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Oxidative damage status of sows under heat stress environment in
different gestation housing systems for maternal well-being and
productivity

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Objectives

The primary objective of this study is to evaluate the impact of environmental temperature (heat stress) and gestation housing system (behavioral stress) on maternal well-being and productivity. Oxidative stress status will be used as a main indicator of well-being of sows relevant to their productivity. Specific Aims are (1) to determine the status of oxidative stress that sows receive during different stages of gestation and lactation, and (2) to understand its relations to heat stress (hot-humid summer or other seasons) and social stress (individual crate or group pen housing). Completion of Specific Aim (1) will provide fundamental understanding of the types of oxidative stress that sows receive during specific gestation and lactation period which will provide an important basis of Specific Aim (2). Completion of Specific Aim (2) will demonstrate how oxidative stress status and production efficiency of sows are affected by environmental temperature and types of gestation housing system. We hypothesize that oxidative stress increases during late gestation and early lactation especially for sows under heat stress in a group-pen housing system and this increase in oxidative damages reduce overall health status and productivity.

Experiment design

One hundred multi-parity sows were selected for two experiments. Experiment one was summer study designed to evaluate effect of different housing system on sow's reproductive performance, oxidative stress and behavior under high temperature. And experiment two was non-summer study designed to evaluate the effect of different housing system on sow's reproductive performance, oxidative stress and behavior under cool and cold temperature. Both experiments had same design. And each experiment included fifty sows. In both experiments, sows were weighted after pregnancy was confirmed on day 35 post-service and sows were randomly assigned to two housing treatments either crates (C, n=12) or pens (P, n=12) in groups of three. On day 108 of pregnancy (i.e. 7 days before predicted farrowing date), all sows were weighted and transferred to farrowing barn into standard farrowing crates (2.1×1.5 m). Sows body weight were measured on d 35 and 109 of gestation and on d 1 and 18 of lactation. Backfat thickness of each sow was measured on d 1 and 18 of lactation using

an ultrasound scanner. Reproductive performance of a sow was measured after farrowing. The measurements included the number of born alive, dead, or mummified, birth weight, weaning weight, and litter size at weaning. Blood samples were collected from the jugular vein of each sow on d 35, 60, 90, and 109 of gestation and on d3 and 18 of lactation. Blood was drawn into 9 mL Monovette tubes containing EDTA. Plasma samples were collected by centrifuging at 3000 g (15min, 4°C), and put in liquid nitrogen for 1hour, then stored at -80°C. White blood cells (WBC) were separated immediately after blood was collected using Histopaque-1077 following protocol methods. The WBC samples were stored in liquid nitrogen until analyzed. One female piglet and one male piglet closest to the average weight were chosen from each litter for blood sampling on d 3 and 18 of lactation. Blood was collected into Vacutainers without anticoagulant. Serum were centrifuged at 3,000 g, 4°C for 15 min and stored at -80°C. Milk samples were collected from each sow on d 1 and 18 of lactation. After injection of oxytocin, 30 mL milk was collected from each sow and stored at -80°C. Plasma samples were used to measure oxidative stress status including: malondialdehyde (MDA) as an indicator of lipid peroxidation, protein carbonyl content as an indicator of protein oxidation, 8-hydroxydeoxyguanosine (8-OHdG) as an indicator as DNA damage.

Results

Reproductive performance

In summer study (Table 1), there were no differences in sow's body weight loss, backfat loss, ADFI between treatments. The ADG of pigs and litter performances had no difference between treatments. The results indicated that group housing during gestation did not improve or decrease sow's reproductive performance. In non-summer study (Table 2), sows in crates had less body weight loss than sows in pens ($P<0.05$). But sows in crates had higher backfat loss than sows in pens ($P<0.05$). Litter size at birth had no difference between sow in crate and sow in pen. However, litter size at weaning was larger in crate than the sow housed in pen ($P<0.05$). The ADG of piglets was higher in control group ($P<0.001$). There was no difference in sow's parity, and ADFI between treatments. Piglet's litter weight at birth and weaning had no difference between treatments. The results indicated that sows under group housing during

gestation had more body weight loss and smaller litter size at weaning. But sows in crates has more backfat loss than sows housed in pens, and piglet's average daily gain was higher in sows group housed in crates.

