LACTOGENESIS: LATE GESTATION DIETS AND HORMONAL INTERVENTION

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Executive Summary

In primiparous sows, feed intake capacity during lactation is generally insufficient to meet nutrient requirements for lactation. As a consequence, milk production may be limited and due to the discrepancy between nutrient intake and demand, excessive mobilisation of body reserves may occur, impeding on reproductive performance after weaning. Voluntary feed intake may be limited due to the fact that gilts have not reached their mature body weight at first farrowing, but also due to feeding strategy during the preceding pregnancy. High feed levels during late gestation, intended to increase birth weight, generally result in a lower feed intake during subsequent lactation. This may be due to the high feed levels inducing a certain state of pregnancy diabetes, and/or the fact that the high feed level during gestation results in a greater body fat mass of the gilts at farrowing. Sows can develop a degree of diabetes, although mild, during late gestation, but which is aggravated by a high feed level, and which renders them glucose intolerant to some extent. Glucose intolerance (a slower clearance of glucose from the circulation after a meal) may benefit foetal growth during late gestation, but may also limit feed intake and milk production after farrowing because of the delayed glucose clearance.

Diets with a high fibre content, bulky diets, when fed during gestation have a more gradual postprandial release of glucose and are generally reported to increase feed intake of a standard diet during lactation. However, there is hardly any evidence of the effect of bulky diets on glucose tolerance. It is therefore questionable whether effects of bulky diets are through improved glucose tolerance or through other mechanisms such as gut fill or reduced body fatness. Studies with bulky diets have mainly included low feed levels during gestation (2 to 2.5 kg). There is no evidence for the effect of bulky diets in gilts that are fed at a high energy level during late gestation (around 45 MJ DE/d), a common practice in commercial piggeries. The current study therefore was designed to induce a certain state of glucose intolerance by feeding gilts a high feed level during late gestation, and to assess whether a diet fed at the same energy level but with a slower release of glucose (bulky diet), would ameliorate the effects on feed intake and piglet growth during lactation

Forty-nine crossbred gilts were fed three different diets during the last month of their gestation: 2.5 kg of a standard diet (n =15), 3.5 kg of the same standard diet (n = 17), or 3.5 kg of a high fibre diet, with 10.6% fibre as opposed to 4.4% fibre in the standard diet (n = 17). The fibre diet was designed to be isocaloric and isonitrogenous to the standard diet. During subsequent lactation, all gilts were fed the same lactation diet. Sixteen gilts were subjected to an oral glucose tolerance test (GTT) around day 110 of gestation. The high feed level (3.5 kg of standard or fibre diet) resulted in a higher weight gain during gestation. Gilts fed the high fibre diet tended to have ($P < 0.10$) piglets with a greater birth weight at farrowing (1535 g) than gilts fed the standard diet at 3.5 kg (1404 g). The gilts fed 3.5 kg of the standard diet (n.s.) or the fibre diet ($P < 0.05$) had a lower feed intake and more body weight loss during lactation, than gilts fed 2.5 kg during gestation. Insulin profiles after the GTT were higher for gilts fed the fibre diet, indicating a better glucose tolerance. Gilts fed 2.5 kg or 3.5 kg of the standard diet had a similar insulin profile. Glucose profiles were similar across treatments. Leptin levels around day 110 of

gestation were higher, although not significantly for the gilts fed 3.5 kg, and leptin was negatively correlated to feed intake during the third week of lactation ($r = -0.28$; $P < 0.05$).

This study shows that a high feed level during late gestation reduces feed intake during lactation and that a high fibre diet during gestation does not negate this effect when fed at a high energy level. The results suggest that feed level during gestation and the resulting body fat mass, rather than glucose tolerance, impacts on feed intake during lactation. Since a feed level above 2.5 to 3.0 kg does not result in extra benefit in terms of piglet birth weight, and clearly reduces feed intake during lactation, it is recommended to feed gilts between 2.5 and 3.0 kg (and not more) during late gestation, in order to maximize feed intake and milk production during lactation. Effects of fibre inclusion in gestation diets, particularly in the context of group housing, require further studies.

