# Effects of extra feeding in mid-pregnancy for three successive parities on lean sows' productive performance and longevity

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Cerisuelo, A., Sala, R., Gasa, J., Carrión, D., Coma, J., Chapinal, N. and Baucells, M. D. 2010. **Effects of extra feeding in mid-pregnancy for three successive parities on lean sows' productive performance and longevity**. Can. J. Anim. Sci. **90**: 521–528. The aim of this study was to investigate the long-term effects of increasing feeding allowance during mid-pregnancy in sows. A total of 103 PIC pregnant sows (mixed parity) were allocated to two treatments: control (C, $n = 49$) were fed 2.5–3.0 kg $d^{-1}$ (12.1 MJ ME $kg^{-1}$) and extra-fed (E, $n = 54$) received +2.0 kg $d^{-1}$ of the same feed from day 45 to 85 of gestation over three consecutive cycles. Body weight, backfat thickness (BF) and loin depth were measured on days 45 and 85 of gestation, farrowing and weaning. Litter and sows performance were recorded during lactation and post-weaning. Overall culling rates were 61 and 67% for C and E groups, respectively. After three cycles, E sows showed a positive BF balance in contrast to C sows (E = +1.46 mm and C = −1.81 mm, $P < 0.05$). In cycle 3, E sows presented greater piglet birth weights than C sows, being mainly evident in sows that were nulliparous at the onset of the experiment ($P < 0.05$). Extra-fed sows showed a greater incidence of mastitis-metritis-agalactia syndrome than C sows ($P = 0.003$). Thus, increasing feeding allowance during mid-pregnancy positively affected BF balance and birth weight in nulliparous sows, but impaired the sows' ability to produce milk in the long-term.

**Key words:** Sow nutrition, body reserves, sow performance

Cerisuelo, A., Sala, R., Gasa, J., Carrión, D., Coma, J., Chapinal, N. et Baucells, M. D. 2010. **Effets de l'augmentation de l'apport d'aliment au milieu de la gestation au cours de trois cycles successifs d'élevage sur les performances zootechniques et la longévité de truies maigres**. Can. J. Anim. Sci. **90**: 521–528. L'objectif de cette étude est de déterminer l'effet à long terme de l'accroissement de l'apport d'aliment au milieu de la gestation en truies. Au total, 103 truies PIC gestantes (de différents rangs de portée) sont réparties en deux traitements; un lot témoin (T, $n = 49$) recevant 2.5–3.0 kg $j^{-1}$ (12.1 MJ EM $kg^{-1}$); et un lot sur-alimenté (SA, $n = 54$) recevant un supplément de +2 kg $j^{-1}$ du même aliment entre 45 et 85 jours de gestation, au cours de trois cycles successifs d'élevage. Le poids vif, l'épaisseur de lard dorsal (ELD) et l'épaisseur de la longe sont mesurés aux jours 45 et 85 de gestation, à la mise bas et au sevrage. Les performances des truies et des porcelets sont mesurées au cours de la lactation et après le sevrage. Le taux d'élimination des truies s'élève à respectivement 61% et 67% pour les lots T et SA. Après trois cycles, les truies SA présentent un bilan d'ELD positif alors qu'il est négatif pour les truies T (SA = +1.46 mm et T = −1.81 mm, $P < 0.05$). En cycle 3, les truies SA donnent naissance à des porcelets plus lourds que les truies T, cet effet étant plus net pour les truies qui étaient nullipares au début de l'expérience ($P < 0.05$). L'incidence du syndrome mammite-métrite-agalactie est plus élevée pour le lot SA que pour le lot T ($P = 0.003$). L'accroissement du niveau alimentaire au milieu de la gestation a donc un effet positif sur le bilan d'ELD et le poids des porcelets à la naissance, mais ceci pourrait s'accompagner d'un effet négatif à long terme sur la production de lait chez les truies.

**Mots clés:** Nutrition des truies, réserves corporelles, performances des truies



Lifetime, welfare and overall productive-reproductive efficiency of the breeding herd have been strongly related to nutrition and, hence, the maintenance of adequate levels of body reserves (Whittemore 1993; Maes et al. 2004). A major concern on the hyperprolific lean sow genotypes is the depletion of body reserves occurring from cycle to cycle, which leads to early culling due to reproductive failure (Mahan 1998; Eissen et al. 2000; Boulot et al. 2008). Feeding sows to maximize prolificacy and longevity is becoming increasingly difficult; the greater demands for productivity have also increased nutrient demands. Moreover, genetic selection for leanness has developed animals with lower fat stores and small appetite, which is mostly evident

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**Abbreviations:** **ADG**, average litter daily gain; **BCS**, body condition score; **BF**, backfat thickness; **BW**, body weight; **LD**, loin depth; **WMI**, weaning to mating interval during lactation (Eissen et al. 2000). Overall, this leads to a severe drain on body weight and body reserves in lactation and, consequently, an impairment of productive and reproductive performance (Prunier and Quesnel 2000; Clowes et al. 2003, Thaker and Bilkei 2005). The sow's feeding pattern has been lightly modified in the past 30 yr. Therefore, in concordance with the change in nutrient requirements, it seems necessary to review feeding strategies and to adapt them to current hyperprolific and lean sows.

Pregnant sows are generally fed restrictedly in order to avoid excessive fatness at farrowing and a decrease in lactation feed intake (Dourmad 1991). But this feeding strategy does not always allow recovery of the amount of body reserves lost in the previous lactation (Young et al. 1990; Mahan 1998). Additionally, evidence demonstrates that in lean genotypes, larger amounts of body reserves at farrowing (fat and lean) may be able to buffer detrimental effects of body reserve losses during lactation on reproductive performance (Dourmad et al. 1994; Clowes et al. 2003). Increasing feed allowances during gestation could thus be beneficial to maintain sow body reserves from cycle to cycle, and to improve herd performance.