Oxidative stress parameters

MDA concentration did not differ between crate (C) and pen (P) housing system on d 35, 60, 90, and 109 of gestation and on d 3 and 18 of lactation in both two experiments (Table 3, 4). Protein carbonyl concentration in P on d 109 of gestation was decreased ($p < 0.05$) compared with C by 23.2% in experiment 1. There were no differences between treatments on other sampling days during gestation and lactation period in experiment 1 (Table 5). Protein carbonyl concentration did not differ between C and P on d 35, 60, 90, and 109 of gestation and on d 3 and 18 of lactation (Table 6). The 8-OHdG concentration did not differ between C and P on d 35, 60, 90, and 109 of gestation and d 18 of lactation in experiment 1. However, 8-OHdG concentration in P on d 3 of lactation was decreased ($p < 0.05$) compared with C by 13.9% in experiment 1 (Table 7). The concentration of 8-OHdG on d 35 of gestation in P was lower than C ($p < 0.05$). There were no differences between treatments on other sampling days in experiment 2 (Table 8). For sows allotted to crate, the plasma MDA concentrations on d 90 and 109 of gestation and on d 3 of lactation in summer study were greater than MDA concentrations in non-summer study (Table 9). Protein carbonyl concentrations on d 35 and 109 of gestation and on d 18 of lactation in summer study were higher than protein carbonyl concentration in non-summer study (Table 11). Meanwhile, 8-OHdG concentrations on d 35, 60, and 90 of gestation and on d 3 and 18 of lactation in summer study were less than MDA concentrations in non-summer study (Table 13). The 8-OHdG concentration on d 109 of gestation in summer study tends to have less value than 8-OHdG concentrations in non-summer study (Table 13). For sows allotted to pens, the plasma MDA concentrations on d 35, 90, and 109 of gestation and on d 3 of lactation in summer study were greater than MDA concentrations in non-summer study (Table 10). Protein carbonyl concentrations on d 109 of gestation and on d 18 of lactation in summer study were higher than Protein carbonyl concentration in non-summer study (Table 12). However, protein carbonyl concentration on d 35 of gestation

in summer study was less than protein carbonyl concentration in non-summer study (Table 12). Meanwhile, 8-OHdG concentrations on d 60 and 90 of gestation and on d 3 of lactation in summer study were less than MDA concentrations in non-summer study (Table 14). The 8-OHdG concentration on d 18 of lactation in summer study tends to have less value than 8-OHdG concentrations in non-summer study (Table 14).

PLAN FOR YEAR 2

Behavior of sows was measured during gestation and lactation to compare their aggressive and stereotypic behaviors between gestation housing systems and between different ambient temperature (summer vs. non-summer). Behavior measurements will be analyzed by December, 2010. Analysis of oxidative stress will be finished by December 2010. Immunoglobulins in plasma and milk samples and cytokines in plasma will be measured by February 2011. Data analysis will be completed by March 2011. Final report will be written by June 2011.

