THE EFFECTS OF TRANSPORT ON THE BEHAVIOUR AND PERFORMANCE OF EARLY WEANED PIGLETS

By

Steinar Wamnes

A Thesis Submitted to the Faculty of Graduate
Studies in Partial Fulfillment of the Requirements for
the Degree of

MASTER OF SCIENCE
Conferred October 2005

Department of Animal Science
University of Manitoba
Winnipeg Manitoba
Canada R3T 2N2

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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ABSTRACT

The swine industry in North America has progressively adopted a segregated early weaning (SEW) management system, in which transportation is an essential element. Early weaning (EW) involves profound changes in social reorganization and feeding requirements and is believed to cause significant stress to piglets. The effects of transport as an additional stressor to EW is not well understood. However, the effects may be additive, exacerbating the negative effects of early weaning (Lewis et al., 2005).

The aim of this study was to examine the post-weaning performance and behaviour of early weaned piglets as affected by transport duration, season, weaning weight and transport type. Two groups of 48 Cotswold piglets were weaned at 17 ± 1 d of age and assigned to road transport or simulated transport during one of 2 seasons (summer or winter) and for 4 durations (0 h, 6 h, 12 h or 24 h). As in commercial transport, feed and water were not provided while in transit, and supplemental heat was not utilized during winter transport. Following transport, piglets were grouped in pens of four individuals of similar weaning weight, producing pens of relative light, medium and heavy pigs. Body weights were recorded daily for 8 d and on d 10, 12 and 14. Piglet behaviour was recorded on days 1-4, 7 and 14 following weaning and transport. Continuous sampling was used to record occurrence, duration and frequency of individual feeding and drinking bouts in two hour blocks over the first three days following introduction to the nursery pen. In addition, instantaneous scan sampling was performed at 10-min intervals on days 1-4, 7 and 14 in order to study general activity.

As transport duration increased, weight loss increased in a linear trend, reaching significance between the 6 h and 24 h transport groups ($P < 0.001$). Increased drinking behaviour during the first day in housing was associated with increased time without access to feed and water during transport (0 h: 0.5%, 6 h: 1.1%, 12 h: 2.0%, and 24 h: 3.2%, $P < 0.05$), reflecting the relative need to recoup water loss and reestablish homeostasis. Weaning itself was a significant stressor, as non-transported piglets expressed weight loss and day of recovery consistent with 12 h and 24 h transport groups. Non-transported piglets (1.5%) spent less time feeding than transported piglets (average 3.1%) during the first 3 days in housing, reaching significance relative to 12 h and 24 h transport groups on day 2 ($P < 0.02$). While transport durations of 6 h, 12 h, and 24 h did not appear to increase weaning stress, depriving early weaned piglets of water may pose a welfare concern. Piglets transported in winter reached their lowest weight significantly later than piglets transported in summer (2.31 d vs. 1.92 d, $P < 0.05$) suggesting prolonged growth check associated with winter transport. Piglets transported in winter also showed reduced average daily gain (ADG) (0.34 kg vs. 0.37 kg, $P < 0.05$) and lower FCE ($P < 0.0001$) relative to piglets transported in summer. Furthermore, increased levels of activity (less time lying and more time standing idle, $P < 0.05$) during the first four days following transport in winter may suggest that transport in winter caused more stress to piglets than transport in summer. Heavy piglets expressed a prolonged growth check ($P < 0.02$) and reduced FCE ($P < 0.05$) relative to light piglets, and reduced ADG ($P < 0.01$) relative to light and medium piglets. However, this was not believed to be related to transport induced stress. The causative factors were hypothesized to be increased fighting and reduced feeding behaviour in heavy relative to light and medium piglets. Following road transport, piglets expressed an extended growth check ($P < 0.02$), higher weight loss ($P < 0.007$), and required more time to recover their weaning weight ($P < 0.02$) relative to simulated transport groups. Piglets assigned to road transport also spent less time feeding ($P < 0.05$) and more time engaged in oral/nasal behaviour ($P < 0.05$ on d 3) during the first 3 days post transport, suggesting increased levels of transport stress associated with one or more factors of road transport, including noise, vibration, movement and temperature fluctuations.

While transport duration did not appear to substantially increase weaning stress in this study, water deprivation during long journeys is a welfare concern. Our results suggest that transport in winter is more detrimental to EW piglets than transport in summer and that this effect was exacerbated by road transport relative to simulated transport. Transport did not appear to affect light medium and heavy piglets any different, but grouping piglets of similar weight did. Groups of large piglets showed compromised performance due to low initial feed intake and high levels of aggression relative to small and medium pigs during the first day in weanling pens.

ACKNOWLEDGEMENTS

The research for this project would not have been possible without the funding generously provided by ARDI and Manitoba Pork and the trial animals donated by Cotswold Canada Inc.

My sincere thanks to Dr. Nora J. Lewis, my advisor, for the continuous support, encouragement, direction and the invaluable suggestions that she provided throughout my graduate program. Also, sincere thanks to the members of my examining committee, Dr. Laurie Connor, Dr. Martin Nyachoti and Dr. Barry Prentice for the support they have shown and the time they have expended.

A sincere thank you to Robert J. Berry for the numerous hours that he contributed towards the preparation and conduct of the experimental trials. Sincere thanks also to Dr. Gary Crow and Dr. Loreen Onishchuk for the invaluable assistance and advice they provided regarding the statistical analysis.

Special thanks to my wife Dana C. Batson Wamnes, LL.B., for encouraging me to strive towards my goals, for her patience, and particularly for all the support she has given me.

Thank you to the staff at Glenea Swine Unit, the Animal Science Research Unit for all of their help and the volunteer drivers for their time.

DEDICATION

I would like to dedicate this thesis to my wife, Dana Christine, for believing in me and for supporting and encouraging me with numerous pep-talks during my undergraduate and graduate studies.

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LIST OF ABBREVIATIONS

ADG	Average daily gain
ADFI	Average daily feed intake
CARC	Canadian Agrifood Research Council
CCAC	Canadian Council on Animal Care
EW	Early weaning
FCE	Feed conversion efficiency
GLM	General linear model
HPA	Hypothalamic-pituitary-adreno-cortical
IS	Immune system
LS	Least squares
MEW	Medicated early weaning
PVC	Polyvinyl chloride
SAS	Statistical analysis systems
SEM	Standard error of means
SEW	Segregated early weaning

1.0 GENERAL INTRODUCTION

Segregated early weaning (SEW) is a management system that is utilized extensively by swine producers in North America. Some well known advantages of this management practice includes reduced transfer of disease, reduced use of antibiotics, increased growth potential in piglets of high health, and more intensive use of high cost production units. In modern swine production facilities, piglets can theoretically be weaned as young as 7 days of age due to improved management and the use of highly complex diets that are well suited to the immature digestive system of very young piglets (Weary et al., 1999). However, early weaning involves profound environmental changes in housing and social reorganization, as well as an abrupt transition from liquid to solid feed. These factors are believed to cause the commonly observed post-weaning weight-gain depression in EW piglets (Metz and Gonyou, 1990; Robert et al., 1997; Weary et al., 1999; Worobec et al., 1999). In addition, piglets weaned earlier than 4 weeks of age often express high levels of abnormal behaviour, such as excessive oral/nasal manipulation of pen-mates and objects (Metz and Gonyou, 1990; Bøe, 1993; Gonyou et al., 1998; Worobec et al., 1999; Weary et al., 1999), prolonged vocalization (Weary and Fraser, 1997; Weary et al., 1999; Mason et al., 2003) and an overall increase in activity (Metz and Gonyou, 1990, Bøe, 1993; Gonyou et al., 1998). These behaviours are believed to reflect difficulties in coping with the traumatic experience of abrupt and early weaning and are therefore an indication of compromised welfare (Weary et al., 1999; Worobec et al., 1999). These findings have led to legislation and directives being implemented by most European countries, preventing piglets from being weaned earlier than 3 weeks of age. Most producers in Canada are currently weaning piglets around 17 days of age (CARC, 2001).

A SEW management system necessitates the transport of piglets to a separate production site. Transport is an additive stressor involving mixing, crowding, feed and water deprivation, cold, heat, temperature fluctuations, vibration and noise, and can be a severe stressor for very young piglets (Stephens and Perry, 1990; Berry and Lewis, 2001a). The level of stress perceived by the pig due to each component of transport cannot be readily evaluated, but is probably dependant on the intensity and duration of each of the factors, as well as the interaction between any two or more of these (Stephens and Perry, 1990). Previous studies involving transport of grower and slaughter pigs have shown that transport (simulated transport and road transport) may induce increased weight loss (Lambooy et al., 1985; Lambooy, 1988), increased levels of stress hormones (McClone et al., 1993; Bradshaw et al., 1996a,b; Hicks et al., 1998; Parrot et al., 1998), motion sickness (Bradshaw et al., 1996a,b; Randall and Bradshaw, 1998), fatigue (Lambooy, 1988) and alteration in immune function (McGlone et al., 1993; Morrow-Tesch et al., 1994; Hicks et al., 1998). Although millions of piglets are transported within North America every year (Statistics Canada, 2005), limited data exist on the effects of transport on early-weaned piglets (Berry and Lewis, 2001a). However, subjecting piglets to multiple stressors has been shown to reduce piglet productivity, health and welfare (Dybkjær, 1992; Ekkel et al., 1995; Hyun et al., 1998), and it may therefore be reasonable to assume that transport stressors will exacerbate the stress already experienced by piglets due to early weaning (Bergeron and Lewis, 1997; Berry and Lewis, 2001a). By investigating the concurrent effects of some of the main factors of transport, we may gain valuable knowledge about the tolerance and responses of early weaned piglets to transport. This information may then be used to improve transport conditions in the future. Furthermore, improving transport conditions may improve post-weaning performance and welfare.

The objectives of this work were to study the performance and behaviour of early weaned piglets as affected by 1) the duration of transport, 2) season of transport, 3) weaning weight, and 4) the general effects of road transport including noise, vibration, movement and fluctuating temperatures to assess overall welfare following early weaning and transport. Relative performance and post-weaning behaviour were used as indicators of the ability of piglets to recover from EW and transport-induced stress, and therefore an indication of their welfare.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Segregated early weaning (SEW) of piglets has become a trend in the North American swine industry (Carroll et al., 1998; Worobec et al., 1999). In SEW, piglets are weaned and separated from the sow herd 10-20 days post farrowing (Worobec et al., 1999). This management practice is utilized in order to take advantage of piglet growth potential and reduce vertical transfer of disease (Henry, 2001). In modern swine production facilities, piglets can be weaned as early as 7 days due to improved management and feeding of highly complex diets. While most European countries are subject to legislation and directives implemented by the European Union that prevent piglets from being weaned earlier than 3 weeks, most producers in Canada are currently weaning piglets between 14 and 20 days of age, with an average around 17 days of age (CARC, 2003). Previous studies have shown that early weaning (EW) causes reduced post-weaning feed intake (Leibbrandt et al., 1975), increased levels of oral/nasal behaviour (Gonyou et al. 1998) and increased levels of vocalization (Weary et al., 1999). Early weaning is therefore believed to cause significant stress to piglets, but the process is practiced in order to improve productivity (Bøe, 1993). Profound environmental changes in housing and social reorganization, as well as the transition from liquid to solid feed, are aspects of the weaning process that collectively contribute to commonly observed weight-gain depression in piglets (Metz and Gonyou, 1990; Robert et al., 1997; Weary et al., 1999; Worobec et al., 1999). Furthermore, the common practice of transporting newly weaned piglets to separate production facilities is believed to have an adverse effect on piglet performance immediately following weaning (Berry and Lewis, 2001a). Transport is an additive stressor involving noise, temperature fluctuations, mixing, vibration and crowding, and is therefore a concern with respect to animal welfare (Stephens and Perry, 1990). The level of stress perceived by the pig due to each component of transport cannot be readily evaluated, but is probably dependant on the intensity and duration of each of the factors, as well as the interaction between any two or more of these (Stephens and Perry, 1990). Previous studies involving transport of grower and slaughter pigs have shown that transport (simulated transport and road transport) may induce increased levels of saliva or plasma cortisol (McClone et al., 1993; Bradshaw et al., 1996a,b; Hicks et al., 1998; Parrot et al., 1998), changes in behaviour (Hicks et al., 1998), motion sickness (Bradshaw et al., 1996a,b; Randall and Bradshaw, 1998), fatigue (Lambooy, 1988), weight loss (Lambooy et al., 1985; Lambooy, 1988) and alteration in immune function (McGlone et al., 1993; Morrow-Tesch et al., 1994; Hicks et al., 1998). Although the Canadian export of live pigs involved the transport of approximately 3.089 million piglets (weighing < 7 kg) across the US border in 2004 (Statistics Canada, 2005), limited data exist on the effects of transport on early-weaned piglets (Berry and Lewis, 2001a). However, subjecting piglets to multiple stressors has been shown to reduce piglet productivity, health and welfare (Dybkjær, 1992; Ekkel et al., 1995; Hyun et al., 1998) and it may therefore be reasonable to assume that transport stressors will exacerbate the stress already experienced by piglets due to early weaning (Bergeron and Lewis, 1997; Berry and Lewis, 2001a). With the current extensive utilization of SEW production practices, problems affecting even a small percentage of animals will have a large economic and welfare impact (Lewis and Wamnes, 2005). More research is therefor needed to improve our current knowledge about the tolerance and responses of EW piglets to transport.

2.2 WEANING

2.2.1 Weaning under semi-natural conditions

Under natural or semi-natural conditions, weaning in swine is a gradual process (Robert et al., 1999). During the first week post-partum, the sow spends most of her time with her piglets in the nest with only small forays from it (Stolba and Wood-Gush, 1989). During the second and third week, the piglets begin to follow the dam when she leaves the nest and engage in play and exploration (Newberry and Wood-Gush, 1988; Stolba and Wood-Gush, 1989). At this time, the suckling frequency starts to gradually decline and the piglets become more reliant on solid food obtained by rooting and grazing (Bøe, 1991; Jensen and Recén, 1989). On average, sows observed in semi-natural environments wean their piglets at 12-13 weeks (Stolba and Wood-Gush, 1989). However, in a Swedish population of domestic pigs under free-ranging conditions, Jensen and Recén (1989) reported that weaning occurred between 16-20 weeks. Bøe (1991) studied sows and piglets housed in enriched pens, where sows could leave the piglets by stepping over a piglet-proof barrier, and found that weaning was completed by 11-12 weeks. Variability in weaning time is believed to be governed by factors such as breed, age of the sow (Jensen and Recén, 1989) and the availability of alternative sources of feed for the piglets (Jensen, 1988; Jensen and Recén, 1989). The latter affecting the cost/benefit ratio of continued suckling versus reliance on solid feed to fulfill the nutritional demands of the piglets.

2.2.2 Weaning under intensive husbandry conditions

In conventional commercial housing, lactating sows are restrained in farrowing crates which make it difficult for sows to limit the amount of suckling stimulation they receive from the piglets (Fraser et al., 1995), therefore strongly biasing the parent-offspring conflict in favour of the piglets. Cronin et al. (1991) measured plasma cortisol levels as an indicator of stress in lactating sows which were either restrained in farrowing crates or allowed some freedom of movement within the farrowing pen. After 4 weeks of lactation, plasma cortisol levels were significantly higher in the confined sows (Cronin et al., 1991). Although the piglets of confined sows initially benefit from the large amount of milk they obtain, they also develop a strong dependency on a pure milk diet, making them poorly prepared for the inevitable abrupt weaning (Fraser et al., 1995) which involves acute changes in both the pattern of intake and the type of diet (Le Dividich and Seve, 2000). Piglets are required to switch from milk to solid feed before they have developed normal behavioural regulation of solid feed intake and before the digestive system and enzymes are sufficiently developed to handle the new diet (Weary et al., 1999).

2.2.3 Previous trends towards early weaning

Sow productivity is primarily determined by the number of offspring produced in a year (Metz and Gonyou, 1990). Therefore, by reducing the farrowing interval (early weaning), individual sows would theoretically produce more piglets per year and facilitate more intensive use of expensive farrowing/lactation facilities (Pettigrew et al., 1995). As a result, piglet weaning age has gradually decreased over the last 30 years

(Carroll et al., 1998). However, early weaning of piglets was identified as a welfare issue even when 'early' meant three to four weeks of age (Robert et al., 1999). Studies indicated that weaning imposed significant stress on piglets, resulting in decreased post-weaning weight-gain and abnormal behaviours such as belly-nosing and flank-biting (Hoenshell et al., 2000). Leibbrandt et al. (1975) weaned piglets at 2, 3 and 4 weeks of age and found that feed intake and rate of gain increased more rapidly after weaning as weaning age increased. However, the younger piglets exhibited compensatory growth. At two weeks post weaning, energy intake was similar for all weaning groups and by 6 weeks of age all weaning groups were equal in weight (Leibbrandt et al., 1975). Metz and Gonyou (1990) weaned piglets at 2 and 4 weeks of age and observed a 48 hr delay in normal feed intake in the younger animals. Although piglets weaned at 4 weeks of age recovered from their growth check by day 3, early weaned piglets did not regain their weaning weight until day 7 post-weaning (Metz and Gonyou, 1990). By examining the white cell count as a parameter of physiological stress 3 days after weaning, Metz and Gonyou (1990) found significantly higher neutrophil/lymphocyte ratios in piglets weaned at 2 weeks than at 4 weeks of age. Animal welfare concerns regarding early weaning has led to a European Economic Community Directive for weaning at no less than 3 weeks of age while actual legislation prevents weaning earlier than 4 weeks of age in Norway and Sweden (Carroll et al., 1998). Canada's recommendations for early weaning are currently between 14-20 days of age (CARC, 2003).

2.2.4 Development of segregated early weaning

Segregated early weaning (SEW) was introduced in Canada in the mid 80s with the objective of eradicating or controlling diseases (Robert et al., 1999). SEW involves removing piglets from the sow before the passive immunity provided by maternal antibodies has waned, thus decreasing the transmission of disease from the sow to the litter (CARC, 2003). However, passive immunity will only provide protection against disease organisms that the sow has previously been exposed to. Novel pathogens introduced to the piglets' environment have the potential to cause a disease outbreak (Henry, 2001). Therefore, whenever mixing is required, it becomes imperative to wean piglets of similar health status and age (ideally within 2 days of age) into a clean, controlled environment, facilitating the particular needs of SEW pigs (CARC, 2003). Most producers in Canada who are currently practicing SEW strategies are weaning piglets between 14 and 20 days of age, with an average of 17 days (CARC, 2003). Ideally, piglets should be moved to a nursery at least 5 km from the sows and other herds in order to accomplish the disease reduction aims of the SEW system (Bergeron and Lewis, 1997; CARC, 2003).

The performance benefits of reduced exposure to pathogens are well known (Robert et al., 1999). Williams et al. (1993; 1994) studied the impact of immune system activation on growth performance and nutrition. Piglets managed under medicated early weaning (MEW), weaned between 10-14 days and segregated by site to an all-in-all-out nursery were considered to have low immune system activation (low IS). In contrast, high immune system activation (high IS) was produced by not vaccinating the sows and weaning non-medicated piglets into an on-site continuous-flow nursery at 19 days of age.

Growth rate during the nursery phase (from 6 to 27 kg) was found to be 29-42% faster in the low IS piglets relative to the high IS piglets (Williams et al., 1993; 1994). Activation of the immune system diverts amino acids and energy away from protein synthesis and muscle growth and toward proliferation of immune cells and production of immunoglobulins (Pettigrew et al., 1995). Slower growth may then result even when obvious illness is not apparent. However, the benefits of weaning piglets from high health herds before the age of 3 weeks are more questionable. Although high health piglets hold the potential for superior post-weaning performance, early weaning exposes the young animals to multiple stressors that may ultimately prove detrimental to their early development.

2.2.5 Performance of segregated early weaned piglets

Previous studies involving early weaning of piglets under conventional production systems have shown that piglets are slow to develop normal levels of feeding behaviour (Leibbrandt et al., 1975; Bark et al., 1986; Metz and Gonyou, 1990). Provision of adequate nutritional support as the young piglets are abruptly switched from sow's milk to dry feed has been a major challenge of SEW management (Kim et al., 2001). However, the highly complex and palatable nursery diets now available are much better suited to the immature digestive system of young piglets and support a more acceptable rate of growth in these younger piglets (Weary et al., 1999). McCracken et al. (1995) weaned piglets at 19 days of age to either a corn-soy or a milk-based diet. Pigs offered the milk-based diet began to eat earlier and ate more than pigs offered the cereal diet. Piglets fed the milk-based diet also had higher plasma insulin concentrations and less reduction in villus height in the duodenum. Both these responses are believed to be a reflection of increased feed intake (McCracken et al., 1995). Insulin is known to increase protein synthesis by enhancing amino acid uptake by muscle cells and to inhibit metabolism of adipose stores (McCracken et al., 1995, 1999; Pluske et al., 1996).

Zijlstra et al. (1996) compared the performance of littermates that were allowed to stay with their dam and continue suckling or were weaned at 18 days of age onto either dry feed, or milk replacer in combination with a complex nursery diet. The results showed that when feed intake was maintained, performance was not compromised in early weaned piglets. Piglets fed a combination of milk replacer and nursery diet actually out-performed those left on the sow immediately after weaning (Zijlstra et al., 1996). Although feeding liquid milk may have little application in commercial pig production (Henry, 2001), Kim et al. (2001) examined the efficacy of liquid feeding as a means to facilitate the weaning transition of young SEW piglets. Results showed that piglets fed the liquid diet were 21% heavier than pigs fed the dry pellet diet 14 days following weaning. Gain, feed intake and gain/feed of liquid fed pigs were 44%, 18% and 22% greater respectively (Kim et al., 2001). In addition, the growth advantage achieved by liquid feeding during the first 2 weeks after weaning was maintained through the growing and finishing periods such that market weight was reached 3.7 days sooner than the dry-fed controls (Kim et al., 2001).

Recent work has shown that complex diets in the form of crumbles or pellets are equally effective in realizing acceptable performance in SEW pigs. Gonyou et al. (1998) weaned pigs at 12 and 21 days of age and observed a slight delay in normal feeding behaviour in the younger piglets. However, both age groups fed at a normal level (10%

of time) within 48 hr and expressed similar performance in the following 5-6 weeks (Gonyou et al., 1998). Carroll et al. (1998) weaned pigs at 2 or 3 weeks of age and found that ADG fell to a lower level in the 2-week-old than in the 3-week-old piglets during the first days post weaning, but returned to pre-weaning levels within 7 days in both groups. Worobec et al. (1999) weaned piglets at 7, 14 and 28 days of age and found that piglets weaned at 7 days gained less weight than their suckling littermates during the first week post-weaning. At 6 weeks of age, piglets weaned at 7 days remained significantly lighter relative to piglets weaned at 14 and 28 days of age. These results suggest that compensatory growth does not occur when piglets are weaned before 14 days of age and that welfare may therefore be compromised (Worobec et al., 1999). However, these results may be related to feed quality.

Weary et al. (1999) showed that when piglets were weaned at 2 weeks onto a high-complexity diet, they achieved weight gains and 28 d weights comparable to piglets which were weaned at 4 weeks onto a low-complexity standard nursery diet, indicating that performance primarily depends on the quality of the diet. Similarly, Hoenshell et al. (2000) studied the effects of weaning piglets early (10 days of age) or late (30 days of age) from a high health herd without segregation from the farrowing facility. When fed a complex nursery diet for 20 days post weaning, early weaned piglets had a greater cumulative and periodic ADG soon after weaning but, overall performance from birth to slaughter did not differ between groups (Hoenshell et al., 2000). However, any difference in weight-gain depression between early and late weaned pigs was not reported.

Based on post-weaning weight-gain potential, SEW may be perceived as an overall favourable production practice (Robert et al., 1999). However, the fact that specialized diets may allow early-weaned piglets to achieve satisfactory growth rates does not necessarily address all the animal welfare concerns associated with early weaning (Weary et al., 1999). The traumatic experience of early abrupt weaning may induce anomalous and destructive behaviours in piglets causing reduced performance and overall compromised welfare.

2.2.6 Behaviour of segregated early weaned piglets

Behavioural research has shown that detrimental responses to early weaning tend to be more severe as the age at weaning decreases from 3 weeks (CARC, 2003). In spite of this, SEW management systems recommend weaning piglets 8-10 weeks before natural weaning would likely have occurred. Piglets weaned earlier than 4 weeks of age often express high levels of abnormal behaviour, such as belly-nosing and excessive oral manipulation of pen-mates and objects (Metz and Gonyou, 1990; Gonyou et al., 1998; Bøe, 1993; Worobec et al., 1999; Weary et al.,1999), prolonged vocalization (Weary and Fraser, 1997; Weary et al., 1999; Mason et al., 2003) and overall increase in activity (Metz and Gonyou, 1990, Bøe, 1993; Gonyou et al., 1998). These behaviours are believed to reflect an inability to cope with the traumatic experience of abrupt weaning and are therefore an indication of compromised welfare (Weary et al., 1999; Worobec et al., 1999).

Metz and Gonyou (1990) compared piglets weaned at 2 or 4 weeks in a conventional production system and found that on days 4 and 6 post-weaning, piglets weaned at 2 weeks of age were generally more active than those weaned at 4 weeks of age. While some belly-nosing developed in the groups weaned at 2 weeks of age, this behaviour was rarely seen in the piglets weaned at 4 weeks. The authors suggested that nosing littermates acted as a substitute for nosing the sow's udder. This was probably independent of feeding behaviour since belly-nosing first appeared several days post-weaning, at a time when adequate feed intake was already achieved. Bøe (1993) weaned piglets at 4 and 6 weeks of age and observed their behaviour at 8 and 12 weeks of age. Belly-nosing was found to be more prevalent in the 'early' weaned group during both observation periods, indicating that this aberrant behaviour may persist into the growing/finishing period. The overall level of activity was also higher in piglets weaned at 4 weeks, confirming the findings of Metz and Gonyou (1990).

