freedom, used to test the effects of pen, replicate, weight, age and time period, are shown.