Assessment of the Non All-in All-out System and the All-in All-out System for Sows and Their Suckling Piglets

J. H. Jeon, S. C. Yeon[1], S. Kim[1], D. H. Kim[2] and H. H. Chang*

Division of Applied Life Science, Institute of Agriculture & Life Sciences, Graduate School

Gyeongsang National University, Jinju 660-701, Korea

ABSTRACT : The goal of this study was to investigate the behavior of sows and their piglets reared using the non-all-in all-out system and the all-in all-out system during a 3-week lactation period. The 24 Landrace×Yorkshire sows (range of parity: 2 to 4) and their litters (range of litter size: 8 to 13 piglets) for each treatment (8 sows/replication) were used in this experiment. The sows were housed in farrowing crates (0.6×2.1 m) located in pens (2.4×1.8 m) with totally perforated metal flooring. The crates were kept in an experimental room that was thermostatically controlled to approximately 23°C. A 250-W infrared heat lamp was turned on above the creep area during lactation. The sows and piglets were conventionally managed. The animals were recorded during a 24-h period at 1, 4, 7, 14 and 21 days postpartum. The videotapes were scanned every minute to obtain an instantaneous behavioral sample. In the behaviors of sows, lateral recumbency decreased and ventral recumbency increased from 1 day postpartum to 21 days postpartum. In comparison to the AIAOS, sows in the NAIAOS spent much less time on lateral recumbency ($p<0.01$), whereas they spent much more time on ventral recumbency and sitting at 4 days postpartum ($p<0.05$ and $p<0.05$). In the behaviors of piglets, lying increased and unsuccessful suckling decreased until 21 days postpartum. Compared to the AIAOS at 4 days postpartum, piglets in the NAIAOS spent less time lying ($p<0.01$), whereas they spent much more time walking and unsuccessful suckling ($p<0.01$ and $p<0.05$). These results suggest that the all-in all-out system may be preferable to the non-all-in all-out system for promoting welfare. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 6 : 909-914)***

Key Words : Sow, Piglet, Behavior, All-in all-out System, Welfare

INTRODUCTION

In the current swine industry, the all-in all-out system (about 50% in Korea) has been used largely to prevent diseases, better synchronize the sows' return to estrus, and reduce manual labor. Sows are moved into a farrowing room about 7 days before parturition and are reared until weaning in the same room. According to previous studies (Jensen, 1988; Götz, 1991; Jensen et al., 1991; Lou and Hurnik, 1998), the rearing environment affects the behavior of the sows and their piglets. The sows' and piglets' behavior affects the mortality rate and growth of the piglets, which impacts the number of piglets available for market, and the time needed for them to reach market weight (Mahan and Lepine, 1991). Body damage, impaired growth, and disease are indicators of poor welfare (Broom, 1991). A piglet's mortality rate during the 3-week lactation period ranges from 14.2 (Fahmy and Bernard, 1971) to 23.5% (Dyck and Swierstra, 1987). The three main causes of death are stillbirth, crushing by the sow, and starvation (English and Morrison, 1984; Dyck and Swierstra, 1987). Of these, crushing by the sow and starvation are closely associated with communication between the sow and its piglet. If the sow hears the call of its piglet in the danger of being crushed, the sow can change its posture and the piglet will survive. Starvation occurs if the piglets fail to achieve regular and adequate suckling (Fahmy and Bernard, 1971; English and Morrison, 1984; Dyck and Swierstra, 1987). If piglets get inadequate milk after birth because they can not communicate with their sow due to other noise, they become hypothermic and weak and may be crushed by their sow (Fahmy and Bernard, 1971; Dyck and Swierstra, 1987). The piglet's weaning weight is affected by the sow's nursing frequency (Spinka et al., 1997). Some sows and their piglets housed in a farrowing room occasionally show nursing–suckling behaviors synchronized by mutual sound …stimuli (Walser, 1986; Kasanen and Algers, 2002).

The goal of this study was to investigate the behavior of sows and their piglets reared in the non-all-in all-out system (NAIAOS) and the all-in all-out system (AIAOS) during the first 3 weeks of lactation, and to evaluate the NAIAOS and the AIAOS from a behavioral standpoint.

