Comparative study on the relations between backfat thickness in late-pregnant gilts, mammary development and piglet growth[1]

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ABSTRACT: The potential relation between body condition of gilts in late-pregnancy and litter BW gain as well as mammary development was studied using 2 sets of data. Gilts either from a commercial herd (Part 1, $n = 182$) or from a series of trials looking at mammary development (Part 2, $n = 172$) were separated in 3 groups according to backfat thickness (BF) on d 110 of gestation. Group categorization was similar for Parts 1 and 2 of the study and was: low (LOW), 13.6 ± 1.6 mm (mean ± SD); medium (MED), 17.6 ± 1.0 mm (mean ± SD); and high BF (HIGH), 21.8 ± 1.8 mm (mean ± SD) for Part 1, and LOW, 14.2 ± 1.3 mm (mean ± SD); MED, 18.1 ± 1.0 mm (mean ± SD), and HIGH 23.4 ± 2.6 mm (mean ± SD) for Part 2. The effects of BF group on piglet BW gain (Part 1) or on various mammary gland characteristics (Part 2) were determined using ANOVA. Litters from HIGH sows tended to have a greater lactation BW gain than those from LOW sows ($P < 0.10$). Sows with HIGH BF had more mammary parenchymal tissue and more total protein and total DNA than MED and LOW sows ($P < 0.05$), which led to greater total protein and total DNA contents ($P < 0.05$). There were strong positive correlations ($P < 0.0001$) between parenchymal weight and total protein, total DNA, and total RNA. Results suggest that it is beneficial for primiparous sows to have greater BF (i.e., 20 to 26 mm) at the end of gestation to achieve optimal mammary development and greater litter BW gain in the subsequent lactation.

Key words: backfat thickness, gestation, lactation, mammary development, piglet growth, sow

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INTRODUCTION

Sow milk yield is a major determinant for the growth rate of suckling piglets. It can be affected by various factors and one that requires more attention is body condition of gilts. It is known that conditioning of gilts can impact lifetime reproductive performances, hence longevity in the herd (see review by Rozeboom, 2015). Certain authors recommended aiming for a backfat thickness (BF) between 16 and 19 mm (Tarrés et al., 2006) or between 18 and 20 mm (Yang et al., 1989) at first parturition to optimize fertility, productivity, survival and to lower the incidence of leg problems. A longitudinal study done over 5 parities with sows showing a wide range of BF indicated an advantage in terms of lifetime performance for sows that were genetically fatter (Lewis and Bunter, 2013). However, the potential relationship between body condition of gilts in late gestation and litter growth rate is still not clear. Obesity (BF of 36 mm) has a negative impact on mammary development (Head and Williams, 1991), which potentially translates into lower milk yield (Head et al., 1991). Furthermore, differences in BF that are seen commercially on d 110 of gestation affect mammary development in gilts (Farmer et al., 2016a,b). However, in all studies looking at mammary development, animals were slaughtered and the impact of varying BF on litter performance could not be evaluated. The use of 2 data sets, 1 from a commercial herd and the other from studies where mammary development was measured, and separation of these gilts into groups according to BF, could allow

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to establish the potential relation between body condition of gilts in late pregnancy, litter growth rate and various mammary development traits.

MATERIALS AND METHODS

This study was performed using 2 data sets. One based on zootechnical data from gestating and lactating primiparous sows in a commercial herd, and the other containing more detailed mammary development measures obtained from sows in research trials performed at the Sherbrooke Research and Development Centre of Agriculture and Agri-Food Canada. Animals used in the AAFC trials were purchased from commercial sources.

Part 1 – Sow Data from a Commercial Herd

Data from 182 primiparous sows (Landrace × Large White) from the Bonanza Sow barn (La Broquerie, MB, Canada) that met the criteria of having 12 ± 2 piglets after standardization at 24 h postpartum and a lactation length of 20 ± 2 d were used in the current study. These sows farrowed between June 2015 and March 2016 and were cared for according to the national guidelines for the care and use of animals (CCAC, 2009). Sows had been bred with semen from Duroc boars and were kept in individual stalls throughout gestation. They were fed 2.35 kg/d of a standard gestation diet (2,289 kcal/kg NE, 0.56% standard ileal digestible lysine) until d 99 of gestation and 3 kg/d of the same diet from d 100 to d 110 of gestation. They were then moved to farrowing crates and were fed 3.2 kg/d of a standard lactation diet (2,367 kcal/kg NE, 1.10% standard ileal digestible lysine). On the first 4 d of lactation feed was provided progressively with a 1 kg/d increase in 1 daily meal. As of d 5 of lactation, sows were fed ad libitum. Animals were weighed and BF was measured ultrasonically at the last rib (Vetkoplus; NOVEKO Int., Lachine, QC, Canada) at 110 d of gestation and at weaning. Measurements of BF were obtained by the same person throughout the trial after a training period ensuring there was no more than 1 mm difference in accuracy between readings. The apparatus was calibrated yearly.

