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Uterine spaciousness during embryo and fetal development in multiparous sows improves birth weight and postnatal growth performance

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ABSTRACT

The offspring of unilaterally cauterized (CAUT) and non-cauterized control (CTRL) sows were used to study the effects of increased uterine space on postnatal average daily gain (ADG), backfat and loin depth, mortality, and adrenocorticotrophic hormone (ACTH) induced cortisol response. At gestation day (D) 35, the total number of embryos was significantly decreased in CAUT sows (CAUT=9.1 ± 3.0, CTRL=15.3 ± 4.3; P=0.001). At birth, piglet weight (WT_{D0}), gender, and morphometrics were recorded. Offspring were weighed at D21 of age, weaning, week (W) 7, 12, 16, and 19 of age. Average daily gain (ADG) was calculated during the lactation (ADG_{LACT}; 0–21days), up to weaning (ADG_{WEAN}, 1–3W), nursery (ADG_{NUR}, 3–7W), finisher (ADG_{FIN}, 7–19W), and birth to market ($ADG_{LIFETIME}$, 0–19W) periods. P2 backfat (BF) and loin eye (LOIN) depth were measured ultrasonically at 70 and 110 kg live weight. Saliva samples were collected from offspring following 5 IU/kg ACTH challenge at W12 and W20 of age. Offspring from CAUT sows were heavier than CTRL at birth and D21 ($P<0.05$), and trended higher at W7 (P=0.06). ADG_{LACT} and ADG_{WEAN} were higher in CAUT pigs ($P<0.05$). Pigs with higher ADG_{LACT} had higher $ADG_{LIFETIME}$ ($P<0.001$) after controlling for WT_{D0}. WT_{D0} however, was the most consistent factor affecting ADG in all growth periods assessed. We conclude that the postnatal growth benefits of additional uterine space associated with

Abbreviations: ACTH, adrenocorticotrophic hormone; ADG, average daily body weight gain; BF, backfat depth measured ultrasonically at the P2 site (i.e. BF_{70}=backfat at D70); BMI, body mass index (WT_{D0}/CRL^2); CAUT, animals of the unilateral oviductal cauterized group; CL, corpora lutea; CRL, crown rump length; CTRL, animals of the non cauterized group; D, day of age; DEN, density or number of pigs in the pen (i.e. DEN_{NURS}=density of nursery pens); ELISA, enzyme linked immunosorbent assay; EMB_TOT, total number of embryos counted at gestation day 35; FIN, during the finisher period (7–19 weeks of age); FOS_{YN}, whether or not a piglet was cross-fostered between litters during lactation (yes no); GNDR, sex of piglet; GRP, treatment group (i.e. CAUT or CTRL); LACT, during the lactation period (0–26 days of age); LIFETIME, during the life of the progeny (birth to 19 weeks of age); LOIN, loin (longissimus dorsi) muscle depth measured ultrasonically at the P2 site; LS_{POSFOS}, litter size suckling dam after cross fostering was completed within 24 h of birth; MT_{PRE}, preweaning mortality/deaths; MT_{POST}, postweaning mortality/deaths; NURS, during the nursery period (3–7 weeks of age); PIC, Pig Improvement Company; REP, repetition (as in one or two); UCACS, University of Saskatchewan's Committee for Animal Care and Supply; W, week of age; WT, piglet weight at (i.e. WT_{D0}=birth weight); XTMELOGIT, multilevel mixed-effects logistic regression (STATA. v11); XTMIXED, multilevel mixed-effects linear regression (STATA v11)

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a reduction in intrauterine crowding are primarily mediated through increased birth weight. Moreover, improving lactational growth rate can help offset the poor lifetime growth rates of low birth weight piglets.

1. Introduction

Research in humans and animals has shown the importance of normal fetal development in the prevention of metabolic diseases later in life. In humans, poor fetal and early postnatal growth is associated with the development of type-2 diabetes (Hales and Barker, 2001), cardiovascular and metabolic diseases in adult life. In pigs, low birth weight or body mass index are associated with altered metabolism, fat deposition (Poore and Fowden, 2004) and altered hypothalamic-pituitary-adrenal axis response which may indirectly affect the stress and inflammatory responses in postnatal life (Poore and Fowden, 2003). Intrauterine growth restriction (IUGR) is associated with impaired fetal and placental growth, and reduced number of secondary myofibres measured at gestation day 90 (Town et al., 2004). Piglets of lighter birth weight had lighter body weight in later life (Quiniou et al., 2002), and they grew slower and were fatter at slaughter (Rehfeldt and Kuhn, 2006). This latter finding was associated with decreased myofibre hyperplasia and increased myofibre hypertrophy, and resulted in an earlier plateau of myofibre growth in low compared to high birth weight pigs (Rehfeldt and Kuhn, 2006). Regarding the effect of birth weight on backfat depth, contradictory results are reported. No difference was noted at slaughter (Gondret et al., 2005), whereas low birth weight pigs had higher backfat depth compared to high birth weight pigs when measured at 12 months of age (Poore and Fowden, 2004), suggesting an age-dependent effect.