MATERIALS AND METHODS

Animals, housing, and management

The 48 Landrace×Yorkshire sows (range of parity: 2 to 4) and their litters (Landrace×Yorkshire×Duroc; range of

* Corresponding Author: H. H. Chang. Tel: +82-55-7515510, Fax: +82-55-7516113, E-mail: hhchang@nongae.gsnu.ac.kr

[1] Department of Veterinary Medicine, College of Veterinary Medicine, Gyeongsang National University, Jinju 660-701, Korea.

[2] Department of Animal Resources Technology, Jinju National University, Jinju 660-758, Korea.

Received September 29, 2005; Accepted February 9, 2006

Table 1. Composition of diets fed to lactating sow (%)

Ingredient	Lactation
Corn	52.39
Soybean meal	29.00
Wheat	7.83
Wheat barn	2.00
Tallow	5.00
Lysine (95%)	0.20
Methionine (50%)	0.05
Limestone	0.83
Tricalcium phosphate	1.90
Salt	0.30
Vitamin-mineral mix[1]	0.40
Antibiotics	0.10
Total	100.00
Chemical composition	
ME (kcal/kg)	3,386.00
Protein	18.60
Lysine	1.19
Methionine	0.31
Calcium	0.90
Phosphorus	0.73

[1] Composition per kg of premix: 2,750,000 IU vitamin A, 220,000 IU vitamin D_3, 1,450 mg riboflavin, 11,000 mg d-pantothenic acid, 11,000 mg niacin, 110,000 mg choline, 11 mg vitamin B_{12}, 1,100 mg menadione, 2.2 g ethoxyquin, 11,000 IU vitamin E; Contained 20% Zn, 10% Fe, 5.5% Mn, 1.1% Cu, 0.15% I.

litter size: 8 to 13 piglets) were used in this experiment from the 1 day postpartum to weaning. The windowless farrowing house of the NAIAOS (n = 24 sows; 8 sows/replication) for 72 sows and their piglets was not divided into compartments, whereas that of the AIAOS (n = 24 sows; 8 sows/replication) was divided to raise 8 sows and their piglets in each room. The sows were housed in farrowing crates (0.6×2.1 m) located in pens (2.4×1.8 m) with totally perforated metal flooring. All sows were moved into the farrowing crates, which were kept in rooms that were insulated and thermostatically controlled to about 23°C. A 250-W infrared heat lamp was installed above the creep area and turned on until weaning. Some newborn piglets were cross-fostered immediately after parturition and all piglets had their teeth clipped and tail docked at 1 day postpartum. The male piglets were castrated at approximately 3 days postpartum. The sows were fed a standard ration of commercial concentrate twice daily, between 07:00 and 08:00 h and between 18:00 and 19:00 h, and they had unlimited access to water at all times (Table 1). The piglets were supplied creep feed from 10 days of age (Reese et al., 2001; Table 2).

Table 2. Composition of diets fed to suckling piglet (%)

Ingredient	Creep
Corn	55.61
Soybean meal	27.04
Dried whole whey	15.00
Defluorinated phosphate	0.93
Limestone	0.77
Salt	0.30
Vitamin-mineral mix[1]	0.35
Total	100.00
Chemical composition	
ME (kcal/kg)	3,300.00
Protein	25.23
Lysine	1.48
Methionine	0.38
Calcium	0.55
Phosphorus	0.46

[1] Composition per kg of premix: 1,760,000 IU vitamin A, 176,000 IU vitamin D_3, 1,760 mg riboflavin, 8,800 mg d-pantothenic acid, 8,800 mg niacin, 195,800 mg choline chloride, 8.8 mg vitamin B_{12}, 200 mg menadione, 176 mg d-biotin, 4,400 IU vitamin E; Contained 15% Zn, 17.5% Fe, 6% Mn, 1.75% Cu, 2% I.