In early gestation, feeding levels are maintained low in order to avoid possible embryo mortality. On the other hand, during the final part of gestation sow nutrient demands increase exponentially due to foetal growth, thereby limiting nutrient use for sow body reserves recovery. Thus, as was also observed by Ji et al. (2005), the optimum time during gestation to influence maternal body reserves through increasing feeding levels might be the middle period (30 to 90 d). Additionally, studies suggest that extra maternal feeding during this period might impact foetal growth and muscle development (Dwyer et al. 1994; Cerisuelo et al. 2009), although its consequences on sow condition have not been previously addressed.

The purpose of the present study was to determine the consequences of increasing feed intake, including both energy and protein allowances, during mid-pregnancy on body reserve management and productive-reproductive performance in sows of different parities over three successive cycles.

## MATERIALS AND METHODS

### Animals and Experimental Design

The experiment was conducted during a 13-mo period (January 2003–February 2004), and received prior approval from the Animal Protocol Review Committee of the Universitat Autònoma de Barcelona (Spain). The study involved 103 PIC Camborough (Landrace × Large White) sows from zero to four parities that were kept under study during three successive reproductive cycles (day 45 of gestation to day 45 of gestation of the subsequent cycle). Animals were selected on day 40 of gestation in cycle 1 (after positive pregnancy test), blocked by parity, day of mating, body weight (BW) (kg) and body condition [back fat (BF; mm) and loin depth (LD; mm)] and allotted randomly into two treatment groups: Control (C, $n = 49$) and Extra-fed (E, $n = 54$) sows. Mean sow parity was 2.28 (Table 1) and the average sow weight, BF and LD at allocation were 194.3 ± 37.7 kg, 17.0 ± 3.6 mm and 55.1 ± 4.3 mm, respectively.

Treatments involved two different feeding levels allowed during mid-gestation (from day 45 to day 85 of gestation). Sows were fed a fixed amount of feed, ranging from 2.5 to 3.0 kg $d^{-1}$ of a standard commercial diet (12.1 MJ ME $kg^{-1}$ and 0.62% lysine on average) from mating to day 45 of gestation, and from day 85 of gestation to parturition. This fixed amount of feed was assigned to each sow individually at mating according to its BCS. Body condition score was always measured by the same operator, using a 1 to 5 scale. From day 45 to day 85 of gestation, C sows maintained their previous feeding level, while sows in the E group received an extra amount of feed (same feed) of 2.0 kg $d^{-1}$ above the C level. The desired E feeding level was gradually reached in 4 d (days 41 to 45 of gestation). The presence of feed refusals was monitored daily during the experimental period. Gestation and lactation diet composition is given as ranges of minimum, maximum and average levels in Table 2.

### Housing, Management and Measurements

The management, housing and husbandry conformed to European Union Guidelines. During gestation, sows were housed in individual stalls and fed twice daily (0800 and 1430) with dry feed in a trough feeder. In each cycle, sows were all allocated to the same room and grouped by treatment. Water was available ad libitum in the trough between feeding times. Maximum and minimum temperatures in the gestation barn were recorded daily. About 1 wk before farrowing (110 d of gestation) sows were moved to the farrowing crates. The average lactation length was 22 ± 2 d. Feed during lactation was given as dry feed twice a day (0800 and 1430) and the sows had free access to water via nipple drinkers placed in the feeder. For all sows, feeding level during lactation was gradually increased, from 0 kg $d^{-1}$ on the day of farrowing, to a maximum of 7.7 kg $d^{-1}$ (as-fed basis) on day 14 of lactation, and then maintained at this level until weaning.

**Table 1. Parity distribution of sows in cycle 1**

| | Treatment | |
|---|---|---|
| Parity | Control sows | Extra-fed sows |
| 0 | 18 | 22 |
| 1 | 9 | 13 |
| 2 | 9 | 10 |
| 3 | 10 | 6 |
| 4 | 3 | 3 |
| Total | 49 | 54 |

**Table 2. Composition and nutrient content (minimum and maximum levels) of the gestation and lactation diets (as-fed basis)**

| | Gestation | | | Lactation | | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Average | Minimum | Maximum | Average |
| *Ingredient (%)* | | | | | | |
| Barley | 20.5 | 55.8 | 33.7 | 28.0 | 40.0 | 32.1 |
| Wheat bran | 11.5 | 43.8 | 34.3 | 8.0 | 24.3 | 17.5 |
| Sugar beet molasses | 2.0 | 6.5 | 5.2 | 3.0 | 6.0 | 3.3 |
| Wheat | 6.0 | 9.0 | 7.9 | 9.1 | 43.0 | 20.9 |
| Cassava meal | – | – | – | 15.0 | 17.5 | 16.3 |
| Soybean meal, 44% CP | 3.5 | 6.6 | 4.9 | 11.3 | 25.3 | 18.4 |
| Sunflower meal | – | 12.3 | 8.1 | 3.0 | 10.0 | 6.4 |
| Animal fat | 2.8 | 6.0 | 4.6 | 5.8 | 6.2 | 6.0 |
| Calcium carbonate | 1.2 | 1.5 | 1.4 | 1.4 | 1.8 | 1.6 |
| NaCl | 0.20 | 0.33 | 0.25 | 0.39 | 0.48 | 0.45 |
| Monocalcium phosphate | – | 0.55 | 0.17 | 0.50 | 0.90 | 0.71 |
| L-LysineHCl – 50% | – | 0.15 | 0.03 | – | 0.38 | 0.16 |
| Choline chloride – 75% | – | 0.03 | 0.01 | – | 0.03 | 0.02 |
| Vitamin and mineral premix[z] | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| *Calculated composition (%)* | | | | | | |
| ME (MJ kg$^{-1}$) | 12.0 | 12.3 | 12.1 | 12.8 | 13.0 | 12.9 |
| Crude fat | 6.8 | 8.1 | 7.3 | 7.2 | 8.2 | 7.8 |
| Crude fibre | 7.3 | 7.7 | 7.5 | 6.3 | 6.6 | 6.4 |
| Crude protein | 13.8 | 15.3 | 14.6 | 16.5 | 17.8 | 17.2 |
| Lysine | 0.59 | 0.65 | 0.62 | 0.88 | 0.90 | 0.89 |
| Ca | 0.68 | 0.71 | 0.70 | 0.90 | 0.92 | 0.91 |
| Available P | 0.23 | 0.28 | 0.26 | 0.30 | 0.35 | 0.33 |