More recent research involving piglets managed under SEW systems has revealed similar findings. Gonyou et al. (1998) studied the behaviour of pigs weaned at 12 and 21 days of age from weaning to market and found that the earlier weaned piglets spent more time eating, drinking, nosing other pigs and chewing on objects during the first 6 weeks following weaning. Piglets weaned at 12 days of age also continued to nose and chew their pen mates more during the growing/finishing period than those weaned at 21 days of age (Gonyou et al., 1998). Partial, within-pen, correlations indicated that less active pigs grew faster and were less likely to nose or nibble other pigs (Gonyou et al., 1998). These findings were confirmed by Li and Gonyou (2002) who studied belly-nosing and associated behaviour in piglets weaned at 12-14 days of age. On day 7, post-weaning piglets spent on average 2.4% of their time belly-nosing, while 5% of the pigs spent more than 8% of their time nosing their pen mates. Furthermore, Li and Gonyou (2002) found that the frequencies of social interaction leading to belly-nosing and belly-nosing leading to social interaction were higher than expected on a random basis, indicating a common causal factor for these behaviours. The same relationship was not found between belly-nosing and feeding or drinking, suggesting that belly-nosing may be more closely associated with social interaction (udder massage) than with feeding (hunger) or drinking (Li and Gonyou, 2002). Gardner et al. (2001) came to the same conclusion when they weaned piglets between 14 and 18 days and did not find that quality of diet affected the development of belly-nosing post-weaning.

Earlier research suggested that belly-nosing in early weaned piglets may be related to stress (Dybkjær, 1992; Gonyou et al,. 1998; Worobec et al., 1999). Gardner et al. (2001) weaned piglets at 12-14 days of age and subjected them to varying degrees of social stressors in an attempt to determine if the degree of stress influenced the development of belly-nosing behaviour. Piglets were assigned to groups of mixed or unmixed litters and housed in pens of low ($0.4m^2$/pig) or high ($0.15m^2$/pig) density. Although belly-nosing developed in all treatment groups by day 7 post weaning, there were no differences in the frequencies of the behaviour between treatments (Gardner et al., 2001). The authors therefore concluded that belly-nosing may not be a general behavioural indicator of stress.

Premature separation from the sow has been known to cause distress in early weaned piglets, often expressed by prolonged vocalization, restless activity and oral manipulation of pen-mates and objects (Gonyou et al., 1998; Worobec et al., 1999; Weary et al., 1999). Weary et al. (1999) examined the effect of age and diet on behavioural responses of piglets to separation from the dam. Results showed that piglets weaned at 2 weeks of age achieved weight gains comparable to piglets weaned at 4 weeks when fed a high quality diet. However, vocalization and belly-nosing were significantly greater following 2-week than 4-week weaning suggesting that separation, distress and frustration of suckling motivation are more severe for piglets weaned at younger ages (Weary et al., 1999). Worobec et al. (1999) weaned piglets at 7, 14 and 28 days and found that in addition to spending more time belly-nosing and drinking and less time feeding, piglets weaned at 7 days showed more escape behaviour and spent less time interacting with pen mates when compared with piglets weaned at 14 or 28 days. Weaning piglets on or before 14 days of age may therefore produce behaviour patterns indicating reduced welfare (Worobec et al., 1999). In contrast, Hoenshell et al. (2000) found very few differences in the behaviour of piglets weaned at 10 or 30 days of age. However, piglets were observed from weaning to slaughter and the relatively low frequency of observations in this study probably precluded an accurate determination of time spent in low frequency abnormal behaviours.

Although most studies indicate that piglets do not adapt well to weaning before the age of 21 days, there appears to be large within-litter variation in post weaning behaviour (Gonyou et al., 1998; Worobec et al., 1999; Li and Gonyou, 2002). Giroux et al. (2000) studied the relationship between individual behavioural traits and post-weaning growth following SEW at 17 ± 1 day and found five factors that could explain 81% of the total variation between individual piglet response to different behavioural tests. These factors were tentatively labelled: 1) reaction to an unknown human (25%), 2) active response to stress (walking or running and performing a high number of vocalisations during a 4 min stay alone in an unfamiliar pen) (21%), 3) passive response to stress (standing, urinating and defecating during a 4 min stay alone in an unfamiliar pen) (14%), 4) feeding behaviour (10%), and 5) rank order (9%). Behavioural tests and piglet rank order was determined when piglets were between 20 and 25 days old. Among these factors, a passive response to stress was positively correlated with weight gain in the first week post-weaning as was high rank order during the first 4 weeks following weaning (Giroux et al., 2000). In contrast, Blackshaw et al. (1987, 1994) did not find a correlation between social rank and post-weaning weight gain.

Mason et al. (2003) found that individual differences in short-term response to weaning was correlated with piglet weight at weaning. When piglets were weaned at 21 or 35 days of age, earlier weaned piglets performed high pitch 'distress' or 'separation calls' more often and for a longer period of time following weaning relative to the piglets weaned later, indicating that the process of weaning is more stressful for younger animals (Fraser, 1973; Weary and Fraser, 1997; Weary et al., 1999; Mason et al.; 2003). Regardless of piglet age at weaning, relatively heavier piglets were more aggressive and belly-nosed their littermates more frequently immediately following weaning (Mason et al., 2003). Also, weaning caused large piglets to perform more frequent low pitch 'begging calls' and small piglets to perform more high pitch 'separation calls' (Weary and Fraser, 1997; Weary et al., 1999; Mason et al., 2003). These results suggest that while early weaning may cause heavier piglets to experience more nutritional deprivation due to their reliance on milk during the lactation period, smaller piglets (that received less milk during lactation) may be more likely to suffer from stress due to maternal separation (Mason et al., 2003).

2.3 POST-WEANING ENVIRONMENT

2.3.1 Effect of environmental temperature

Early weaned piglets (< 21 days of age) consume very little feed during the first 2-3 days following weaning (Leibbrandt et al., 1975; Metz and Gonyou, 1990; Bøe, 1993; Gonyou et al., 1998; Berry and Lewis, 2001a) and will therefore draw energy from body reserves stored during the lactation period (Noblet and Dividich, 1982). Heat production for homeostasis, is linearly related to the environmental temperature resulting in increased energy use at lower temperatures (Noblet and Dividich, 1982). To prevent severe energy deficiency and emaciation in the time period before piglets are established on feed, it becomes imperative to provide climatic conditions appropriate for the young animals' requirements (CARC, 2003). Although these requirements depend on the interaction of multiple factors such as group size, quality of feed, presence or absence of bedding material and size or age of piglets, current recommendations call for air temperatures between 28-32 °C during the first 2 weeks post weaning (CARC, 2003). A 2 °C reduction in temperature every week thereafter (down to 18-20 °C) is believed to closely match the nursery pigs' thermal comfort level (CARC, 2003). These recommendations are based on results from numerous research experiments where piglet performance and apparent comfort levels have been closely studied at various weaning ages.

Le Dividich (1981) weaned piglets at 3 weeks of age and subjected them, in groups of six, to various environmental temperature patterns during the next 6 weeks. Results indicated that a temperature regime of 28 °C during the first week followed by a 2 °C reduction per week over the next 5 weeks provided the most favourable environment for growth and overall performance. In a similar experiment, Noblet and Le Dividich (1982) penned piglets individually and studied their energy balance relative to environmental temperature and feed intake. Animals were weaned between 20 and 26 days of age and subjected to an ambient temperature of 32, 28 or 24 °C during the first week, followed by a 1 °C reduction in environmental temperature every week for the next 5 weeks (Noblet and Le Dividich, 1982). The most favourable lean growth was observed in piglets subjected to the 24-18 °C temperature pattern, provided piglets were not underfed (Noblet and Le Dividich, 1982). Subjecting piglets to a constant cold environment (20 °C) during a 6 week experimental period did not appear to affect the overall feed intake (Le Dividich, 1981). However, these piglets expressed a lower average daily gain (ADG) and seemed to be negatively affected by a switch to a simpler diet halfway through the experiment (Le Dividich, 1981). Similarly, Morrow-Tesch et al. (1994) found that 6 week old pigs subjected to a constant warm environment (33 ± 2 °C) for 4 weeks, performed worse than pigs in a "neutral" environment (24 ± 2 °C). In addition, continuous temperature fluctuations (± 4 °C) proved to have detrimental effects on piglet performance and health, particularly during the first week post-weaning (Le Dividich, 1981).

Although current recommendations regarding nursery temperatures are based on a 24-hr constant temperature (Brumm and Shelton, 1991), biological heat production is not constant throughout the day (McCracken and Caldwell, 1980). McCracken and Caldwell (1980) used an open circuit respiration chamber to estimate the heat production in groups of pigs between the age of 10 and 33 days at various environmental temperatures. Piglets produced the least heat on the second or third day following weaning, coinciding with very low energy intake on these days. Weekly measurements thereafter revealed a consistent diurnal pattern in heat production with the lowest values being observed between 24:00 h and 08:00 h (McCracken and Caldwell, 1980). Brumm and Shelton (1991) studied the effects of reducing the nocturnal temperature in the nursery room of piglets weaned at 3 to 4 weeks of age. Reducing the nocturnal temperature by 6°C or 10°C one week post-weaning, relative to a control regimen of 30°C followed by a 2°C decrease every week, did not negatively affect nursery performance (Brumm and Shelton, 1991). These results may indicate that nursery pigs can tolerate reduced night time temperatures under otherwise optimal environmental and management conditions (Brumm and Shelton, 1991; Brumm et al., 1995). However, commercial production environments and practices vary greatly, precluding general recommendations for reduced nocturnal temperature regimes.

2.3.2 Environmental effects on abnormal behaviour

The importance of oral activity in the daily behavioural repertoire of the pig has been indicated through observations of domestic pigs in semi-natural environments. Suckling piglets, observed under semi-natural conditions, have been found to spend more than half of their active time grazing and rooting for food (Newberry and Wood-Gush, 1988; Stolba and Wood-Gush, 1989; Jensen and Stangel, 1992; Petersen, 1994).

Recent studies comparing the pre-and post-weaning behaviour of piglets reared in commercial indoor and outdoor environments showed that indoor-reared piglets spent more time manipulating the sow's udder and were more likely to engage in agonistic interactions before and after weaning (Cox and Cooper, 2001). In contrast, outdoor-reared piglets spent more time feeding immediately following weaning and spent more time rooting during weeks 2-8 post weaning (Webster and Dawkins, 2000). These results indicate that piglets are highly motivated to manipulate their environment through oral behaviour and that rooting and exploring in a semi-natural environment may be substituted by pig and pen-directed behaviour in a barren intensive housing system (Dybkjær, 1992).

Bøe (1993) studied the effects of familiarity and enrichment of piglet environment following weaning (4 and 6 weeks). Litters either remained in the familiar farrowing pens enriched with sawdust as bedding, or were moved to barren flat-deck nursery pens. At 8 weeks of age, piglets in flat-decks were observed lying, sitting and tail-biting more frequently and spent more time exploring their environments and pen mates compared to piglets in the enriched farrowing pens. In contrast, piglets in farrowing pens spent 42.7% of their active time manipulating the bedding (Bøe, 1993). Beattie et al. (1996) studied the effects of environmental enrichment and space allowance on the behaviour of 6 week old pigs and found that the provision of rooting substrates (peat and straw) reduced the duration of aberrant social behaviours and that reduced space allowance was less important. Kelly et al. (2000) weaned 3 to 4 week old piglets into a deep straw, straw-flow or a flat-deck housing system and observed their behaviour at regular intervals during the entire grower period (4 to 5 weeks). In accordance with earlier studies (Bøe, 1993; Beattie et al., 1996) the provision of straw significantly reduced pig and pen-directed behaviour and increased rooting and straw-directed behaviour (Kelly et al., 2000). Piglets in deep-straw also spent significantly more time playing relative to piglets in any other housing systems (Kelly et al., 2000). It has been theorized that increased play behaviour may be a reliable indicator of high overall well-being (Lawrence and Appleby, 1996; Kelly et al., 2000).

Andersen et al. (2000) studied the effects of resource distribution on aggression in groups of unacquainted pigs and found that 7 week old pigs would actively defend the area of the pen where straw was distributed. In a similar study, Morgan et al. (1998) found aggressive interactions to be more common in straw-bedded pens than in barren pens. However, Morgan et al. (1998) used a single-space feeder which, when coupled with the provision of straw as a resource, may have contributed to an increased level of aggressive interactions. In contrast, Arey and Franklin (1995) did not find the provision of straw to affect the number of fights but that the number of unacquainted pigs within the pen did. However, pigs were only observed for the first 5 days following mixing, during this time the process of establishing a stable hierarchy within pens may have taken precedence over the motivation to manipulate the bedding.

Results from studies investigating the effects of bedding on piglet behaviour are often confounded by other variables such as age, environmental conditions and housing systems (Fraser et al., 1991). Fraser et al. (1991) placed 7 week old pigs, in groups of 3, in pens with or without deep straw bedding. To control for aggressive interactions due to mixing, piglets were allowed one week to adapt to their new environment before observations commenced. Results showed that aggression towards pen mates and overall activity within the pen did not change with the provision of straw. However, pig-directed behaviour was reduced, indicating that straw acted as a stimulus and outlet for rooting and chewing (Fraser et al., 1991). Similar results were found when 10 week old pigs were placed, in groups of 8, in pens with or without straw provided in a rack (Fraser et al., 1991). Petersen et al. (1995) found a significant reduction in aberrant pig and pen-directed behaviour among piglets housed in pens enriched with straw, logs and branches relative to piglets housed under barren conditions. This was particularly the case immediately following weaning. Piglets from enriched environments also spent less time manipulating the sows' udder just before weaning compared to piglets from the barren environment (22 and 39% respectively) (Petersen et al., 1995).

Adding straw or other bedding material to pens in modern swine production facilities may not always be practical due to the extensive use of fully slated floors for manure management (Kelly et al., 2000). However, enrichment of the environment through the provision of toys and other objects has proven to be effective in satisfying appetitive behaviours related to oral activities (Grandin, 1989; Schaefer et al., 1990; Petersen et al., 1995). Efforts made to re-direct piglet oral behaviour from abrasive social interactions to play and investigatory behaviour may positively affect piglet performance and welfare. By reducing skin wounds caused by fighting and pig-directed oral behaviour, opportunistic pathogens are less likely to tax the piglet's immune system. Less physiological and psychological stress may in turn motivate the piglet to engage in feeding, which is imperative in regards to early weaned piglets' ability to successfully cope with weaning (and transport).

2.4 GROUP COMPOSITION AND AGGRESSION

Today, it is common management practice to mix newly weaned piglets from different litters, often by size and/or sex (split sex feeding), in an attempt to provide equal opportunity to access feed in the nursery (Friend et al. 1983). This practice may, however, be questionable with respect to animal welfare. Some studies have shown that mixing of unfamiliar pigs increases the level of aggression within the social group (Friend et al., 1983; Rushen, 1987; Arey and Franklin, 1995; Stookey and Gonyou, 1998; Turner et al., 2001). Other studies have shown that evenly sized pigs tend to take longer to determine a winner and loser during a social conflict (Friend et al., 1983; Rushen, 1987; Algers et al., 1990; Francis et al., 1996; Erhard and Mendl, 1997; Jensen and Yngvesson, 1998; Andersen et al., 2000; D'Eath, 2002). In addition, some studies have linked a genetic factor to individual aggressiveness in pigs, creating great variability in aggression both within and between litters (Erhard and Mendl, 1997; Erhard et al., 1997; Forkman et al., 1995). Aggressive interactions tend to decrease over time (Blackshaw et al., 1987; Worobec et al., 1999; Mason et al., 2003), and a stable dominance hierarchy is usually established within 24 h of mixing (McGlone, 1985; Fraser and Rushen, 1987; Fraser et al., 1995; Erhard and Mendl, 1997; Turner et al., 2001). Nevertheless, measures taken to reduce aggression during the formation of a social hierarchy order may increase production efficiency, reduce stress and increase welfare of piglets (McGlone, 1985).

By using a cross-fostering model, Stookey and Gonyou (1998) found that recognition among young piglets is gained through rearing associations and does not involve kin recognition based on phenotypic assessment. Puppe (1998) found similar results when mixing 12 week old grower pigs. While relatedness had no effect on aggressive interactions, pigs that were familiar expressed less aggression in the pen area compared to unfamiliar pigs. However, familiarity had no effect on aggressive interactions in the trough area, indicating that pigs are highly motivated to defend a food source regardless of social relations with pen-mates (Puppe, 1998). Other studies have found a correlation between aggression and the number of unfamiliar individuals within a newly mixed group, but only during the first 3 h of mixing (Blackshaw et al., 1987; Francis et al., 1996: Friend et al., 1983). Mixing unfamiliar piglets did not affect subsequent performance (Blackshaw et al., 1987; Friend et al., 1983).

Piglet relative size within the group is another factor believed to affect the level of aggression within a newly mixed group. Rushen (1987) mixed 5 to 6 week old piglets in groups of 4 (one large and one small piglet from each of two litters). While unacquainted piglets fought more than litter-mates, fights were much shorter and involved fewer bites if there was a large weight difference between opponents (>25%). More fights occurred between large compared to small unacquainted pigs, suggesting that large piglets have more difficulties establishing dominance relationships, and that the presence of larger, more dominant pigs, suppress fighting behaviour in smaller pigs (Rushen, 1987). D'Eath (2002) mixed 7 week old pigs from two litters into groups of eight and found that heavier pigs within the group were more involved in fighting, won more fights and received a greater number of skin wounds compared to smaller pigs during the first 2 d following mixing. Olesen et al. (1996) found similar results when weaning and re-grouping 4-week-old piglets. When resting, pigs were observed lying with litter mates more frequently on d 1 (76.1%) than on d 2 (58.2%), indicating an increased tolerance for unfamiliar individuals with time (D'Eath, 2002). The study also showed that individual aggression affected the severity of aggressive interactions at mixing and that piglet relative weight was not correlated with aggression. Groups with high levels of aggression expressed compromised weight gain in the 5 days following mixing. This may have been caused by reduced appetite due to high levels of stress hormones, low feed intake relative to energy expenditure or because aggressive piglets monopolized the feeder (D'Eath, 2002). Andersen et al. (2000) studied the relationship between weight asymmetry and aggression in grower pigs. Seven-week-old unacquainted pigs were grouped in pens of 4 and mixed according to body weight, producing large (3.1 ± 0.2 kg) or small (1.2 ± 0.1 kg) weight asymmetry between each pig in the group. Individual fights were shorter in groups with large weight asymmetry than in groups with small weight asymmetry and the two largest pigs in groups of small weight asymmetry spent significantly more time fighting than the two smallest pigs during the first hour following mixing. Piglet weight explained 25% of fights won in groups of large weight asymmetry compared to only 10% in groups of small weight asymmetry, suggesting that the weight difference between two opponents have to be large (> 20%) in order for pigs to perceive differences in relative strength and fighting ability (Andersen et al., 2000; Erhard and Mendl, 1997; Rushen and Pajor, 1987). In contrast, Jensen and Yngvesson (1998) did not find weight asymmetry (average 23%) to shorten fights or to reduce the number of social interactions escalating to overt fighting. However, aggressive interactions in this study were observed through staged paired encounters of short duration (< 35 min), without the social dynamics usually present in a group of newly mixed unacquainted pigs. Erhard and Mendl (1997) found great variability in aggression expressed by individual pigs, both within and between litters. Seven- week-old pigs were tested individually for aggression by briefly (max 3.5 min) introducing a younger and lighter 'intruder' piglet into their home pen. The time from first contact until the resident pig attacked the intruder (attack latency) was used as a measure of aggression. Four weeks later, the same pigs were re-tested using the same procedure. While results showed that aggression was not related to sex, age or body weight of the resident pig, individual aggressiveness (attack latency) was consistent over time (from 7-11 weeks of age). The authors suggested that aggression may therefore have a genetic factor, explaining the variability between, as well as within litters. However, relative size and individual aggressiveness are believed to interact since studies have shown that aggressive interactions instigated by aggressive pigs (regardless of size) are often won by larger pigs (Rushen, 1987; Erhard et al., 1997; Francis et al., 1996; D'Eath, 2002 and others).

2.5 EFFECT OF TRANSPORT

Previous research has indicated that handling and transport, both commercial and experimental, can have detrimental effects on pig performance and welfare (Stephens and Perry, 1990; Bergeron and Lewis, 1997). Transport is believed to be a multiple stressor representing both psychological (mixing, handling and novelty) and physical (hunger, thirst, fatigue, injury and thermal extremes) factors of stress (Grandin, 1997). The level of stress perceived by the pig due to each component of transport cannot be readily evaluated, but is probably dependent on the intensity and duration of each of the factors, as well as the interaction between any two or more of these (Stephens and Perry, 1990).

Previous studies involving transport of grower and slaughter pigs have shown that transport (simulated transport and road transport) may induce increased levels of saliva or plasma cortisol (McClone et al., 1993; Bradshaw et al., 1996a,b; Hicks et al., 1998; Parrot et al., 1998), change in behaviour (Hicks et al., 1998), motion sickness (Bradshaw et al., 1996a,b; Randall and Bradshaw, 1998), fatigue (Lambooy, 1988), weight loss

(Lambooy et al., 1985; Lambooy, 1988) and alteration in immune function (McGlone et al., 1993; Morrow-Tesch et al., 1994; Hicks et al., 1998). Although the Canadian export of live pigs involved the transport of approximately 3.089 million piglets (weighing < 7 kg) across the US border in 2004 (Statistics Canada, 2005), limited data exist on the effects of transport on early-weaned piglets (Berry and Lewis, 2001a). However, subjecting piglets to multiple stressors has been shown to reduce piglet productivity, health and welfare (Dybkjær, 1992; Ekkel et al., 1995; Hyun et al., 1998), and it may therefore be reasonable to assume that transport stressors will exacerbate the stress already experienced by piglets due to early weaning (Bergeron and Lewis, 1997; Berry and Lewis, 2001a). A study by Berry and Lewis (2001a), involving simulated transport of early-weaned piglets (17 ± 1 d), showed that transport duration and temperature may have detrimental effects on piglet performance up to 7 d post-transport.

Activation of the sympathetic-adrenomedullary system which involves the immediate release of catecholamines (such as adrenaline and noradrenaline), and the hypothalamic-pituitary-adreno-cortical (HPA) system which involves the release of glucocorticoids (such as cortisol), are two major physiological response mechanisms to stress in mammalian species (Trunkfield and Broom, 1990; Minton, 1994). Changes in plasma and saliva hormone concentrations are frequently used in animal research as parameters to measure the level of stress experienced by the animal (Bergeron and Lewis, 1997; Cook et al., 1996; Minton, 1994; Trunkfield and Broom, 1990).

Bradshaw et al. (1996a) prepared six pre-pubertal grower pigs with jugular vein catheters to facilitate non-invasive regular blood sampling during transport (every 30 min.). Pigs were loaded on to a commercial transporter in individual pens and kept on the stationary truck for 8 h (control). Two days later, the procedure was repeated (with the same pigs) while the truck was driven for 8 h. Results showed increased levels of cortisol following loading during both scenarios, but remained higher for longer during road transport (first 5 h for experimental and first 2.5 h for control) (Bradshaw et al., 1996a). In a similar experiment, pigs were transported for two 100-min journeys, separated by a 100-min 'rest' period. Each 100-min journey was classified as either 'rough' or 'smooth' based on the quality of roads travelled. The transport procedure was performed on two consecutive days (Bradshaw et al., 1996b). Plasma cortisol concentrations increased due to loading and transport on both days and remained higher for longer on rough compared with smooth journeys. Pigs showed a greater response to transport on day 1 compared to day 2, indicating some level of habituation to repeated transport (Bradshaw et al., 1996b). Studies have shown that vibration and motion associated with transport may be aversive to pigs (Stephens et al., 1985; Bradshaw et al., 1996a,b; Randall and Bradshaw, 1998). Stephens et al. (1985) trained grower pigs to operate a switch panel, controlling the activation (or in-activation) of a pen designed to simulate transport motions and noise. Results showed that trained pigs would keep the apparatus off 75% of the time. The higher the intensity and noise produced by the transport simulator, the more motivated pigs were to in-activate the apparatus (Stephens et al., 1985). When the simulated transport pen was set to be activated for 30 sec every time the switch panel was touched, none of the trained animals were motivated to respond (Stephens et al., 1985). Vibration and movement during real or simulated transport can cause motion sickness in pigs and may therefore be perceived as negative stimuli. Randall and Bradshaw (1998) transported 40 kg grower pigs for short (100 min) journeys and 80 kg grower pigs for longer (4.5 h) journeys and found that 25-30% of the pigs exhibited symptoms of motion sickness. Bradshaw et al. (1996a) reported similar findings after transporting young grower pigs (35 kg) for an 8 h journey. In these studies, incidences of retching, vomiting, chewing and foaming at the mouth were described as behaviours associated with motion sickness.

Commercial transport of pigs usually requires the mixing of unacquainted animals. Mixing may result in high levels of aggressive behaviour, injuries and overall increased levels of stress, both for dominant and submissive individuals. Bradshaw et al. (1996a) compared the behaviour and salivary cortisol levels of slaughter pigs subjected to commercial transport of 1.5 h duration. Pigs were either mixed or kept in their familiar social groups of 4. Mixed groups expressed 3 times the activity level of familiar groups, mostly due to increased fighting behaviour. Mixed pigs also had higher levels of salivary cortisol during loading and transport compared to pigs that were kept in their social groups (Bradshaw et al., 1996a). In contrast, Lambooy et al. (1985) and Lambooy (1988) video-recorded slaughter hogs during transport journeys lasting from 28 to 44 h and found pigs spent most of the time lying or sitting. As lying became more prevalent through the course of the journeys, it was concluded that pigs became increasingly fatigued (Lambooy et al., 1985; Lambooy, 1988). However, the studies did not articulate if pigs were penned as familiar social groups or mixed during transport. Hicks et al. (1998) video-taped pre-pubertal grower pigs during 4 h of road transport and found pigs to spend the majority of time lying down. Pigs were transported in familiar social groups of three, and individual pigs were identified as socially dominant, intermediate or submissive. Although transport stress caused an increase in plasma cortisol relative to non-transported pigs, this did not reach significance. Furthermore, social status did not affect the release of cortisol in pre-pubertal pigs following 4 h of road transport (McGlone et al., 1993; Hicks et al., 1998).