Observations

On the days of observation, all piglets were marked on the back with a conspicuous number. The behavior of the animals was recorded during a 24-h period at 1, 4, 7, 14 and 21 days postpartum using invisible LED (light-emitting diode) lamps (950-nm wavelength), CCD (charge-coupled device) cameras, multiplexers, and time lapsed VCRs (videocassette recorder). Piglets that were ill or crushed

Table 3. The mutually exclusive behavioral categories used for behavioral observation

Behavior		Definition
Sow	Lateral recumbency	Lying on side with one shoulder completely touching the ground, which included nursing
	Ventral recumbency	Lying on udder with neither shoulder touching the ground
	Sitting	Partly erect on extended front legs with the caudal end of body contacting the floor
	Standing	Upright with all four feet on the ground
	Feeding	Lowering head into the feeder
	Drinking	Touching the nipple water drinker with snout
Piglet	Lying	Combined category of lying laterally and lying sternally
	Walking	Relatively low or fast speed locomotion on the ground in which propulsive force derives from the action of legs, which included standing and sitting
	Successful suckling	Successfully switching from teat massage and slow suckling movements to the rapid, regular suckling movements indicative of milk ingestion (Fraser, 1980) when at least 50% of the littermates did so (Milligan, 2001)
	Unsuccessful suckling	Failed to switch from teat massage and slow suckling movements to the rapid, regular suckling movements indicative of milk ingestion when at least 50% of the littermates did so

Table 4. Percentage (±SD) of the behaviors of sows according to days postpartum

Behavior	Management system		p value
	NAIAOS[1]	AIAOS[2]	
Lateral recumbency			
Day 1 postpartum	91.94±2.33^{a}	91.70±4.82^{a}	0.9190
Day 4 postpartum	77.77±7.56^{Bb}	91.46±2.98^{Aa}	0.0065
Day 7 postpartum	76.44±12.65^{b}	86.17±4.72^{b}	0.1405
Day 14 postpartum	76.91±3.78^{b}	78.32±3.38^{d}	0.5297
Day 21 postpartum	76.87±4.65^{b}	81.69±1.33^{c}	0.0601
Ventral recumbency			
Day 1 postpartum	3.56±2.39^{b}	3.05±2.19^{b}	0.7188
Day 4 postpartum	13.33±6.51^{Aa}	3.56±2.68^{Bb}	0.0153
Day 7 postpartum	13.24±10.85^{a}	4.61±3.96^{b}	0.1293
Day 14 postpartum	12.17±3.90^{a}	10.10±1.32^{a}	0.2843
Day 21 postpartum	12.52±4.16^{a}	9.61±1.00^{a}	0.1676
Sitting			
Day 1 postpartum	0.55±0.81^{c}	2.40±1.89	0.0756
Day 4 postpartum	2.80±1.58^{Aab}	0.96±0.77^{B}	0.0349
Day 7 postpartum	1.78±2.12^{bc}	2.11±1.72	0.7833
Day 14 postpartum	3.65±0.56^{a}	2.82±1.91	0.3704
Day 21 postpartum	3.33±0.83^{ab}	2.73±1.45	0.4214
Standing			
Day 1 postpartum	2.57±1.65^{b}	1.55±1.28^{c}	0.2810
Day 4 postpartum	3.82±2.55^{b}	1.93±0.91^{c}	0.1536
Day 7 postpartum	5.57±2.36^{a}	3.91±1.33^{ab}	0.1838
Day 14 postpartum	4.07±0.30^{ab}	4.73±1.51^{a}	0.3539
Day 21 postpartum	3.60±2.08^{b}	2.98±1.02^{b}	0.5427
Feeding			
Day 1 postpartum	0.66±0.37^{d}	0.88±0.71^{c}	0.5327
Day 4 postpartum	1.29±0.26^{c}	1.06±0.50^{c}	0.3603
Day 7 postpartum	1.96±0.10^{ab}	2.13±0.73^{b}	0.5962
Day 14 postpartum	1.90±0.29^{b}	2.71±0.82^{a}	0.0705
Day 21 postpartum	2.16±0.05^{a}	1.86±0.33^{b}	0.0927
Drinking			
Day 1 postpartum	0.72±0.39^{d}	0.43±0.35^{b}	0.2141
Day 4 postpartum	1.00±0.19^{c}	1.03±0.36^{a}	0.8596
Day 7 postpartum	1.02±0.05^{c}	1.07±0.36^{a}	0.7810
Day 14 postpartum	1.31±0.28^{b}	1.31±0.40^{a}	0.9944
Day 21 postpartum	1.52±0.05^{a}	1.13±0.50^{a}	0.1269

[1] NAIAOS: Non-all-in all-out system.
[2] AIAOS: All-in all-out system.
$^{A, B}$ Means in rows with different superscripts differ significantly.
$^{a, b, c, d}$ Means in columns with different superscripts differ significantly ($p<0.05$).

were excluded from this experiment. The videotapes were scanned every minute to obtain an instantaneous behavioral sample. The mutually exclusive behavioral categories recorded are shown in Table 3.

