Long-term effects of low and high protein feeding to pregnant sows on offspring at market weight

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Abstract

To study the impact of maternal low and high protein intake on carcass and meat quality of the offspring, 40 pregnant German Landrace gilts were fed iso-energetic diets (11.6 MJ ME/kg DM) with high (HP, 30%; n=14), low (LP, 6%; n=14) or control protein (CP, 12%; n=12) levels throughout gestation. Birth weight was lower in LP and HP compared with CP piglets (1.19, 1.22, 1.38 kg, respectively). Ultimate live weight and carcass weight at slaughter (d 188) of 63 pigs born to 34 gilts did not differ by diet. However, LP pigs exhibited a lower lean percentage and a higher proportion of subcutaneous fat compared with CP pigs. The reduction in lean and increases in subcutaneous and internal fat depots were found in LP pigs of high and medium, but not of low birth weight with *a priori* higher fatness. This was associated with greater thickness and adipocyte numbers of the 2nd back fat layer. Meat quality of LP and HP pigs tended towards lower shear force and conductivity, and increased pH at 45 min *postmortem*. In conclusion, maternal dietary protein level induces lasting effects on carcass and meat quality of the offspring. (supported by DFG, KA 1844/1-1, PAK 24).

Introduction

Prenatal growth in the pig, as in other mammals, is determined by the genotype of the conceptus, but largely depends on the maternal uterine milieu of hormones, nutrients, and growth factors. During pregnancy the developing foetus is completely dependent on the supply with nutrients and the removal of metabolic by-products through the maternal organism. Overall, pigs seem to be remarkably resistant to manipulations of gestational feeding with regard to changes in birth weight and litter size, which is associated with the sow's ability to mobilize maternal nutrient reserves. There are indications, however, that specific maternal gestational dietary factors persistently affect performance and health of the offspring. Nevertheless, in pigs the available results on maternal dietary impact during gestation on offspring growth and performance in the longer term are rather inconsistent and scarce. The objective of this study was to investigate the impact of low and high protein intake of pregnant gilts on carcass and meat quality and on cellular muscle and adipose tissue characteristics of the offspring at market weight.

Material and methods

German Landrace gilts were fed iso-energetic diets (11.6 MJ ME/kg DM) with high (HP, 30%; n=14), low (LP, 6%; n=14) or control protein (CP, 12%; n=12) levels throughout gestation. Within 48 h *post partum*, piglets were cross-fostered to sows of 2nd to 4th parity, which were on the control diet during gestation, with litter size being standardized to 11. Male piglets were castrated at d 4 of age and all pigs were weaned at d 28 and kept individually from d 32. The experiment was carried out in successive repeats with 6 gilts (2 per diet). Pigs from each sow were regularly slaughtered for detailed analyses at days 1 (n=4), 27 (n=2), 81 (n=2), and 188 (n=2) of age. Offspring was fed *ad libitum* with starter mixtures until d 76 of age and subsequently with a pre-finishing starter until d 105 and a finishing diet until slaughter (Trede & v. Pein, Itzehoe, Germany). In this study, results are presented for pigs of market weight (d 188).

Carcass composition and meat quality were analyzed on the left carcass half as described by Kuhn et al. (2004) with the exception that the percentages of lean and SC fat are based on the manual dissection of four primal cuts; loin, neck, ham, and shoulder. Meat quality traits were measured on both *longissimus* (LD) and *semitendinosus* (ST) muscles. Micro-structural and biochemical characteristics of LD, ST and (or) *biceps femoris* muscles were determined according to Rehfeldt at al. (2007; 2008), fat cell characteristics according to Rehfeldt et al. (1996). RNA isolation, reverse transcription and real-time PCR of SC fat were performed as described by Kalbe et al. (2008). Leptin-specific primers were used according to McNeel et al. (2000). For statistical analysis data were subjected to ANOVA by the mixed procedure of SAS (SAS Inst. Inc., Cary, NC, USA) with diet, sex, litter size group (L1<13; L2≥13) and birth weight group (low, middle, heavy within litter) as fixed factors and the sow within diet*L as random factor. As two further repeats are going to be analyzed, results presented are considered preliminary.