Weight-loss during transportation ranging from 2.9 to 12.7% has been reported and may depend on the weight (and age) of pigs, environmental conditions and duration of transport (Lambooy et al., 1985; Lambooy, 1988; Jesse et al., 1990; McGlone et al., 1993; Hicks et al., 1998; Berry and Lewis, 2001a). Current commercial transport practices do not provide pigs with feed or water in transit. As a result, weight-loss during transport is inevitable due to loss of gut contents, body water (urination and breathing), and utilization of stored protein and fat (Jones et al., 1985; Bergeron and Lewis, 1997). Lambooy et al. (1985) transported slaughter pigs for 44 h with or without access to water. After transport, pigs had lost, on average, 7.1% of live weight, half of which was determined to be lost carcass weight. The authors did not find the provision of water to reduce weight-loss during transport as pigs were reluctant to use the drinking nipples during transport. Lambooy (1988) observed a 4% live-weight loss during experimental journeys (25 h) and 6 % during commercial long haul transportation (31 h), suggesting higher weight-loss with increased transport duration. McGlone et al. (1993) reported a 5.1 % weight-loss in young grower pigs (27.5 kg) following 4 h of transport. Three days post transport, shipped pigs expressed lower weight gain and reduced feed intake relative to non-shipped pigs, indicating lasting negative effects of transport stress (McGlone et al., 1993). However, in a similar experiment, Hicks et al. (1998) observed only 2.9% weight-loss following 4 h of transport and no negative effects on pig performance during a 5-d post transport period. At the extreme end, Brumm and Peo (1985) reported post transport weight loss to range from 8.4 to 12.7% following 1000 km journeys. Although no explanation was offered by the authors, variable weight-loss between trials may have been due to variable transport duration. A study by Berry and Lewis (2001a) showed that SEW piglets (17 ± 1 d) expressed average weight losses of 6.5% when exposed to 24 h of simulated transport during 'cold' (20°C) and 'hot' (35°C) environmental temperatures immediately following weaning. 'Simulated transport' in this study did not involve motion or sounds experienced during road transport, but rather focused on the stress of feed and water deprivation, and unfavorable temperatures commonly experienced during transport. While the above transport treatments resulted in compromised weight-gain compared with controls during the first 7 days post-transport, no differences were detected by d 14 of the trial.

Numerous studies have discussed the benefits and disadvantages of early weaning. In addition, transport has been identified as a multiple stressor, causing increased weight-loss and possibly reduced welfare in grower and slaughter pigs. However, while millions of early weaned piglets are transported within North America every year, only a very few studies currently provide information regarding the responses and tolerances of early weaned piglets to transportation. The subject of the current study will provide data and information that could be used to improve transport conditions, which may then improve piglet performance and welfare.

3.0 MANUSCRIPT 1

Performance and welfare of early weaned piglets as effected by transport duration, season, weaning weight and transport type

3.1 ABSTRACT

Segregated early weaning is a management system that is utilized extensively by the North American swine industry and involves the transport of millions of early weaned piglets every year. In spite of this, the responses and tolerances of early weaned piglets to transport are not well documented. It is believed that the added stress of transport may predispose piglets to increased disease risk and compromised early post-weaning performance. Transport of early-weaned piglets is therefore considered to be a welfare issue. The objectives of this work were to study the performance of early weaned piglets as affected by 1) the duration of transport, 2) season of transport, 3) weaning weight, and 4) the general effects of road transport, including noise, vibration, movement and fluctuating temperatures to assess overall welfare following early weaning and transport.

Two groups of 48 Cotswold piglets were weaned at 17 ± 1 d of age and assigned to road transport or simulated transport during one of 2 seasons (summer or winter) and 4 durations (0 h, 6 h, 12 h or 24 h). As in commercial transport, feed and water were not provided while in transit, and supplemental heat was not utilized during winter transport. Following transport, piglets were grouped in pens of four individuals of similar weight, producing pens of relative light (5.26 ± 0.72 kg), medium (6.19 ± 0.7 kg) and heavy (7.4 ± 1.07 kg) pigs. Body weights were recorded daily for 8 d and on d 10, 12 and 14.

From an average weaning weight of 6.28 ± 0.09 kg, piglets lost 6.33 ± 0.23% or 0.4 ± 0.1 kg of body weight. As transport duration increased, weight loss increased in a linear trend and was significantly different between the 6 h and 24 h transport groups ($P < 0.001$). These results suggest that transport of long duration (>12 h) may cause additional stress to early weaned piglets. The minimum weight of 5.88 ± 0.1 kg was reached 2.24 ± 0.13 d post weaning. Time between the day of lowest body weight and day of recovery averaged 1.27 ± 0.1 d and weaning weight was recovered at 3.55 ± 0.16 d post weaning. Average daily gain (ADG) from day of recovery to d 14 of the trial averaged 0.355 ± 0.009 kg or 5.77 ± 0.02% of piglet weaning weight. Piglets transported in winter reached their lowest weight significantly later than piglets transported in summer (2.31 vs. 1.92 ± 0.01 d, $P < 0.05$) suggesting prolonged growth check associated with winter transport. Piglets transported in winter also showed reduced ADG (0.34 vs. 0.37 ± 0.009 kg, $P < 0.05$) and lower FCE ($P < 0.0001$) relative to piglets transported in summer, suggesting that transport in winter caused more stress to piglets than transport in summer. Heavy piglets lost weight for longer relative to light piglets (2.26 d vs. 1.7 d, $P < 0.02$), but relative weight loss was not affected by initial weaning weight. Following growth check recovery, heavy piglets showed reduced relative weight-gain (5.05 % ADG) relative to light (6.14 % ADG) and medium (6.1% ADG) piglets ($P < 0.01$), and reduced FCE relative to light piglets ($P < 0.05$). However, these differences were not believed to reflect increased levels of transport stress in heavy piglets. Piglets exposed to road transport required more time to recover their weaning weight following transport in winter (4.08 ± 0.18 d) than in summer (3.18 ± 0.18 d) and more time than simulated transport groups during either season (average 3.15 ± 0.18 d, $P < 0.05$). Higher ADG (P

< 0.02) and better FCE (P < 0.02) were observed in piglets assigned to road transport in summer relative to piglets assigned to road transport in winter, indicating that some factors of transport (including noise, vibration, movement or fluctuating temperatures) may have negative effects on piglet early post-weaning performance and welfare.

3.2 INTRODUCTION

Segregated early weaning (SEW) is a production practice that has become a trend in the North American swine industry (Carroll et al., 1998; Worobec et al., 1999). In SEW, piglets are weaned and separated from the sow herd within 3 weeks post farrowing (Worobec et al., 1999). This management practice is utilized in order to reduce vertical transfer of disease and therefore improving piglets' early post-weaning growth potential (Henry, 2001). While legislation and directives prevent piglets from being weaned earlier than 3 weeks in most European countries, Canadian producers are currently weaning piglets at an average age of 17 days (CARC, 2003).

In spite of their high health status, early weaned (EW) piglets often show low levels of feed intake immediately following weaning. Profound environmental changes in housing and social reorganization, as well as the transition from liquid to solid feed, are believed to be aspects of the weaning process that collectively contribute to commonly observed weight-gain depression in early weaned piglets (Metz and Gonyou, 1990; Robert et al., 1997; Weary et al., 1999; Worobec et al., 1999). In addition, a SEW management system requires piglets to be moved by truck to a separate production site at least 5 km away from the sow herd (Bergeron and Lewis, 1997; CARC, 2003). Transport is an additive stressor, involving mixing, crowding, feed and water deprivation, cold, heat, temperature fluctuations, vibration and noise, and is therefore a major concern with respect to animal welfare (Stephens and Perry, 1990). While millions of EW piglets are transported within North America every year (Statistics Canada, 2005), limited research currently exist on piglets' response and tolerance to transport. Studies involving transport of grower and slaughter pigs have shown that transport (simulated transport and road transport) may induce increased levels of saliva or plasma cortisol relative to controls (McClone et al., 1993; Bradshaw et al., 1996a,b; Hicks et al., 1998; Parrot et al., 1998) indicating that pigs perceive transport as stressful. The duration of transport is believed to be a primary factor (Berry and Lewis, 2001a). Increased weight loss due to prolonged feed and water deprivation associated with long journeys has been observed in young piglets (Berry and Lewis, 2001a) and older animals (Lambooy et al., 1985; Lambooy, 1988). This effect may be exacerbated during high temperatures, increasing the risk of pigs becoming dehydrated (Berry and Lewis, 2001a). In North America, early weaned piglets are transported throughout the year, exposing them to a wide range of environmental conditions. A recent study by Lewis et al. (2005) found that transport in winter resulted in more poor doers (piglets less than weaning weight at 7 d) than transport in fall and winter, implying that transport in winter may compromise piglet early post weaning performance.

The objectives of this experiment were to study the performance of early weaned piglets as affected by 1) the duration of transport, 2) season of transport, 3) weaning weight, and 4) the general effects of road transport, including noise, vibration, movement and fluctuating temperatures to assess overall welfare following early weaning and transport. Relative performance was used as an indicator of the ability of piglets to recover from EW and transport induced stress, and therefore an indicator of welfare. This study was conducted in conjunction with a study on the behaviour of early-weaned piglets as affected by transport under the same experimental conditions (Manuscript 2).

3.3 MATERIALS AND METHODS

3.3.1 Animals and housing

One hundred and ninety two Cotswold (Cotswold Canada Inc.) piglets, with a mean initial body weight of 6.28 ± 0.09, kg were weaned at 17 ± 1 d of age and immediately placed on trial. Standard farrowing practices were utilized and creep feed was available in the farrowing crate from 15 d of age.

Following weaning and transport, piglets were housed in a temperature controlled room which was maintained at 30 °C for the first week, and then gradually reduced by 0.5 °C every second day to 28 °C. Piglets were fed a commercial medicated nutritionally balanced weaner diet based on corn and soya meal containing 20% crude protein (Appendix 1). Feed and water were supplied *ad libitum*. Piglets that continued to lose weight (in excess of 10 grams per day) after 4 days in housing were given electrolytes as required relative to daily weight-loss and body condition. Continuous 24-hour light was utilized for video recording purposes for a concomitant behavioural study (Manuscript 2).

Piglets were assigned, in groups of four, to raised weaner pens. Each pen measured 1.06 x 1.72 m, which allowed 0.43 m^2 per pig. Individual pens were equipped with one water nipple (adjusted to piglet shoulder height), one free-flow stainless steel pellet feeder (designed for weanlings), and a plastic coated expanded metal floor. Pens were bordered on three sides with metal partitions that allowed piglets limited visual and physical contact between pens; the remaining side consisted of a solid PVC partition. A chain was hung from the mid point of the longest side as an enrichment device. Animal care was conducted in accordance with the Canadian Council on Animal Care Guidelines (CCAC, 1993) and followed The Recommended Code of Practice for the Care and Handling of Farm Animals: Pigs (Connor, 1993).

3.3.2 Experimental design

The experiment was carried out in two seasons (winter and summer). In each season, 96 piglets were assigned to either road transport or simulated transport. Transport was initiated at 08:30 h and ended at 14:30 and 20:30 for 6 h and 12 h transport groups respectively, and at 08:30 the following day for 24 h transport groups. In an effort to keep the environmental temperature regimes during the two types of transport as similar as possible, simulated transport was carried out 2 days after the initiation of road transport. This allowed for average environmental temperatures during road transport, to be recorded and reproduced during simulated transport.

Within each transport type (road or simulated) piglets were ranked from 1-48 according to their relative weight two days prior to weaning. Piglets were then categorized as heavy (1-16), medium (17-32) or light (33-48) according to their weight rank. Within the weight groups (16 pigs), four piglets were randomly assigned to either 0 h, 6 h, 12 h or 24 h of transport; representing control groups, short, medium and long journeys respectively (Appendix 2). Mixing litters was given priority over mixing sexes, resulting in one single sex group in trial 1 (winter) and one single sex group in trial 2 (summer). A black non-toxic permanent marker was used to identify individual animals during transport and later in their housing pen. Following 25 minutes of transport from the farrowing unit, control (0 h) piglets were placed directly in the housing pens upon arrival at the research facility. Following 6 h, 12 h and 24 h of transport, piglets were immediately transferred to the same housing accommodation as control animals.

3.3.2.1 Road transport

Road transport was carried out using a one-ton cube-van with solid side-paneling and a vertical sliding tail-gate. Partial double walls in the cargo compartment (aluminum outer walls and plywood inner walls) prevented excessive condensation and protected the animals from the cold outer walls during winter transport. Daylight entered the cargo area through a translucent roof but no artificial light was supplied at night. The vehicle was not equipped with controlled ventilation for the cargo compartment and no supplemental heat was provided during winter transport. In accordance with commercial transport practices, piglets received no feed or water while in transit. A 'transport pen' was built by stacking two layers of small square bales of straw across the width of the compartment. Since it was deemed impractical to adjust the pen-size during the transport trial, piglets transported for 12 h and 24 h were provided with more space (0.125 and 0.25 m^2/piglet, respectively) than the recommended maximum of 0.085 m^2 for piglets up to 9.0 kg. (CARC, 2001). This adhered to the commercial transport recommendations of allowing more space per pig during long distance transport (more than 4 h in transit). In accordance with industry standards, both straw and shavings were provided as bedding material during the winter trial, while only shavings were used during the summer trial.

Two electronic temperature probes[1] were used to obtain van temperatures every minute; one along a side wall and the other immediately above the piglets. Temperature data was averaged over ten minutes and stored on a data logger[2]. Average ambient temperatures in the Winnipeg area during the hours of road transport were obtained from the Environment Canada database[3].

City driving was kept to a minimum in order to simulate the motions experienced by piglets during a typical long range commercial transport along highways. Short hourly stops were made to make visual appraisal of piglet condition via a small door from the driver's cabin. The truck was also stopped for 10-20 minutes to unload 6 h and 12 h transport groups. The effect of potential transport stressors such as noise, vibration, movement, temperature fluctuation and handling was not believed to differ significantly between commercial transport and the transport design used in the current study. In contrast to commercial transport, the current design allowed for regular inspection of piglets during transport.

3.3.2.2 Simulated transport

Transport was simulated using high-sided wooden boxes (0.9 m W x 1.25 m L x 0.75 m H) placed in a temperature-controlled room. Consistent with practices during road transport, transport boxes were bedded with shavings in the summer and shavings and straw during the winter trial. Eight to twelve piglets were placed into each box at any

[1]Campbell Scientific CS500-L

[2]Campbell Scientific CR10X

[3]www.climate.weatheroffice.ec.gc.ca/climateData/hourlydata_e.html

time, providing a space allowance of 0.14 to 0.095 m^2/piglet respectively. The minimum space allowance was kept above the recommended 0.085 m^2/piglet up to 9 kg. (CARC, 2001) to be consistent with the conditions provided during road transport. Feed and water were not available in the transport box and all lights were turned off at approximately the same time as darkness occurred outside. Piglets were inspected regularly during transport, ensuring that animal welfare was not compromised. To keep the average temperatures the same during road and simulated transport, average temperatures recorded above the piglets during the first 6 h, 6-12 h and 12-24 h of road transport were reproduced in the simulated transport room. The average temperatures observed during 0-6 h and 6-12 h of road transport during the winter trial (8.4 °C and 7.1 °C respectively) and during the summer trial (23.0 °C and 25.7 °C respectively) were replicated within 1 °C. The average temperatures observed during 12-24 h of road transport in winter (-0.15 °C) and summer (17.4 °C) were matched as closely as allowed by barn conditions (± 3 °C).

3.3.2.3 Performance measures

Piglet body weights were recorded on entry to the trial (weaning weight), and daily thereafter until 8 days post-weaning. Live-weights were then recorded on day 10, 12 and 14. This data was used to calculate six variables indicative of piglet performance: 1) the day at which the piglet reached its lowest weight (day min); 2) piglet weight on day min (min weight); 3) weight loss on day min, presented as a number as well as a percentage of piglet weaning weight (weight loss and percent weight loss); 4) the day at which the piglet returned to its weaning weight (day of recovery); 5) the number of days required to re-gain the weaning weight following the day of minimum weight (day min to recover) and 6) the average daily gain, presented as a number as well as a percentage of weaning weight, from day of recovery to 14 d post weaning (ADG and percent ADG). In addition, daily feed weigh-backs were used to determine feed consumption in each pen during the first 14 days following weaning and transport.

3.3.3 Statistical Analysis

Data were analyzed using a factorial design for the weight data and a split-plot in time design for the feed data. The model statement included effects of season (summer, winter), transport type (road transport, simulated transport), transport duration (0 h, 6 h, 12 h, 24 h) and weight group (light, medium, heavy). The pen was the experimental unit. Regarding the feed data, the main plot included pens within transport treatments and the sub-plot included days of observation. Three piglets from each season did not recover their weaning weight within 7 d in housing and were therefore removed from the data-set. The six performance variables derived from piglet daily body weights were calculated using simple algorithms. The lowest body weight was determined by comparing current minimum weight to the next weight. Day of minimum weight, weight loss and percent weight loss were then determined. Day of recovery was calculated using the following formula:

$db + [(ww - wb)/((wc - wb)/(dc - db))]$ where db, wb = day and weight on the day before weaning weight was exceeded; ww = weaning weight; dc, wc = day and weight on the day the weaning weight was exceeded. The time from the minimum weight to the day of recovery was then determined. Average daily gain (ADG) was calculated from day of recovery to 14 d post weaning. Percent weight loss and percent ADG were calculated relative to piglet weaning weight. Given that the model statement included effects of initial weaning weight, this could not be used as a covariate in the analysis. Percent weight-loss and percent ADG were therefore utilized. The distribution of the data-set in each case met the assumptions of normality and homogeneity of variance, as a result no transformations were required (Steel et al., 1997). All data were analyzed on a pen basis and presented as least squares (LS) means ± SEM. Given that all main effects (season, transport type, transport duration and weight grouping), and all two-way interactions in this model were considered fixed effects, a mixed model was not used. Performance data were analyzed using a general linear model repeated measures analysis of variance (SAS 8.2; Proc GLM, SAS Institute, 2001) (Appendix 3). Since three and four-way interactions were found to be non-significant, their mean squares in the analysis of variance could be used to provide an estimate of error (Cochran and Cox, 1957). Pair-wise differences between treatment means were tested using Bonferroni inequality test. Performance variables were analyzed with the following model:

$$Y_{ijklmn} = \mu + S_i + T_k + W_l + R_m + (S\times T)_{ik} + (S\times R)_{im} + (S\times W)_{il} + (R\times T)_{mk} + (R\times W)_{ml} + (T\times W)_{kl} + e_1(S\times T\times W\times R)_{ijklm} + D_n + (S\times D)_{in} + (T\times D)_{kn} + (W\times D)_{ln} + (R\times D)_{mn} + e_{2,ijklmn}$$

Y_{ijklmn} = observation of the j^{th} pen during the i^{th} season, in the k^{th} type of transport, in the l^{th} grouping category at the m^{th} transport duration, on the n^{th} day

μ = mean

S_i = effect of the i^{th} season; i = summer, winter

T_k = effect of the k^{th} transport type; k = road transport, simulated transport

W_l = effect of the l^{th} weight group; l = light, medium, heavy

R_m = effect of the mth transport duration; m = 0 h, 6 h, 12 h, 24 h

$(S\times T)_{ik}$ = interactive effect of the kth transport type during the ith season

$(S\times R)_{im}$ = interactive effect of the mth transport duration during the ith season

$(S\times W)_{il}$ = interactive effect of the lth weight group during the ith season

$(R\times T)_{mk}$ = interactive effect of the mth transport duration and the kth transport type

$(R\times W)_{ml}$ = interactive effect of the mth transport duration and the lth weight group

$(T\times W)_{kl}$ = interactive effect of the kth transport type and the lth weight group

$e_1(S\times T\times W\times R)_{ijklm}$ = error term representing the effect of the jth pen during the ith season, in the kth type of transport, in the lth weight group, at the mth transport duration

D_n = effect of the nth day[4]

$(S\times D)_{in}$ = interactive effect of the ith season on the nth day

$(T\times D)_{kn}$ = interactive effect of the kth transport type on the nth day

$(W\times D)_{ln}$ = interactive effect of the lth weight group on the nth day

$(R\times D)_{mn}$ = interactive effect of the mth transport duration on the nth day

$e_{2,ijklmn}$ = residual error

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[4] Day effect only applied to the analysis of feed data

3.4 RESULTS

3.4.1 Performance measures

From an average weaning weight of 6.28 ± 0.09 kg, piglets lost 0.4 ± 0.016 kg or 6.33 ± 1.2% of body weight. The minimum weight of 5.87 ± 0.08 kg was reached 2.11 ± 0.13 d post weaning. Time between the day of lowest body weight and day of recovery averaged 1.27 ± 0.09 d and weaning weight was recovered at 3.39 ± 0.13 d post weaning. Average daily gain from day of recovery to d 14 of the trial averaged 0.352 ± 0.009 kg or 5.76 ± 0.18% of piglet weaning weight (Fig. 1). All main effects of transport duration, season, weight group and transport type affected at least one of these performance parameters. Average daily feed intake (ADFI) on d 1-4 was relatively low (0.083 ± 0.008 kg/pig) for all piglets and did not differ between treatments. ADFI on d 1-14 was 0.348 ± 0.007 kg/pig and was significantly affected by piglet initial weaning weight. Feed conversion efficiency (FCE) on d 1-14 averaged 0.92 ± 0.007 and was significantly affected by season, season and transport type, and weaning weight.

3.4.2 Transport duration

Transport duration had a significant effect on weight-loss during the first 3 days following weaning and transport. As transport duration increased, weight loss increased in a linear trend (Table 1). Piglets subjected to 6 h transport lost significantly less weight than piglets transported for 24 h (0.326 kg vs. 0.450 kg, $P < 0.001$) but did not differ significantly from piglets transported for 12 h (0.378 kg) (Table 1). Non-transported piglets (0.435 kg) expressed similar weight loss to 12 h and 24 h transport groups but lost significantly more weight than groups transported for 6 h ($P < 0.01$). Transport duration did not significantly affect the day of recovery. However, non-transported piglets (3.82 d) required significantly more time to recover their weaning weight than groups transported for 6 h (2.9 d, $P < 0.01$) (Table 1). Piglets transported for 12 h and 24 h were intermediate and not significantly different than controls or piglets transported for 6 h. The other production parameters were not significantly affected by transport duration. However, a similar pattern was evident in day min, min weight and day min to recover (Table 1).

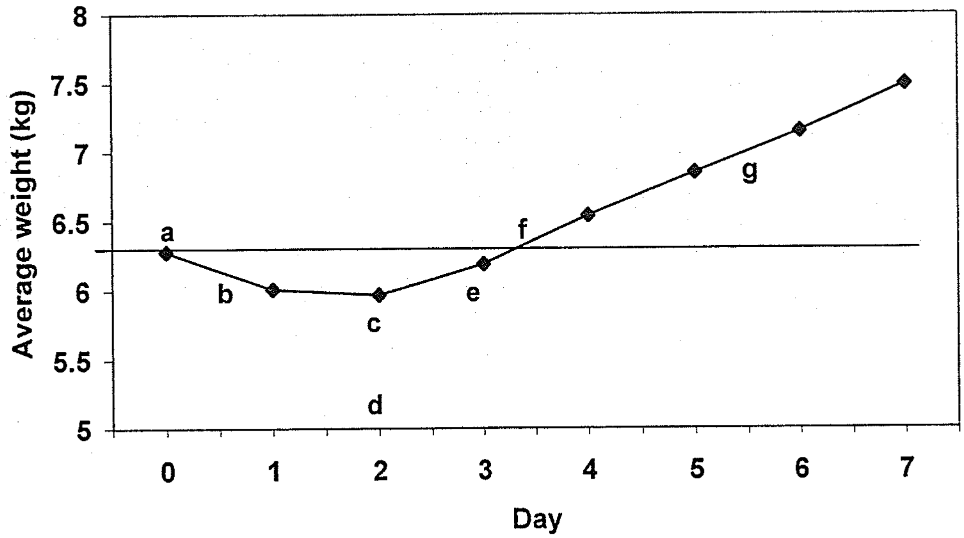

Figure 1. Average growth curve for early weaned piglets (LS Means ± SEM, n = 186).

The curve shows a) the average weaning weight of the piglet (6.28 ± 0.09 kg), b) weight loss due to initially inadequate feed and water consumption following weaning (0.397 ± 0.016 kg), c) the minimum weight reached (5.87 ± 0.08 kg), d) the time post-weaning at which the minimum weight is reached (2.11 ± 0.13 d), e) time between the day of lowest body weight and day of recovery (1.27 ± 0.09 d), f) return to weaning weight (3.39 ± 0.13 d), and g) subsequent weight gain (ADG 0.352 ± 0.009 kg). This growth curve represents the average values following controlled road transport or simulated transport for 0h, 6h, 12h, or 24h during summer or winter in Manitoba.

Table 1. The effect of transport duration on the performance of early weaned piglets (LS Means ± SEM)

Parameter	Transport duration 0h (n=12)	6h (n=12)	12h (n=12)	24h (n= 12)	SEM	P-value
Weaning weight (kg)	6.36	6.19	6.26	6.28	0.13	NS
Day min (d)	2.39	1.93	2.17	1.96	0.18	NS
Min weight (kg)	5.92	5.86	5.88	5.83	0.12	NS
Weight loss (kg)	0.435[b]	0.326[a]	0.378[ab]	0.450[b]	0.022	< 0.01
Weight loss (%)	6.79[b]	5.34[a]	6.06[ab]	7.14[b]	0.28	< 0.01
Day of recovery (d)	3.82[b]	2.9[a]	3.44[ab]	3.38[ab]	0.18	< 0.01
Day min to recover (d)	1.43	0.97	1.27	1.42	0.12	NS
ADG (kg)	0.355	0.340	0.355	0.358	0.013	NS
ADG (%)	5.73	5.68	5.82	5.82	0.26	NS
ADFI d 1-4 (kg)	0.071	0.098	0.079	0.082	0.010	NS
ADFI d 1-14 (kg)	0.275	0.280	0.289	0.286	0.013	NS
FCE d 1-14	0.89	0.93	0.93	0.92	0.01	NS

[ab]Values with different superscripts within a row indicate statistical differences ($P < 0.05$, n = pens).
NS = No significant differences between treatments ($P > 0.05$).