Table 1. Effect of group housing during gestation on sow's reproductive performance in summer study

Item	Treatments		SEM ¹	SME ²	P-value
	Crate	Pen			
Sows, n (during lactation)	8	9			
Average parity	4.9	5.3	0.89	0.84	0.748
BW loss lb	2.06	-13.89	10.08	9.51	0.268
BF loss mm	0.54	0.78	0.86	0.81	0.841
Average daily feed intake, kg	4.79	4.19	0.3	0.28	0.172
Litter size at birth	10.6	10	0.65	0.61	0.508
Litter size at weaning	8.13	8.2	0.55	0.52	0.922
Litter weight at birth	16.56	15.03	0.92	0.86	0.242
Litter weight at weaning	48.05	46.38	2.47	2.33	0.630
Average daily weight gain, g	221	213	12.9	12.2	0.655

Table 2. Effect of group housing during gestation on sow's reproductive performance in non-summer study

Item	Treatments		SEM ¹	SME ²	P-value
	Crate	Pen			
Sows, n (during lactation)	8	10			
Average parity	5.13	5.36	0.5	0.450.84	0.7432
BW loss lb	0.625	-26.75	6.82	6.10	0.0086
BF loss mm	-4.5	-1.25	0.67	0.60	0.0023
Average daily feed intake, kg	3.66	4.59	0.36	0.32	0.0741
Litter size at birth	12.38	10.64	0.72	0.64	0.0908
Litter size at weaning	10.63	8.26	0.6	0.54	0.0097
Litter weight at birth	17.88	15.66	1.07	0.96	0.142
Litter weight at weaning	53.14	48.45	3.34	3.52	0.3883
Average daily weight gain, g	421.85	261.73	25.84	23.11	0.0003

Table 3. MDA concentration in plasma of sows allotted to two different housing systems in experiment 1

	d35	d60	day 90	day 109	lac 3	lac 18
SC	6.141±0.941	6.298±1.203	7.405±1.1	9.023±1.112	9.009±1.488	5.920±0.567
SP	7.133±0.841	5.550±1.076	7.160±1.1	9.132±0.995	8.135±1.331	5.859±0.534

Table 4. MDA concentration in plasma of sows allotted to two different housing systems in experiment 2

	d35	d60	d90	d109	lac 3	lac 18
FC	4.421±0.746	4.748±0.807	3.957±0.511	2.437±0.497	4.084±0.876	6.293±0.779
FP	4.823±0.667	4.845±0.721	4.043±0.457	3.032±0.444	4.649±0.783	5.842±0.696

Table 5. Protein carbonyl concentration in plasma of sows allotted to two different housing systems in experiment 1

	d35	d60	d90	d109	lac 3	lac 18
SC	1.409±0.214	1.104±0.140	1.007±0.092	2.675±0.164 ^a	1.423±0.082	1.788±0.119
SP	1.232±0.191	0.925±0.125	1.109±0.092	2.055±0.147 ^b	1.241±0.073	1.769±0.112

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table 6. Protein carbonyl concentration in plasma of sows allotted to two different housing systems in experiment 2

	d35	d60	d90	d109	lac 3	lac 18
FC	1.569±0.203	1.067±0.160	1.031±0.107	2.616±0.171	1.417±0.103	1.830±0.138
FP	1.268±0.172	0.917±0.135	1.110±0.107	2.046±0.145	1.220±0.087	1.748±0.133

Table 7. 8-OHdG concentration in plasma of sows allotted to two different housing systems in experiment 2

	d35	d60	d90	d109	lac 3	lac 18
SC	0.371±0.069	0.553±0.073	0.524±0.094	0.887±0.117	0.624±0.056 ^a	0.283±0.081
SP	0.326±0.061	0.419±0.064	0.547±0.088	0.962±0.103	0.430±0.04 ^b	0.257±0.071

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table 8. 8-OHdG concentration in plasma of sows allotted to two different housing systems in experiment 2

	d35	d60	d90	d109	lac 3	lac 18
FC	0.711±0.071 ^a	1.106±0.12 8	1.052±0.103	1.241±0.139	1.114±0.126	0.529±0.123
FP	0.469±0.064 ^b	0.851±0.11 4	0.894±0.093	1.027±0.124	1.201±0.112	0.588±0.110