Within 24 h of birth, cross-fostering was done in litters that did not have a minimum of 6 piglets. All piglets were weighed at 24 h and at weaning (20 ± 2 d). No creep feed was provided to suckling piglets so that their BW gain could reflect sow milk yield. Mortalities were recorded.

Part 2 – Mammary Development Data from Research Trials

All animals for which data are reported here were cared for according to the national guidelines for the care and use of animals (CCAC, 2009) and procedures were approved by the Institutional Animal Care Committee of the Sherbrooke Research and Development Centre of Agriculture and Agri-Food Canada. Gilts (*n* = 171) from 6 studies performed between the years 1997 and 2015 were used (see Table 1 for description). They were bred with semen from a pool of Duroc boars, housed in individual stalls (0.6 m × 2.1 m), and slaughtered on d 110 ± 1 of gestation. Gilts were weighed and had their BF measured ultrasonically at P2 of the last rib (Vetkoplus; NOVEKO Int., Lachine, QC, Canada or WED-3000; Schenzhen Well D Medical Electronics Co., Guangdong, China) on the day before slaughter. Measurements of BF were obtained by the same 2 persons throughout a project and these were not necessarily the same for all projects. They were all trained on site by the same person and readings were taken in duplicates with less than 2 mm difference accepted between readings. The average was used as value. The apparatus was calibrated yearly.

At slaughter, mammary glands from both sides of the abdominal wall were excised. Those from 1 side of the udder were stored at –20°C and once frozen were cut into 2-cm slices and stored again at –20°C. Each slice was later trimmed of skin and teats and mammary

Table 1. Description of the studies from which gilts are included in part 2 of the current trial

Reference	Number of gilts	Breed	Description of study
Farmer et al., 2000.	15	F1 Yorkshire × Landrace	Control gilts from a study where prolactin was inhibited in the last third of gestation
Farmer and Petitclerc, 2003.	12	F2 (Yorkshire × Landrace) × Yorkshire	Control gilts from a study where prolactin was inhibited in specific periods of late gestation
Farmer et al., 2012a.	32	F1 Yorkshire × Landrace	Periods of diet deprivation (70% of protein and DE) and diet overallowance (115% of protein and DE) in growing-finishing
Farmer et al., 2014.	28	F1 Yorkshire × Landrace	Diet deprivation (70% of protein and DE) for 10 wk followed by overallowance (115% of protein and DE) during gestation
Farmer et al., 2016b.	39	F1 Yorkshire × Landrace	Creating differences in BF at the end of gestation via different feeding levels in gestation
Farmer et al., 2016a.	45	F1 Yorkshire × Landrace	Maintaining differences in BF from mating to end of gestation via different feeding levels

parenchymal tissue was dissected from surrounding adipose tissue (i.e., extraparenchymal tissue) at 4°C. Both parenchymal and extraparenchymal tissue weights from this side of the udder were recorded. Parenchymal tissue from all dissected and sliced glands was homogenized and a representative sample was used for determination of composition by chemical analysis. The RNA content of parenchymal tissue was measured by ultra-violet spectrophotometry (Volkin and Cohn, 1954) and the DNA content of parenchymal tissue was evaluated in all samples using a method based on fluorescence of a DNA stain (Labarca and Paigen, 1980). Dry matter, protein, and lipid contents were also determined (methods 950.46, 928.08 and 991.39, respectively; AOAC, 2005) in parenchyma.