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1. Introduction

The peri-parturient period in sows and other domestic animals is a transitional period which requires the dam to adapt from an anabolic state where nutrients are directed towards accretion of body reserves and foetal growth during gestation, to a catabolic state where nutrients and mobilised body reserves are directed towards milk production. In primiparous sows, feed intake capacity during lactation is generally insufficient to meet nutrient requirements for lactation. As a consequence, milk production may be limited and due to the discrepancy between nutrient intake and demand, excessive mobilisation of body reserves may occur, impeding on reproductive performance after weaning. Voluntary feed intake may be limited due to the fact that gilts have not reached their mature body weight at first farrowing, but also due to the development of a certain state of pregnancy diabetes (Pere et al., 2000). Sows develop a degree of diabetes, although mild (Etienne et al., 1997), during late gestation, which renders them glucose intolerant to some extent. Glucose intolerance may benefit foetal growth during late gestation, but may also limit feed intake and milk production after farrowing because of delayed glucose clearance from the systemic circulation.

High feeding levels during gestation have been shown to induce glucose intolerance, and to reduce feed intake during lactation (Weldon et al., 1994; Xue et al., 1997). The reduced lactational feed intake may be caused by impaired glucose tolerance, but may also be due to increased body fat in sows on a high feed intake (Quesnel et al., 2009).

Diets with a high fibre content (bulky diets), have been proposed to reduce glucose intolerance and hence improve feed intake during lactation. Bulky diets during gestation have a more gradual postprandial release of glucose (Matte et al., 1994; Farmer et al., 1996; Renteria-Flores et al., 2008; Quesnel et al., 2009) and are generally reported to increase feed intake of a standard diet during lactation (Farmer et al., 2002; Quesnel et al., 2009). However, there is hardly any evidence of the effect of bulky diets on glucose tolerance. It is therefore questionable whether effects of bulky diets are through improved glucose tolerance or through other mechanisms such as gut fill or reduced body fatness.

Although most studies report effects of feeding level during gestation on lactational feed intake, studies with bulky diets have mainly included low feed levels during gestation (2 to 2.5 kg). There is no evidence for the effect of bulky diets in gilts that are fed at a high energy level during late gestation (around 45 MJ DE/d), a common practice in commercial piggeries.

The current study was designed to induce a certain state of glucose intolerance by feeding gilts a high feed level during late gestation, and to assess whether a diet fed at isocaloric level but with a slower release of glucose (bulky diet), would ameliorate the effects on feed intake and piglet growth during lactation, as compared to sows fed a high feed level during late gestation.

2. Methodology

Cross-bred gilts (n=49) were allocated to one of three treatments 30 days before farrowing, based on their body weights. Treatments 2.5C and 3.5C were fed the same (control) diet during gestation, but at 2.5 kg/d and 3.5 kg/d, respectively. Treatment 3.5F gilts were fed isocalorically and isonitrogenously to 3.5C, using a diet in which starch rich ingredients (mainly cereals) were replaced by fibre rich ingredients (millrun, oat hulls and lupins) and fat, to achieve a higher fibre content but the same energy density as the control diet (Table 1). Treatments 3.5C and 3.5F were therefore meant to increase the energy- and protein intake compared to the control treatment (2.5C), but using energy sources differing in timing of glucose release. The 3.5C treatment was expected to induce glucose intolerance compared to the 2.5C treatment, and the high fibre content in the 3.5C diet was expected to counteract or reduce this effect, due to a more gradual post-prandial glucose release (Farmer et al., 2002; Quesnel et al., 2009). The high fibre diet was formulated to contain more fibre but the same energy density, to ensure all allocated feed was consumed. During gestation, gilts were housed in individual stalls and fed twice a day. At the start of the treatments, gilts had a body weight of around 205 kg. During gestation, gilts were weighed every week.

