SHORT COMMUNICATION

Methods to supply chilled drinking water for lactating sows during high ambient temperatures

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Abstract

The aim of this study was to determine an effective method to supply chilled water (CW) for lactating sows during high ambient temperatures. One hundred twenty multiparous sows (Yorkshire × Landrace; parity range: 2 to 5) and their litters [Duroc × (Yorkshire × Landrace)] were divided into four groups of 30 sows each. Each group was used to investigate the effects of the four water supplying methods (Control: free access to unchilled water at 22°C; FACW: free access to chilled drinking water at 15°C; RACW: restricted access to chilled water at 15°C; and RACW+SS: restricted access to chilled water at 15°C + sound stimulus) under farm conditions with ambient temperatures above 25°C. Sows in the FACW, RACW, and RACW+SS groups ate and drank more than the sows in the control group that received water at 22°C (P<0.01). Respiration rate and rectal temperature were lower in sows in the CW groups than in the control group (P<0.01). Litter size on 0 day post-partum and at weaning did not differ among treatments, whereas average weaning weight and average daily gain (ADG) of piglets from the FACW, RACW, and RACW+SS groups were higher than those in the control group (P<0.01). There were no differences in the measured variables among treatment groups that received water chilled to 15°C (P>0.05). These results suggest that the optimal CW supplying method, from an energy viewpoint, may be RACW.

Introduction

High ambient temperatures result in reduced feed intake in sows, and this in turn reduces milk yield and litter growth (Black et al., 1993; Quiniou and Noblet, 1999; Renaudeau and Noblet, 2001). Also, reductions of 55 g per degree of temperature increase above 22°C in feed intake have been reported (Le Bellego et al., 2002).

Attempts have been made to reduce heat stress in pigs, including drip cooling, snout cooling, cooling pad, and cooled floors systems (Murphy et al., 1987; Midwest Plan Service, 1977; Panagakis et al., 1996; van Wagenberg et al., 2000). The drip cooling method is able to blister the skin of sows caused by continuous friction and moistness, and the snout cooling is not effective enough to reduce heat stress. In addition, the cooling pad is not suitable in damp weather and the cooled floor tends to induce diarrhea. Recently, some research approach about reduction of heat stress in a different way. Huynh et al. (2006) reported that water bath had positive effects on the physiologic responses under tropical climate conditions. According to Jeon et al. (2006), the chilled drinking water (CW) supply system reduced heat stress without detriment.

Suckling piglets respond to nursing calls (Castren et al., 1989). According to Shillito Walsers (1986) and Kasanen and Algers (2002), nursing and suckling behaviours were synchronized by nursing and suckling sound stimuli. Jeon et al. (2003) reported that the artificial sound of nursing-suckling effectively induced nursing and suckling behaviour in pigs. Piglets were trained to open a food-box, upon the cessation of a 600-cycle buzzer (Curtis, 1937) and sound stimuli is used as a training cue in varied species (Pryor, 1985; Harding et al., 2004; Bizley et al., 2013). Therefore, it was assumed that the artificial drinking sound stimulus might induce the drinking behaviour of sows.

This study was performed to find out the optimal supply method of CW based on feeding and drinking pattern of sows, and the influence of sound stimulus on conditioning sows to drink more CW.

Materials and methods

Animals, housing, and management

One hundred twenty multiparous sows (Yorkshire × Landrace; parity range: 2 to 5) and their litters [Duroc × (Yorkshire × Landrace)] were housed in farrowing crates (210×60 cm) in pens (240 × 160 cm) in a windowless farrowing house with the slatted pen floors. Ventilation was automatically controlled by fans. An infrared lamp (250 W) was installed above each creep area and was turned on manually when the room temperature fell below 29°C.

All sows were moved into the experimental farrowing house approximately seven days prior to farrowing. They were fed a standard ration of commercial concentrate (Table 1) three times a day, at 08:00, 13:00, and 18:00 h and had free access to drinking water until farrowing. On farrowing day, sows received 1 kg of diet and the ration was increased by 0.8 kg/d on days 1 and 2, and by 1 kg/d on days 3 and 4, as suggested by Quiniou and Noblet (1999). Sows had free access to feed from 5 days to weaning on day 21, and free access to water. Within 24 h post-partum, some piglets were cross-fostered so that each sow had 9 to 12 piglets. All piglets had their teeth clipped and tail docked on day 1 post-partum and male piglets were castrated when they were 3 days old. Creep feed intake can affect average daily gain (ADG) of piglets (Reese et al., 2001). Therefore, piglets were not given creep feed in order to evaluate the effects of only chilled water on the performance of litters and milk production.