Statistical Analyses

The Pearson correlation coefficient between BF and average litter BW gain was calculated for sows in Part 1 of the study. Correlation coefficients between BF and numerous mammary gland characteristics for sows in Part 2 of the study were also determined. Sows from Part 1 of the study were separated in 3 groups according to BF pre-farrowing. This separation was performed with the FASTCLUS procedure of SAS (SAS Inst. Inc., Cary, NC) using a disjoint cluster analysis on the basis of distances computed between values (k-means clustering). The procedure determines the 3 cluster centers (Low, LOW; Medium, MED; High, HIGH) and assigns animals to the nearest cluster mean so that the squared distances from the cluster are minimized. Once this categorization was established, the same limits were then used to separate sows from Part 2 of the study. The MIXED procedure of SAS was then used to test for group effects (with 3 levels). Multiple comparisons were corrected with a Tukey adjustment, and the unadjusted probability comparing the 2 extreme groups (LOW vs. HIGH) is also presented. For Part 1, the dependent variables were average BW of piglets at 24 h and at weaning, average piglet BW gain, sow BF loss in lactation and BF at weaning. For Part 2, dependent variables were a series of mammary development characteristics. Data in Tables are presented as least squares means ± SEM, except when otherwise mentioned.

RESULTS

Part 1- Sow Data from a Commercial Herd

Separation of the sows in 3 groups according to their BF on d 110 of gestation led to the following: 1) low BF (LOW, n = 49), mean = 13.6 mm, SD = 1.6, minimum = 9.9, maximum = 15.6, 2) medium BF (MED, n = 92), mean = 17.6 mm, SD = 1.0, minimum = 15.9, maximum = 19.5, and 3) high BF (HIGH, n = 41), mean = 21.8, SD = 1.8, minimum = 19.9, maximum = 26.3.

There was a group effect (P < 0.001) on BF loss in lactation and BF at weaning (Table 2), and BW of sows at weaning was affected by their BF grouping but BW loss in lactation was not altered (P > 0.10, Table 2). There was no group effect on average piglet BW at 24 h, at weaning, or on average piglet BW gain between 24 h and weaning (Table 2). However, when looking at the unadjusted mean comparison, there was a tendency (P = 0.08) for average piglet BW gain between 24 h and weaning to be greater for HIGH than for LOW sows (Table 2). The correlation between BF on d 110 of gestation and average piglet BW gain between 24 h and weaning was 0.17 (P > 0.10).

Part 2 – Mammary Development Data from Research Trials

Separation of the sows in 3 groups using the same categorization as for Part 1 of the study led to the following: 1) low BF (LOW, n = 59), mean = 14.2 mm, SD = 1.3, minimum = 10.7, maximum = 16.0, 2) medium BF (MED, n = 59), mean = 18.1 mm, SD = 1.0, minimum = 16.4, maximum = 19.9, and 3) high BF (HIGH, n = 53), mean = 23.4, SD = 2.6, minimum = 20.0, maximum = 32.5.

Table 3 shows mammary gland characteristics for the 3 BF groups. There was a group effect ($P \leq 0.01$) on all measured variables except for DNA concentration and total parenchymal RNA (P > 0.10). Extraparenchymal tissue weight increased with increasing BF (P < 0.05) from LOW to MED to HIGH sows. Mean comparison also showed that HIGH sows had more mammary

Table 2. Zootechnical data for sows of low (LOW; mean of 13.6 mm, n = 49), medium (MED; mean of 17.6 mm, n = 92), or high (HIGH; mean of 21.8 mm, n = 41) backfat on d 110 of gestation and for their litters

	Groups			
Item	LOW	MED	HIGH	SEM[1]
Birth (24 h postpartum)				
Average piglet BW, kg	1.59	1.58	1.60	0.04
Weaning				
Age, d	20.7	20.7	20.9	0.21
Average piglet BW, kg	5.17	5.27	5.50	0.15
Average piglet lactation BW gain, kg	3.59	3.69	3.90	0.13
Sow BF, mm	12.0[a]	14.9[b]	18.2[c]	0.30
Sow BF lactation loss, mm	1.59[a]	2.69[b]	3.58[c]	0.26
Sow BW, kg	208.4[d]	216.2[e]	221.8[e]	2.5
Sow BW lactation loss, kg	28.6	29.9	30.6	2.2

[a–c]Means within a row with different superscripts differ (P < 0.01).

[d,e]Means within a row with different superscripts differ (P < 0.05).

[1]Maximum value.