3.4.3 Season

On average, piglets lost weight for longer (day min) following winter transport than following summer transport (2.31 d vs. 1.92 d, $P < 0.05$) although this did not significantly affect relative weight loss (Table 2). As a reflection of initial weaning weight, piglet weight on day min (min weight) was lower in summer (5.63 kg) than in winter (6.12 kg, $P < 0.0005$). Nevertheless, the lighter piglets subjected to weaning and transport during summer conditions performed significantly better than piglets subjected to weaning and transport during winter conditions. Increased performance by summer groups was expressed as higher ADG ($P < 0.002$) and better FCE ($P < 0.0001$) compared to winter groups (Table 2). Other production parameters were not significantly affected by season. Season and transport type had a significant effect on day of recovery. Piglets assigned to road transport required more time to recover their weaning weight following transport in winter (4.08 d) than in summer (3.18 d) and more time than simulated transport groups during either season (average 3.15 d, $P < 0.03$) (Table 3). While minimum weight was a reflection of initial weaning weight, piglets transported by road in winter lost significantly more weight than piglets assigned to simulated transport in summer ($P < 0.02$) (Table 3).

Table 2. The effect of season on the performance of early weaned piglets (LS Means ± SEM)

Parameter	Season: Winter (n=24)	Season: Summer (n=24)	SEM	P-value
Weaning weight (kg)	6.55[b]	5.99[a]	0.09	0.0002
Day min (d)	2.31[b]	1.92[a]	0.13	0.047
Min weight (kg)	6.12[b]	5.63[a]	0.084	0.0004
Weight loss (kg)	0.430[b]	0.365[a]	0.016	0.0068
Weight loss (%)	6.61	6.06	0.016	NS
Day of recovery (d)	3.56	3.21	0.13	NS
Day min to recover (d)	1.25	1.29	0.085	NS
ADG (kg)	0.337[a]	0.367[b]	0.009	0.0315
ADG (%)	5.29[a]	6.24[b]	0.18	0.0011
ADFI d 1-4 (kg)	0.085	0.080	0.007	NS
ADFI d 1-14 (kg)	0.275	0.289	0.009	NS
FCE d 1-14	0.89[a]	0.95[b]	0.008	0.0001

[ab]Values with different superscripts within a row indicate statistical differences ($P < 0.05$, n = pens).
NS = No significant differences between treatments ($P > 0.05$).

Table 3. The effect of season and transport type on the performance of early weaned piglets (LS Means ± SEM)

	Season					
	Winter		Summer			
Parameter	Road (n=12)	Sim (n=12)	Road (n=12)	Sim (n=12)	SEM	P-value
Weaning weight (kg)	6.79^{b}	6.31^{ab}	5.91^{a}	6.07^{a}	0.13	< 0.004
Day min (d)	2.67	1.94	2.04	1.8	0.18	NS
Min weight (kg)	6.31^{b}	5.93^{ab}	5.53^{a}	5.73^{a}	0.12	< 0.02
Weight loss (kg)	0.478^{b}	0.382^{a}	0.381^{a}	0.348^{a}	0.022	< 0.04
Weight loss (%)	7.14^{b}	6.08^{ab}	6.38^{ab}	5.74^{a}	0.28	< 0.02
Day of recovery (d)	4.08^{b}	3.04^{a}	3.18^{a}	3.25^{a}	0.18	< 0.03
Day min to recover (d)	1.41	1.1	1.13	1.45	0.12	NS
ADG (kg)	0.351^{ab}	0.328^{a}	0.382^{b}	0.351^{ab}	0.013	< 0.03
ADG (%)	5.37^{a}	5.2^{a}	6.61^{b}	5.87^{ab}	0.26	< 0.02
ADFI d 1-4 (kg)	0.065	0.079	0.084	0.076	0.010	NS
ADFI d 1-14 (kg)	0.274	0.277	0.296	0.283	0.012	NS
FCE d 1-14	0.87^{a}	0.90^{ab}	0.96^{c}	0.94^{bc}	0.01	< 0.02

[abc]Values with different superscripts within a row indicate statistical differences ($P < 0.05$, n = pens).

NS = No significant differences between treatments ($P > 0.05$).

A similar trend was observed between piglets transported by road in winter and piglets assigned to either simulated transport in winter or road transport in summer. Increased performance by piglets assigned to road transport in summer was indicated by increased ADG ($P < 0.02$) and better FCE ($P < 0.02$) relative to piglets assigned to road transport in winter. No other production parameters were significantly affected but a numeric trend was evident in disfavour of road transport in winter (Table3).

3.4.4 Weaning weight

Weaning weight had a significant effect on days to minimum weight (day min), piglet weight on day min (min weight) and ADG (Table 4). Light piglets at weaning required less time (1.7 d) to reach day min than medium (2.26 d) and heavy (2.38 d) piglets. However, only light and heavy piglets differed significantly ($P < 0.02$) (Table 4). As expected, light piglets at weaning had a lower weight on day min (4.94 kg) than medium (5.77 kg) and heavy (6.92 kg, $P < 0.0003$) piglets, but relative weight loss (average 6.33%) was not affected by weaning weight. Piglet performance between day of recovery and d 14 post-transport was significantly different between weight groups, as relative weight-gain (percent ADG) was higher for light (6.14%) and medium (6.1%) than for heavy piglets (5.05%, $P < 0.01$) (Table 4). Light piglets also showed better FCE compared to heavy piglets (0.94 vs. 0.90, $P < 0.05$) during the first 14 days following weaning and transport. Other production parameters were not significantly affected by weaning weight. However, heavy piglets showed a trend of delayed recovery relative to light piglets ($P = 0.09$) (Table 4).

Table 4. The effect of weaning weight on the performance of early weaned piglets (LS Means ± SEM)

Parameter	Weaning weight Light (n=16)	Medium (n=16)	Heavy (n=16)	SEM	P-value
Weaning weight (kg)	5.26[a]	6.17[b]	7.38[c]	0.11	< 0.0001
Day min (d)	1.7[a]	2.26[ab]	2.38[b]	0.16	< 0.02
Min weight (kg)	4.94[a]	5.77[b]	6.92[c]	0.1	< 0.0003
Weight loss (kg)	0.319[a]	0.404[b]	0.469[b]	0.019	< 0.02
Weight loss (%)	6.12	6.52	6.35	0.25	NS
Day of recovery (d)	3.06	3.53	3.58	0.16	NS
Day min to recover (d)	1.36	1.26	1.2	0.1	NS
ADG (kg)	0.319[a]	0.372[b]	0.365[b]	0.011	< 0.02
ADG (%)	6.14[b]	6.10[b]	5.05[a]	0.22	< 0.01
ADFI d 1-4 (kg)	0.089	0.081	0.077	0.009	NS
ADFI d 1-14 (kg)	0.266	0.296	0.285	0.011	NS
FCE d 1-14	0.94[b]	0.93[ab]	0.90[a]	0.017	< 0.05

[abc]Values with different superscripts within a row indicate statistical differences ($P < 0.05$, n = pens).

NS = No significant differences between treatments ($P > 0.05$).

3.4.5 Transport type

Transport type significantly affected the magnitude of the post-weaning growth check (Table 5). Piglets assigned to road transport required more time to reach day min compared to piglets assigned to simulated transport in a temperature controlled room (2.36 d vs. 1.87 d, $P < 0.02$). Piglets assigned to road transport also lost significantly more weight (6.76% vs. 5.91%, $P < 0.007$), and required more time to recover their weaning weight than piglets assigned to simulated transport (3.63 d vs. 3.14 d, $P < 0.02$) (Table 5). However, following the day of recovery, piglets assigned to road transport showed higher ADG relative to simulated transport groups (0.366 kg vs. 0.338 kg, $P < 0.04$). Other production parameters were not significantly affected by transport type (Table 5).

Table 5. The effect of transport type on the performance of early weaned piglets (LS Means ± SEM)

Parameter	Transport type: Road (n=24)	Transport type: Simulated (n=24)	SEM	P-value
Weaning weight (kg)	6.35	6.19	0.09	NS
Day min (d)	2.36[b]	1.87[a]	0.13	0.0139
Min weight (kg)	5.92	5.83	0.08	NS
Weight loss (kg)	0.429[b]	0.365[a]	0.016	0.0078
Weight loss (%)	6.76[b]	5.91[a]	0.2	0.0066
Day of recovery (d)	3.63[b]	3.14[a]	0.13	0.0151
Day min to recover (d)	1.27	1.28	0.085	NS
ADG (kg)	0.366[b]	0.338[a]	0.009	0.0343
ADG (%)	5.98	5.54	0.18	NS
ADFI d 1-4 (kg)	0.075	0.090	0.007	NS
ADFI d 1-14 (kg)	0.285	0.280	0.009	NS
FCE d 4-14	0.92	0.92	0.008	NS

[ab]Values with different superscripts within a row indicate statistical differences ($P < 0.05$, n = pens).
NS = No significant differences between treatments ($P > 0.05$).

3.4.6 Ambient and truck temperatures

Temperatures recorded inside the truck followed a similar diurnal pattern during both summer and winter transport (Fig. 2). Following loading of piglets in the morning, both the truck shell temperature and the temperature above the piglets increased gradually during the first 6 h of transport and remained high throughout the day-light hours relative to outside ambient temperatures (Fig. 2 and Appendix 4). In the evening (dusk), the truck shell temperature and the temperature above the piglets decreased in a similar pattern during both seasonal journeys. As the day-light hours were fewer in winter than in summer, reduced truck temperatures occurred earlier during winter than during summer transport. While only a marginal difference was observed between the temperature at the truck shell and above the piglets during summer transport (average < 1 °C), the difference was more obvious during winter transport (average 4.8 °C) (Fig 2. and Appendix 4). This difference indicated higher heat loss during winter transport, as some of the heat produced by the piglets would have escaped through the truck shell. The air temperature above the piglets was, on average, 6 °C higher than the ambient temperature during summer transport and 15.5 °C higher than the ambient temperature during winter transport.

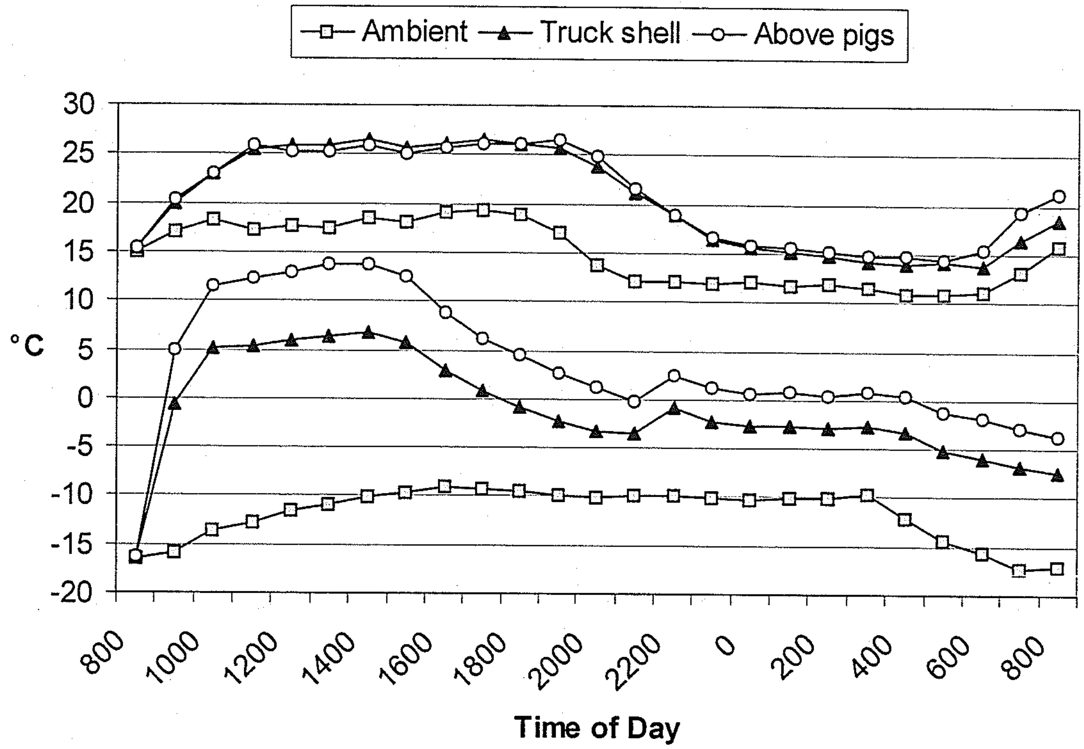

Figure 2. Average ambient temperatures at Winnipeg International Airport[5], and average truck temperatures recorded at the truck shell and directly above the piglets during road transport in summer (top three lines) and winter (bottom three lines).

[5] www.climate.weatheroffice.ec.gc.ca/climateData/hourlydata_e.html

3.5 DISCUSSION

3.5.1 Transport duration

Piglets lost, on average, 6.3% of live-weight during the first 3.4 days following weaning and transport. As transport duration increased, weight loss increased in a linear trend and was significantly different between the 6 h and 24 h transport groups. These results agree with data obtained from similar studies performed in this laboratory and with other studies involving older pigs. Berry and Lewis (2001a) reported average weight losses of 6.5% in EW piglets (17 ± 1 d) exposed to 24 h of simulated transport during 'cool' (20°C) and 'hot' (35°C) environmental temperatures. Lambooy et al. (1985) and Lambooy (1988) transported slaughter hogs for 25 h, 31 h and 44 h and found live weight loss to increase with transport duration (4, 6 and 7.1% respectively). McGlone et al. (1993) reported a 5.1% weight loss in young grower pigs (27.5 kg) following only 4 h of transport. In addition, shipped pigs in their study showed reduced feed intake and weight-gain relative to non-shipped pigs during the first 3 days post transport, indicating lasting negative effects of transport stress. In accordance with current commercial transport practices, piglets in the current study were not provided with feed or water while in transit. Under these conditions, most of the weight loss during transport was expected to be due to loss of body water (75%) and gut contents (20%) (Jones et al., 1985; Brumm et al., 1987) resulting in increased weight loss with longer transport duration.

In the current study, non-transported piglets expressed higher weight losses (6.79%) and delayed day of recovery (3.82 d) relative to piglets transported for 6 h (5.34% and 2.9 d respectively), but consistent with the majority of piglets transported for

12 h and 24 h (average 6.6% and 3.41 d), suggesting that early weaning itself resulted in significant weight loss. Other transport trials at this laboratory have shown similar results (personal communication, N. Lewis, 2004a). While non-transported piglets were offered feed and water soon after weaning, weaning stress may have reduced their motivation to drink and feed during the first day in housing. This may explain the observed consistency in weight loss and day of recovery between control groups and piglets transported for 12 h and 24 h during the first 3 days following weaning. In contrast, piglets transported and deprived of water for 6 h may have been more motivated to drink than non-transported piglets, and better able to replace water losses than piglets transported for 12 h and 24 h. Consequently, 6 h transport groups experienced reduced weight loss and a shorter growth check.

3.5.2 Season

The combined stress of low temperatures and road transport appeared to cause the most detriment to piglet post weaning performance, as winter transport by road significantly increased the day of recovery relative to road transport in summer and simulated transport during either season. While the observed differences between transport groups may have been caused by one or several factors of road transport (noise, vibration, movement or fluctuating temperatures), the lack of differences between transport types in summer suggest that cold, and possibly fluctuating temperatures in winter were significant stressors to piglets. Berry and Lewis (2001a) found that piglets subjected to simulated transport (24 h) in a 'cool' environment (20°C) expressed compromised weight-gain compared to controls during the first 7 d post treatment. While piglets subjected to road transport in the current study experienced continuously fluctuating temperatures in the truck, simulated transport groups experienced a temperature adjustment only every 6 h. In addition, piglets transported by road were exposed to slightly lower temperatures than piglets assigned to simulated transport during the winter trial (up to 3 °C). Given the highly controlled and favorable environmental conditions these piglets have become accustomed to during the nursing period, fluctuating temperatures may be perceived as a significant stress factor. Dividich (1981) found continuous temperature fluctuations (± 4 °C) during the first week in housing following weaning (22 d) to have detrimental effects on piglet performance and health. While, the effects of temperature fluctuations on early weaned piglets over a shorter time period (< 1 d) is not documented in the literature, similar negative effects of temperature fluctuations may have been found in the current study. In addition to delayed recovery, piglets transported by road during winter conditions in the current study expressed reduced percent ADG and lower FCE compared to piglets transported by road during summer conditions. While cold temperatures during winter transport may have caused additional stress to piglets, other factors may also have contributed to the observed seasonal differences in piglet early post-weaning performance. Although piglets were provided with straw during winter transport, piglets' lack of experience in efficiently utilizing bedding for insulation may have limited its purpose as such. Piglets in the current study were not observed burrowing into the straw, therefore greatly reducing the insulation value of the bedding. Instead, piglets were observed manipulating the straw to a uniform packed layer which were then used as an insulation mat as piglets came to rest on top of it. As a result, seasonal differences in piglet early post-weaning performance may have been reduced if piglets were provided with more, or possibly, different bedding material during winter transport.

3.5.3 Weaning weight

Piglets with high weaning weight expressed compromised post-weaning performance as heavy piglets required significantly more time to reach the day of minimum weight than light piglets. In addition, heavy piglets expressed reduced percent ADG (relative weight-gain) between day of recovery and d 14 post-transport compared to light and medium piglets, and reduced FCE relative to light piglets. Since no interactive effects of weight group and transport duration were observed, these differences were not believed to be related to transport induced stress. Differences between weight groups were more likely due to the differences in feeding behaviour and aggression frequently observed in piglets of varying weights (Manuscript 2).

Although early weaned piglets typically have a very low motivation to consume dry feed immediately following weaning (Metz and Gonyou, 1990; Worobec et al., 1999; Berry and Lewis, 2001a) heavy piglets in particular, are believed to have developed a strong dependency on a pure milk diet, making them poorly prepared for abrupt weaning (Weary and Fraser, 1997; Weary et al., 1999). Large differences in teat quality during the pre-weaning period may drive piglets on poor producing teats to consume alternative sources of feed (Mason et al., 2003). Piglets on these teats are often individuals of smaller relative size. This may explain why light and medium piglets in the current study expressed reduced weight loss compared to heavy piglets. Bruinix et al. (2001) observed groups of light piglets (4-wk-old) to feed significantly more than groups of heavy piglets during the first 3 days following weaning. Groups of medium sized piglets did not differ from either weight group. Reduced performance by heavy compared to light and medium piglets in the current study may therefore be explained by the theory of heavy piglets being poorly prepared for early weaning due to a high dependency on a pure milk diet.

Alternatively, grouping heavy piglets may have caused high levels of aggression, and therefore reduced levels of maintenance behaviours like feeding, drinking and resting. This may have exacerbated the negative energy balance due to early weaning, causing reduced performance and compromised welfare in heavy piglets relative to light and medium piglets. Intense aggression is a commonly observed behavioural response when pigs from different litters are mixed (Arey and Franklin, 1995; Bradshaw et al., 1987; Stookey and Gonyou, 1998; Turner et al., 2001). This early period of fighting usually prevails throughout the first 24 h following mixing or until a stable dominance hierarchy is established (Fraser and Rushen, 1987; Fraser et al., 1995). Since piglets are believed to evaluate their opponent's fighting ability based on relative size, more intense aggression is usually observed in pens of uniform piglets (Rushen, 1987; Andersen et al., 2000). Also, since body weight is an indirect indicator of social rank within the group (Erhard and Mendl, 1997; Rushen, 1987; Jensen and Yngvesson, 1998; Andersen et al., 2000), it may be expected that large piglets are more motivated to start fights and to reciprocate when challenged. This theory is supported by studies showing that large piglets are more commonly engaged in aggressive interactions than small and medium piglets immediately following mixing (Erhard and Mendl, 1997; Rushen, 1987; Jensen and Yngvesson, 1998; Andersen et al., 2000). Groups of large piglets of similar weight and age may therefore have more difficulty establishing a stable dominance hierarchy due to their previous experience as 'winners' in social conflicts with smaller litter mates. Undecided fights between evenly matched opponents may have been repeated, resulting in prolonged aggressive encounters (McGlone, 1985). In contrast, small and medium piglets may be better at evaluating their relative fighting ability based on different outcomes from previous conflicts (D'Eath, 2002). As a result, in the present study, these piglets were less affected by being grouped with similar sized pen mates.

3.5.4 Transport type

Piglets may have been negatively affected by one or more factors experienced during road transport, including noise, vibration, movement and fluctuating temperatures. This was reflected in longer time required to reach day min, higher weight loss and delayed day of recovery compared to simulated transport groups. These differences may have been due to increased water loss in piglets transported by road relative to simulated transport groups. Becker et al. (1989) found higher hematocrit values in slaughter hogs subjected to transport (11 h) and fasting (48 h and 72 h) than in pigs subjected to fasting only, indicating increased dehydration associated with effects of road transport. The added stressors of road transport, including noise, vibration, movement and fluctuating temperatures, may similarly have induced additional water loss relative to simulated transport in the current study. Hyan et al. (1998) found the addition of individual environmental stressors (mixing, crowding and fluctuating temperature) to negatively affect performance in grower pigs, and that the individual stressors were additive. Some studies have suggested that noise, vibration and movement associated with road transport is aversive to pigs (Stephens and Perry, 1990), causing anxiety and motion sickness

(Bradshaw et al., 1996a,b; Randall and Bradshaw, 1998), others have found no effects of transport (Parrot and Mission, 1989; Jesse et al., 1990). While these studies involved grower or slaughter pigs it would be reasonable to expect transport to have similar effects on early weaned piglets. Although no signs of travel sickness such as retching, vomiting and/or foaming at the mouth (Bradshaw et al., 1996b) were observed in piglets assigned to road transport in the current study, vomiting has occurred in other studies from this laboratory (personal communication, N. Lewis, 2004b).

Although piglets assigned to road transport in the current study showed higher weight loss and delayed day of recovery compared to piglets assigned to simulated transport, subsequent performance (ADG) was similar for all pigs, regardless of transport type. These results suggest that road transport causes stress to early weaned piglets, prolonging post weaning growth-check but not affecting later production.

3.6 CONCLUSION

1) As transport duration increased, weight loss increased with a linear trend and was significantly different between the 6 h and 24 h transport groups. These results suggest that transport of long duration (> 12 h) may cause additional stress to early weaned piglets. However, subsequent performance was not affected by transport duration, suggesting that early weaned piglets have the ability to overcome the added stress of transport.

2) Piglets transported by road in winter expressed a prolonged growth check, reduced ADG and lower FCE compared to piglets transported by road in summer. These results suggest that transport in winter is more stressful to piglets than transport in summer.

3) Heavy piglets showed reduced performance compared to light and medium piglets. Two theories are hypothesized: a) Groups of heavy piglets expressed higher levels of aggression, resulting in increased water loss and reduced levels of maintenance behaviours, such as feeding, drinking and resting, which exacerbated the negative energy balance due to early weaning. b) Heavy piglets may have had less previous experience consuming dry feed, possibly due to a higher reliance on a milk-based diet relative to smaller littermates and therefore expressed less initial feeding behaviour.

4) Piglets assigned to road transport lost weight for longer, lost more weight and showed delayed day of recovery compared to piglets assigned to simulated transport. These results suggest that some factors of transport, including noise, vibration, movement or fluctuating temperatures, may have negative effects on early post weaning performance and welfare. Transport may therefore cause additional stress to early weaned piglets during the first 4 days following weaning and transport.

4.0 MANUSCRIPT 2

Behaviour and welfare of early weaned piglets as effected by transport duration, season, weaning weight and transport type

4.1 ABSTRACT

Segregated early weaning (SEW) is currently a common management system in North American. As SEW necessitates the transport of piglets to a separate production facility, millions of early weaned piglets are transported across North America every year. In spite of this, the responses and tolerances of early weaned piglets to transport are not well documented. It is believed that the added stress of transport may predispose piglets to increased disease risk, exacerbate weaning stress, and reduce piglet performance immediately following weaning and transport. Transport of early-weaned piglets is therefore considered to be a welfare issue. Compromised welfare due to increased levels of stress may be detected through piglet behaviour, often before any differences in performance parameters appear. The objectives of this work were to study the behaviour of early weaned piglets as affected by 1) the duration of transport, 2) season of transport, 3) weaning weight, and 4) the general effects of road transport, including noise, vibration, movement and fluctuating temperatures, to assess overall welfare following early weaning and transport.

Two groups of 48 Cotswold piglets were weaned at 17 ± 1 d of age and assigned to controlled road transport or simulated transport during one of 2 seasons (summer or winter) and for 4 durations (0h, 6h, 12h or 24h). As in commercial transport, feed and water were not provided while in transit, and supplemental heat was not utilized during

winter transport. Following transport, piglets were grouped in pens of four individuals of similar weight, producing pens of relative light (5.26 ± 0.72 kg), medium (6.19 ± 0.7 kg) and heavy (7.4 ± 1.07 kg) pigs. Piglet behaviour was recorded on days 1-4, 7 and 14 post weaning and transport. Continuous sampling was used to record occurrence, duration and frequency of individual feeding and drinking bouts in two hour blocks over the first three days following introduction to the nursery pen. In addition, instantaneous scan sampling was performed at 10-min intervals on days 1-4, 7 and 14 in order to study general activity.

As transport duration increased, the proportion of time piglets were observed drinking increased with a linear trend from non-transported piglets (0 h) (0.5%) to piglets transported for 6 h (1.1%), 12 h (2.0%) and 24 h (3.2%, $P < 0.05$) reflecting the relative need to recoup water loss and reestablish homeostasis. According to the behaviour indicators used in this study, increased transport duration did not appear to increase weaning stress. However, depriving early weaned piglets of water may pose a welfare concern. Non-transported piglets spent significantly less time feeding (1.5%) than transported piglets (average 3.1%) during the first 3 d in housing. However, significant differences were observed on d 2 only ($P < 0.02$). Piglets showed increased levels of activity (less time lying and more time standing idle, $P < 0.05$) following weaning and transport in winter, suggesting that transport in winter is more stressful to piglets than transport in summer. Heavy piglets spent more time fighting ($P < 0.005$) during the first day in housing, and less time feeding ($P < 0.05$) during the first 3 d in housing compared to light and medium piglets, but these differences did not appear to be caused by transport stress. During the first 3 d in weanling pens, piglets spent less time feeding following road transport (2.4%) than following simulated transport (2.9%, $P < 0.05$). Piglets transported by road also spent more time engaged in oral/nasal behaviour (3.4%) compared to simulated transport groups (1.2%, $P < 0.05$), although this reached significance on d 3 only ($P < 0.05$). These results suggest that increased levels of transport stress are associated with one or more factors of road transport, including temperature fluctuations, noise, vibration, and movement.