These animal tests were implemented under the approval of the Institutional Animal Care and Use Committee of Gyeongnam National University of Science and Technology in South Korea.
Observation of sows behaviour

Twenty-four Yorkshire × Landrace sows (range of parity: 2 to 5) and their litters [Duroc × (Yorkshire × Landrace)]; range of litter size: 8 to 13 piglets) were used in this experiment from day 0 post-partum to weaning (21 d). Sows were housed in farrowing crates (210 × 60 cm) located in pens (240 × 160 cm) with perforated metal flooring in a compartment. The piglets were not cross-fostered and have birth weight of more than 800 g. The experimental room was insulated and thermostatically controlled to about 27°C. An infrared heat lamp of 250 W was installed above each creep area and turned on until weaning. The sows were fed a standard ration of commercial concentrate (Table 1) three times a day (08:00, 13:00, and 18:00 h), and had free access to drinking water until farrowing. The piglets were supplied creep feed from 10 days of age (Reese et al., 2001).

In order to find feeding and drinking behaviour pattern, sows behaviour was recorded during a 24-hour period at 1, 4, 7, 14, and 21 days post-partum using invisible LED lamps (950-nm wavelength), CCD cameras, multiplexers, and time lapsed VCRs. The videotapes were scanned every minute to obtain an instantaneous behavioural sample.

The mutually exclusive behavioural categories were recorded as follows:

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, which included feeding and drinking.

The standing frequency increased at 6 to 8, 14 to 16, and 18 to 20 h, which was related with feeding time. Thus, a time schedule for restricted access to CW (RACW) was made out so that CW was continuously provided from 6 to 8, 14 to 16, and from 18 to 20 h and for 30 min every leftover hour.

Experimental design

Four farrowing rooms were used for the four treatment groups (Control: free access to unchilled water; FACW: free access to CW; RACW: restricted access to CW; RACW+SS: restricted access to CW + sound stimulus). Sows and their litters were randomly assigned to one of the four treatment groups. FACW group was given CW from 06:00 to 20:00 h.

### Table 1. Composition of diets fed to lactating sows.

| Ingredients         | %   |
|---------------------|-----|
| Corn                | 52.39 |
| Soybean meal        | 29.00 |
| Wheat               | 7.83  |
| Wheat barn          | 2.00  |
| Tallow              | 5.00  |
| L-Lysine (95%)      | 0.20  |
| DL-Methionine (50%) | 0.05  |
| Limestone           | 0.83  |
| Tricalcium phosphate| 1.90  |
| Salt                | 0.30  |
| Vitamin-mineral mix | 0.40  |
| Antibiotics         | 0.10  |
| Total               | 100.00 |

### Chemical composition

- ME, kcal/kg: 3437.80
- Crude protein, %: 18.59
- Crude fat, %: 7.78
- Crude fibre, %: 4.79
- Crude ash, %: 6.53
- Lysine, %: 1.19
- Methionine, %: 0.31
- Calcium, %: 0.90
- Phosphorus, %: 0.73

*Composition per kg of mix: vitamin A, 2,750,000 U; vitamin D₃, 220,000 U; riboflavin, 1,659 mg; d-pantothenic acid, 11,000 mg; niacin, 11,000 mg; choline, 110,000 mg; vitamin B₁₂, 11 mg; menadione, 1.1 mg; ethoxyquin, 2.2 g; vitamin E, 11,000 U; contained: Zn, 20%; Fe, 10%; Mn, 5.5%; Cu, 1.1%; I, 0.15%.