Results and discussion

Carcass quality. Maternal low and high protein diets did not affect ultimate live weight and carcass weight of the offspring at slaughter showing that the decreases in birth weight found in HP and LP pigs were compensated during postnatal life (Table 1). Likewise, the proportions of internal organs and internal fat depots (perirenal; omental) were not influenced by the diets. However, lean meat percentage obtained by manual dissection was clearly lower in offspring of LP fed mothers (by 2.6 %units) compared with the control (Fig. 1). Correspondingly, the percentage of SC fat was higher, and back fat thickness at the level of $13^{th}/14^{th}$ rib tended to be increased (Table 1).

Table 1. Selected carcass characteristics of pigs at market weight born to gilts fed high (HP) or low (LP) compared with control levels (CP) of protein throughout gestation (LSMeans ± SE)

	CP	HP	LP	*P*
No. of pigs	21	21	21	
Live weight	126.3 ± 3.1	128.7 ± 3.5	124.6 ± 3.2	0.70
Carcass weight (kg)	102.3 ± 2.4	103.9 ± 2.8	100.4 ± 2.5	0.64
Internal organs (%)[a]	7.91 ± 0.17	8.19 ± 0.20	8.23 ± 0.18	0.38
Internal fat (%)[a]	3.19 ± 0.11	3.30 ± 0.14	3.30 ± 0.12	0.74
Backfat thickness (mm)[b]	21.8 ± 1.46	23.1 ± 1.72	26.1 ± 1.54	0.13
Fat cell diameter (µm)[b]	67.0 ± 3.13	74.9 ± 3.30	72.1 ± 2.77	0.23
Fat cell number[b]	143.7 ± 7.87	130.6 ± 8.65	146.7 ± 6.90	0.35

[a]Calculated from whole empty body; [b]Measured at $13^{th}/14^{th}$ rib level (without skin)

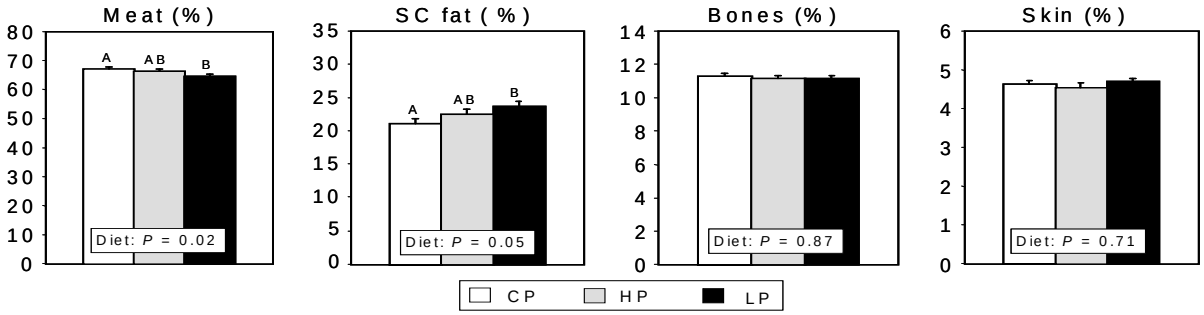

Figure 1. Carcass composition by manual dissection into meat, subcutaneous (SC) fat, bones and skin of pigs at market weight born to gilts fed high (HP) or low (LP) compared with control levels (CP) of protein throughout gestation (LSMeans ± SE). Different letters indicate significant differences ($P \leq 0.05$).

These effects were more pronounced in pigs originating from large litters (Fig. 2). Already at birth, impaired muscle accretion has only been observed in piglets from large LP litters. SC fat percentage and back fat thickness in newborns were not significantly different (unpubl.), although higher activity of fatty acid synthase has been observed in SC fat of LP piglets (Gondret et al., 2008). Taken together, pigs of large litters were more affected by maternal LP diet than from small litters suggesting that there was a deficiency in foetal protein supply required for muscle development, which could not be compensated for by mobilizing maternal reserves, when a certain number of foetuses was exceeded.