Table 3. Mammary gland composition on d 110 of gestation for sows with a low (LOW; mean of 14.2 mm, $n = 59$), medium (MED; mean of 18.1 mm, $n = 59$), or high (HIGH; mean of 23.4 mm, $n = 53$) backfat

	Groups			
Item	LOW	MED	HIGH	SEM[1]
Extraparenchymal tissue, g	1125[d]	1287[e]	1709[f]	47
Parenchymal tissue, g	1257[d]	1325[d]	1533[e]	59
DM, %	37.3[a]	39.9[b]	40.9[b]	0.53
Fat[2], %	60.8[a]	64.9[b]	64.8[b]	0.94
Fat, g	280.3[a]	338.4[b]	395.4[c]	13.4
Protein[2], %	36.4[a]	32.7[b]	32.4[b]	0.85
Protein, g	170.2[d]	171.5[d]	203.0[e]	9.2
DNA[2], mg/g	9.55	8.91	9.18	0.33
DNA, g total	4.44[d]	4.63[d]	5.71[e]	0.27
Protein/DNA	41.2[a]	38.7[a]	35.3[b]	1.4
RNA[2], mg/g	8.74[a]	7.69[b]	7.36[b]	0.20
RNA, g total	4.07	4.03	4.53	0.20
RNA/DNA	0.98[d]	0.91[d]	0.80[e]	0.03

[a–c]Means within a row with different superscripts differ ($P < 0.01$).
[d–f]Means within a row with different superscripts differ ($P < 0.05$).
[1]Maximum value.
[2]Expressed on a DM basis.

parenchymal tissue and more total protein and total DNA than MED and LOW sows ($P < 0.05$, Tukey adjusted). Sows with LOW BF had less percent DM, percent fat and more percent protein and RNA concentration than MED and HIGH sows ($P < 0.01$). When looking at the comparison between the 2 extreme BF groups using the unadjusted probability, all measured mammary gland variables differed significantly ($P \leq 0.01$), except for total ARN for which there was a tendency ($P < 0.10$).

Correlations between BF on d 110 of gestation and the various mammary characteristics measured are shown in Table 4. There were significant correlations ($P < 0.05$) between BF and all measured variables in mammary tissue, except for DNA concentration and percent parenchymal fat. The greatest correlation was observed between BF and extra-parenchymal tissue weight ($P < 0.0001$), followed by total parenchymal fat ($P < 0.0001$), percent DM ($P < 0.0001$) and then parenchymal weight ($P = 0.0001$). There was a negative correlation between BF and RNA concentration ($P = 0.0001$; Table 4) but total RNA was positively correlated with BF ($P = 0.003$). Total DNA was also positively correlated with BF ($P = 0.001$). When looking at correlations among the mammary gland characteristics on d 110 of gestation (data not shown), many variables were related. Of interest were the strong positive correlations ($P < 0.0001$) between parenchymal weight and total protein ($r = 0.94$), total fat ($r = 0.79$), total DNA ($r = 0.83$), and total RNA ($r = 0.94$) in parenchyma. There was also a positive

Table 4. Correlation coefficients between BF on d 110 of gestation and measured mammary gland characteristics

Item	Correlation	Significance level (P)
Extraparenchymal tissue, g	0.59	< 0.0001
Parenchymal tissue, g	0.29	0.0001
DM, %	0.34	< 0.0001
Fat[1], %	0.15	0.05
Fat, g	0.44	< 0.001
Protein[1], %	–0.18	0.02
Protein, g	0.27	0.0004
DNA[1], mg/g	–0.14	0.06
DNA, g total	0.24	0.001
Protein/DNA	0.02	0.75
RNA[1], mg/g	–0.29	0.0001
RNA, g total	0.23	0.003
RNA/DNA	–0.07	0.38

[1]Expressed on a DM basis.

relation ($P < 0.0001$) between total DNA and total protein ($r = 0.85$) or total RNA ($r = 0.85$), as well as a negative association between percent protein and percent fat ($r = –0.97$, $P < 0.0001$).

DISCUSSION

Through a comparative study using data sets from different populations, current findings provide a first look at the potential links between body condition of primiparous sows at the end of gestation, mammary development at that same time and subsequent litter performance. The effect of body condition on mammary gland development in primiparous sows at the end of gestation was previously demonstrated (Farmer et al., 2016a,b) but animals were slaughtered and lactation performance could not be determined. The link between body condition and reproductive performance was suggested by many authors (Yang et al., 1989; Tarrés et al., 2006; Schenkel et al., 2010; Lewis and Bunter, 2013; Rozeboom, 2015) but mammary development was not investigated. The only report on the relation between body condition, mammary development in late gestation and subsequent milk yield is that of Head and Williams (1995). However, that study was performed with only 7 sows per body condition group, which is not adequate to study a factor as variable as piglet growth. Nevertheless, it provided indications that such a line of study would be of interest.