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table 9. MDA concentration in plasma of sows allotted to crate in experiment 1,2

	d35	d60	day 90	day 109	lac 3	lac 18
SC	6.141±0.822	6.298±1.029	7.405±0.912 ^a	9.023±0.984 ^a	9.009±1.286 ^a	5.920±0.701
FC	4.421±0.822	4.748±1.029	3.957±0.912 ^b	2.437±0.984 ^b	4.084±1.286 ^b	6.293±0.701

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table 10. MDA concentration in plasma of sows allotted to pen in experiment 1,2

	d35	d60	day 90	day 109	lac 3	lac 18
SP	7.133±0.778 ^a	5.550±0.913	7.160±0.77 ^a	9.132±0.673 ^a	8.135±1.044 ^a	5.859±0.534
FP	4.823±0.778 ^b	4.845±0.913	4.043±0.457 ^b	3.032±0.673 ^b	4.649±1.044 ^b	5.842±0.600

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table 11. Protein carbonyl concentration in plasma of sows allotted to crate in experiment 1,2

	d35	d60	d90	d109	lac 3	lac 18
SC	1.409±0.240 ^a	1.104±0.22 9	1.007±0.122	2.675±0.181 ^a	1.423±0.106	1.788±0.128 ^a
FC	2.921±0.240 ^b	1.593±0.22 9	0.898±0.122	1.089±0.181 ^b	1.375±0.106	0.664±0.128 ^b

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table 12. Protein carbonyl concentration in plasma of sows allotted to pen in experiment 1,2

	d35	d60	d90	d109	lac 3	lac 18
SP	1.232±0.174 ^b	0.925±0.149	1.109±0.092	2.055±0.168 ^b	1.241±0.171	1.769±0.083 ^b
FP	2.844±0.174 ^a	1.114±0.149	1.298±0.203	1.196±0.168 ^a	1.345±0.171	0.622±0.079 ^a

^{a-b} Means within a column with different superscripts differ ($P<0.05$).

Table13. 8-OHdG concentration in plasma of sows allotted to crate in experiment 1,2

	d35	d60	d90	d109	lac 3	lac 18
SC	0.371±0.069 ^a	0.553±0.073 ^a	0.524±0.094 ^a	0.887±0.112 ^c	0.624±0.056 ^a	0.283±0.074 ^a
FC	0.711±0.071 ^b	1.106±0.128 ^b	1.052±0.084 ^b	1.241±0.114 ^d	1.114±0.117 ^b	0.529±0.070 ^b

^{a-b} Means within a column with different superscripts differ ($P < 0.05$).

^{c-d} Means within a column with different superscripts show a tendency to differ ($0.05 \leq P < 0.10$)

Table14. 8-OHdG concentration in plasma of sows allotted to pen in experiment 1,2

	d35	d60	d90	d109	lac 3	lac 18
SP	0.326±0.065	0.419±0.084 ^a	0.547±0.088 ^a	0.962±0.103	0.430±0.049 ^a	0.257±0.071 ^c
FP	0.469±0.062	0.851±0.080 ^b	0.894±0.093 ^b	1.027±0.124	1.201±0.073 ^b	0.588±0.110 ^d

^{a-b} Means within a column with different superscripts differ ($P < 0.05$).

^{c-d} Means within a column with different superscripts show a tendency to differ ($0.05 \leq P < 0.10$)

Fig. 1. MDA concentration in plasma of sows allotted to crate and pen in experiment 1,2