[z]Provided per kilogram of feed: 10 000 IU of vitamin A; 2000 IU of vitamin $D_3$; 40 mg of vitamin E; 6 mg of vitamin K; 1 mg of vitamin $B_1$; 6 mg of vitamin $B_2$; 0.02 mg of vitamin $B_{12}$; 29 mg of nicotinic acid; 11.71 mg of pantothenic acid; 0.5 mg of folic acid, 0.06 mg of biotin; 80 mg of Fe; 25 mg of Cu; 0.40 mg of Co; 100 mg of Zn; 43.20 mg of Mn; 2.25 mg of I and 0.09 mg of Se.

At 24 h post-farrowing, litter size was adjusted to 10–11 pigs per litter and cross-fostering was only allowed among sows of the same treatment. No creep feeding was provided to the piglets during lactation. From 2 d post-weaning, sows were checked every morning in order to detect oestrus using a teasing boar. Oestrus was identified through lordosis reflex and vulva status. Sows were inseminated via artificial insemination on the day the heat was detected and thereafter every 24 h for a maximum of 3 consecutive days. A PIC Industrial halothane negative boar was used. From the first insemination (day the oestrus was detected) until the pregnancy test (30 d of gestation), sows were monitored daily in order to detect a return to oestrus, infections and other incidences. The culling rates of sows over the three cycles were also recorded.

Sows were weighed on day 45 of gestation, at $48 \pm 24$ h post-farrowing and at weaning. Backfat thickness and LD were measured above the last rib at approximately 6.0–6.5 cm from the midline using an A-mode ultrasound device (Renco sonograder 4.2, Renco Corporation, Minneapolis, MN) on days 40, 85 and 110 of gestation and on day $18 \pm 1$ of lactation. The point of the initial scan was marked to ensure that subsequent scans were recorded at the same place.

At farrowing, piglets, including total, alive and stillborn, were counted and weighed individually. The number of pigs and their weights were recorded again, after cross-fostering and on day $18 \pm 1$ of lactation. Mastitis-metritis-agalactia incidence (MMA) in sows, piglet mortality and causes of death during lactation were recorded. The main criteria (clinical evidence) used for determining MMA syndrome was a shortage of milk visualized as poor piglet growth and high piglet mortality due to starvation (sows with fewer than four pigs remaining on day 18 of lactation). Other signs detected were udder tissue poorly developed, hard and oedema. Weaning-to-mating interval was also recorded. By program design, sows that were not detected in oestrus after 7 d or more from weaning and also sows that returned to oestrus after insemination were not maintained in the next cycle. Other reasons for sow elimination were abortion, lameness, total agalactia and other health problems.

## Statistics

All the analyses were performed using the SAS statistical package, Version 9.1 (SAS Institute Inc. 2001). The main classification effect considered was the feeding treatment (feed allowance during mid-gestation). Experimental cycle and sow parity (initial sow parity in cycle 1) were also added in the model, but they were only discussed when significant interactions with treatment were found. Data from the 37 sows that ultimately completed the three cycles (initial BF and LD levels and changes and overall productive performance) were also analysed according to the procedures described below for these variables. To test differences between culling rates and MMA incidence a chi-square analyse (PROC FREQ) was performed. Sows' BW and body condition (BF and LD) evolution over the three cycles were analysed according to a repeated measures model using the MIXED procedure and considering sows as the repeated factor. Net changes of sows' body condition, ADG during lactation and WMI were analysed through an ANOVA model using SAS GLM procedure. For litter ADG, litter weight at 24 h post-farrowing (after cross-fostering) was used as a covariate term. The numbers of total born, born alive, stillborn and pigs on day 18 of lactation were analysed using a statistical model for counting data (GENMOD procedure). Litter and average piglet weight at birth and on day 18 of lactation were evaluated through an ANOVA model using a GLM procedure. Litter size was used as a covariate term for litter weight and average piglet weight at birth. Litter weight and piglet weight after cross-fostering were used as covariates for litter weight and piglet weight, respectively, on day 18 of lactation.