Statistical analysis

The number of times in which the animals engaged in each of the designated behavioral categories was counted for each observation day. These numbers were then converted into percentages. Data were analyzed using analysis of variance procedures, and were also tested for normality. The data were approximately normal and so were analyzed without transformation. The paired student *t*-test was used to compare the behaviors of sows and piglets reared using the NAIAOS and the AIAOS. The postures of piglets' standing and sitting were excluded from the analyses because these values were almost all zero. All analyses were performed using SAS (SAS Inst., Cary, NC, 2000).

RESULTS

Sow behaviors

In the NAIAOS, the frequency of lateral recumbency decreased rapidly from 1 day postpartum to 4 days postpartum ($p<0.05$; Table 4) and then was maintained at an almost constant level, while that of ventral recumbency increased rapidly from 1 day postpartum to 4 days postpartum ($p<0.05$) and then was maintained at an almost constant level. In the AIAOS, the lateral recumbency frequency decreased from 4 days postpartum to 21 days postpartum ($p<0.05$), while the ventral recumbency frequency was maintained at an almost constant level from 1 day postpartum to 7 days postpartum and then increased rapidly ($p<0.05$). The frequency of sitting in the NAIAOS increased gradually from 1 day postpartum to 21 days postpartum ($p<0.05$), whereas that in the AIAOS was maintained at an almost constant level during the experimental period. In both the NAIAOS and the AIAOS, the standing posture increased gradually up to 14 days postpartum, and then decreased ($p<0.05$). The frequency of feeding in both the NAIAOS and the AIAOS increased gradually from 1 day postpartum to 7 days postpartum ($p<0.05$), and then was maintained at an almost constant level. The drinking frequency in the NAIAOS increased gradually from 1 day postpartum to 21 days postpartum ($p<0.05$), whereas that in the AIAOS increased from 1 day postpartum to 4 days postpartum ($p<0.05$) and then was maintained at an almost constant level. The order of behavioral frequency in both the NAIAOS and the AIAOS during the experimental period was lateral recumbency, ventral recumbency, sitting, standing, feeding, and drinking. In comparison to the AIAOS at 4 days postpartum, sows in the NAIAOS spent much less time on lateral recumbency ($p<0.01$), whereas they spent much more time on ventral recumbency and sitting ($p<0.05$ and $p<0.05$).

Piglet behaviors

In the NAIAOS, the frequency of lying increased rapidly from 4 days postpartum to 7 days postpartum, decreased rapidly from 7 days postpartum to 14 days postpartum, and then increased again ($p<0.05$; Table 5). In the AIAOS, the frequency of lying increased gradually from