4.2 INTRODUCTION

Segregated early weaning (SEW) of piglets has become a trend in the North American swine industry (Carroll et al., 1998; Worobec et al., 1999). In SEW, piglets are weaned and separated from the sow herd 10-20 days post farrowing (Worobec et al., 1999). This management practice is utilized in order to reduce vertical transfer of disease (Henry, 2001), and to take advantage of the increased growth potential frequently observed in high health piglets (Pettigrew et al., 1995). While most European countries are subject to legislation and directives implemented by the European Union that prevent piglets from being weaned earlier than 3 weeks, most producers in Canada are currently weaning piglets between 14 and 20 days of age, with an average around 17 days of age (CARC, 2003).

Previous studies have shown that early weaning (EW) causes reduced post-weaning feed intake (Leibbrandt et al., 1975), increased levels of oral/nasal behaviour (Gonyou et al. 1998), and increased levels of vocalization (Weary et al., 1999). Therefore, early weaning is believed to cause significant stress to piglets. Profound environmental changes in housing and social reorganisation, as well as the transition from liquid to solid feed, are aspects of the weaning process that collectively contribute to commonly observed weight-gain depression in piglets (Metz and Gonyou, 1990; Robert et al., 1997; Weary et al., 1999; Worobec et al., 1999). In addition, a SEW management system necessitates the transport of piglets to a separate production site. Transport is an additive stressor, involving mixing, crowding, feed and water deprivation, cold, heat, temperature fluctuations, vibration and noise, and is therefore a major concern with respect to animal welfare (Stephens and Perry, 1990). Millions of early weaned piglets are transported within North America every year (Statistics Canada, 2005). Studies involving transport of grower and slaughter pigs have shown that transport (simulated transport and road transport) may cause increased levels of stress hormones (McClone et al., 1993; Bradshaw et al., 1996a,b; Hicks et al., 1998; Parrot et al., 1998), change in behaviour (Hicks et al., 1998), fatigue (Lambooy, 1988) and increased weight loss relative to controls (Lambooy et al., 1985). When weaning coincides with transport, the stressors may be additive, increasing the detrimental effects of early weaning. Temperature and duration of transport are believed to be two primary factors affecting piglet response to early weaning and transport (Berry and Lewis, 2001a). While the duration of journeys within Canada typically falls within the range of 4-20 h, transport across the US border may extend beyond 24 h.

The objectives of this work were to study the behaviour of early weaned piglets as affected by 1) the duration of transport, 2) season of transport, 3) weaning weight, and 4) the general effects of road transport, including noise, vibration, movement and fluctuating temperatures, to assess overall welfare following early weaning and transport. Piglet behaviour was used as an indicator of the ability of piglets to recover from EW and transport induced stress, and therefore an indication of their welfare. This study was conducted in conjunction with a study on the performance of early-weaned piglets as affected by transport under the same experimental conditions (Manuscript 1).

4.3 MATERIALS AND METHODS

Animals and housing, and experimental design where the same as described in materials and methods in Manuscript 1, with the following exception. In the current Manuscript data acquisition and analysis were focused on piglet behaviour.

4.3.1 Behavioural observations

Piglet activities were recorded using six low light level black and white cameras, a multiplexer and a time-lapse video recorder[6]. Video recording occurred on days 1-4, 7 and 14 post weaning and transport. Two methods were used to sample data from the tapes. Continuous sampling was used to record the interval between piglet entry to the nursery pen and the time of the first observation of drinking and feeding (drinking and feeding latency). In addition, continuous sampling was used to record occurrence, duration and frequency of individual feeding and drinking bouts in two hour blocks over the first three days following introduction to the nursery pen: 0-2 h, 6-8 h, 12-14 h, 18-20 h, 24-26 h, 30-32 h, 36-38 h, 42-44 h, 48-50 h, 54-56 h, 60-62 h and 66-68 h.

In order to study general activity, instantaneous scan sampling was performed at 10-min intervals on days 1-4, 7 and 14. The following mutually exclusive behavioural

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[6] WV-BP 134 Panasonic Video Cameras, WJ-FS 216 Panasonic Digital Video Multiplexer and a Panasonic AG 6720A Time Lapse Video Cassette Recorder

categories were recorded: (1) Standing idle: Piglet was standing still without performing any other apparent behaviour. (2) Lying: Piglet was lying down with head in raised or lowered position, sleeping or awake. (3) Sitting: Piglet was supported on its hind quarter with front legs extended. (4) Drinking: Piglet was holding the drinking nipple in its mouth or appeared to be drinking water resulting from another pig activating the drinking nipple. (5) Feeding: A pig was considered feeding if its head was inside the feeder and it was apparent that the pig was not resting. (6) Playing: Low intensity, apparently non-aggressive interactions with pen-mates or neighboring piglets. (7) Orally manipulating chain: Nibbling on or chasing the provided chain. (8) Orally manipulating piglet: The exclusive behaviour of biting or nibbling on any body-part of pen-mates irrespective of posture. (9) Belly-nosing: When a piglet was using its snout to repeatedly push or massage a pen-mate. (10) Fighting: High intensity, apparently aggressive interactions between two or more piglets usually resulting in a "winner" and a "loser". (11) Other: Behaviours that did not fit into any of the other behaviour categories including, but not limited to, walking, exploring and rooting.

4.3.2 Statistical analysis

Data were analyzed using a split-plot in time design. The model statement included effects of season (summer, winter), transport type (road transport, simulated transport), transport duration (0 h, 6 h, 12 h, 24 h) and weight group (light, medium, heavy). The pen was the experimental unit. The main plot included pens within transport treatments and the sub-plot included days of observation. Data obtained from continuous observation periods did not meet the assumptions of normality and homogeneity of variance and were therefore subjected to log transformation before analysis (Steel et al., 1997). Scan sampling data were normalized using an arc sine square root transformation. The category 'oral/nasal manipulation' was comprised of three different behavioural elements, which were directed to the piglet's physical and social surroundings (orally manipulating a chain, orally manipulating pen mates and belly nosing). Due to their relatively low individual expression, these related behaviours were grouped for the purpose of analysis and were discussed as one behavioural element. All data were analyzed on a pen basis and presented as non-transformed least squares (LS) means ± SEM of the original percentages. Given that all main effects (season, transport type, transport duration and weight grouping), and all two-way interactions in this model were considered fixed effects, a mixed model was not used. Behaviour data were analyzed using a general linear model repeated measures analysis of variance (SAS 8.2; Proc GLM, SAS Institute, 2001) (Appendix 5). Since three and four-way interactions were found to be negligible, their mean squares in the analysis of variance could be used to provide an estimate of error (Cochran and Cox, 1957).). Pair-wise differences between treatment means were tested using Bonferroni inequality test. Behavioural variables were analyzed with the following model:

$$Y_{ijklmn} = \mu + S_i + T_k + W_l + R_m + (S\times T)_{ik} + (S\times R)_{im} + (S\times W)_{il} + (R\times T)_{mk} + (R\times W)_{ml} + (T\times W)_{kl} + e(S\times T\times W\times R)_{ijklm} + D_n + (S\times D)_{in} + (T\times D)_{kn} + (W\times D)_{ln} + (R\times D)_{mn} + e_{2,ijklmn}$$

Y_{ijklmn} = observation of the j^{th} pen during the i^{th} season, in the k^{th} type of transport, in the l^{th} grouping category at the m^{th} transport duration, on the n^{th} day

μ = mean

S_i = effect of the i^{th} season; i = summer, winter

T_k = effect of the k^{th} transport type; k = road transport, simulated transport

W_l = effect of the l^{th} weight group; l = light, medium, heavy

R_m = effect of the m^{th} transport duration; m = 0 h, 6 h, 12 h, 24 h

$(S\times T)_{ik}$ = interactive effect of the k^{th} transport type during the i^{th} season

$(S\times R)_{im}$ = interactive effect of the m^{th} transport duration during the i^{th} season

$(S\times W)_{il}$ = interactive effect of the l^{th} weight group during the i^{th} season

$(R\times T)_{mk}$ = interactive effect of the m^{th} transport duration and the k^{th} transport type

$(R\times W)_{ml}$ = interactive effect of the m^{th} transport duration and the l^{th} weight group

$(T\times W)_{kl}$ = interactive effect of the k^{th} transport type and the l^{th} weight group

$e(S\times T\times W\times R)_{ijklm}$ = error term representing the effect of the j^{th} pen during the i^{th} season, in the k^{th} type of transport, in the l^{th} weight group, at the m^{th} transport duration

D_n = effect of the n^{th} day

$(S\times D)_{in}$ = interactive effect of the i^{th} season on the n^{th} day

$(T\times D)_{kn}$ = interactive effect of the k^{th} transport type on the n^{th} day

$(W\times D)_{ln}$ = interactive effect of the l^{th} weight group on the n^{th} day

$(R\times D)_{mn}$ = interactive effect of the m^{th} transport duration on the n^{th} day

$e_{2,ijklmn}$ = residual error

4.4 RESULTS

4.4.1 Drinking behaviour

The proportion of time spent drinking on day 1 increased with a linear trend from non-transported piglets (0 h) (0.48%) to piglets transported for 6 h (1.05%), 12 h (2.0%) and 24 h (3.23%, $P < 0.05$) (Table 6). The time interval between entry into weanling pens and first visit to the drinker (drinking latency) was significantly longer for non-transported piglets (40.9 min) than for 12 h (3.95 min) and 24 h (1.89 min) transport groups ($P < 0.05$). Drinking latency for the 6 h transport group (11.84 min) was intermediate. By day 2, there were no significant differences in drinking behaviour between piglets in different transport groups. Non-transported piglets expressed a low and consistent level of drinking behaviour (0.52%) during the first 3 days in housing (Table 6). Piglets transported for 6 h spent more time drinking on day 1 relative to day 2 and day 3, but the difference was not significant. However, piglets transported for 12 h and 24 h spent significantly more time drinking on day 1 relative to day 2 and 3 in housing ($P < 0.001$). Increased drinking on the first day in housing was a result of an increase in the frequency of drinking bouts for all transported groups ($P < 0.02$) (Table 6). Piglets transported for 24 h also increased drinking bout duration ($P < 0.001$) (Table 6).

Season affected both drinking bout frequency and duration during the first day in housing, although total drinking time was not affected. Piglets transported during summer had significantly less frequent (32.1 vs. 37.66, $P < 0.002$) but longer drinking bouts (14.78 vs. 11.42 sec/bout, $P < 0.005$) than piglets transported during winter

(Table 7). Both summer and winter groups spent more time drinking and expressed significantly higher frequency of drinking bouts on day 1 than on day 2 and 3 post transport ($P < 0.0001$). Summer groups expressed significantly longer drinking bouts on day 1 (14.78 sec/bout) than on day 2 and 3 (average 10.65 sec/bout, $P < 0.005$). Summer groups also expressed significantly longer drinking bouts on day 1 (14.78 sec/bout) relative to winter groups on day 1–3 (average 10.55 sec/bout, $P < 0.005$) (Table 7). Winter groups expressed longer drinking bouts on day 1 (11.42 sec/bout) relative to day 2 (8.97 sec/bout, $P < 0.01$) but similar to day 3 (11.27 sec/bout) (Table 7).

Table 6. The effect of transport duration and day on total drinking time, drinking frequency and bout length (LS Means ± SEM)

Transport Duration (n=12)	Day 1	Day 2	Day 3	SEM
	Total drinking[x]			
0h	0.48^{a}	0.53	0.54	± 0.001
6h	1.05^{b}	0.67	0.79	
12h	2.00^{c}_{2}	0.63_{1}	0.61_{1}	
24h	3.23^{d}_{2}	0.72_{1}	0.67_{1}	
	Drinking frequency[y]			
0h	13.52^{a}	15.33	14.96	± 1.09
6h	26.25^{b}_{2}	19.48_{1}	20.31_{1}	
12h	44.52^{c}_{2}	17.69_{1}	15.42_{1}	
24h	55.23^{c}_{2}	22.67_{1}	17.71_{1}	
	Drinking bout length[z]			
0h	10.76^{a}	9.71	10.06	± 0.66
6h	11.68^{a}	10.04	11.17	
12h	12.94^{ab}	10.29	11.63	
24h	17.01^{b}_{2}	9.02_{1}	11.22_{1}	

The letter superscripts that appear within the columns and the numerical subscripts that appear across columns indicate statistical differences ($P < 0.05$, n = pens).

[x]Total drinking: Percentage of observed time drinking.
[y]Drinking frequency: Average daily visits to the drinker.
[z]Drinking bout length: Average duration (seconds) of a visit to the drinker.

Table 7. The effect of season and day on total drinking time, drinking frequency and bout length (LS Means ± SEM)

Parameter	Season (n=24)	Day 1	Day 2	Day 3	SEM
Total Drinking[x]	Summer	1.82_2	0.67_1	0.66_1	± 0.07
	Winter	1.56_2	0.61_1	0.64_1	
Drinking Frequency[y]	Summer	32.1^{a}_{2}	18.18_1	17.49_1	± 0.77
	Winter	37.66^{b}_{2}	19.41_1	16.71_1	
Drinking Bout Length[z]	Summer	14.78^{a}_{2}	10.52_1	10.77_1	± 0.47
	Winter	11.42^{b}_{2}	8.97_1	11.27_2	

The letter superscripts that appear within the columns and the numerical subscripts that appear across columns indicate statistical differences ($P< 0.05$, n = pens).

[x]Total drinking: Percentage of observed time drinking.
[y]Drinking frequency: Average daily visits to the drinker.
[z]Drinking bout length: Average duration (seconds) of a visit to the drinker.

4.4.2 Feeding behaviour

The proportion of time spent feeding increased significantly over the first 3 days in housing. Piglets spent on average 0.25 % of the time feeding on day 1. By day 2, feeding increased to 1.95 % and reached 5.77 % by day 3 ($P < 0.001$) (Table 8). Non-transported piglets spent on average less time feeding (1.48 %) than transported piglets (average 3.05 %) during the first 3 days in housing. However, this reached significance on day 2 only, when control groups (0.43 %) fed significantly less than groups transported for 12 h (2.06 %) and 24 h (3.62 %) ($P < 0.05$). Increased feeding on the second day in housing was a result of an increase in the frequency of feeding bouts for all transported groups relative to controls ($P < 0.02$). While feeding bout length increased with transport duration this only reached significance between the 0 h and 6 h groups relative to piglets transported for 24 h ($P < 0.05$) (Table 8).

During the first 3 days in weanling pens, piglets subjected to road transport in a truck spent less time feeding (2.4%) than piglets subjected to simulated transport in a temperature controlled room (2.9%, $P < 0.05$). This reduced feeding behaviour was a reflection of significantly less frequent (10.8 vs. 12.3 bouts/d, $P < 0.05$) and shorter feeding bouts (40.9 vs. 52.1 sec/bout, $P < 0.05$). Also, road transport produced a significantly longer feeding latency in large piglets (road transport: 1190 min., simulated transport: 172 min., $P < 0.05$), but not in medium (average 459 min.) or light piglets (average 468 min.). The proportion of time spent feeding increased progressively from groups of large (2.0 %) through medium (2.8 %) and small (3.2 %) piglets, but was significantly different between groups of large and small piglets only ($P < 0.05$).

Table 8. The effect of transport duration and day on total feeding time, feeding frequency and bout length (LS Means ± SEM)

Transport Duration (n=12)	Day 1	Day 2	Day 3	SEM
		Total feeding[x]		
0h	0.09_1	0.43^{a}_{1}	3.91_2	± 0.49
6h	0.14_1	1.68^{ab}_{2}	6.04_3	
12h	0.18_1	2.06^{b}_{2}	6.21_3	
24h	0.58_1	3.62^{b}_{2}	6.93_3	
		Feeding frequency[y]		
0h	2.17_1	3.52^{a}_{1}	15.65_2	± 1.92
6h	2.29_1	10.69^{b}_{2}	25.40_3	
12h	2.73_1	12.21^{b}_{2}	21.10_2	
24h	4.48_1	14.88^{b}_{2}	24.00_2	
		Feeding bout length[z]		
0h	12.19_1	33.85^{a}_{2}	59.74_2	± 5.29
6h	16.25_1	36.47^{b}_{2}	71.02_2	
12h	16.30_1	46.94^{ab}_{2}	86.82_2	
24h	24.26_1	66.45^{b}_{2}	87.80_2	

The letter superscripts that appear within the columns and the numerical subscripts that appear across columns indicate statistical differences ($P < 0.05$, n = pens).

[x]Total feeding: Percentage of observed time feeding.
[y]Feeding frequency: Average daily visits to the feeder.
[z]Feeding bout length: Average duration (seconds) of a visit to the feeder.

4.4.3 General behaviour

4.4.3.1 Daily time budget

Piglets were observed lying in 77.2% of scan observations (Table 9). In 7.2% of the observations piglets were feeding and in another 3.7% piglets were observed engaging in oral/nasal manipulation of pen mates or objects (orally manipulating pig, orally manipulating chain, or belly-nosing). Piglets were observed standing idle 2.9% of the time and spent 1.7% of the time drinking. Piglets spent on average 1.5% of their time engaged in play behaviour. Fighting was infrequent following the first day in weanling pens and was on average observed only 0.6% of the time. Piglets spent 5.2% of the day in the other behaviour category (including but not limited to, walking, exploring and rooting) (Table 9).

Table 9. Average daily time budget: Mean percentage of observed time piglets spent in a particular behavioural category (LS Means ± SEM)

Behaviour	%	SEM
Lying/Resting	77.2	0.36
Feeding	7.2	0.19
Oral/Nasal	3.7	0.19
Standing idle	2.9	0.19
Drinking	1.7	0.13
Playing	1.5	0.09
Fighting	0.6	0.06
Other	5.2	0.21

Instantaneous scan sampling was performed at 10-min intervals on days 1-4, 7 and 14 following weaning and transport. Mutually exclusive behavioural categories were recorded (n = 48 pens).

4.4.3.2 Transport duration

Significant interactive effects of transport duration and day were observed for feeding but not for drinking behaviour. While all transported groups fed significantly more on day 2 (6 h: 2.9%, 12 h: 4.2%, 24 h: 5.6%) than on day 1 (6 h: 0.4%, 12 h: 0.3%, 24 h: 0.9%) ($P < 0.002$), control groups expressed low levels of feeding during the first 2 days in housing (day 1: 0.2%, day 2: 1.16%) (Fig.3). The frequency of feeding was higher on day 3 (0 h: 6.3%, $P < 0.0001$; 6 h: 8.1%, $P < 0.0001$; 12 h: 8.6%, $P < 0.005$; 24 h: 9.1%, 0.05) than on day 2 for all groups. Piglets subjected to 12 h (4.2%) and 24 h (5.6%) transport spent significantly more time feeding than control groups (0.12%) during the second day in housing ($P < 0.002$). All piglets reached a relatively uniform level of feeding behaviour by day 3 (average 8.0%). This level was maintained throughout the remaining experimental period (average day 4: 8.8%, 7: 8.4% and 14: 7.9%). Observation of post transport behaviour necessarily began at the end of the transport period, consequently groups transported for 6 h, 12 h, and 24 h were 0.25, 0.5 and 1 day older than the non-transported piglets on any given day 'in housing'. Therefore, the difference in feeding behaviour between treatment groups on day 2 in housing may have been influenced by piglet age as well as the effects of transport duration. Comparing 0 h groups from day 2 (18 d, 0.12%) with 24 h transport groups from day 1 (18 d, 0.9%) did not show a significant difference in feeding behaviour. Furthermore, no difference was found between control groups on day 3 (19 d, 6.3%) and 24 h transported groups on day 2 (19 d, 5.6%), indicating that piglets spent the same amount of time feeding relative to age, regardless of duration of transport (Fig. 3).

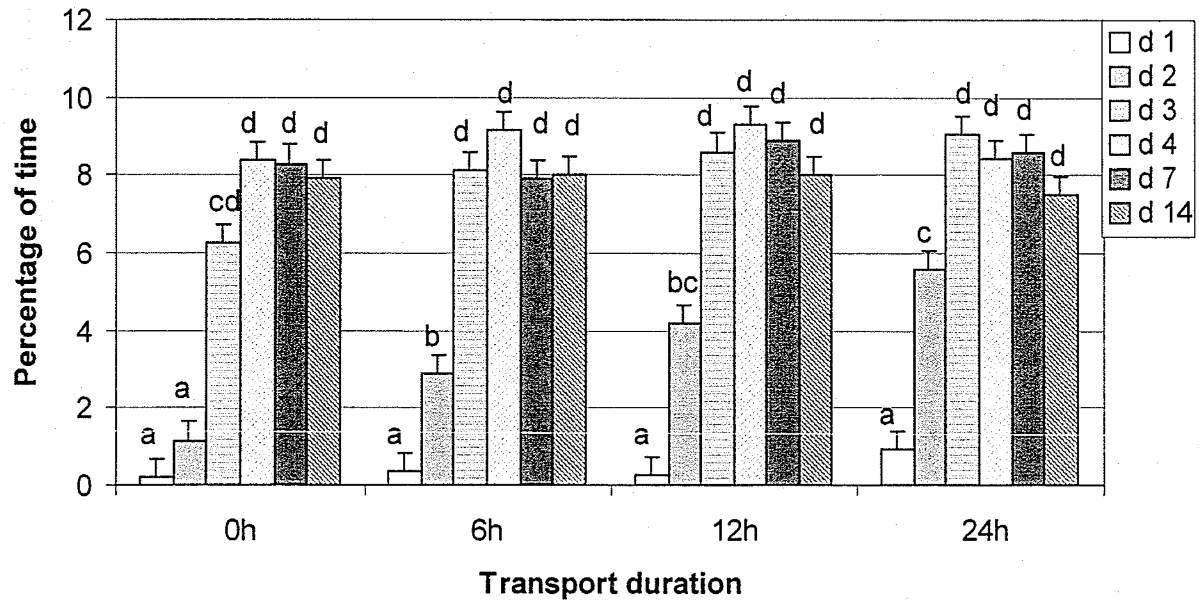

Figure 3. Mean percentage of time piglets were observed feeding on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.05$, $n = 12$ pens).

Frequency of lying was significantly affected by transport duration on day 1 and 2. Transported piglets (6 h: 79.3%, 12 h: 79.8%, 24 h: 79.1%) spent more time lying than piglets in control groups (75.2%, $P < 0.01$) (Fig. 4). A trend in the opposite direction was observed during the second day in housing. While non-transported piglets (81.4%) were observed lying more than transported groups (6 h: 79.9%, 12 h: 78.3%, 24 h: 76.6%), the difference reached significance between control and 12 h ($P < 0.05$) and 24 h ($P < 0.001$) groups only. By the third day in housing piglets in all groups, transported and control, spent similar amounts of time lying (average 78.5%). Although control groups were observed lying significantly less on day 1 (75.2%) than on day 2 (81.4%, $P < 0.001$), there were no significant differences between transported groups on any given day or between days (Fig. 4).

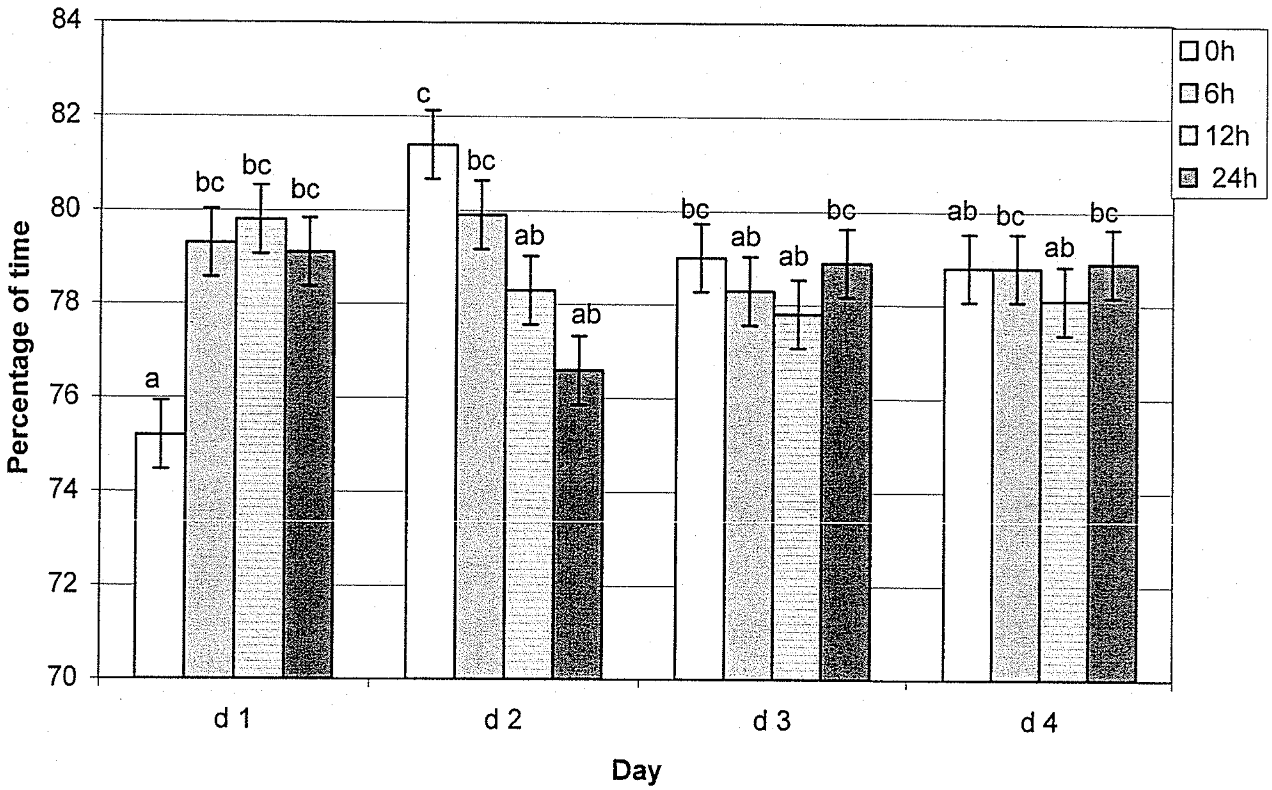

Figure 4. Mean percentage of time piglets were observed lying on days 1-4 after weaning and transport (LS Means ± SE). Bars with different letters differ significantly ($P < 0.05$, $n = 12$ pens).