## RESULTS

Out of the 103 sows initially assigned to the study, 54 animals (C = 26 and E = 28) remained until weaning in cycle 3, and 37 animals (C = 19 and E = 18) remained until day 45 of pregnancy in cycle 3. A total of 30 sows (61%) from the C group and 36 sows (67%) from the E group were then removed from the study over the three cycles studied (from day 45 of gestation in cycle 1 to day 45 of gestation in cycle 3; $P = 0.565$). The different causes of sows' removal are summarized in Table 3. The main reason for culling was failure to conceive (returning to oestrus after mating); C group showed a higher percentage of sows eliminated due to returning to oestrus after mating (C = 40.8% and E = 31.5%), but based on a chi-square analysis this difference was not significant ($P = 0.324$). Three sows were eliminated due to MMA and four sows were eliminated from the study due to extended WMI, all from the E group. In addition to the three sows eliminated due to total MMA, partial MMA syndrome was diagnosed in nine sows, all of them from the E group ($P = 0.003$). Six of these nine sows belonged to parity 3 or onwards and three to parity 1 or 2 (66.7% vs. 33.3%, $P = 0.254$). Further causes of culling, such as abortion, sudden death, prolapse and illness, were occasional and not related to dietary treatments.

**Table 3. Culled sows and main causes for culling in the three cycles (C: control sows and E: extra-fed sows)**

| | Experimental cycle[z] | | | | | |
|---|---|---|---|---|---|---|
| | Cycle 1 | | Cycle 2 | | Cycle 3 | |
| Item | C | E | C | E | C | E |
| No observations | 49 | 54 | 36 | 39 | 27 | 31 |
| Culled sows (%) | 26.5 | 27.8 | 25.0 | 20.5 | 29.6 | 41.9 |
| *Reasons for culling* | | | | | | |
| Return to oestrus after mating | 7 | 8 | 6 | 5 | 7 | 4 |
| Delayed weaning to mating interval | 0 | 2 | 0 | 0 | 0 | 2 |
| Abortion | 1 | 0 | 0 | 0 | 0 | 1 |
| MMA syndrome | 0 | 2 | 0 | 1 | 0 | 0 |
| Severe lameness | 0 | 0 | 1 | 1 | 0 | 1 |
| Sudden death | 1 | 3 | 0 | 0 | 0 | 1 |
| Others (illness, sudden death, rectum and uterus prolapse ...) | 4 | 0 | 2 | 1 | 1 | 4 |

[z]Experimental cycle is defined as day 45 of gestation to day 45 of gestation of the subsequent cycle.

No feed refusals were observed in the C and E groups of sows during the experimental period in cycle 1 and cycle 3. Feed intake in both treatment groups from day 45 to day 85 of gestation was the maximum expected for each sow (cycle 1, C = 2.8 and E = 4.9 kg $d^{-1}$; cycle 3, C = 2.9 and E = 4.9 kg $d^{-1}$). In cycle 2, the maximum temperatures in the barn exceeded 30°C (maximum of 35°C and minimum of 15°C) and feed intake during the experimental period in the E group was lower than the desired level ($88.1 \pm 0.61$% of the desired level), while feed intake in the C group was not affected by the high temperatures (C = 2.8 and E = 4.3 kg $d^{-1}$, Table 4).

There was no experimental cycle × treatment response criteria interaction. Therefore, gestation treatment means are reported for each of the three reproductive cycles and for the overall (average of the three reproductive cycles) treatment response criteria (Table 4). The total number of observations (confirmed pregnancy) for all the three experimental cycles combined was 112 for sows fed the C diet and 124 for sows fed the E regime. Increasing feeding level during mid-gestation led to greater BF and LD gains during the experimental period (day 45 to day 85 of pregnancy, $P < 0.05$, Table 3) in the three cycles studied and overall (average of the three experimental cycles). This led to greater BF levels at farrowing and also at weaning in E sows from cycle 2 and cycle 3, but LD did not show this accumulative pattern. Also, BW gained from day 45 of gestation until farrowing was significantly greater in E compared with C sows in cycle 2 and cycle 3 and overall ($P < 0.01$). No differences were detected in BW, BF and LD losses during lactation between treatments. Additionally, no initial parity (cycle 1) × treatment effect was detected for body reserves balance.

Feed supplementation during mid-pregnancy did not affect the number of total born, born alive and stillborn pigs (Table 4). However, in cycle 3, E sows showed a greater average piglet weight at birth ($P < 0.05$) and a tendency to a greater litter weight ($P < 0.10$) compared with C sows. This effect on piglet birth weight was also evidenced in the mean values of the three cycles ($P = 0.097$). Overall, maternal dietary treatment did not show significant effects on lactation performance. However, in cycle 3, sows from the E group tended to have fewer pigs on day 18 of lactation compared with C sows (C = 9.3 and E = 8.3, $P = 0.078$). This result was supported by pig mortality rates, which tended to be

**Table 4. Effects of extra-feeding sows (E) vs. feeding conventionally (C) in mid-gestation on sow body reserves and litter performance over three consecutive reproductive cycles[z]**