Table 5. Percentage (±SD) of the behaviors of piglets according to age

Behavior	Management system		p value
	NAIAOS[1]	AIAOS[2]	
Lying			
Day 1 postpartum	66.80±8.77^{b}	64.83±7.82^{d}	0.7038
Day 4 postpartum	62.37±4.61^{Bb}	70.61±1.54^{Abc}	0.0072
Day 7 postpartum	71.88±2.15^{a}	73.61±2.37^{b}	0.2359
Day 14 postpartum	63.52±7.02^{b}	68.19±2.62^{c}	0.1925
Day 21 postpartum	75.94±1.55^{a}	76.99±1.27^{a}	0.2484
Walking			
Day 1 postpartum	9.03±3.40^{b}	8.27±1.64^{c}	0.6450
Day 4 postpartum	11.65±3.33^{Ab}	5.15±1.07^{Bd}	0.0048
Day 7 postpartum	10.88±2.85^{b}	11.20±2.09^{b}	0.8363
Day 14 postpartum	17.73±6.34^{a}	13.10±1.83^{a}	0.1536
Day 21 postpartum	10.06±1.92^{b}	9.24±1.52^{c}	0.4514
Successful suckling			
Day 1 postpartum	12.84±4.08^{ab}	15.38±3.96^{b}	0.3205
Day 4 postpartum	15.27±2.75^{a}	17.56±0.86^{a}	0.1127
Day 7 postpartum	12.42±1.27^{b}	11.67±0.53^{d}	0.2473
Day 14 postpartum	13.18±4.36^{ab}	13.93±3.03^{bc}	0.7482
Day 21 postpartum	12.37±0.40^{b}	12.54±0.35^{cd}	0.4759
Unsuccessful suckling			
Day 1 postpartum	11.22±3.91^{a}	11.37±3.10^{a}	0.9445
Day 4 postpartum	10.72±2.86^{Aa}	6.68±0.31^{Bb}	0.0213
Day 7 postpartum	4.82±1.34^{b}	3.52±0.35^{d}	0.0733
Day 14 postpartum	5.58±1.32^{b}	4.78±0.41^{c}	0.2271
Day 21 postpartum	1.64±0.61^{c}	1.24±0.08^{e}	0.1875

[1] NAIAOS: Non-all-in all-out system.
[2] AIAOS: All-in all-out system.
$^{A, B}$ Means in rows with different superscripts differ significantly.
$^{a, b, c, d, e}$ Means in columns with different superscripts differ significantly ($p<0.05$).

1 day postpartum to 7 days postpartum, decreased rapidly from 7 days postpartum to 14 days postpartum, and then increased again ($p<0.05$). The walking frequency in the NAIAOS increased rapidly from 7 days postpartum to 14 days postpartum and then decreased ($p<0.05$), whereas that in the AIAOS decreased from 1 day postpartum to 4 days postpartum, increased from 4 days postpartum to 14 days postpartum, and then decreased ($p<0.05$). The successful suckling frequency in the NAIAOS was maintained at almost constant levels during the experimental period, whereas that in the AIAOS increased from 1 day postpartum to 4 days postpartum, decreased from 4 days postpartum to 7 days postpartum ($p<0.05$), and then was maintained at almost constant levels. The frequency of unsuccessful suckling in both the NAIAOS and the AIAOS decreased gradually between 1 and 21 days postpartum ($p<0.05$). The order of behavioral frequency in both the NAIAOS and the AIAOS during the experimental period was lying, successful suckling, walking, and unsuccessful suckling. In comparison to the AIAOS at 4 days postpartum, piglets in the NAIAOS spent much less time lying ($p<0.01$), whereas they spent much more time walking and unsuccessful suckling ($p<0.01$ and $p<0.05$).

DISCUSSION

The results in both the NAIAOS and the AIAOS from this study showed that lateral recumbency decreased and ventral recumbency increased during the postpartum period. The study by Götz (1991), observing 3 sows at 1, 2 and 3 weeks postpartum in a similar experimental environment, showed that lateral recumbency decreased between the first week and the following 2 weeks, similar to the results of this study. The data on lateral recumbency and ventral recumbency may have reflected the recovery of the animal's body from parturition (Jeon et al., 2003). In the current study, the frequency of sitting and standing in both the NAIAOS and the AIAOS increased gradually from 1 day postpartum to 14 days postpartum. Jensen (1988) and Stangel and Jensen (1991) reported that, with the advance of lactation, foraging and locomotion increased in a seminatural enclosure, whereas lying down, both laterally and ventrally, decreased. The rise in activity after parturition closely related to the recovery of the animal's body from parturition (Jeon et al., 2003). The order of behavioral frequency at 1 and 4 days postpartum in both the NAIAOS and the AIAOS was lateral recumbency, ventral recumbency, sitting, standing, feeding, and drinking and this was similar to the results reported by Lewis and Hurnik (1985) and Lou and Hurnik (1998). In this study, the nursing frequency was a part of lateral recumbency frequency and the same as the successful suckling frequency of piglets. The nursing frequency in both the NAIAOS and the AIAOS was maintained at an almost constant level. The almost constant trend in nursing frequency between 1 and 3 weeks postpartum was in agreement with previous results (Götz, 1991) for sows in a similar experimental environment, but differed from the decreasing trend seen in seminaturally reared sows (Jensen, 1986, 1988). This difference may be attributable to the more frequent nursing that occurred in response to the grunting sound stimuli from different sows in a room compared to a seminatural environment (Bate et al., 1999; Kasanen and Algers, 2002) or the difference in individual milk yields of the animals used in each study. Compared to the AIAOS at 4 days postpartum, sows in the NAIAOS spent much less time on lateral recumbency, whereas they spent much more time on ventral recumbency and sitting. The lower lateral recumbency frequency and higher ventral recumbency and sitting frequency of sows in the NAIAOS may be due to the response to the more frequent troublesome massage of piglets that occurred in response to the nursing-suckling sound stimuli from different sows and litters in a room compared to the AIAOS (Bate et al., 1999; Kasanen and Algers, 2002). This suggests that the AIAOS is preferable to