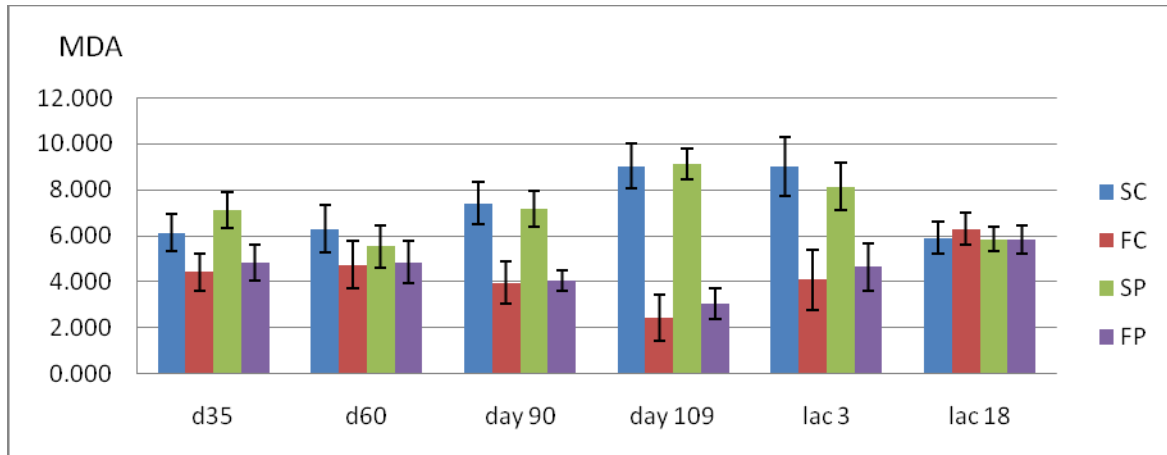


Fig. 2. Protein carbonyl concentration in plasma of sows allotted to crate and pen in experiment 1,2

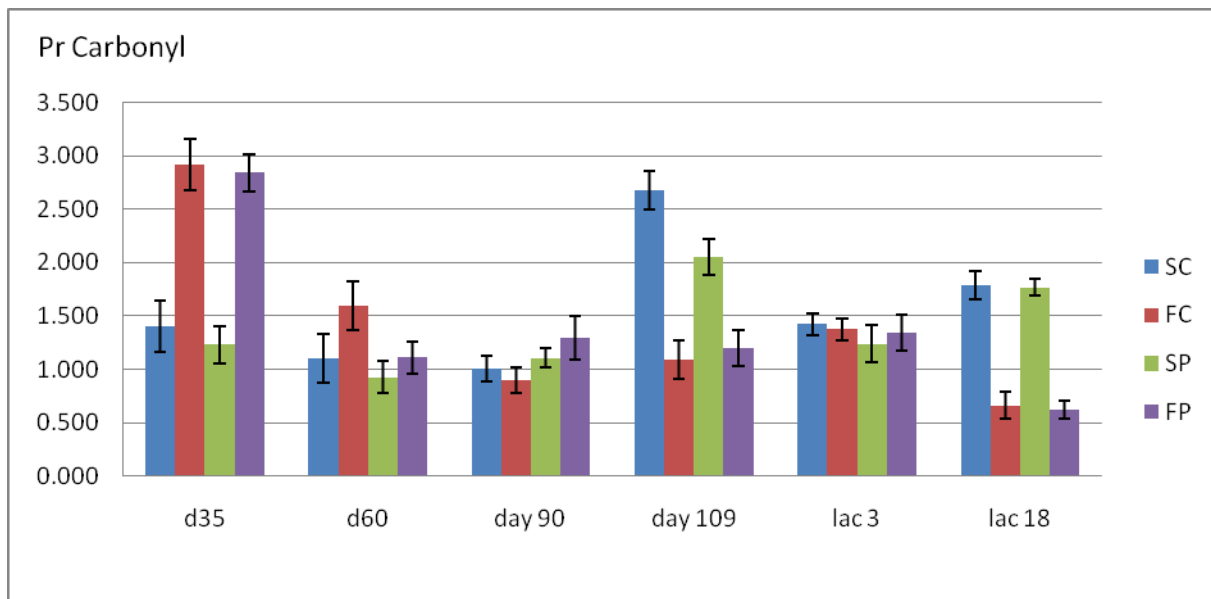


Fig. 3. 8-OHdG concentration in plasma of sows allotted to crate and pen in experiment 1,2