4.4.3.3 Season

Feeding behaviour was affected by season but only on day 14 of the trial, when groups of piglets transported in summer spent significantly less time feeding than the piglets transported in winter (6.85% vs. 8.85%, $P < 0.05$) (Table 10). Time spent lying was affected by season but not on all days. While piglets transported in summer (79.8%) spent significantly more time lying than piglets transported in winter (77.5%, $P < 0.05$) during the first 4 days in housing, there was no difference between seasons on day 7 (average 75.6%). On day 14, piglets from the summer trial (78.0%) spent on average significantly more time lying than piglets from the winter trial (74.9%, $P < 0.05$) (Table 10). Piglets spent significantly more time standing idle during the winter trial compared to the summer trial in the first 4 days ($P < 0.017$) and on day 14 ($P < 0.001$). However, the decrease in expression of this behaviour (2.5%) through the 14 days of the trial was similar for both seasons.

4.4.3.4 Weaning weight

Heavy piglets fought significantly more (3.2%) than light (1.9%) and medium (1.8%) sized piglets during the first day in the weanling pens ($P < 0.005$) (Fig. 5). This was continued as a trend on day 2. Although all piglets expressed an overall reduction in aggressive behaviour with time, the pattern of reduction varied by weight group. While groups of light and heavy piglets fought significantly less on day 2 (small: 1.1%, large: 1.7%) than on day 1 (small: 1.9%, $P < 0.002$; large: 3.2%, $P < 0.0005$), medium sized piglets did not express a significant reduction in fighting behaviour until day 3 (day 1:

Table 10. The effect of season and day on the behaviour of early weaned piglets (LS Means ± SEM)

Parameter[*]	Season (n=24)	Day[**] 1-4	7	14	SEM
Feeding	Summer	5.06_1	8.51_3	6.85^a_2	± 0.25
	Winter	5.3_1	8.3_2	8.85^b_1	
Lying	Summer	79.8^b_2	75.7_1	78.0^b_2	± 0.43
	Winter	77.5^a_2	75.5_1	74.9^a_1	
Standing idle	Summer	3.84^a_3	2.36_2	1.27^a_1	± 0.17
	Winter	5.13^b_2	2.2_1	2.63^b_1	
Playing	Summer	0.8_1	1.3^a_2	1.7^a_3	± 0.12
	Winter	0.94_1	2.15^b_2	2.15^b_2	

The letter superscripts that appear within the columns and the numerical subscripts that appear across columns indicate statistical differences ($P < 0.05$, n = pens).

[*]Percentage of observed time feeding, lying, standing idle and playing.
[**]Average values over the first four days, day 7 and day 14 following weaning and transport.

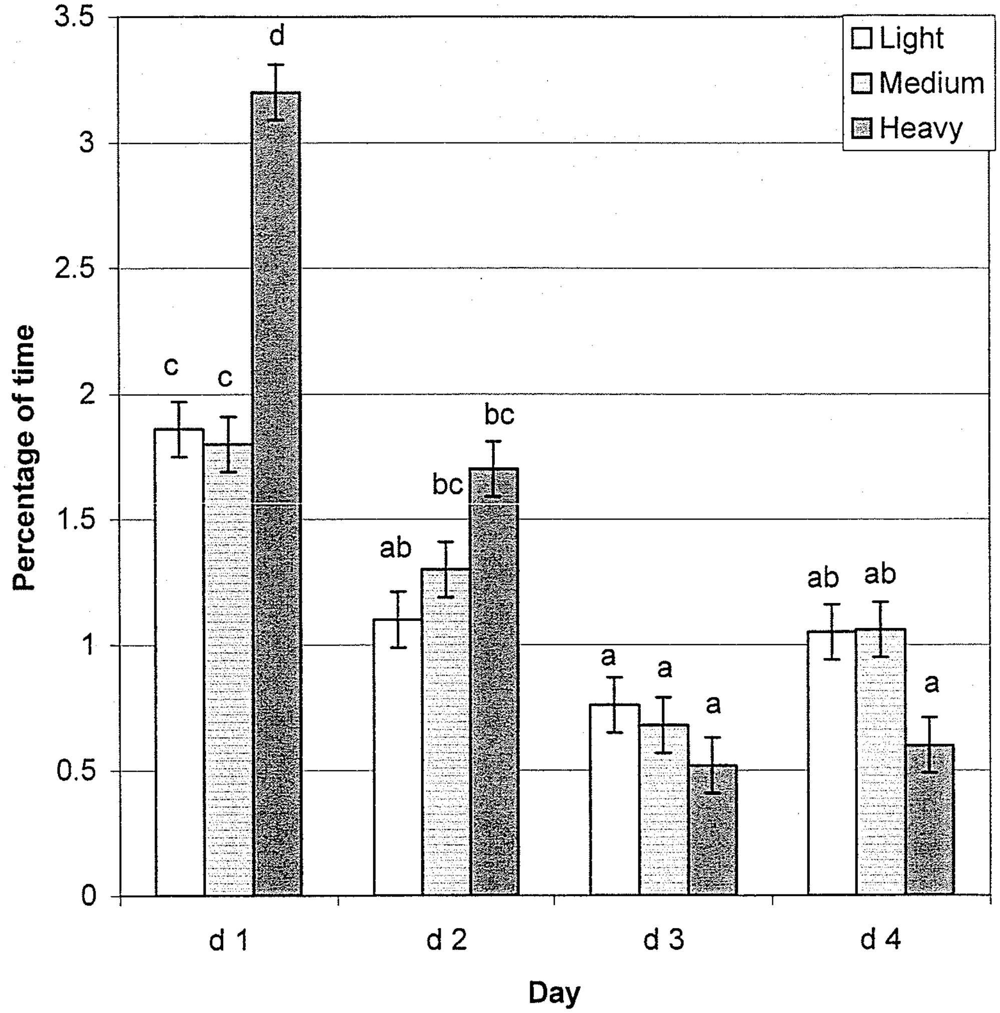

Figure 5. Mean percentage of time groups of light, medium and heavy piglets were observed fighting on days 1-4 after weaning and transport (LS Means ± SE). Bars with different letters differ significantly ($P < 0.05$, $n = 16$ pens).

1.8%, day 3: 0.7%, $P < 0.002$). Weaning weight did not affect the percentage of time piglets were observed fighting on days 2-4 in weanling pens (Fig 5).

4.4.3.5 Transport type

Piglets subjected to road transport spent more time engaging in oral/nasal manipulation of pen mates and objects (3.4%) than piglets subjected to simulated transport (1.2%) during the first 4 days in housing (Fig. 6). Although, this reached significance only on day 3 ($P < 0.05$). Piglets subjected to road transport spent significantly less time engaged in oral/nasal manipulation during the first day in housing (0.9%) than on day 2-4 (average 3.1%, $P < 0.01$). Piglets subjected to simulated transport did not differ significantly between days and spent on average 1.6% of the time engaged in oral/nasal manipulation of pen mates and objects (Fig 6).

On average, piglets spent more time playing following weaning and transport in winter (1.8%) than in summer (1.3%) ($P < 0.05$). While play behaviour showed a gradual increase with succeeding days during the summer trial ($P < 0.05$), piglets expressed a rapid increase in play behaviour on day 7 relative to day 1-4 during the winter trial ($P < 0.001$). This level was then maintained throughout the trial period (Table 10).

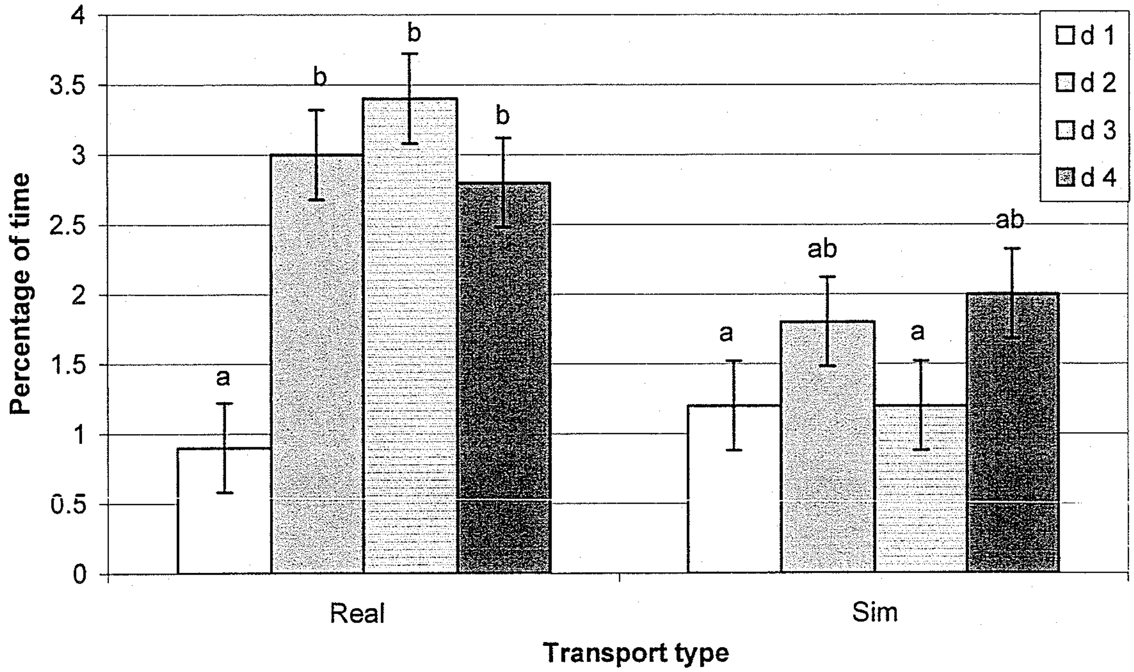

Figure 6. Mean percentage of time piglets were observed engaged in oral/nasal manipulation of pen-mates or objects on days 1-4 following weaning and real or simulated transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.05$, $n = 24$ pens).

4.4.3.6 Day

The proportion of time spent feeding was very low for all piglets during the first day in housing (0.4%). Feeding behaviour then increased rapidly and reached a plateau on day 3 (8.0%, $P < 0.001$) which was maintained on all consecutive days of observation (d 4, 7 and 14: average 8.4%) (Fig. 7). The proportion of time spent lying (resting) was significantly higher during the first 4 days in housing (78.6%) than on day 7 (75.6%, $P < 0.001$) and 14 (77.4%, $P < 0.05$) (Fig. 8). The average time spent standing idle decreased gradually throughout the trial period ($P < 0.05$) and was not significantly different between consecutive days of observation (Fig. 9). In contrast, there was a significant increase in oral/nasal manipulation of pen-mates or objects with time. Overall, these behaviours were exhibited at very low rates during the first day in housing (1.0%) but increased significantly during day 2 (2.4%, $P < 0.0005$). While day 2, 3 and 4 remained similar (average 2.4%), the average rate of oral/nasal manipulation increased significantly by day 7 of trial (4.6%, $P < 0.0005$) (Fig. 10). Play behaviour was low and similar for all piglets during the first 4 days in housing (average 0.8%). By day 7, play had increased to 1.3% ($P < 0.001$) and remained at this level throughout the trial period (Fig. 11). In contrast to play behaviour, fighting between pen-mates decreased gradually and significantly through successive days of observation ($P < 0.001$). While the proportion of time spent fighting was relatively high on day 1 (2.3%), aggressive interactions were rarely seen by day 14 of trial (0.08%) (Fig. 12).

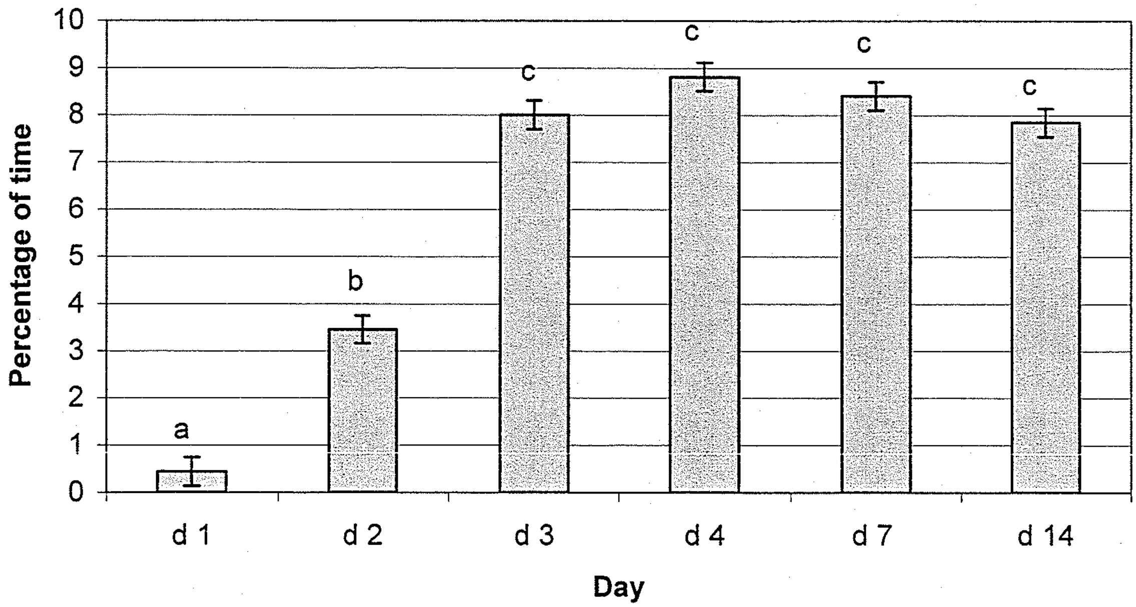

Figure 7. Mean percentage of time piglets were observed feeding on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.001$, $n = 48$ pens).

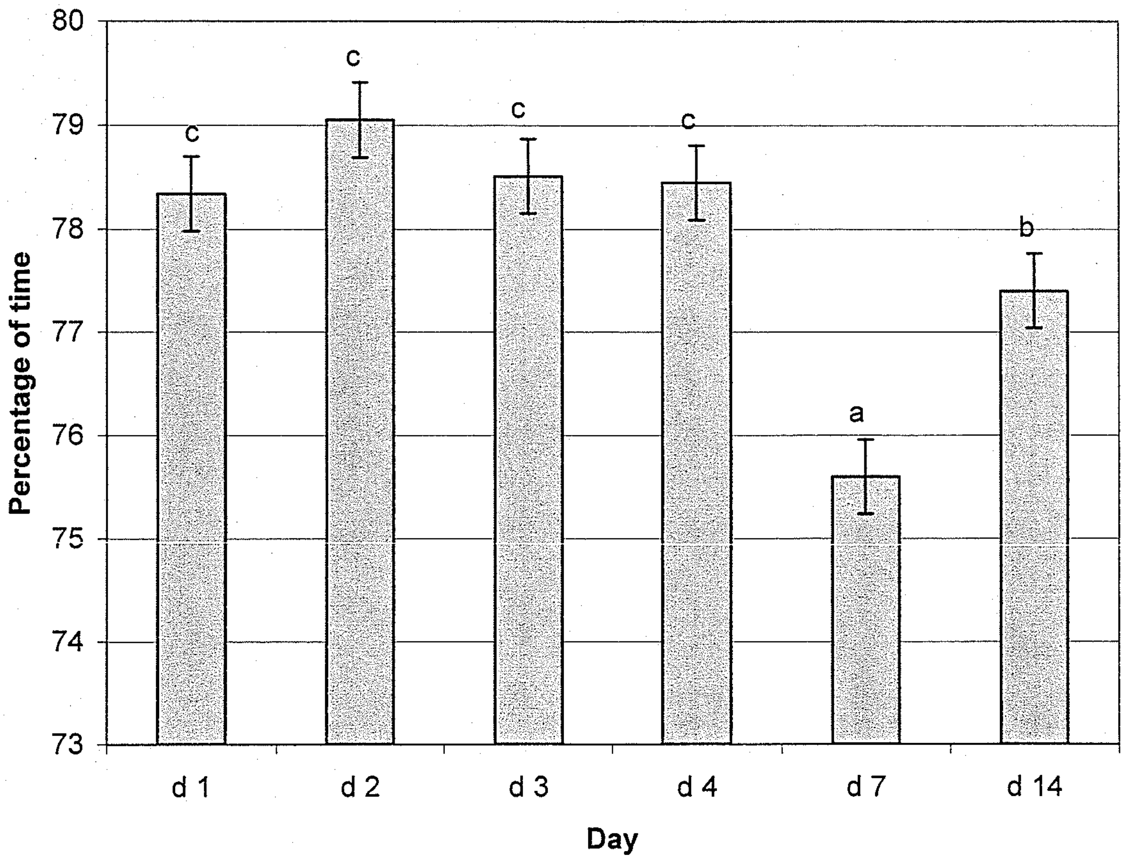

Figure 8. Mean percentage of time piglets were observed lying on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.05$, $n = 48$ pens).

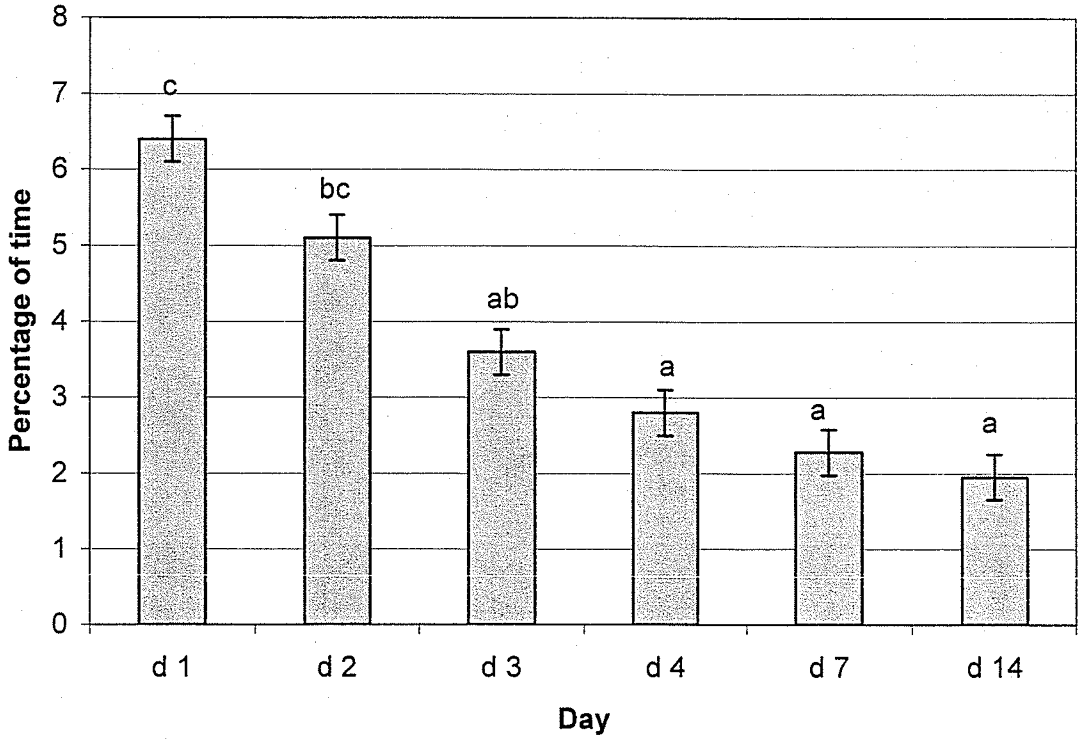

Figure 9. Mean percentage of time piglets were observed standing idle on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.05$, $n = 48$ pens).

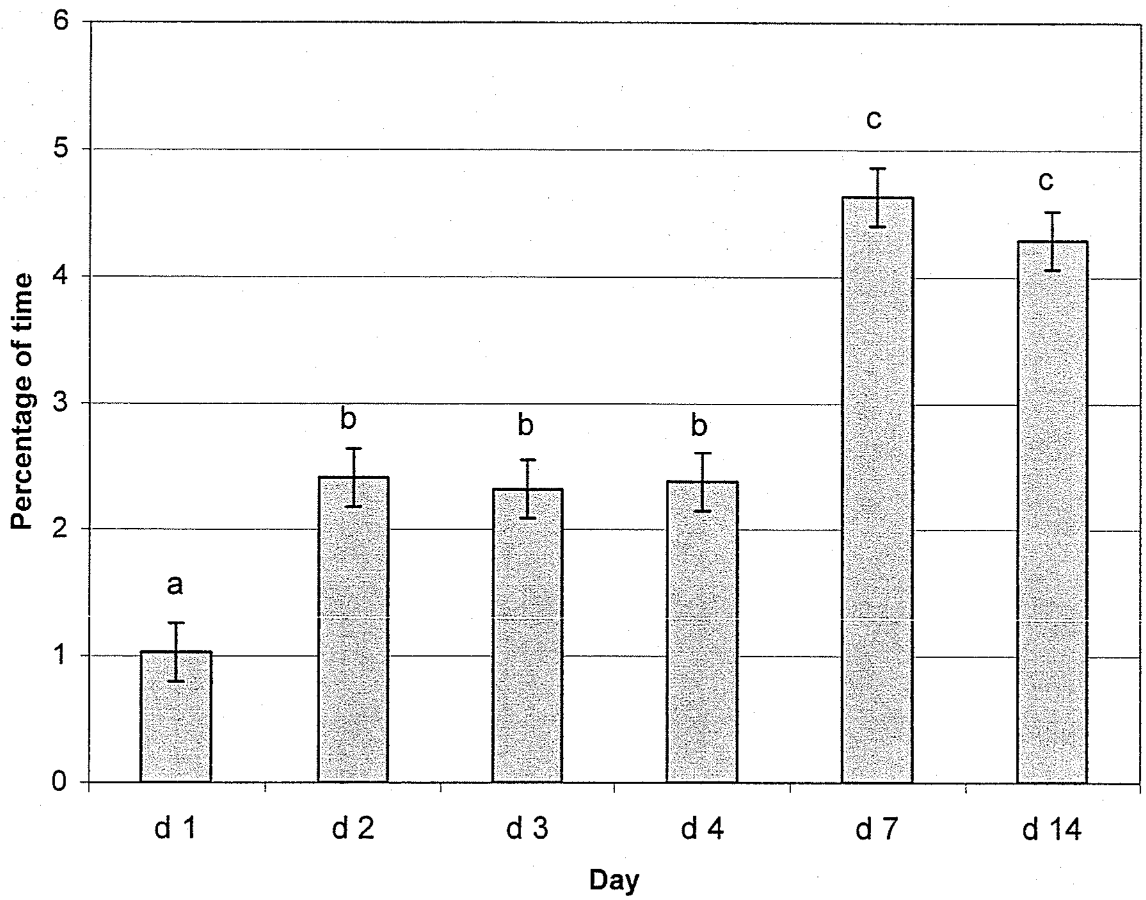

Figure 10. Mean percentage of time piglets were observed engaged in oral/nasal manipulation of pen-mates or objects on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.0005$, $n = 48$ pens).

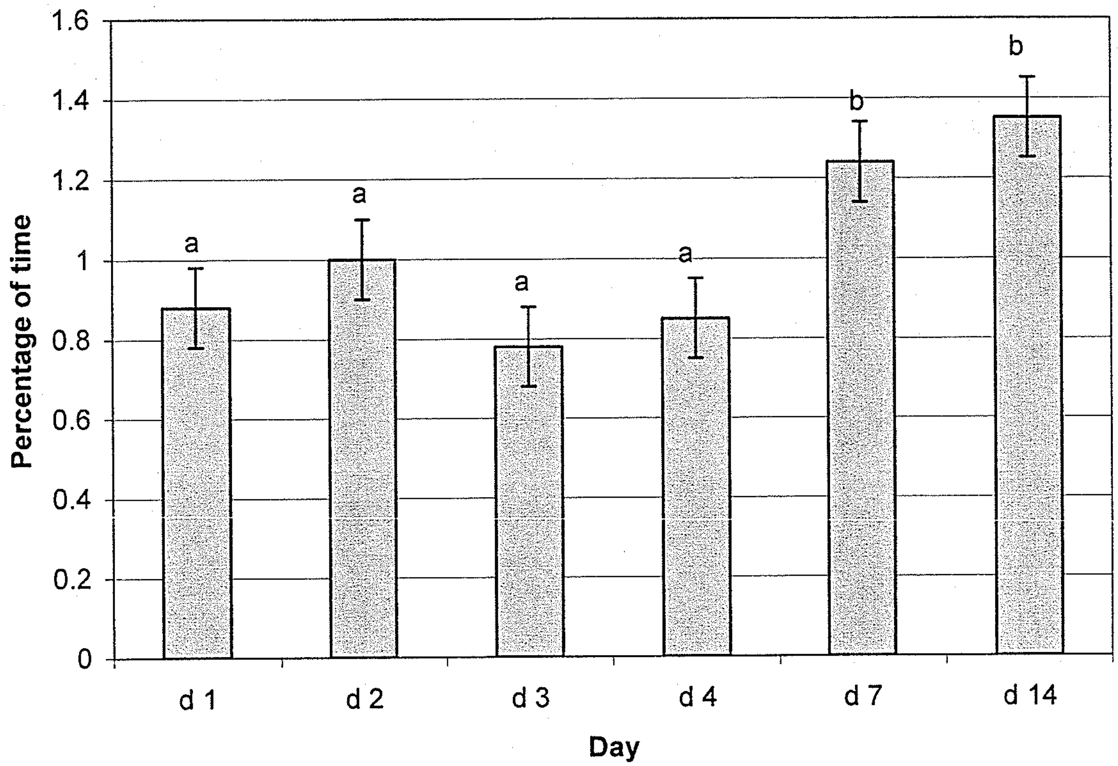

Figure 11. Mean percentage of time piglets were observed playing on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.01$, $n = 48$ pens).