Figure 1. Overall scheme of the chilled drinking water supplying device. The thermometer ① sends a signal for temperature in a farrowing room to the controller ②. The controller sends a signal to the switch ③. When temperature in farrowing room is above 25℃ and the timer ⑧ is operated by schedule, the switch turns on the refrigerator ④, circulation pump ⑤, solenoid valve ⑥ of chilled water line, speaker ⑩ and turns off the solenoid valve ⑦ of unchilled drinking water line. Then chilled drinking water from the refrigerator is circulated through the chilled water line and supplied through the nipple line. The computer ⑨ is turned on during the experimental period.
when ambient temperature rose above 25°C, and RACW and RACW+SS group were given CW when the ambient temperature rose above 25°C and according to the time schedule outlined above. In RACW+SS group, the sound stimulus (sound of feeding and drinking) was played by a computer system (Figure 1), when sows were given CW.

Water was chilled at 15°C in a refrigerator (Figure 1), as the 15°C drinking water be most effective (Jeon et al., 2006). A thermometer was installed 150 cm from the floor in a farrowing room; when temperature in the room was above 25°C, CW started circulating through the CW line by a controller. A refrigerator with a storage capacity of 100 L was used to ensure that CW was available at any given time. The CW line was insulated to keep water temperature constant.

Measurements

For all sows, refusals were removed and new feed was offered in the morning. Average daily feed intake was determined as the difference between the individual allowance and refusals collected in the next morning. Water consumption was monitored with individual water flow meters (Samwon MW-13, Seoul, South Korea). Back fat thickness in each sow was measured ultrasonically (Aloka SSD-500V, Wallingford, CT, USA) at a level of the last rib and 65 mm from the dorsal midline (Quiniou and Noblet, 1999; Renaudeau et al., 2001) before farrowing and at weaning. Respiration rate and rectal temperature (Sato SK-1250MC, Japan) were measured immediately after each feeding, since sows were drinking water while feeding (Fraser and Broom, 1997). Respiration rate was determined on sows at rest by counting the number of flank movements per min (Quiniou and Noblet, 1999; Renaudeau et al., 2001). Rectal temperature was determined with a digital thermometer inserted 5.5 cm into the rectum (Bull et al., 1997). Oestrus detection was carried out every 12 h from 3 days after weaning until the end of oestrus. Occurrence of oestrus was defined by the standing reflex in front of a boar and reddening and swelling of vulva. Both temperature and relative humidity in the farrowing rooms were recorded once per 10 min throughout the experimental period by an automated computer system (SY-MPM, Korea), and were averaged to yield a weekly mean. Litter weight and litter size were recorded on day 0 after cross-fostering and on day 21 at weaning. Milk production was estimated from piglets ADG and average birth weight (Noblet and Etienne, 1989).

Results and discussion

Average weekly temperature and relative humidity in the farrowing rooms were above 29°C and 73%, respectively, throughout the whole experimental period (Figure 2). Maximum temperature and relative humidity were 31.2°C and 85.7%, respectively. Minimum temperature and relative humidity were 28.7°C and 54.6%. Sows in all the CW groups ate and drank more than control group (P<0.01; Table 2). There were no treatment differences in the loss of back fat (P>0.05; Table 2). Body weight (BW) of sows was not measured in this study, but the lack of differences in back fat suggests that BW loss of sows was also not different among treatments (Pluske et al., 1998). Others have also showed reducing heat stress improves feed intake in pigs. For example, Murphy et al. (1987) reported that dripping water on lactating sows using horticultural emitters increased feed intake. Respiration rate and rectal temperature were lower in sows provided with chilled water than those with regular water (P<0.01; Table 2). This result is consistent with earlier findings from sows (Jeon et al., 2006) and cattle (Baker et al., 1988; Wilks et al., 1990).

| Table 2. Effects of chilled drinking water supplying methods on performance (mean±SD) of lactating sows. |
|-------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Supplying methods              | Sows, n           | Feed intake, kg/d | Water consumption, L/d | Back fat thickness, mm | Back fat thickness loss | Milk production, kg/d° |
| Control                       | 30                | 2.47±0.25         | 31.1±2.4           | 27.9±8.1             | 4.1±3.8             | 6.5±1.3            |
| FACW                          | 30                | 3.28±0.43         | 38.3±4.2           | 27.1±4.6             | 2.1±3.9             | 7.6±1.6            |
| RACW                          | 30                | 3.26±0.43         | 37.9±4.4           | 25.0±4.1             | 2.5±5.3             | 7.4±1.4            |
| RACW+SS                       | 30                | 3.25±0.48         | 38.4±3.6           | 25.7±6.8             | 2.9±3.1             | 7.5±1.1            |
|                               |                   |                   |                   |                   |                   |                   |
|                               |                   |                   |                   |                   |                   |                   |
|                               |                   |                   |                   |                   |                   |                   |
| P                             | 0.0001            | 0.0001            | 0.3415             | 0.2276               | 0.0046             | 0.0406             |