The relation between BF in late gestation and piglet growth rate observed in the current study corroborates findings of Rempel et al. (2015), who also used a large number of animals. Amdi et al. (2014) also demonstrated that maternal body condition at mating has an effect on piglet growth rate; piglets born from gilts with a BF of 19 mm had improved growth compared with piglets from sows with 12 mm BF. This could have been partly due to the fact that fatter sows had 25% more milk fat than thin sows on d 21 of lactation (Amdi et al., 2013). The greater extraparenchymal weight reported in the current study with increased BF was to be expected due to improved body condition. The fact that total parenchymal fat also increased with BF is of interest and this was due both to a greater fat percent and to a greater parenchymal weight. To the contrary, the observed effects of BF on total protein and total DNA were solely due to greater parenchymal weight and not to increased parenchymal concentrations of these variables. In fact, percent protein decreased with increasing BF. It therefore appears that increasing parenchymal weight in late gestation should be the major goal to improve milk yield and growth of suckling piglets in the subsequent lactation. Yet, it is not known if this effect would last in the following parities. Rozeboom et al. (1996) showed that body reserves of gilts at first breeding impacts BW of mature sows but has no long-term effect on BF. However, it is not known if changes in mammary development of gilts related to their body condition in late gestation would still be present in subsequent parities. It was demonstrated that non-use of a teat in first lactation will decrease its milk yield in second lactation (Farmer et al., 2012b) but the potential impact of mammary development in late gestation on lactation performance in subsequent parities was never investigated. Lewis and Bunter (2013) suggested a lasting effect of fatness on productivity of sows over 5 parities, and an effect of BF at weaning on subsequent litter size was also reported (Schenkel et al., 2010). Kim et al. (2016) further reported a long-term effect of BF with multiparous sows having a BF ≥ 20 mm on d 107 of gestation showing increased growth of their piglets until weaning, and this over 2 consecutive parities. Yet, further research is needed to determine if the effect of BF on mammary development would be present in subsequent parities.

The strong positive correlations between parenchymal weight and total protein, total DNA and total RNA in parenchyma suggest that a measure of parenchymal weight could be a good estimate of important mammary composition variables. It would be of interest to develop methods to estimate mammary parenchymal weight in live animals to assess their mammary development. Balzani et al. (2015) developed a methodology to look at udder conformation in sows but they did not attempt to find measures that would estimate the volume of mammary glands and they did not relate any measured variables with piglet growth. Such information would be very pertinent for producers.

Current results suggest that it is beneficial for primiparous sows to have greater BF (i.e., 20 to 26 mm) at the end of gestation to show optimal mammary development and increased litter BW gain in the subsequent lactation. However, the exact cut-off point is not clear and will likely be affected by breed. When a cut-off point of 18 mm BF was used to compare lactation performances of primiparous sows, and 20 mm was used as cut-off point for multiparous sows, no differences in piglet growth rate were reported (Rekiel et al., 2015). However, the sample size was small (10 or 20 sows per group). Kim et al. (2015) compared numerous small ranges of BF on d 109 of gestation and concluded that, irrespective of parity, litter weight gain increases quadratically with BF to reach an optimal breakpoint between 17 and 21 mm, above which there is no further increase in BW gain. In fact, sows with very high BF (> 25 mm) had litters with smaller BW gain compared with sows having 20 to 24 mm BF. Interestingly, when using 17.6 mm as cut-off point (MED sows) to compare parenchymal tissue composition, current results show a greater fat percent and lower protein percent and RNA concentrations in sows with greater BF. Previous and current findings therefore indicate that it is more detrimental for primiparous sows to be too lean than too fat at the end of gestation. This is in accordance with the recommendation from Schenkel et al. (2010) who stated the importance of achieving adequate body condition at parturition. It also corroborates the negative correlation reported between BF around puberty and longevity in sows (López-Serrano et al., 2000). Those last authors attributed this effect to decreased pregnancy rate and greater occurrences of leg weakness syndrome but the potential impact on mammary development was not studied. Overall, information from published and current results indicate that either too low (< 15 mm) or too high (> 26 mm) a BF in late gestation may lead to reduced piglet growth rate. Maintaining a moderate body condition therefore seems to be the best strategy.

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