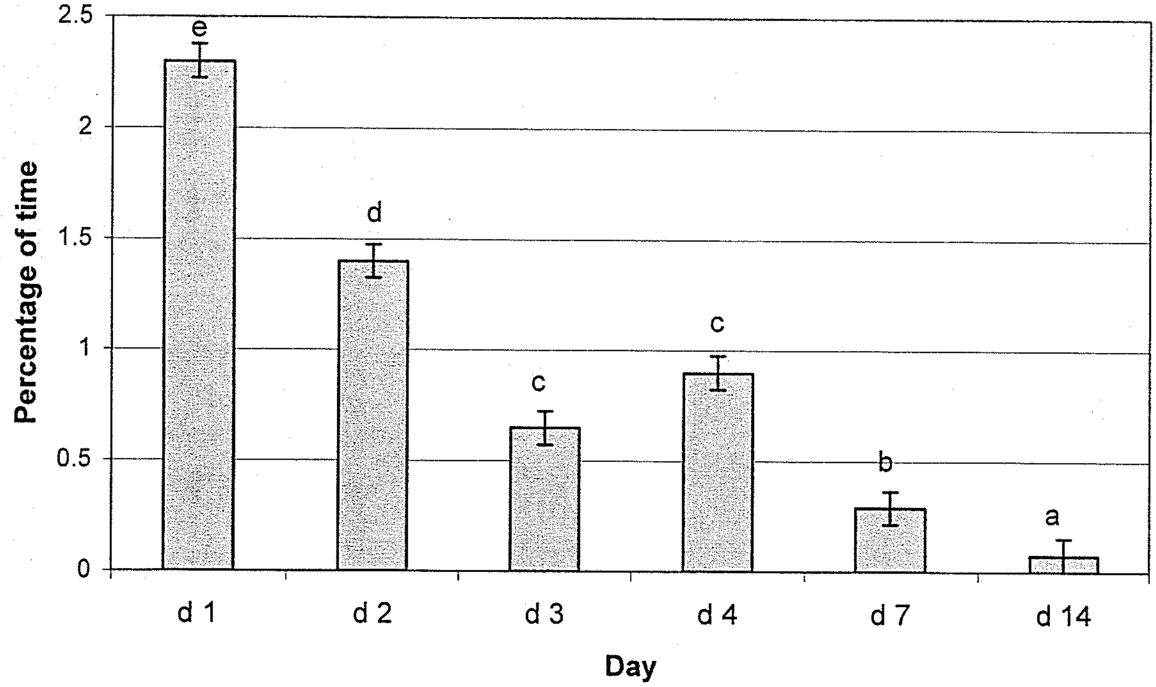

Figure 12. Mean percentage of time piglets were observed fighting on days 1-4, 7 and 14 after weaning and transport (LS Means ± SEM). Bars with different letters differ significantly ($P < 0.001$, $n = 48$ pens).

4.4.4 Ambient and truck temperatures

Average temperatures recorded above the piglets during road transport in winter ranged from 8.4°C during the warmest 6 h of the day to -1.2°C during the coldest 6 h of the day. Corresponding temperatures during road transport in summer ranged from 25.7°C during the warmest 6 h of the day to 16.4°C during the coolest 6 h of the day. During both seasons, the air temperature above the piglets was governed by a combination of piglets' level of activity and outside ambient temperature. As a result, lower temperatures were recorded above the piglets during the night than during the day (See Manuscript 1 for more details on ambient and truck temperatures during transport).

4.5 DISCUSSION

4.5.1 Transport duration

Drinking increased significantly with increased transport duration on the first day following weaning and transport. As water was not available during transport, drinking was expected to increase in proportion to the period of deprivation. Similar results have been reported by Berry and Lewis (2001b). In their study, hematocrit values also increased with transport duration, reaching significance at 24 h of transport relative to controls. Other transport variables may also affect dehydration. Becker et al. (1989) found higher hematocrit values in slaughter hogs subjected to transport (11 h) and fasting (48 h and 72 h) than in hogs subjected to fasting only, indicating that increased dehydration may be associated with stressors such as noise, vibration, fluctuating temperature and movement. This effect may be further exacerbated in early weaned piglets, based on their dependancy on a liquid diet and higher surface to volume ratio relative to adult pigs (Bergeron and Lewis, 1997).

In the current study, transported piglets increased drinking by increasing bout frequency. This increase was expressed as a linear trend relative to transport duration and reflected the relative need to recoup water loss and reestablish homeostasis. Piglets transported for 24 h also increased drinking bout length, which may be a natural behavioural response to the increased water requirement.

The observation that initial (d 1-3) feeding frequency increased with increased transport duration was in agreement with findings reported by Berry and Lewis (2001b). While all transported piglets exhibited significantly more frequent feeding bouts than controls, 24 h transport groups also expressed significantly longer feeding bouts. Fasting for 24 h has been shown to increase feeding motivation in 17-18 d old piglets (Lee et al., 1999) as well as in older pigs (Farmer et al., 2001). The duration of fasting (in transit) in the current study may similarly have increased piglet appetitive behaviour during the first 3 days in housing.

Weaning age has been shown to affect piglet consumption of dry feed immediately following weaning (Metz and Gonyou, 1990; Gonyou et al., 1998; Worobec et al., 1999). While piglets weaned at 21 d of age were found to develop 'normal' (9%) levels of feeding within 12 h of weaning, piglets weaned at 12 d of age did not reach the same level until 36 h post weaning (Gonyou et al., 1998). McCracken et al. (1995) reported rapid post-weaning gut maturation in SEW piglets (19 d of age), including significant growth of the small intestine during the first 5 days following weaning. This rapid process of gut maturation may partially explain the pattern of initial feed intake observed in the current study. Results from scan sampling data showed that all transported groups expressed increased feeding behaviour on day 2 relative to day 1 in housing. Also, piglets transported for 12 h and 24 h were observed feeding significantly more than control groups on day 2. Control groups from day 2 (18 d of age) and 24 h transport groups from day 1 (18 d of age) expressed similar feeding behaviour. Furthermore, no difference was found between control groups on day 3 (19 d of age) and 24 h transport groups on day 2 (19 d of age), indicating that piglets spent the same amount of time feeding relative to age, regardless of transport duration. While all piglets fed more on day 3 than on day 2, this did not reach significance in the 24 h transport groups because feeding behaviour was already high on day 2 (9%). Increased feeding motivation observed in piglets transported for 24 h in the present study may therefore be caused by a combination of hunger and relative age of the piglets at the time when feed becomes available to them.

Total resting times in the current study were similar to those observed in other studies involving early weaned piglets (Metz and Gonyou, 1990; Worobec et al., 1999; Li and Gonyou, 2002). Increased resting behaviour by the control groups, but not by the transported piglets, on day 2 in housing may have been a compensatory behaviour due to lack of rest on day 1, possibly due to weaning stress. This compensatory behaviour was not observed in transported piglets, possibly because transport favoured resting behaviour. Low lying time and high levels of activity may be indicative of piglets experiencing a higher level of stress (Bøe, 1993). Gonyou et al. (1998) reported a negative relationship between high activity and growth in pigs weaned at 12 and 21 days of age. Also, Gardner et al. (2001) found that "known stressors" such as increased stocking density and mixing, reduced lying time in piglets weaned at 12-14 days of age. Using resting behaviour as an indicator of the level of stress experienced by the piglets, it appeared that the control groups experienced more stress than the transported groups. However, the piglets' behaviour during transport in the current study was not observed, making it difficult to directly compare treatment groups during the first day post weaning. Studies involving long distance transport of slaughter hogs (Lambooy, 1988; Lambooy et al., 1985) and 4 hour transport of young grower pigs (Hicks et al., 1998) have shown that pigs spend most of the time in transit lying down, presumably resting. Even if this "resting behaviour" during transport is induced as a coping mechanism against fatigue, it may affect the piglets' requirement for rest during the subsequent days.

Weaning stress in non-transported piglets was indicated by low frequency of lying during the first day post-weaning, followed by compensatory resting and reduced appetitive behaviours during the second day post weaning. Increased levels of feeding behaviour observed in transported piglets relative to controls during the second day in housing may have been caused by a combination of hunger and relative age of piglets at the time when feed became available to them. Given the parameters used in the current study, these results suggest that transport durations of 6 h, 12 h and 24 h does not produce any obvious behavioural indications of compromised welfare in early weaned piglets. However, water deprivation may pose a welfare concern.

4.5.2 Season

Season had a direct effect on the frequency of drinking during the first 3 days in housing. Piglets transported in summer exhibited less frequent, but significantly longer drinking bouts than piglets transported in winter. Theoretically, the higher temperatures experienced during the summer trial resulted in a higher level of water loss. This increased motivation to drink following summer transport, was reflected in longer bout length rather than more frequent bouts, possibly due to the competition at the drinker.

Feeding behaviour was marginally affected by season. Piglets transported in winter fed significantly more on day 14 than piglets transported in summer. This was most likely due to a high ambient temperature during day 14 of the summer trial (high of 28.1 °C). High room temperatures have been shown to reduce appetite as well as increase fatigue (Hicks et al., 1998). Piglets were observed to rest significantly more in the summer than in the winter on day 14 of the trial, which supported this hypothesis. Piglets transported in the summer were observed lying more frequently with a concurrent drop in the frequency of standing idle and playing. Increased activity (including standing idle), has been suggested to be indicative of a higher level of stress (Bøe, 1993; Worobec et al., 1999; Metz and Gonyou, 1990; Gonyou et al., 1998). However, increased play behaviour has been suggested to be an indication of reduced levels of stress and therefore an indication of increased welfare (Lawrence and Appleby, 1996; Kelly et al., 2000; Donaldson et al., 2002). Since these measures of welfare are contradictory, and because high temperatures are known to reduce activity, it is most likely that these observed changes in behaviour are a result of summer temperatures rather than transport stress, especially since this difference was observed 14 days post-transport.

4.5.3 Weaning weight

The proportion of time spent fighting was higher during the first day in housing (2.3%) and aggressive interactions decreased daily thereafter and were rarely seen by day 14 of the trial (0.08%). Similar findings have been reported by Worobec et al. (1999) and Mason et al (2003). Intense aggression is a commonly observed behavioural response when pigs from different litters are mixed (Arey and Franklin, 1995; Bradshaw et al., 1987; Stookey and Gonyou, 1998; Turner et al., 2001). This early period of fighting usually prevails throughout the first 24 h or until a stable dominance hierarchy is established (Fraser and Rushen, 1987; Fraser et al., 1995).

Although the weight range within groups (light, medium and heavy) in the current study were similar, groups of heavy piglets were observed fighting significantly more frequently (3.2%) than groups of light (1.8%) and medium piglets (1.8%) during the first day in housing. This continued as a trend on day 2 and had disappeared by day 3. Olesen et al. (1996) found total skin lesions and weight to be positively correlated, indicating that fights between heavier pigs are more severe than fights between lighter pigs. Since body weight is an indirect indicator of social rank within the group (Erhard and Mendl, 1997; Rushen, 1987; Jensen and Yngvesson, 1998; Andersen et al., 2000), it may be expected that large piglets are more motivated to start fights and to reciprocate when challenged. Groups of heavy piglets of similar weight and age may therefore have more difficulties establishing a stable dominance hierarchy due to their previous experience as “winners” in social conflicts with smaller littermates. Given that these piglets have not routinely lost fights and are therefore less likely to “give up”, undecided fights between opponents may be repeated, resulting in prolonged aggressive encounters

(McGlone, 1985). In contrast, light and medium piglets may be better at evaluating their relative fighting ability based on different outcomes from previous conflicts (D'Eath, 2002). As a result, in the present study, less overall aggression was observed in these groups.

In contrast with other studies (Friend et al., 1983; Blackshaw et al., 1987; Arey and Franklin, 1995; Francis et al., 1996), the most intense fighting did not occur immediately after piglets were placed in housing, at least not for the transported groups. This was particularly apparent regarding piglets transported for 12 and 24 hour which, on average, spent the first hour in the new pen drinking. Competition for a place at the drinker appeared, for the most part, to be non agonistic and did not result in overt aggression. However, piglets had been mixed for 6, 12 and 24 hr during transport, such that familiarity and fighting while in transit may have contributed to reduce the overall level of acute aggression when piglets were separated into smaller groups in housing.

Heavy piglets in the current study expressed longer feeding latencies than light and medium piglets, although this only reached significance between heavy and light piglets assigned to road transport. Other researchers have found similar results and several possible explanations have been suggested. While early weaned piglets typically have a very low motivation to consume dry feed immediately following weaning (Metz and Gonyou, 1990; Worobec et al., 1999; Berry and Lewis, 2001) large piglets in particular, are believed to have developed a strong dependency on a pure milk diet, making them poorly prepared for abrupt weaning (Weary and Fraser, 1997; Weary et al., 1999). Fraser et al. (1988) found that newborn piglets with low milk intake expressed increased drinking behaviour and water usage. Consequently, it may be hypothesized that the smaller piglets in the current study had more experience using a water nipple, consumed more water following weaning and transport, and were therefore more motivated to start feeding when in housing. Furthermore, large differences in teat quality during the pre-weaning period may drive piglets on poor producing teats to consume alternative food sources (Mason et al., 2003). Piglets on these teats are often individuals of smaller relative size. Large piglets were observed feeding significantly less than small piglets during the first 3 days in housing, which supported this conclusion. Bruinix et al. (2001) found similar results when weaning 27-d-old piglets. Alternatively, delayed and low feeding behaviour in groups of heavy piglets relative to light and medium piglets may have been due to the high frequency of aggressive interactions in the former groups, possibly disrupting normal feeding patterns.

Large piglets in uniform weight groups expressed significantly more aggression than small and medium sized piglets during the first day in housing. High levels of fighting in groups of large piglets may have exacerbated water loss due to weaning and transport, causing large piglets to be more dehydrated with time and therefore less motivated to feed compared to groups of small and medium piglets. This, combined with the time required for fighting, may have caused the extended feeding latency observed in groups of large piglets after road transport. Alternatively, low motivation to engage in feeding by large piglets during the first 3 days post weaning may have been a reflection of their higher reliance on a milk based diet relative to smaller litter mates. Although these results show that heavy piglets exhibit behavioural characteristics that are different from light and medium piglets, the differences did not appear to be directly related to transport stress.

4.5.4 Transport Type

Results from continuous observation periods showed that piglets exposed to simulated transport spent more time feeding than piglets exposed to road transport during the first 3 days in housing ($P < 0.05$). This decreased feeding behaviour following road transport was expressed through a decrease in both the frequency ($P < 0.05$) and duration ($P < 0.05$) of feeding bouts. Furthermore, heavy piglets delayed initial feeding after exposure to road transport but not to simulated transport. Previous studies have found increased levels of stress hormones and expression of motion sickness in pre-pubertal grower pigs following transportation (Bradshaw et al., 1996a,b; Randall and Bradshaw, 1998; Parrott et al., 1998). It is therefore possible that the effects of road transport act in synergy with weaning induced stress responses, temporarily reducing feeding motivation in early weaned piglets. Some studies have shown that noise, vibration and movement associated with road transport is aversive to pigs (Stephens and Perry, 1990), causing anxiety and motion sickness (Bradshaw et a., 1996; Randall and Bradshaw, 1998), others have found no effects of transport (Parrot and Mission, 1989; Jesse et al., 1990). Although no incidences of obvious travel sickness such as retching, vomiting and/or foaming at the mouth (Bradshaw et al., 1996b) was observed in piglets assigned to road transport in the current study, vomiting has occurred in other studies by this laboratory (personal communication, N. Lewis, 2004b).

Transport type had a direct effect on the temporal pattern of oral/nasal manipulation during the first 4 days in housing. Piglets subjected to road transport spent significantly less time engaged in oral/nasal manipulation during the first day in housing (0.9%) than on day 2-4 (3.1%). In contrast, piglets subjected to simulated transport did not differ significantly between days and spent, on average, 1.6% of the time engaged in this behaviour. It has previously been suggested that oral/nasal behaviour may induce serotonergic neurotransmission in piglets (Gonyou et al., 1998). Oral/nasal behaviour may therefore function as a coping mechanism when piglets are experiencing a high level of stress (Gonyou et al., 1998). Belly nosing, as an element of oral/nasal behaviour in this study, has been observed more frequently in piglets weaned at younger ages (Metz and Gonyou, 1990; Gonyou et al., 1998; Worobec, 1999; Weary et al., 1999) and in less enriched environments (Dybkjær, 1992; Kelly et al., 2000) suggesting that this behaviour is stress induced. However, the onset of oral/nasal manipulation of objects and pen mates is usually not observed until 4 days post weaning, followed by a peak between 2 and 3 weeks post weaning (Metz and Gonyou, 1990; Gonyou et al., 1998; Worobec, 1999; Weary et al., 1999; Gardner et al., 2001). At this time, most piglets are feeding normally and a stable hierarchy within the pen has been established, suggesting that reduced stress from weaning and mixing should prevail. Piglets exposed to road transport in the current study expressed more oral/nasal behaviour than simulated transport groups on day 2-4, suggesting that road transport causes more stress than simulated transport and therefore induces a 'coping mechanism' at an earlier stage in the post weaning period. By day 7 this difference no longer existed, suggesting that piglets had overcome the effects of road transport by this time. The observed differences in oral/nasal behaviour between transport groups may indicate that piglets find some elements of road transport (noise, vibration, movement or fluctuating temperatures) more stressful than simulated transport. Dybkjær (1992) found an increased occurrence of oral/nasal manipulation in 4 week old piglets subjected to social 'stressors' such as mixing and crowding. However, the category oral/nasal manipulation in the present study was comprised of three different behavioural elements, which were directed to the piglet's physical and social surroundings (orally manipulating a chain, orally manipulating pen mates and belly nosing). As suggested by others (Dybkjær, 1992; Petersen et al., 1995), it may be that these elements have different motivation and are released by different stimuli. Therefore, not all aspects of oral/nasal behaviour observed in the current study were necessarily stress related, making direct comparisons with other research difficult. Nevertheless, our results suggest that road transport has a transient effect on the temporal pattern of oral/nasal behaviour in early weaned piglets, which may be related to increased stress. However, by d 4 in housing, piglets appeared to have overcome the adverse effects of road transport, as feeding and oral/nasal behaviour no longer differed between treatment groups.

4.6 CONCLUSION

1) Increased post transport drinking and feeding behaviour were associated with increased time without access to feed and water during transport. Six hours, 12 h and 24 h of transport did not produce behaviour indicators suggesting increased weaning stress with increased transport duration. However, water deprivation may pose a welfare concern during long journeys.

2) Piglets showed increased levels of activity following weaning and transport in winter, suggesting that transport in winter was more stressful to piglets than transport in summer.

3) Heavy piglets spent more time fighting and less time feeding than light and medium piglets, but these differences did not appear to be caused by transport stress.

4) Piglets assigned to road transport expressed reduced feeding and increased oral/nasal behaviour during the first 3 days post transport, suggesting increased levels of transport stress associated with one or more factors of road transport such as noise, vibration, movement and temperature fluctuations.

5.0 GENERAL DISCUSSION

5.1 Transport duration

Piglets lost, on average, 6.3% of live-weight during the first 3.4 days following weaning and transport. As transport duration increased, weight loss increased in a linear trend and reached significance between the 6 h and 24 h transport groups. These results agree with data obtained from similar studies performed in this laboratory and with other studies involving older pigs. Berry and Lewis (2001a) reported average weight losses of 6.5% in EW piglets (17 ± 1 d) exposed to 24 h of simulated transport during 'cool' (20°C) and 'hot' (35°C) environmental temperatures. In their study, hematocrit values also increased with transport duration, reaching significance at 24 h of transport relative to controls. Lambooy et al. (1985) and Lambooy (1988) transported slaughter hogs for 25 h, 31 h and 44 h and found live weight loss to increase with transport duration (4, 6 and 7.1% respectively). McGlone et al. (1993) reported a 5.1% weight loss in young grower pigs (27.5 kg) following only 4 h of transport. In addition, shipped pigs in their study showed reduced feed intake and weight-gain relative to non-shipped pigs during the first 3 days post transport, indicating lasting negative effects of transport stress. In accordance with current commercial transport practices, piglets in the current study were not provided with feed or water while in transit. Under these conditions, most of the weight loss during transport was expected to be due to loss of body water (75%) and gut contents (20%) (Jones et al., 1985; Brumm et al., 1987) resulting in increased weight loss with longer transport duration. As a response to increased water loss, piglet drinking behaviour in the current study increased significantly with increased transport duration on the first day following weaning and transport. Transported piglets increased total drinking by increasing drinking frequency. This increase was expressed as a linear trend relative to transport duration and reflected the relative need to recoup water loss and reestablish homeostasis. Piglets transported for 24 h also increased drinking bout length, which may be a natural behavioural response to the increased water requirement. Similar results have been reported by Berry and Lewis (2001b). While transport duration is believed to be the most important cause of water loss in pigs during transit, other transport variables may also affect dehydration. Becker et al. (1989) found higher hematocrit values in slaughter hogs subjected to transport (11 h) and fasting (48 h and 72 h) than in hogs subjected to fasting only, indicating that increased dehydration may be associated with stressors such as noise, vibration, fluctuating temperature and movement. This effect may be further exacerbated in early weaned piglets, based on their dependency on a liquid diet and higher surface to volume ratio relative to adult pigs (Bergeron and Lewis, 1997).

In the current study, non-transported piglets expressed higher weight losses (6.79%) and delayed day of recovery (3.82 d) relative to piglets transported for 6 h (5.34% and 2.9 d respectively), but consistent with the majority of piglets transported for 12 h and 24 h (average 6.6% and 3.41 d), suggesting that early weaning itself resulted in significant weight loss. Other transport trials at this laboratory have shown similar results (personal communication, N. Lewis, 2004a). While non-transported piglets were offered feed and water soon after weaning, the effects of weaning may have reduced their motivation to drink and feed during the first day in housing. This may explain the observed consistency in weight loss and day of recovery between control groups and piglets transported for 12 h and 24 h during the first 3 days following weaning. In contrast, piglets transported and deprived of water for 6 h may have been more motivated to drink than non-transported piglets, and better able to replace water losses than piglets transported for 12 h and 24 h. Consequently, 6 h transport groups experienced reduced weight loss and a shorter growth check. The observation that initial (3 d) feeding frequency increased with increased transport duration was in agreement with findings reported by Berry and Lewis (2001b). While all transported piglets exhibited significantly more frequent feeding bouts than controls, 24 h transport groups also expressed significantly longer feeding bouts. Fasting for 24 h has been shown to increase feeding motivation in 17-18 d old piglets (Lee et al., 1999) as well as in older pigs (Farmer et al., 2001). The duration of fasting (in transit) in the current study may similarly have increased piglet appetitive behaviour during the first 2 days in weanling pens.

Weaning age has been shown to affect piglet consumption of dry feed immediately following weaning (Metz and Gonyou, 1990; Gonyou et al., 1998; Worobec et al., 1999). While piglets weaned at 21 d of age were found to develop 'normal' (9%) levels of feeding within 12 h of weaning, piglets weaned at 12 d of age did not reach the same level until 36 h post weaning (Gonyou et al., 1998). McCracken et al. (1995) reported rapid post weaning gut maturation in SEW piglets (19 d of age), including significant growth of the small intestine during the first 5 days following weaning. This rapid process of gut maturation may partially explain the pattern of initial feed intake observed in the current study. Results from scan sampling data showed that all transported groups expressed increased feeding behaviour on day 2 relative to day 1 in housing. Also, piglets transported for 12 h and 24 h were observed feeding significantly more than control groups on day 2. Control groups from day 2 (18 d of age) and 24 h transport groups from day 1 (18 d of age) expressed similar feeding behaviour. Furthermore, no difference was found between control groups on day 3 (19 d of age) and 24 h transport groups on day 2 (19 d of age), indicating that piglets spent the same amount of time feeding relative to age, regardless of transport duration. Increased feeding motivation observed in piglets transported for 24 h in the present study may therefore be caused by a combination of hunger and relative age (maturation) of the piglets at the time when feed becomes available to them.

Total resting times in the current study were similar to those observed in other studies involving early weaned piglets (Metz and Gonyou, 1990; Worobec et al., 1999; Li and Gonyou, 2002). Increased resting behaviour by the control groups, but not by the transported piglets, on day 2 in housing may have been a compensatory behaviour due to lack of rest on day 1, possibly due to weaning stress. This compensatory behaviour was not observed in transported piglets, possibly because transport favoured resting behaviour. Low lying time and high levels of activity may be indicative of piglets experiencing a higher level of stress (Bøe, 1993). Gonyou et al. (1998) reported a negative relationship between high activity and growth in pigs weaned at 12 and 21 days of age. Also, Gardner et al. (2001) found that "known stressors" such as increased stocking density and mixing, reduced lying time in piglets weaned at 12-14 days of age. Using resting behaviour as an indicator of the level of stress experienced by the piglets, it appeared that the control groups experienced more stress than the transported groups. However, the piglets' behaviour during transport in the current study was not observed, making it difficult to directly compare treatment groups during the first day post weaning. Studies involving long distance transport of slaughter hogs (Lambooy, 1988; Lambooy et al., 1985) and 4 hour transport of young grower pigs (Hicks et al., 1998) have shown that pigs spend most of the time in transit lying down, presumably resting. Even if this "resting behaviour" during transport is induced as a coping mechanism against fatigue, it may affect the piglets' requirement for rest during the subsequent days.

Increased weight loss and post transport drinking behaviour were associated with increased time without access to water during transport. Frequent post transport drinking behaviour indicated an increased level of dehydration with time in transit. Duration of fasting (in transit) and relative age may have been factors affecting piglet motivation to engage in appetitive behaviour following early weaning and transport. Weaning itself was a significant stressor, as non-transported piglets expressed weight loss and day of recovery consistent with piglets transported for 12 h and 24 h. Weaning stress in non-transported piglets was also indicated by a low frequency of resting during the first day post-weaning. These results suggest that increasing transport durations may put piglets at risk for dehydration and stress. However early weaning itself is a substantial stressor associated with low levels of resting, feeding and drinking.