| Table 3. Effects of chilled drinking water supplying methods on performance (mean±SD) of piglets. |
|-------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Supplying methods              | Litter size, piglets/litter | At day 1 post-partum | At weaning | Average birth weight, kg | Average weaning weight, kg | Average daily gain, g |
| Control                       | 9.7±2.1           | 10.1±3.1          | 8.8±1.8          | 1.7±0.2           | 5.8±1.0           | 199±45            |
| FACW                          | 10.1±3.1          | 10.9±2.2          | 9.1±1.8          | 1.6±0.2           | 6.5±0.4           | 233±21            |
| RACW                          | 9.9±2.6           | 9.5±2.6           | 9.3±1.0          | 1.6±0.2           | 6.4±0.4           | 227±34            |
| RACW+SS                       | 9.5±2.6           | 9.5±2.6           | 9.0±1.3          | 1.6±0.2           | 6.3±0.6           | 223±24            |

Control, free access to unchilled drinking water (22°C); FACW, free access to chilled drinking water (15°C); RACW, restricted access to chilled drinking water (15°C); RACW+SS, restricted access to chilled drinking water (15°C)+sound stimulus. Estimated from litter average daily gain and size (Noblet and Etienne, 1989). *Means with different superscripts are significantly different in the same rows.
Estimated milk production was higher in the CW treatment groups compared with the control group (P<0.05; Table 2). Average weaning weight and average daily gain also increased feed in treatment groups (Table 3). According to Black et al. (1993), reduced milk production during heat stress may be due to alterations in blood flow away from the mammary gland, increased heat dissipation, or due to alterations in endocrine responses in sows during high ambient temperatures (Messias de Braganca et al., 1998). Renaudeau and Noblet (2001) reported that alterations in blood flow into the mammary gland may be mediated by the reduced feed intake or increased rate of tissue mobilization at high temperatures. The mammary gland continued to grow after farrowing (Kim et al., 1999). It is possible that high environmental temperatures during lactation may reduce the rate of mammary growth directly, thereby leading to decline in milk output and litter body weight gain.

Proportion of sows coming into oestrus within 5 days after weaning was not different among treatment groups (P<0.05): 77.8% in control, 84.4% in FACW, 80.0% in RACW, and 83.3% in RACW+SS (Figure 3).

The result of this study showed that CW increased feed intake, water consumption, milk production, weaning weight, and ADG and decreased rectal temperature and respiration rate (Table 2 and 3). Our findings indicate that access to CW mitigates heat stress in sows experiencing high ambient temperatures. We found that providing CW improved the performance of sows and litters, and found no differences between the three methods of delivering the CW in terms of any of our response measures. We had expected that the RACW + SS sows would be more likely to consume CW, either due to social facilitation or because they learned to associate this sound cue with CW availability.

However, sound stimulus did not affect the performances of sows and their litters. We did not find observable reason in this study, but sows seem to difficultly recognize the sound stimulus because sound stimulus involved the feeding sound. Although this study showed the results of research work, further studies are necessary for the right use of the sound stimulus.

The lack of differences between the free and restricted access to CW indicates that, from an energy viewpoint, an optimal method to supply CW may be RACW, as this method requires about half the energy of FACW in the current study. In other words, continuous CW provision needs to maintain the temperature of water (15°C) during daytime but it is unnecessary for intermittent CW provision.

Conclusions

Providing CW can improve the performance of sows and litters and reduce the heat stress effectively. However continuous CW provision needs a lot of energy to maintain the temperature of water. We found the standing frequency and CW was continuously provided from 6 to 8, 14 to 16, and from 18 to 20 hs and for 30 min every left over hour. We found that providing CW improved the performance of sows and litters, and found no differences among the three methods of delivering the CW, but sound stimulus did not affect the performances of sows and their litters. We therefore assume that the RACW method may reduce the heat stress during high ambient temperature more economically.

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