the NAIAOS in facilitating rest for the sows.

In both the NAIAOS and the AIAOS, the frequency of lying down in piglets was the lowest on their first day postpartum and the unsuccessful suckling frequency was as high as the result reported by Milligan et al. (2001). This was because the piglets were not completely developed (Jeon et al., 2003). The transition from a nonsynchronous neo-suckling to a cyclical and synchronous suckling in piglets occurs within approximately 10 hours after the birth of the first piglet (Lewis and Hurnik, 1985; Castren et al., 1989), and their playful behaviors increase from about 3 days of age (Blackshaw et al., 1997). Activity, including standing, sitting, and moving about, increases with age (Fraser, 1978). As above, the frequency of walking trended to increase with age in both the NAIAOS and the AIAOS. Compared to the AIAOS at 4 days postpartum, piglets in the NAIAOS spent much less time lying down (or resting), whereas they spent much more time walking. This suggests that the AIAOS is preferable to the NAIAOS for allowing the piglets to rest. The lower lying down frequency and higher walking frequency of piglets in the NAIAOS may be due to the response to the more frequent nursing-suckling sound stimuli by different sows and litters in a room compared to the AIAOS (Bate et al., 1999; Kasanen and Algers, 2002). The order of behavioral frequency at 1 and 4 days postpartum was similar to previous results (Lewis and Hurnik, 1985; Lou and Hurnik, 1998). As with the sows, the piglets spent most of their time during the first 3 weeks of life lying down. In both the NAIAOS and the AIAOS, the successful suckling frequency was maintained at an almost constant level during the experimental period, whereas the unsuccessful suckling frequency decreased gradually as the piglets aged. The results were closely associated with the piglets' behavioral development and the sows' recovery from parturition (Jeon et al., 2003), and reflect the findings of Castren et al. (1989) and Newberry and Wood-Gush (1985). Unsuccessful suckling can cause starvation (Fahmy and Bernard, 1971; English and Morrison, 1984; Dyck and Swierstra, 1987), crushing by the sows (Fahmy and Bernard, 1971; Dyck and Swierstra, 1987), and lower weaning weight. Unsuccessful suckling is an indicator of poor welfare according to Broom (1991). If the grunt signal of the sow is masked by different sows' and litters' noises, the odds of unsuccessful suckling may be increased (Algers and Jensen, 1985; Lewis and Hurnik, 1986; Algers and Jensen, 1991; Algers, 1993; Kasanen and Algers, 2002). The unsuccessful suckling in the NAIAOS was higher than in the AIAOS at 4 days postpartum. No starvation occurred in this study. For reasons mentioned previously, it is believed that the AIAOS is more effective than the NAIAOS for reducing unsuccessful suckling.

In conclusion, since sows and piglets can show more frequently comfortable resting and less unsuccessful suckling in the AIAOS than in the NAIAOS, the AIAOS may be preferred over the NAIAOS for enhancing welfare.

ACKNOWLEDGEMENT

This work was supported by the Brain Korea 21 project in 2005.

REFERENCES

Algers, B. 1993. Nursing in pigs: Communicating needs and distributing resources. J. Anim. Sci. 71:2826–2831.