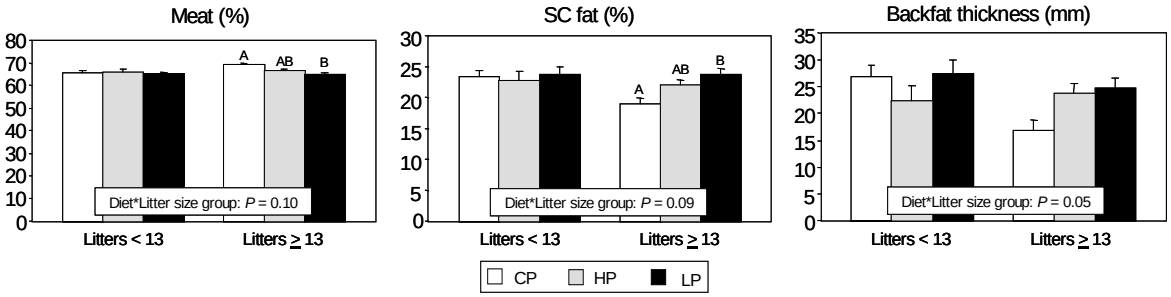

Figure 2. Impact of litter size on the response to maternal diets with high (HP), low (LP) or control levels (CP) of protein in selected carcass characteristics of pigs at market weight (LSMeans ± SE). Different letters indicate significant differences ($P \leq 0.05$).

A number of significant interactions of diet by birth weight group for lean meat percentage (manual dissection and FOM), loin area, percent SC fat, second back fat layer thickness and fat cell number (P=0.02 to 0.05) revealed that the decrease in lean and the increase in SC fat in response to maternal LP diet occurred in pigs of high and middle, but not of low birth weight (not shown). This may indicate that foetuses that are *per se* exposed to suboptimal supply *in utero* are not additionally affected by maternal protein restriction.

Meat quality & muscle structural and biochemical properties. Meat quality characteristics (pH, drip loss, colour, conductivity) of LD and ST muscles were not significantly influenced by the maternal HP and LP diets (not shown). There was a tendency in LD to lower shear force values in HP and LP pigs (P=0.13). ST muscle tended towards lower conductivity (P=0.11) and increased pH_{45} (P=0.13). Likewise, micro-structural and biochemical properties of skeletal muscle, such as fibre size and number, fibre type composition, capillary density, DNA, RNA and protein concentrations, and creatine kinase activity, were not significantly affected by the diet (not shown). The data suggest that diet-dependent intrauterine growth retardation observed in neonatal offspring from LP and HP sows (Lang et al., 2008) does not have severe consequences for meat quality and variables of muscle metabolism in fattening pigs at market age.

mRNA expression of selected genes in adipose tissue. The components of the IGF system were changed by maternal diet in that in HP pigs of large litters the expression was lower as compared with control and LP pigs. These data do not reflect diet-induced differences in the phenotype of SC fat, but suggest that fat deposition is differently regulated in HP pigs. No effects on leptin transcript expression were detectable.

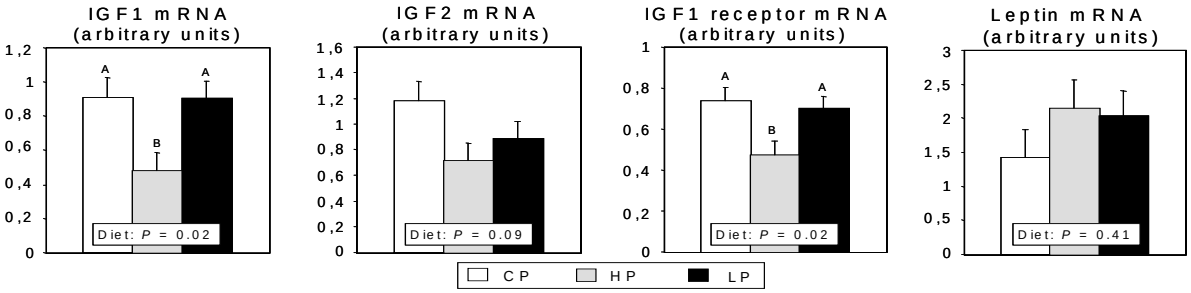

Figure 3. Real-time PCR analysis of IGF1, IGF2, IGF1 receptor and leptin mRNA expression in SC adipose tissue of pigs (litters ≥13) at market weight born to gilts fed high (HP) or low (LP) compared with control levels (CP) of protein throughout gestation (LSMeans ± SE). Different letters indicate significant differences (P≤0.05).

Conclusions

Our preliminary results suggest that the LP diet fed during gestation induces long lasting effects on muscle and fat accretion in the offspring leading to decreased carcass quality of the pigs at market weight in terms of higher fatness. These effects are more pronounced in pigs originating from large litters and in pigs of high or middle birth weight. It seems that the maternal HP diet has no influence on carcass composition of pigs at market weight, although SC fat deposition seems to be regulated differently. Likewise, maternal dietary protein level marginally influences meat quality and structural and functional properties of skeletal muscle.

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