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Technical Note: Application of models to estimate daily heat production of lactating sows

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ABSTRACT

The objectives of this research were to use currently available models of nutrient requirements to estimate heat production of lactating sows and to characterize potential sources of variation. Heat production was estimated using NRC (2012). Sow BW, mean daily litter weight gain (Cabezón et al., 2016a), and daily feed intake data (Cabezón et al., 2016b) from 317 sows of 2 genetic lines (164 and 153 sows) were used to predict the heat production (watts) for each day of lactation. Data were sorted in 4 parity groups: parity 1 (n = 80, P1), parity 2 (n = 57, P2), parities 3 to 5 (n = 142, P3–5), and parity 6 and greater sows (n = 38, P6+). No genetic line differences were observed for the predicted daily heat production (PDHP). The PDHP were 459, 507, 541, and 555 W for P1, P2, P3–5, and P6+ sows, respectively. Parity 1 sows had less PDHP than sows with greater parities ($P < 0.05$). Parity 2 sows had less PDHP than sows of all greater parities ($P < 0.05$). Coefficients of variation were 18.4, 17.6, 17.1, and 15.5% for P1, P2, P3–5, and P6+ sows, respectively. Within parity, variation in daily feed intake accounted for approximately 95% of the variation in PDHP. Heat production increases with parity, and there is substantial variation between sows within parity for PDHP. Strategies to remove the excess heat production of lactating sows should try to account for sources of variation in heat production.

Key words: feed intake, heat production, lactation, parity, sow

INTRODUCTION

During hot summer conditions, lactating sows are not able to dissipate their excess body heat to the environment. The continuous selection for increased litter size and milk production in current sows has reduced their upper critical temperature to approximately 18°C (Quiniou and Noblet, 1999) and increased their heat production 55 to 70% in comparison to past less productive sows (Stinn and Xin, 2014). Heat stress during lactation results in reduced daily feed intakes (**DFI**) and milk production, and negatively affects fertility (Prunier et al., 1997; Knox et al., 2013; Williams et al., 2013).

The seasonal decreases in sow productivity and fertility because of heat stress have substantial economic effects in the pork industry. Heat stress is estimated to cost the United States swine industry over $360 million annually (St-Pierre et al., 2003).

Several cooling systems have been developed to remove the excess heat from sows. Drip and snout cooling systems are currently used in the swine industry (Barbari et al., 2007). Floor cooling has been shown to improve sow productivity and reproductive performance by removal of sow excess heat (Silva et al., 2006, 2009; van Wagenberg et al., 2006). Recently, there has been more interest in developing new strategies to cool sows (F. A. Cabezón, A. P. Schinckel, and R. M. Stwalley, unpublished data). The amount of excess heat removed could be adjusted for known sources of variation in heat production. Also, there are no published data for how much variation in heat production exists within a group of sows of the same genetic line and parity.

To design and evaluate alternative methods and implementation of sow cooling pads, estimates of daily heat production during lactation are needed. Models have been developed that estimate the nutrient requirements of lactating sows (Dourmad et al., 1999, 2008; NRC, 2012); however, these models do not include equations that directly estimate daily heat production. The heat production of sows could be affected by parity and day of lactation and can vary from sow to sow. The objectives of this research were to use currently available models of nutrient requirements to estimate the heat production of lactating sows and to characterize potential sources of variation in heat production.

MATERIALS AND METHODS

Data Input and Model

Daily heat production was estimated using NRC (2012) equations that estimate nutrient requirements of lactating

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sows. Daily milk energy output was predicted from mean daily litter gain and litter size (Dourmad et al., 1999, 2008). There are 3 sources of heat production in lactating sows. The first is the heat production from maintenance requirement (100 × $BW^{0.75}$; NRC, 2012). The second is the inefficiency in which feed energy is converted to milk energy (k_f = 0.7). If body reserves are used to meet the energy demands for milk production, then the third source is the inefficiency to convert body reserves energy into milk energy (k_{br} = 0.87). The model was applied to current highly productive (Cabezón et al., 2016a,b) and past less productive sow (with lower litter size, litter weight gain, and feed intake) lactation data (Shurson et al., 1986; Noblet and Etienne, 1987). The input variables in the model were the sow BW, mean daily litter weight gain, DFI, ME content (Kcal/kg), and the percentage of standardized ileal digestibility of lysine in the diet (NRC, 2012). Because the sow BW data (Cabezón et al., 2016a) were measured before farrowing, 1.7 times the litter birth weight was subtracted from the sow BW measured before farrowing to estimate sow BW during lactation. In the trial of Cabezón et al. (2016b), feed intake was collected daily and a generalized Michaelis-Menten equation was fitted to the data. This study was conducted at a commercial, naturally ventilated farrowing facility located in Rancagua, Chile. The trial was performed during the summer over 14 wk from December 15, 2014, to March 24, 2015, in a Mediterranean climate region, classified as Csb (Köppen, 1948). During the experiment, the mean daily room temperature and relative humidity were 26.0°C and 47.0%, respectively. Only the sows with complete sow BW and mean daily litter weight gain information were used. It should be noted that the unit of heat production used in the current study was watts, which is a unit of power (J/s). This unit was used in previous research to estimate the amount of excess heat removed by cooling pads (van Wagenberg et al., 2006).