| | Experimental cycle | | | | | | Overall means for the three cycles | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | | | |
| Item | C | E | C | E | C | E | C | E | Pooled SE |
| No observations | 49 | 54 | 36 | 39 | 27 | 31 | 112 | 124 | |
| Mean daily feed intake from day 45 to day 85 of gestation (kg) | 2.9 | 4.9 | 2.8 | 4.3 | 2.9 | 4.9 | 2.8 | 4.7 | |
| *Body weight changes and levels (kg)* | | | | | | | | | |
| Changes from day 45 of gestation to farrowing | 23.7 | 26.2 | 14.0*B* | 22.6*A* | 13.2*B* | 31.4*A* | 17.9*B* | 26.1*A* | 1.08 |
| Levels at farrowing | 227.0 | 228.1 | 239.3 | 246.5 | 252.1*B* | 265.2*A* | 232.8 | 237.2 | 3.67 |
| Levels at weaning | 207.2 | 205.9 | 224.6*B* | 236.8*A* | 253.1 | 258.0 | 219.7 | 223.3 | 3.67 |
| *Backfat thickness changes and levels (mm)* | | | | | | | | | |
| Changes from day 45 to day 85 of gestation | 0.1*B* | 1.8*A* | 1.6*B* | 4.2*A* | 2.3*B* | 5.4*A* | 1.2*B* | 3.4*A* | 0.27 |
| Levels at farrowing | 18.6 | 18.5 | 18.0*B* | 19.6*A* | 19.7*B* | 21.9*A* | 18.4*B* | 19.7*A* | 0.35 |
| Levels at weaning | 15.0 | 14.9 | 15.3*B* | 17.2*A* | 15.6*B* | 18.3*A* | 15.1*B* | 16.4*A* | 0.36 |
| *Loin depth changes and levels (mm)* | | | | | | | | | |
| Changes from day 45 to day 85 of gestation | 4.9*B* | 7.5*A* | 0.8*B* | 6.3*A* | 1.5*B* | 6.6*A* | 2.8*B* | 6.9*A* | 0.55 |
| Levels at farrowing | 61.3 | 61.8 | 62.9*B* | 66.3*A* | 63.9 | 65.3 | 62.5 | 64.0 | 0.49 |
| Levels at weaning | 57.4 | 58.4 | 57.4*tb* | 59.4*ta* | 61.7 | 61.5 | 58.4 | 59.2 | 0.50 |
| *Litter performance at birth* | | | | | | | | | |
| No. total born[y] | 12.7 | 12.9 | 13.4 | 13.3 | 13.7 | 13.5 | 13.2 | 13.2 | |
| No. born alive[y] | 11.8 | 12.0 | 12.3 | 11.8 | 12.2 | 11.9 | 12.1 | 11.9 | |
| Stillborn[y] | 0.89 | 0.77 | 1.07 | 1.33 | 1.41 | 1.51 | 1.12 | 1.17 | |
| Litter weight at birth (kg) | 19.0 | 19.5 | 19.2 | 19.5 | 18.7*tb* | 19.8*ta* | 19.0 | 19.5 | 0.25 |
| Piglet birth weight (kg) | 1.55 | 1.59 | 1.48 | 1.50 | 1.38*B* | 1.49*A* | 1.48*t* | 1.53*t* | 0.020 |
| *Litter performance on day 18 of lactation* | | | | | | | | | |
| No. pigs[y] | 10.2 | 10.0 | 9.5 | 9.3 | 9.3*ta* | 8.3*tb* | 9.7 | 9.3 | |
| Litter weight (kg) | 60.4 | 59.2 | 52.3 | 52.0 | 47.5 | 48.7 | 53.4 | 53.4 | 0.70 |
| Piglet weight (kg) | 5.9 | 5.8 | 5.6 | 5.4 | 5.3 | 5.5 | 5.6 | 5.6 | 0.07 |
| ADG[x] (kg) | 2.50 | 2.36 | 2.18 | 2.13 | 2.22 | 2.03 | 2.29*ta* | 2.17*tb* | 0.045 |
| Piglet mortality (%) | 3.2 | 5.3 | 11.2 | 6.5 | 16.0*tb* | 23.9*ta* | 9.8 | 11.9 | 1.37 |

[z]Statistical comparisons were made within each cycle.
[y]In counting data standard error is not given (PROC GENMOD).
[x]ADG, litter average daily gain.
*A*, *B* Values with different letters differ significantly, effect of diet ($P < 0.01$).
*ta, tb* Approaching significance ($P \leq 0.10$).

greater in the E group compared with C sows in cycle 3 ($P = 0.064$). Litter growth rates during lactation were not different between treatments but showed a tendency to be lower in E sows ($P = 0.064$, Table 4) when data of the three cycles were pooled (average of the three experimental cycles).

Additionally, considering data from only the 37 animals that ultimately completed the three cycles, the magnitude of BW and body reserve changes over the three cycles and the mean initial BF and LD levels on day 45 of gestation in cycle 1 (initial point of the study) were calculated and are summarized in Table 5. Also, lifetime (sum of the three cycles) number and weight of pigs farrowed and remaining on day 18 of lactation from this pool of sows ($n = 37$) were calculated and are summarized in Table 5. Extra-fed sows showed greater BW gains than C sows over the three cycles (E = 71.1 kg and C = 53.9, $P = 0.019$) and a positive final BF balance in contrast to C sows, which showed a negative BF balance (E = +1.46 mm and C = −1.81 mm, $P = 0.004$) over the three experimental cycles. At the initial point of the study (day 45 of gestation in cycle 1) BF levels were similar between treatments, independent of the feeding regime followed in gestation (C = 18.4 mm and E = 16.9 mm, $P = 0.127$) and LD levels tended to be higher in the C compared with E group of sows (C = 55.9 mm and E = 52.8 mm, $P = 0.052$). Extra-feed allowance during mid-pregnancy did not affect the total number of pigs farrowed (39–40 pigs) and weaned (28–29 pigs) or mean litter and piglet weights on day 18 of lactation. However, extra-fed sows again showed greater ($P < 0.05$) average litter and piglet weights at birth compared with C sows.