5.2 Season

The combined stress of low temperatures and road transport appeared to cause the most detriment to piglet post weaning performance, as winter transport by road significantly increased the day of recovery, prolonged the growth check, reduced percent ADG and lowered FCE relative to road transport and simulated transport groups in summer. While the observed differences between transport groups may have been caused by one or several factors of road transport, including noise, vibration, movement or fluctuating temperatures, the lack of difference between transport types in summer suggest that cold, and possibly fluctuating temperatures in winter was a significant stressor to piglets. Berry and Lewis (2001a) found that piglets subjected to simulated transport (24 h) in a 'cool' environment (20 °C) expressed compromised weight-gain compared to controls during the first 7 days post treatment. While piglets subjected to road transport in the current study experienced continuously fluctuating temperatures in the truck, simulated transport groups experienced a temperature adjustment only every 6 h. In addition, piglets transported by road were exposed to slightly lower temperatures than piglets assigned to simulated transport during the winter trial (up to 3 °C). Given the highly controlled and favorable environmental conditions these piglets have become accustomed to during the nursing period, fluctuating temperatures may be perceived as a significant stress factor. Dividich (1981) found continuous temperature fluctuations (± 4 °C) during the first week in housing following weaning (22 d) to have detrimental effects on piglet performance and health. While, the effects of temperature fluctuations on early weaned piglets over a shorter time period (< 1day) is not documented in the literature, similar negative effects of temperature fluctuations may have been found in the current study. Although piglets were provided with straw as bedding during winter transport, they did not use this efficiently to minimize heat loss. Instead of burrowing into the straw to stay warm, piglets were observed packing the bedding into a uniform mat and then huddling on top of it. This behaviour is believed to reflect piglets' lack of experience with bedding material and may be altered by using more or different kinds of bedding during winter transport. Initial weaning weight may have been a contributing factor causing differences between transport groups. Piglets transported during the winter were on average 0.5 kg heavier than piglets transported in summer, and piglet weights in the road transport group were lower ($P > 0.05$) than those in the simulated group in winter. This may have contributed to differences in weight-loss and ADG relative to the lighter piglets. Similar feed consumption but significantly lower FCE was observed in winter groups compared to summer groups, which supported this hypothesis.

Season had a direct effect on the frequency of drinking during the first 3 days in housing. Piglets transported in summer exhibited less frequent, but significantly longer drinking bouts than piglets transported in winter. Theoretically, the higher temperatures experienced during the summer trial resulted in a higher level of water loss. This increased motivation to drink following summer transport, was reflected in longer bout length rather than more frequent bouts, possibly due to the competition at the drinker.

Piglets transported in the summer were observed lying more frequently with a concurrent drop in the frequency of standing idle and playing. Increased activity (including standing idle), has been suggested to be indicative of a higher level of stress (Bøe, 1993; Worobec et al., 1999; Metz and Gonyou, 1990; Gonyou et al., 1998). However, increased play behaviour has been suggested to be an indication of reduced levels of stress, and therefore an indication of increased welfare (Lawrence and Appleby, 1996; Kelly et al., 2000; Donaldson et al., 2002). Since these measures of welfare are contradictory, and because high temperatures are known to reduce activity, it is most likely that these observed changes in behaviour are a result of summer temperatures rather than transport stress, especially since this difference was observed 14 days post-transport.

5.3 Weaning weight

Piglets with high weaning weight expressed compromised post weaning performance as heavy piglets required significantly more time to reach the day of minimum weight than light piglets. In addition, heavy piglets expressed reduced percent ADG between day of recovery and d 14 post-transport compared to light and medium piglets. Since no interactive effects of weight group and transport duration were observed, these differences were probably not related to transport induced stress. Differences between weight groups were more likely to be related to the differences in feeding behaviour and aggression frequently observed in piglets of varying weights.

Grouping heavy piglets caused higher levels of aggression, and therefore reduced levels of maintenance behaviours like feeding, drinking and resting. This may have exacerbated the negative energy balance due to early weaning, causing reduced performance and compromised welfare in heavy piglets relative to light and medium piglets. Intense aggression is a commonly observed behavioural response when pigs from different litters are mixed (Arey and Franklin, 1995; Bradshaw et al., 1987; Stookey and Gonyou, 1998; Turner et al., 2001). This early period of fighting usually prevails throughout the first 24 h following mixing or until a stable dominance hierarchy is established (Fraser and Rushen, 1987; Fraser et al., 1995). Although the weight range within groups (light, medium and heavy) in the current study were similar, groups of heavy piglets were observed fighting significantly more frequently than groups of light and medium piglets during the first day in housing. This continued as a trend on day 2 and had disappeared by day 3. Other researchers (Worobec et al., 1999; Mason et al., 2003; Olesen et al., 1996) have found fights between heavier pigs to be more severe than fights between lighter pigs. Since body weight is an indirect indicator of social rank within the group (Erhard and Mendl, 1997; Rushen, 1987; Jensen and Yngvesson, 1998; Andersen et al., 2000), it may be expected that large piglets are more motivated to start fights and to reciprocate when challenged. Groups of heavy piglets of similar weight and age may therefore have more difficulties establishing a stable dominance hierarchy due to their previous experience as 'winners' in social conflicts with smaller litter mates. When piglets have little experience with losing fights and have evenly matched opponents, fights may be repeated, resulting in prolonged aggressive encounters (McGlone, 1985). In contrast, light and medium piglets may be better at evaluating their relative fighting ability based on different outcomes from previous conflicts (D'Eath, 2002). As a result, in the present study, less overall aggression was observed in these groups.

Heavy piglets in the current study expressed longer feeding latencies than light and medium piglets, although this only reached significance between heavy and light piglets assigned to road transport. Other researchers have found similar results and several possible explanations have been suggested. While early weaned piglets typically have a very low motivation to consume dry feed immediately following weaning (Metz and Gonyou, 1990; Worobec et al., 1999; Berry and Lewis, 2001) large piglets in particular, are believed to have developed a strong dependency on a pure milk diet, making them poorly prepared for abrupt weaning (Weary and Fraser, 1997; Weary et al., 1999). Fraser et al. (1988) found that newborn piglets with low milk intake expressed increased drinking behaviour and water usage. Consequently, it may be hypothesized that the smaller piglets in the current study had more experience using a water nipple, consumed more water following weaning and transport, and were therefore more motivated to start feeding when in housing. Furthermore, large differences in teat quality during the pre-weaning period may drive piglets on poor producing teats to consume alternative food sources (Francis et al., 1996; Mason et al., 2003). Piglets on these teats are often individuals of smaller relative size. Large piglets were observed feeding significantly less than small piglets during the first 3 days in housing, which supported this conclusion. Bruinix et al. (2001) found similar results when weaning 27-d-old piglets. Reduced initial feeding behaviour by heavy compared to light and medium piglets in the current study may therefore be explained by the theory of heavy piglets being poorly prepared for early weaning due to a high dependency on a pure milk diet.

Large piglets in uniform weight groups expressed significantly more aggression than small and medium sized piglets during the first day in housing. High levels of fighting in groups of large piglets may have exacerbated water loss due to weaning and transport, causing large piglets to be more dehydrated with time and therefore less motivated to feed compared to groups of small and medium piglets. This may have contributed to the extended feeding latency observed in groups of large piglets after road transport. Alternatively, low motivation to engage in feeding by large piglets during the first 3 days post weaning may have been a reflection of their higher reliance on a milk based diet relative to smaller litter mates. Although these results show that heavy piglets exhibit performance and behavioural characteristics that are different from light and medium piglets, the differences did not appear to be directly related to transport stress.

5.4 Transport type

Piglets appeared to be negatively affected by one or more factors experienced during road transport, including noise, vibration, and movement and fluctuating temperatures. This was reflected in higher weight loss, delayed day of recovery, and reduced feeding behaviour during the first 3 days post weaning compared to simulated transport groups. Decreased feeding behaviour was expressed through a decrease in both the frequency and duration of feeding bouts. This difference may have been due to increased water loss in piglets transported by road relative to simulated transport groups. Becker et al. (1989) found higher hematocrit values in slaughter hogs subjected to transport (11 h) and fasting (48 h and 72h) than in pigs subjected to fasting only, indicating increased dehydration associated with effects of road transport. Hyan et al. (1998) found the addition of individual environmental stressors (mixing, crowding and fluctuating temperature) to negatively affect performance in grower pigs, and that the individual stressors were additive. Some studies have suggested that noise, vibration and movement associated with road transport is aversive to pigs (Stephens and Perry, 1990), causing anxiety and motion sickness (Bradshaw et al., 1996; Randall and Bradshaw, 1998), others have found no effects of transport (Parrot and Mission, 1989; Jesse et al., 1990). While these studies involved grower or slaughter pigs it would be reasonable to expect transport to have similar effects on early weaned piglets. Although no signs of travel sickness such as retching, vomiting and/or foaming at the mouth (Bradshaw et al., 1996b) were observed in piglets assigned to road transport in the current study, vomiting has occurred in other studies by this laboratory (personal communication, N. Lewis, 2004b).

Belly nosing (as an element of oral/nasal behaviour) has been observed more frequently in piglets weaned at younger ages (Metz and Gonyou, 1990; Gonyou et al., 1998; Worobec, 1999; Weary et al., 1999), in less enriched environments (Dybkjær, 1992; Kelly et al., 2000), and following social 'stressors' such as mixing and crowding, suggesting that this behaviour is stress induced. Piglets exposed to road transport in the current study expressed more oral/nasal behaviour than simulated transport groups on day 2-4, suggesting that piglets find some elements of road transport, including noise, vibration, movement or fluctuating temperatures, as more stressful than simulated transport. However, the category oral/nasal manipulation in this study was comprised of three different behavioural elements, which were directed to the piglet's physical and social surroundings (orally manipulating a chain, orally manipulating pen mates and belly nosing). As suggested by others (Dybkjær, 1992; Petersen et al., 1995), it may be that these elements have different motivation and are released by different stimuli. As a result, not all aspects of oral/nasal behaviour observed in the current study were necessarily stress related, making direct comparisons with other research difficult.

Although piglets assigned to road transport showed higher weight loss and delayed day of recovery compared to piglets assigned to simulated transport, subsequent relative weight gain (percent ADG) was similar for all pigs, regardless of transport type. These results suggest that road transport causes stress to early weaned piglets, prolonging post weaning growth-check but not affecting later production. In addition, our results suggest that road transport has a transient effect on the temporal pattern of feeding and oral/nasal behaviour in early weaned piglets, which may be related to increased stress. However, by d 4 in housing, piglets appeared to have overcome the adverse effects of road transport, as feeding and oral/nasal behaviour no longer differed between treatment groups.

6.0 GENERAL CONCLUSION

Increased weight loss and increased post transport drinking and feeding behaviour were associated with increased time without access to feed and water during transport. Duration of fasting in transit and relative age, may have been factors affecting piglet motivation to initiate feeding following early weaning and transport. Weaning itself was a significant stressor, as non-transported piglets expressed weight loss and day of recovery consistent with piglets transported for 12 h and 24 h. Given the parameters used in the current study, these results suggest that transport durations of 6 h, 12 h and 24 h do not substantially increase weaning stress. However, water deprivation may pose a welfare concern.

Piglets transported in winter expressed a prolonged growth check, reduced ADG and lower FCE compared to piglets transported in summer. Piglets also showed increased levels of activity following weaning and transport in winter, suggesting higher levels of stress associated with transport in winter.

Heavy piglets expressed a prolonged growth check and reduced ADG relative to light and medium piglets. Heavy piglets also showed lower FCE during the first 14 days following weaning and transport compared to light piglets. The causative factors were hypothesized to be: 1) heavy piglets spent more time fighting, and 2) heavy piglets spent less time feeding due to a high reliance on a milk based diet during the lactation period and lack of experience consuming dry feed. Although heavy piglets exhibited performance and behavioural characteristics that were different from light and medium piglets, these differences did not appear to be directly related to transport stress. These results show that piglets within the same age range express different performance and behaviour characteristics related to weaning weight, and that uniform weight groups may exacerbate these differences. Grouping piglets of variable size may cause piglets to establish a stable dominance hierarchy more quickly, and to efficiently learn feeding and drinking behaviours from more experienced pen-mates.

Piglets appeared to be negatively affected by one or more of the additional factors of road transport, including noise, vibration, movement and fluctuating temperatures. This was reflected in higher weight loss and delayed day of recovery compared to simulated (duration and temperature) transport groups. Road transport also had a transient effect on the temporal pattern of feeding and oral/nasal behaviour in early weaned piglets, possibly associated with these stressors. However, by d 4 in housing, piglets appeared to have overcome the adverse effects of road transport, as feeding and oral/nasal behaviour no longer differed between treatment groups.

While this study provided valuable information about the overall effects of transport on early weaned piglets, research efforts are still required to improve our knowledge regarding specific effects of the various factors of transport. In particular, research efforts are needed to define the optimum transport environment for EW piglets. As the health status of the North American swine herd continues to improve, there may be economic and welfare advantages in delaying weaning.

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8.0 APPENDICES

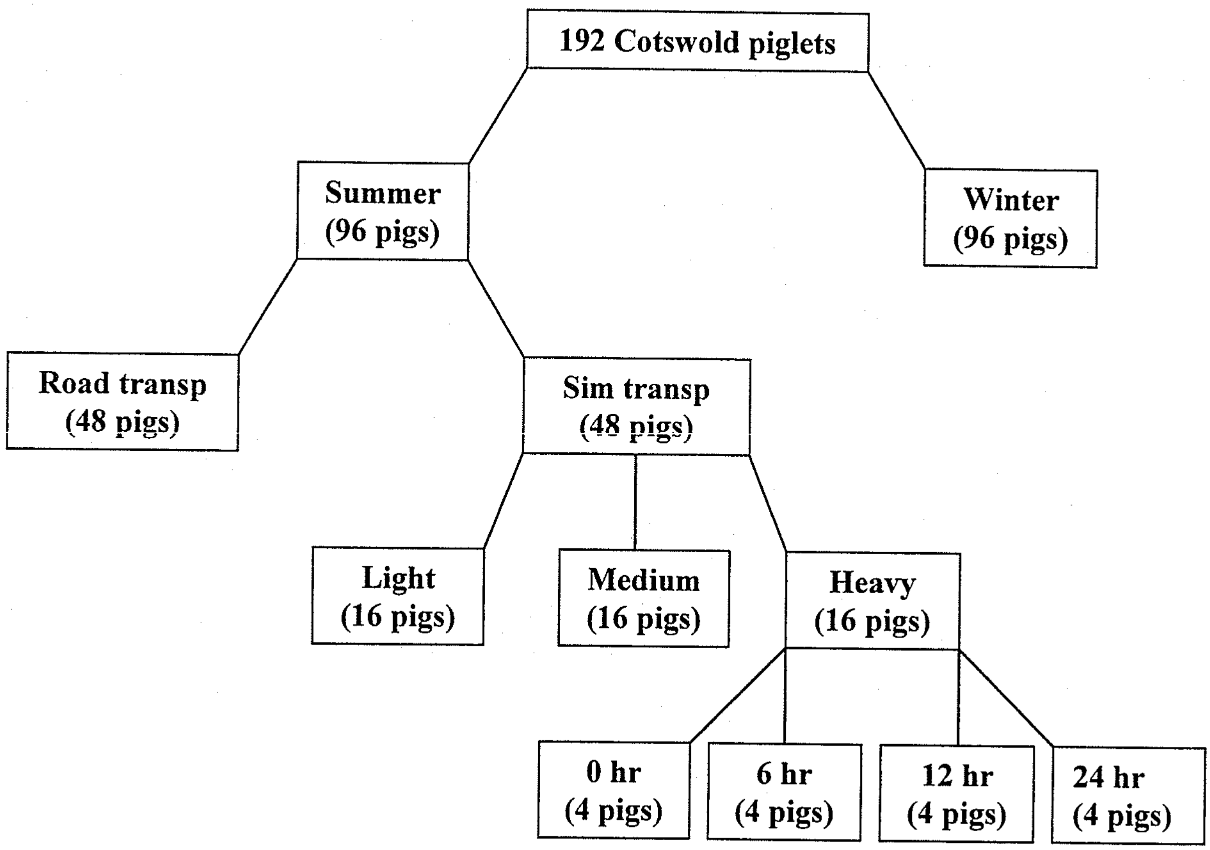
Appendix 1. Formulation of Feed-Rite AP 25/35 Creep Starter Mini Pellets-Medicated

Medicated
Chlortetracycline Hydrochloride.................................... 110 mg/kg
Sulfamethazine.. 110 mg/kg
Penicillin from procaine penicillin.................................. 55 mg/kg

Guaranteed analysis:
Crude Protein (min).. 20%
Crude Fat (min)... 8.1%
Crude Fibre (max)... 2.4%
Salt (NaCl) Actual... 1.2%
Sodium (Na) Actual 0.5%
Calcium (Ca) Actual.. 1.0%
Phosphorus (P) Actual.. 0.8%
Copper (Cu) Actual .... 125 mg/kg
Selenium (Se) Actual .... 0.3 mg/kg
Zinc (Zn) Actual.. 500 mg/kg
Vitamin A (min)... 20,000 iu/kg
Vitamin D3 (min).. 1,500 iu/kg
Vitamin E (min) .... 300 iu/kg

Feed-Rite, A Division of Ridley Inc., Winnipeg, Manitoba, 2001.

Appendix 2. Experimental design



Appendix 3. Sample data-log from analysis of performance data

```
NOTE: Copyright (c) 1999-2001 by SAS Institute Inc., Cary, NC, USA.
NOTE: SAS (r) Proprietary Software Release 8.2 (TS2M0)
      Licensed to UNIVERSITY OF MANITOBA, Site 0002246003.
NOTE: This session is executing on the WIN_PRO  platform.

NOTE: SAS initialization used:
      real time           1.75 seconds
      cpu time            0.46 seconds

NOTE: WORK.GAIN_FEED01 was successfully created.
     Options linesize=78;
     *Variable names on spreadsheet:

     Season Tduration Ttype Wgroup Gain Feed FCE
     ;
     /*PROC IMPORT OUT= WORK.Gain_Feed01
       DATAFILE= "C:\Documents and Settings\dvr\My Documents\Steinar\Gain_Feed01.xls"
          DBMS=EXCEL2000 REPLACE;
          RANGE="sheet2$";
          GETNAMES=YES;
     */

     *Proc print Data=One;
     Proc sort data=Gain_Feed01;
     By Season Tduration Ttype WGroup;

NOTE: There were 48 observations read from the data set WORK.GAIN_FEED01.
NOTE: The data set WORK.GAIN_FEED01 has 48 observations and 7 variables.
NOTE: PROCEDURE SORT used:
      real time           0.01 seconds
      cpu time            0.00 seconds


     Data one;
       Set Gain_Feed01;

       *Log Transformation (1 is added to make transformation of values > 0 positive)
       ;
       LFCE=Log(FCE+1);
     Datalines;

NOTE: There were 48 observations read from the data set WORK.GAIN_FEED01.
NOTE: The data set WORK.ONE has 48 observations and 8 variables.
NOTE: DATA statement used:
      real time           0.04 seconds
      cpu time            0.01 seconds


     Proc Print Data=One;
      Var Season Tduration Ttype Wgroup Gain Feed FCE LFCE;
```

```
NOTE: There were 48 observations read from the data set WORK.ONE.
NOTE: PROCEDURE PRINT used:
      real time           0.00 seconds
      cpu time            0.00 seconds


Proc Univariate Plot Normal Data=One;
 Var Gain Feed FCE LFCE;

NOTE: PROCEDURE UNIVARIATE used:
      real time           0.12 seconds
      cpu time            0.03 seconds


Proc GLM Data=One;
Classes Season Tduration Ttype Wgroup;
  Model Gain Feed FCE LFCE
        = Season Tduration Ttype Wgroup
                   Season*Tduration Season*Ttype Season*Wgroup
                   Tduration*Ttype Tduration*Wgroup Ttype*Wgroup
                   /SS3;
  Lsmeans Season Tduration Ttype Wgroup/Stderr pdiff adjust=bon;
  Lsmeans Season*Tduration Season*Ttype Season*Wgroup Tduration*Ttype
            Tduration*Wgroup Ttype*Wgroup/Stderr pdiff adjust=bon;
  Means Season Tduration Ttype Wgroup;
quit;

NOTE: Means from the MEANS statement are not adjusted for other terms in the
      model.  For adjusted means, use the LSMEANS statement.
NOTE: PROCEDURE GLM used:
      real time           0.76 seconds
      cpu time            0.03 seconds
```

Appendix 4. Average ambient temperatures at Winnipeg International Airport[7], and average truck temperatures recorded at the truck shell and directly above the piglets

	Temperature (° C)			
Parameters	0-6 hour	6-12 hour	12-18 hour	18-24 hour
Summer				
Ambient	17.3	17.8	12.2	12.1
Truck shell	23.2	25.8	18.0	15.1
Above pigs	23.0	25.7	18.4	16.4
Winter				
Ambient	-13.1	-9.7	-10.1	-13.8
Truck shell	2.4	1.4	-2.6	-5.0
Above pigs	8.4	7.1	0.9	-1.2

[7] www.climate.weatheroffice.ec.gc.ca/climateData/hourlydata_e.html

Appendix 5. Sample data-log from analysis of behaviour data

```
NOTE: Copyright (c) 1999-2001 by SAS Institute Inc., Cary, NC, USA.
NOTE: SAS (r) Proprietary Software Release 8.2 (TS2M0)
      Licensed to UNIVERSITY OF MANITOBA, Site 0002246003.
NOTE: This session is executing on the WIN_PRO  platform.

NOTE: SAS initialization used:
      real time           2.39 seconds
      cpu time            0.38 seconds

NOTE: WORK.CONTOBSQ was successfully created.
     Options linesize=78;
     *Variable names on spreadsheet:

     Season Tduration Ttype Wgroup Day Pen Ftotal Ffreq Fbout Dtotal Dfreq Dbout;

     /*PROC IMPORT OUT= WORK.Contobsq
     DATAFILE= "C:\Documents and Settings\dvr\My Documents\Steinar\Contobsq.xls"
          DBMS=EXCEL2000 REPLACE;
          RANGE="sheet1$";
          GETNAMES=YES;
     */

     *Proc print Data=One;
     Proc sort data=Contobsq;
     By Season Tduration Ttype WGroup Day Pen;


NOTE: There were 144 observations read from the data set WORK.CONTOBSQ.
NOTE: The data set WORK.CONTOBSQ has 144 observations and 12 variables.
NOTE: PROCEDURE SORT used:
      real time           0.01 seconds
      cpu time            0.00 seconds


     Data one;
       Set Contobsq;
       PFtotal=Ftotal/28800; PDtotal=Dtotal/28800;
       *Log Transformation (1 is added to make transformation of zero values=0)
       ;
       LFtotal=Log(Ftotal+1);
       LFfreq=Log(Ffreq+1);
       LFbout=Log(Fbout+1);
       LDtotal=Log(Dtotal+1);
       LDfreq=Log(Dfreq+1);
       LDbout=Log(Dbout+1);
       TFtotal=Arsin(Sqrt(PFtotal));
       TDtotal=Arsin(Sqrt(PDtotal));
       *if Tduration='Oh' then delete;
     Datalines;

NOTE: There were 144 observations read from the data set WORK.CONTOBSQ.
NOTE: The data set WORK.ONE has 144 observations and 22 variables.
NOTE: DATA statement used:
```

```
      real time           0.26 seconds
      cpu time            0.01 seconds


Proc Print Data=One;
 Var Season Tduration Ttype Wgroup Day Pen Ftotal LFtotal Ffreq LFfreq Fbout LFbout
     Dtotal LDtotal Dfreq LDfreq Dbout LDbout PFtotal TFtotal PDtotal TDtotal;

NOTE: There were 144 observations read from the data set WORK.ONE.
NOTE: PROCEDURE PRINT used:
      real time           0.23 seconds
      cpu time            0.03 seconds


Proc Univariate Plot Normal Data=One;
 Var Ftotal Ffreq Fbout Dtotal Dfreq Dbout PFtotal PDtotal
    LFtotal LFfreq LFbout LDtotal LDfreq LDbout TFtotal TDtotal;

NOTE: PROCEDURE UNIVARIATE used:
      real time           0.79 seconds
      cpu time            0.04 seconds


Proc GLM Data=One;
  Classes Season Tduration Ttype Wgroup Day Pen;
  Model Ftotal Ffreq Fbout Dtotal Dfreq Dbout PFtotal PDtotal
        LFtotal LFfreq LFbout LDtotal LDfreq LDbout TFtotal TDtotal
        = Season Tduration Ttype Wgroup
                  Season*Tduration Season*Ttype Season*Wgroup
                  Tduration*Ttype Tduration*Wgroup Ttype*Wgroup
                    Season*Tduration*Ttype Season*Tduration*Wgroup
                    Season*Ttype*Wgroup Tduration*Ttype*Wgroup
                     Season*Tduration*Ttype*Wgroup
              Day Day*Season Day*Tduration Day*Ttype Day*Wgroup
                Day*Season*Tduration Day*Season*Ttype Day*Season*Wgroup
                  Day*Tduration*Ttype Day*Tduration*Wgroup Day*Ttype*Wgroup
                    Day*Season*Tduration*Ttype
                      Day*Season*Tduration*Wgroup
                     Day*Season*Ttype*Wgroup Day*Tduration*Ttype*Wgroup/SS3;
  Random Season*Tduration*Ttype*Wgroup/test;
  Lsmeans Season Tduration Ttype Wgroup Season*Tduration Season*Ttype
           Season*Wgroup Tduration*Ttype
            Tduration*Wgroup Ttype*Wgroup/stderr
                         E=Season*Tduration*Ttype*Wgroup pdiff adjust=bon;
  Lsmeans Day Day*Season Day*Tduration Day*Ttype Day*Wgroup/stderr pdiffadjust=bon;
quit;
```