Current Sow Heat Production by Parity and Genetic Line

For current sows, the overall mean sow BW, mean daily litter weight gain (Cabezón et al., 2016a), and DFI curves (Cabezón et al., 2016b) from 317 sows of 2 genetic lines, PIC C-22 (n = 164) and L-42 (n = 153), were used to predict the mean heat production for each day of lactation. The data were sorted in 4 parity groups: parity 1 (n = 80, **P1**), parity 2 (n = 57, **P2**), parities 3 to 5 (n = 142, **P3–5**), and parity 6 and greater sows (n = 38, **P6+**). The sow BW, mean litter weight gain, and average DFI used were 184.4 kg, 2.354 kg/d, and 5.9 kg/d for P1 sows; 212.3 kg, 2.578 kg/d, and 6.5 kg/d for P2; 236.3 kg, 2.606 kg/d, and 6.9 kg/d for P3–5; and 250.9 kg, 2.581 kg/d, and 7.0 kg/d for P6+ sows, respectively.

Actual Feed Intake Curves Versus 2012 NRC Predicted Feed Intake

The predicted daily heat production (**PDHP**) values were compared between current sows using the actual DFI curves (Cabezón et al., 2016b) and using the predicted DFI curves of NRC (2012). Primiparous sows and multiparous sows were compared. The predicted DFI for sows (NRC, 2012) were adjusted for a mean temperature of 26°C to match the temperatures of Cabezón et al. (2016a,b) data.

Heat Production Comparison Between Current and Past Sows

The model was also applied to past less productive sow data (with lower litter size, litter weight gain, and feed intake) to compare the heat production estimates to current highly productive sows. Two papers were identified that reported all of the data required to estimate PDHP. The PDHP for primiparous and multiparous past sows were estimated using Noblet and Etienne (1987) and Shurson et al. (1986) data, respectively. The NRC (2012) DFI function was fitted to the overall mean lactation feed intake data from the past sows. In this manner, the overall DFI of the past sow data was reproduced. The DFI curves for the current sows were adjusted using the lowest 10% mean daily temperatures to match the temperature conditions with the past sows data. The sow BW, mean daily litter weight gain, and average DFI used for past sows were 174.5 kg, 1.879 kg/d, and 4.4 kg/d for primiparous sows (Noblet and Etienne, 1987) and 206.0 kg, 1.629 kg/d, and 4.5 kg/d for multiparous sows (Shurson et al., 1986), respectively. The sow BW, mean daily litter weight gain, and average DFI used for current sows were 184.4 kg, 2.354 kg/d, and 5.9 kg/d for primiparous and 232.8 kg, 2.595 kg/d, and 6.8 kg/d for multiparous sows, respectively.

Heat Production Comparison Between Sows at Different Temperature Conditions

The model was also applied using lactation data for sows housed at a mean temperature of 18 and 29°C (Quiniou and Noblet, 1999). The sow BW, mean daily litter weight gain, and average DFI used were 274.0 kg, 2.458 kg/d, and 5.7 kg/d for 18°C and 268.0 kg, 1.941 kg/d, and 3.1 kg/d for 29°C.

Statistical Analysis

The variance of the PDHP was calculated using the partial regression coefficients and variances for sow BW, mean daily litter weight gain, and DFI. A 2-sample t-test was performed to test for significant differences for PDHP between genetic lines and parities. For all analysis $P < 0.05$ was considered significant, and $P < 0.10$ was considered a trend.

RESULTS AND DISCUSSION

Model Comparison with Previous Research

The overall estimate on PDHP was compared with the heat production reported by Noblet and Etienne (1987), which was 8.14 Mcal/d or 394 W. When the simulation