After weaning, WMI was not affected by the increased feed allowance during mid-gestation in any of the three cycles studied (cycle 1: C = 4.5 d and E = 4.9 d, $P = 0.353$; cycle 2: C = 4.4 d and E = 4.3 d, $P = 0.349$; cycle 3: C = 4.2 d and E = 5.3 d, $P = 0.226$). These mean values include the four sows eliminated from the study due to delayed WMI. Farrowing rates calculated as

**Table 5. Overall body reserves changes (from day 45 of gestation in cycle 1 to day 45 of gestation in cycle 3) and total litter performance over three successive cycles from sows that ultimately completed the three cycles ($n = 37$)**

| | Treatments | | |
|---|---|---|---|
| Treatments | Control | Extra-fed | SE |
| *n* sows | 19 | 18 | |
| *Initial amounts of body reserves* | | | |
| Backfat thickness (mm) | 18.4 | 16.9 | 0.72 |
| Loin depth (mm) | 55.9*ta* | 52.8*tb* | 1.13 |
| *Changes on body reserves* | | | |
| Body weight (kg) | 53.9*a* | 71.1*b* | 5.06 |
| Backfat thickness (mm) | −1.81*A* | 1.46*B* | 0.76 |
| Loin depth (mm) | 6.50*a* | 10.95*b* | 1.37 |
| Birth performance | | | |
| No. total born[z] | 39.1 | 40.2 | |
| Total litter birth weight (kg) | 57.3*B* | 58.2*A* | 1.25 |
| Average piglet birth weight (kg) | 1.49*B* | 1.52*A* | 0.031 |
| *Lactation performance* | | | |
| No. pigs[z] | 28.9 | 28.2 | |
| Total litter weight on day 18 (kg) | 163.3 | 166.2 | 3.46 |
| Average pig weight on day 18 (kg) | 5.62 | 5.55 | 0.090 |

[z]In counting data standard error is not given (PROC GENMOD).
*A*, *B* Values with different letters differ significantly, effect of diet ($P < 0.01$).
*a*, *b* Values with different letters differ significantly, effect of diet ($P < 0.05$).
*ta, tb* Approaching significance ($P \leq 0.10$).

[(farrowed sows/mated sows) × 100)] were also similar between treatments (cycle 2; C = 83.7%, E = 81.0% and cycle 3; C = 76.5%, E = 78.0%).

## DISCUSSION

### Gestation Feeding Regime and Sow Body Reserves

In current intensive production systems, fat tissue is not likely to be accumulated from cycle to cycle and lifetime. In fact, an important feature associated with lean hyperprolific sows is a gradual decline in body condition, which finally affects sows' reproductive performance (Eissen et al. 2000; Thaker and Bilkei 2005; Boulot et al. 2008) and longevity (Brisbane and Chesnais 1996). In the present study, the feeding regime routinely used on farm (C) fully met (1.5–1.7 times maintenance) energy requirements established by the National Research Council (1998) standards for pregnant sows (24.5–26.8 MJ ME $d^{-1}$). In spite of this, C sows were not able to maintain their BF reserves after three reproductive cycles, whereas E sows largely accumulated BF after three cycles of feed supplementation (E = +1.5 mm and C = −1.8 mm, $P < 0.01$; Table 5). Studies reporting the long-term effects of different feeding strategies in pregnant sows are scarce. Young et al. (1990) reported losses of about −1.6 mm of BF after three cycles (breeding to breeding) when feeding pregnant sows a regime with an energy content similar to that of the C group (35 MJ ME $d^{-1}$). Also, Whittemore and Yang (1989) and Mahan (1998) reported reductions of about −1.86 mm and −4.8 mm of BF, respectively, after four and five cycles (breeding to weaning) in sows fed conventionally during gestation. More recently, van der Peet-Schwering et al. (2004) obtained no reductions of BF thickness in group-housed sows fed a similar amount of energy than C sows over three consecutive cycles. Probably, the housing system has an influence on sow requirements and energy balance. Overall, these results evidence the decrease in BF reserves that occur in confined (in stalls) sows after three or four reproductive cycles in normal conditions, which is not desirable in terms of sow productivity and survival within a herd. Feed supplementation during mid-gestation was able to overcome this body reserves depletion in the present study.

On the other hand, both groups of sows were able to gain BW and LD over the three cycles studied. This makes evident the existence of a net maternal growth from cycle to cycle, which was also described by Whitemore and Yang (1989) and Whittemore (1993). Then, in accordance with some other studies in the literature (Whittemore and Yang 1989; Dourmad 1991, Mahan 1998), sow BW and LD net gains are not necessarily followed by BF gains.

Initial BF levels (day 45 of gestation) when considering the 37 sows that ultimately completed the three cycles were similar between groups. However, when these data were analysed by parity (nulliparous vs. multiparous, data not shown) results showed that initial BF levels were similar between treatments in nulliparous sows, but that in multiparous, C sows had greater BF levels at the onset of the study than E sows (nulliparous = C: 16.2 mm and E: 18.4 mm, $P > 0.10$; multiparous = C: 20.5 and E: 15.3, $P < 0.01$). These results suggest that, under our experimental conditions, nulliparous sows that remained in the herd during three cycles require a minimum of 16–18 mm (±3.44 SD) at the beginning of their reproductive life, and that these levels do not depend on the amount of feed provided during pregnancy. This is in agreement with the belief that sows need a minimum of fat reserves at their first mating in order assure optimum sow longevity and lifetime productive performance (Brisbane and Chesnais 1996; Stalder et al. 2005). For multiparous sows, initial BF levels required by the sows that remained in the herd for three consecutive cycles were higher in C than in the E group, depending on the feeding regime followed in gestation. Therefore, increasing feeding allowance during mid-pregnancy seems to be a good strategy to increase the time in the herd of multiparous sows with poor condition (<15 mm BF), at least in terms of body reserves. It must be taken into account that there are multiple causes of sow removal other than body reserves that have not been considered here. However, the converse may be equally valid, since large initial reserves were detrimental to sows given the extra feed, as will be discussed later.