Algers, B. and P. Jensen. 1985. Communication during suckling in the domestic pig: Effects of continuous noise. Appl. Anim. Behav. Sci. 14:49-61.

Algers, B. and P. Jensen. 1991. Teat stimulation and milk production in early lactation of sows. Can. J. Anim. Sci. 71:51-59.

Bate, L. A., T. A. Van Lunen and K. Van Lunen. 1999. Use of nursing sounds to influence performance of piglets. Can. J. Anim. Sci. 79:577.

Blackshaw, J. K., A. J. Swain, A. W. Blackshaw, F. J. M. Thomas, and K. J. Gillies. 1997. The development of playful behaviour in piglets from birth to weaning in three farrowing environments. Appl. Anim. Behav. Sci. 55:37-49.

Broom, D. M. 1991. Animal welfare: Concepts and measurement. J. Anim. Sci. 69:4167-4175.

Castren, H., B. Algers, P. Jensen and H. Saloniemi. 1989. Suckling behaviour and milk consumption in newborn piglets as a response to sow grunting. Appl. Anim. Behav. Sci. 24:227-238.

Dyck, G. W. and E. E. Swierstra. 1987. Causes of piglet death from birth to weaning. Can. J. Anim. Sci. 67:543-547.

English, P. R. and V. Morrison. 1984. Causes and prevention of piglet mortality. Pig News Info. 5:369-376.

Fahmy, M. H. and C. Bernard. 1971. Causes of mortality in Yorkshire pigs from birth to 20 weeks of age. Can. J. Anim. Sci. 51:351-359.

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

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

Götz, M. 1991. Changes in nursing and suckling behaviour of sows and their piglets in farrowing crates. Appl. Anim. Behav. Sci. 31:271-275.

Jensen, P. 1986. Observations on the maternal behaviour of free-ranging domestic pigs. Appl. Anim. Behav. Sci. 16:131-142.

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

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

Jeon, J. H., D. J. Kim, J. H. Han, S. C. Yeon and H. H. Chang. 2003. Behavioral recovery of sows and behavioral development of their piglets postpartum. J. Anim. Sci. Technol. (Korea) 45(6):1089-1096.

Kasanen, S. and B. Algers. 2002. A note on the effects of additional sow gruntings on suckling behaviour in piglets.

Appl. Anim. Behav. Sci. 75:93-101.

Lewis, N. J. and J. F. Hurnik. 1985. The development of nursing behaviour in swine. Appl. Anim. Behav. Sci. 14:225-232.

Lewis, N. J. and J. F. Hurnik. 1986. An approach response of piglets to the sow's nursing vocalizations. Can. J. Anim. Sci. 66:537-539.

Lou, Z. and J. F. Hurnik. 1998. Peripartum sows in three farrowing crates: Posture patterns and behavioural activities. Appl. Anim. Behav. Sci. 58:77-86.

Mahan, D. C. and A. J. Lepine. 1991. Effect of pig weaning weight and associated nursery feeding programs on subsequent performance to 105 kilograms body weight. J. Anim. Sci. 69:1370.

Milligan, B. N., D. Fraser and D. L. Kramer. 2001. Birth weight variation in the domestic pig: Effects on offspring survival, weight gain and suckling behaviour. Appl. Anim. Behav. Sci. 73:179-191.

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

Reese, D. C., T. G. Hartsock and W. E. Morgan Morrow. 2001. Pork Industry Handbook. Purdue University Cooperative Extension Service. PIH-18. Purdue Univ., West Lafayette.

Spinka, M., G. Illmann, B. Algers and Z. Stetkova. 1997. The role of nursing frequency in milk production in domestic pigs. J. Anim. Sci. 75:1223-1228.

Stangel, G. and P. Jensen. 1991. Behaviour of semi-naturally kept sows and piglets (except suckling) during 10 days postpartum. Appl. Anim. Behav. Sci. 31:211-227.

Statistical Analysis Systems Institute, Inc. 2000. User's Guide, Release 8.01, SAS Institute Inc., Cary, NC.

Walser, E. E. S. 1986. Recognition of the sow's voice by neonatal piglets. Behaviour. 99:177-188.