IUGR is also associated with altered early life adrenal function. Following *in vitro* stimulation of adrenal cells, low birth weight offspring from unilaterally hysterectomized ovariectomized (UHO) sows demonstrated higher total plasma cortisol concentration at 3 and 7 days of age (Klemcke et al., 1993). Low birth weight piglets also had higher adrenal weights relative to their body weight. Similarly, adrenal weight and the ratio of adrenal cortex to medulla were significantly higher at 3 months of age in low compared to high birth weight piglets, and adrenal cortex to medulla ratio trended higher at 12 months (Poore and Fowden, 2003).

Past studies investigating the biological effects of enhanced uterine space used alternate methods to alter uterine capacity and were terminated during gestation (Town et al., 2004) or immediately after farrowing (Christenson et al., 1987). Our goal was to evaluate the effects of increased uterine space during embryo and fetal development on postnatal performance up to market age, as well as on backfat (BF) and loin depth (LOIN), and on ACTH stimulated cortisol response in early and late finishing stages. This experiment was based on the hypothesis that offspring from more spacious uterine environments (unilateral oviduct cauterized; CAUT) will exhibit superior performance compared to piglets from control (non-cauterized; CTRL) litters.

Between 2007 and 2012, litter sizes in Canadian farms increased dramatically, from 12.4 to 15.0 total pigs per litter, and 11.0 to 13.3 liveborn piglets per litter (PigChamp.com, 2012). Although the CTRL sows at the time of selection were normal in terms of their reproductive performance, we were primarily interested in investigating their offspring's performance relative to the offspring of CAUT sows that were gestated in more spacious uterine environments. The specific objectives were to determine the impact of unilateral oviduct cauterization on postnatal average daily gain (ADG) during lactation (ADG_{LACT}), nursery (ADG_{NUR}), finisher (ADG_{FIN}), and from birth to market age ($ADG_{LIFETIME}$), BF and LOIN depth measured at 70 kg and 110 kg body weight, and ACTH-stimulated cortisol response assessed at W12 and W20 of age.

2. Materials and methods

The experiment was conducted in a 300-sow farrow to finish farm with the permission of the University of Saskatchewan's Committee for Animal Care and Supply (UCACS). Twenty-five PIC Line 42 (Camborough Plus) sows of parity 4–9 were selected for the experiment. Each delivered between 10 and 17 total piglets and was in good body condition at their previous farrowing and weaning respectively. In addition, they were visually inspected by farm staff and judged to be free of clinical signs of illness involving the respiratory, gastrointestinal, nervous, urogenital and musculoskeletal systems. Previous litter size did not statistically differ between group (CAUT 14.2 ± 1.9, CTRL 13.4 ± 2.2 for total born; CAUT 12.4 ± 3.2, CTRL 12.7 ± 2.2 for liveborn). The selected sows were randomly divided into CTRL and CAUT at weaning and the groups were balanced and blocked by weaning week and parity. After weaning, the selected sows were kept in individual pens and fed 2.5 to 3 kg commercial gestation diet per day (Table 1). Fourteen days post-weaning, a laparoscopic right oviduct cauterization surgery was performed on 13 CAUT sows. No surgery or placebo treatment was performed on the other 12 CRTL sows, which albeit a limitation of the study, was not performed in keeping with UCACS's desire to reduce invasive procedures in animals involved in medical research and the authors' judgment that surgery *per se,* since performed 3 weeks prior to insemination, would have minimal impact on the outcome measures. Had this interval been shorter, surgery per se may have affected subsequent performance.

2.1. Right oviductal cautery surgery

Sows were anesthetized intravenously with sodium thiopental (Thiotal, Vetoquinol Canada Inc, Lavaltrie, QC) (6 mg/kg) and anesthesia was maintained with a close circuit system of isoflurane (Isoflo, Abbott Canada) as