Information on the optimal levels of lean reserves (LD measurements), which are of great importance in terms of quantity (levels) in lean genotypes (Clowes et al. 2003; Stalder et al. 2005), is scarce in the literature. In the present study, sows that remained in the herd for the three consecutive cycles required a minimum of 56 mm (±4.0 SD) and 53 mm (±4.9 SD) of LD in the C and E groups of sows, respectively (Table 5).

## Gestation Feeding and Productive Performance

Increasing feeding allowance during mid-pregnancy in the present study did result in greater piglet weight at birth in cycle 3 and also in the average of the three cycles ($P < 0.01$ and $P < 0.10$, respectively). When data were analysed according to initial parity, results showed that this effect was more marked in sows that were nulliparous at the onset of the experiment compared with multiparous, both in cycle 3 (nulliparous: C = 1.28 and E = 1.58 kg, $P < 0.05$; multiparous: C = 1.46 and E = 1.47 kg, $P > 0.10$) and also in the average of the three cycles (nulliparous: C = 1.37 and E = 1.50 kg, $P < 0.05$; multiparous: C = 1.56 and E = 1.56 kg, $P > 0.10$). In the literature it is suggested that there might be key periods during gestation, other than late gestation, in which sow feeding allowance can affect foetal growth and development (Dwyer et al. 1994; Gatford et al. 2003; Cerisuelo et al. 2009). Moreover, it has been suggested that body reserve accretion in sows over various cycles can also affect litter weight and sow performance (Cromwell et al. 1989; Whittemore 1993). In the present study, the increase in piglet birth weight was detected after three cycles of treatment in nulliparous sows. Therefore, our results suggest a simple effect mediated by an improvement of nulliparous sows' condition over the three cycles, as previously suggested by Cromwell et al. (1989), rather than a direct effect of maternal nutrition on the developing foetus.

Results from this study also suggest that increasing feeding level during gestation over the three consecutive cycles impaired the ability of sows, especially multiparous sows, to produce milk, and also piglet survival during lactation (clinical evidences of mastitis-metritis-agalactia in E sows and high piglet mortality rates). The feeding regime applied in the present study covered part of the mammary gland development period during pregnancy, which is especially important from day 75 to days 90–100 of gestation (Kensinger et al. 1982; Ji et al. 2005). Weldon et al. (1991) reported that greater energy or feed allowance during this period may contribute to the replacement of mammary tissue by fat. Therefore, feed supplementation in the current study might have negatively affected mammary development and milk production. Also, sows with high BF levels at farrowing (>21–22 mm) have a greater risk of suffering from MMA syndrome (Head and Williams 1991; Young et al. 2004). In the present study, the percentage of "fat" sows with more than 21 mm of BF at farrowing in cycle 3 was greater in the E group compared with the C group (E = 65.5% and C = 24.0%, $P < 0.05$). The fact that, in this study, feed supplementation (+2 kg $d^{-1}$) was applied to all sows independent of their body condition could have contributed to the high percentage of "fat" sows and the impairement of lactation performance in the E group.

## Rebreeding Performance

The practise of increasing feeding level during gestation has been widely criticized due to the well-known detrimental impact of fat levels at farrowing on voluntary feed intake during lactation (Dourmad 1991; Revell et al. 1998; Sinclair et al. 2001). Moreover, inadequate feed intake during lactation leads to a drain on body weight and body reserves that might severely impair WMI and productivity in subsequent cycles (Eissen et al. 2000; Prunier and Quesnel 2000; Thaker and Bilkei 2005). In the present study, body weight and body reserve losses during lactation were not different between treatments. According to the lack of differences in body tissue mobilization, rebreeding performance in terms of WMI and farrowing rate were not affected by the gestation feeding treatment. In fact, the percentage of BW lost during lactation did not exceed the 10–15%, which is considered detrimental for post-weaning performance (Thaker and Bilkei 2005).

In conclusion, pregnant sows that received the extra feed supplementation during mid gestation over three successive reproductive cycles were able, unlike restricted sows, to accumulate fat reserves. However, this feeding strategy applied to sows in good condition as a long-term strategy might have negative consequences on milk production and piglet survival during lactation. On the other hand, body reserve accumulation in nulliparous sows after three cycles of extra-feeding might have positive effects on piglet weight at birth. This feeding strategy did not affect loss of body reserves during lactation and postweaning performance. Further investigations are needed to assess whether the manipulation of body composition of young sows constitutes a strategy for producers to increase piglet weight at birth, improve sow longevity, and to assess the economic impact of this practice on pig production.

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**Boulot, S., Quesnel, H. and Quiniou, N. 2008.** Management of high prolificacy in French herds; can we alleviate side effects on piglet survival? Advances in Pork Production Proceedings, Banff Pork Seminar, Banff, BC. p. 213.

**Brisbane, J. R. and Chesnais, J. P. 1996.** Relationship between backfat and sow longevity in Canadian Yorkshire and Landrace pigs. Proceedings of the National Swine Improvement Federation Annual Meeting, Otawa, ON. p. 12.

**Cerisuelo, A., Baucells, M. D., Gasa, J., Coma, J., Carrión, D., Chapinal, N. and Sala, R. 2009.** Increased sow nutrition during midgestation affects muscle fiber development and meat quality, with no consequences on growth performance. J. Anim. Sci. **87**: 729–739.

**Clowes, E. J., Aherne, F. X., Schaefer, A. L., Foxcroft, G. R. and Baracos, V. E. 2003.** Parturition body size and body protein loss during lactation influence performance during lactation and ovarian function at weaning in first-parity sows. J. Anim. Sci. **81**: 1517–1528.

**Cromwell, G. L., Hall, D. D., Clawson, A. J., Combs, G. E., Knabe, D. A., Maxwell, C. V., Noland, P. R., Orr, Jr., D. E. and Prince, T. J. 1989.** Effects of additional feed during late gestation on reproductive performance of sows: a cooperative study. J. Anim. Sci. **67**: 3–14.

**Dourmad, J. Y. 1991.** Effect of feeding level in the gilt during pregnancy on voluntary feed intake during lactation and changes in body composition during gestation and lactation. Livest. Prod. Sci. **27**: 309–319.

**Dourmad, J. Y., Etienne, M., Prunier, A. and Noblet, J. 1994.** The effect of energy and protein intake of sows on their longevity: a review. Livest. Prod. Sci. **40**: 87–97.

**Dwyer, C. M., Stickland, N. C. and Fletcher, J. M. 1994.** The influence of maternal nutrition on muscle fiber number development in the porcine fetus and on subsequent postnatal growth. J. Anim. Sci. **72**: 911–917.

**Eissen, J. J., Kanis, E. and Kemp, B. 2000.** Sow factors affecting voluntary feed intake during lactation. Livest. Prod. Sci. **64**: 147–165.

**Gatford, K. L., Ekert, J. E., Blackmore, K., De Blasio, M. J., Boyce, J. M., Owens, J. A., Campbell, R. G. and Owens, P. C. 2003.** Variable maternal nutrition and growth hormone treatment in the second quarter of pregnancy in pigs alter semitendinosus muscle in adolescent progeny. Br. J. Nutr. **90**: 283–293.

**Head, R. H. and Williams, I. H. 1991.** Mammogenesis is influenced by pregnancy nutrition. Page 33 *in* E. S. Batterham, ed. Manipulating pig production III. Australasian Pig Science Association, South Perth, Australia.

**Ji, F., Wu, G., Blanton, J. R. and Kim, S. W. 2005.** Changes in weight and composition in various tissues of pregnant gilts and their nutritional implications. J. Anim. Sci. **83**: 366–375.

**Kensinger, R. S., Collier, R. J., Bazer, F. W., Ducsay, C. A. and Becker, H. N. 1982.** Nucleic acid, metabolic and histological changes in gilt mammary tissue during pregnancy and lactogenesis. J. Anim. Sci. **54**: 1297–1308.

**Maes, D. G. D., Janssens, G. P. J., Delputte, P., Lammertyn, A. and de Kruif, A. 2004.** Back fat measurements in sows from three commercial pig herds: relationship with reproductive efficiency and correlation with visual body condition scores. Livest. Prod. Sci. **91**: 57–67.

**Mahan, D. C. 1998.** Relationship of gestation protein and feed intake level over a five-parity period using a high-producing sow genotype. J. Anim. Sci. **76**: 533–541.

**National Research Council. 1998.** Nutrient requirements of swine. 10th rev. ed. National Academy Press, Washington, DC.

**Prunier, A. and Quesnel, H. 2000.** Nutritional influences on the hormonal control of reproduction in female pigs. Livest. Prod. Sci. **63**: 1–16.

**Revell, D. K., Williams, I. H., Mullan, B. P., Ranford, J. L. and Smits, R. J. 1998.** Body composition at farrowing and nutrition during lactation affect the performance of primiparous sows: I. Voluntary feed intake, weight loss, and plasma metabolites. J. Anim. Sci. **76**: 1729–1737.

**SAS Institute, Inc. 2001.** SAS user's guide: Statistics. Version 9.1. SAS Institute, Inc., Cary, NC.

**Sinclair, A. G., Bland, V. C. and Edwards, S. A. 2001.** The influence of gestation feeding strategy on body composition of gilts at farrowing and response to dietary protein in a modified lactation. J. Anim. Sci. **79**: 2397–2405.

**Stalder, K. J., Saxton, A. M., Conatser, G. E. and Serenius, T. V. 2005.** Effect of growth and compositional traits on first parity and lifetime reproductive performance in U.S. Landrace sows. Livest. Prod. Sci. **97**: 151–159.

**Thaker, M. Y. C. and Bilkei, G. 2005.** Lactation weight loss influences subsequent reproductive performance of sows. Anim. Reprod. Sci. **88**: 309–318.

**van der Peet-Schwering, C. M. C., Kemp, B., Plagge, J. G., Vereijken, P. F. G., den Hartog, L. A., Spoolder, H. A. M. and Verstegen, M. W. A. 2004.** Performance and individual feed intake characteristics of group-housed sows fed a nonstarch polysaccharides diet *ad libitum* during gestation over three parities. J. Anim. Sci. **82**: 1246–1257.

**Weldon, W. C., Thulin, A. J., MacDougald, O. A., Johnston, L. J., Miller, E. R. and Tucker, H. A. 1991.** Effects of increased dietary energy and protein during late gestation on mammary development in gilts. J. Anim. Sci. **69**: 194–200.

**Whittemore, C. T. 1993.** The science and practice of pig production. Longman Scientific & Technical, Singapore.

**Whittemore, C. T. and Yang, H. 1989.** Physical and chemical composition of the body of breeding sows with differing body subcutaneous fat depth at parturition, differing nutrition during lactation and differing litter size. Anim. Prod. **48**: 203–212.

**Young, L. G., King, G. J., Walton, J. S., McMillan, I., Klevorick, M. and Shaw, J. 1990.** Gestation energy and reproduction in sows over four parities. Can. J. Anim. Sci. **70**: 493–506.

**Young, M. G., Tokach, M. D., Aherne, F. X., Main, R. G., Dritz, S. S., Goodband, R. D. and Nelssen, J. L. 2004.** Comparison of three methods of feeding sows in gestation and the subsequent effects on lactation performance. J. Anim. Sci. **82**: 3058–3070.