Around day 110 of gestation a glucose tolerance test (GTT) was performed on 16 gilts. A day prior to the GTT, gilts were fitted with catheters into an ear vein, to enable frequent blood sampling during the GTT. Gilts were restrained using a snout rope and subsequently, a 1x1.5 mm PVC catheter (Microtube Extrusions, NSW, Australia) was guided through a 14 Gauge insertion needle (Optiva, Smiths Medical, QLD, Australia), up to 50 cm into a lateral or intermediate auricular vein, so that that the catheter would sample from the jugular vein. The exterior part of the catheter was secured in a pouch at the back of the neck, using Tensoplast-Vet tape (BSN Medical, Australia). Catheters were kept patent using a heparinised saline solution. On the day of the GTT, the gilts were not fed until after the GTT. For the GTT, two blood samples were taken prior to feeding glucose. Subsequently, 3 g/kg $BW^{0.75}$ of sugar was fed and blood samples were taken at 10 min intervals, until 90 min after the sugar dose. Blood samples were collected in heparinised tubes and kept on ice until centrifugation.

Table 1. Composition of control and high fibre diets.

	Composition, %	
	Control (2.5C and 3.5C)	High fibre (3.5C)
Ingredient		
Barley11%	65.3	
Wheat 13%	20.1	17.0
Oats		34.3
Millrun 16%		13
Oat hulls GOMF		10.9
Lupins NL sows		8.1
Peas	4.8	
Canola expeller se	2.0	1.0
Meatmeal 52%	3.7	5.3
Fish meal 60%	1.0	1.0
Tallow	0.67	7.9
Limestone	0.9	0.6
Mono dical phos	0.53	
Salt (sodium chloride)	0.3	0.3
Lysine sulphate 65%	0.16	0.14
Threonine L		0.01
Alimet		0.017
Betaine anhydrous	0.2	0.2
Breeder + bioplex pmx	0.25	0.25
Endox	0.02	0.02
	Calculated analysis	
Item		
DE MJ/kg	13.0	13.0
Protein, g/kg	143	143
Fat, %	3.2	11.9
Fibre, %	4.4	10.6
Lysine, %	0.7	0.7

Gilts were moved to the farrowing unit after the GTT, and were continued to be fed according to their allocated treatments until farrowing. At farrowing, birth weight of the piglets and litter size was recorded for all gilts. Litters were subsequently standardised to 11 piglets per gilt within 24 h. Sows and piglets were weighed after standardisation of the litters and at day 7, day 14, and day 21 of lactation. During lactation, all sows were fed the same standard lactation diet (14 MJ DE/kg) and feed allowance was increased step-wise from 2.5 kg after farrowing, with 0.5 kg per day if the sows had finished their feed, up to their maximum feed intake. Feed allocation and refusals were recorded on a daily basis. Sows were fed three times per day during lactation. Gestating and lactating gilts were housed in air-conditioned units. Outside temperature during the four months trial-period varied between 19 °C and 39 °C.

Glucose, insulin and leptin

Blood samples taken during the GTT were analysed for glucose and insulin. Glucose was analysed by colorometric automated analysis on a Hitachi 912 automated centrifugal analyser with a commercial kit (Glucose HK assay kit, Roche Diagnostics, NSW, Australia). Insulin was assayed in duplicate in 100µl plasma using a specific porcine RIA (PI-12K, Millipore, Billerica, USA). The intra- and inter-assay coefficients of variation were less than 15%. The minimum detection limit was 2µU/ml. In addition to the GTT samples, a single blood sample was taken from all gilts by jugular venipuncture on the day that the GTT was performed on the subset of gilts (around day 110). Therefore a single blood sample was available to be analysed for leptin for each gilt. The Leptin was assayed in duplicate in 100ul plasma using a Multi-Species Leptin radioimmunoassay (XL-85K; Millipore, Billerica, USA). The cross reactivity with porcine leptin was 67%. Results are presented as ng/ml HE (Human Equivalent). The intra- and inter-assay coefficients of variation were less than 15%. The minimum detection limit was 1ng/ml HE.

Statistical analysis

All statistical analyses were performed using SAS (SAS/STAT 1990). Body weight of the sows, piglet weights, and feed intake of the sows were analysed using PROC GLM with treatment as factor. Correlation between feed intake and body weight loss, between leptin and feed intake were calculated using PROC CORR.

Insulin and glucose profiles in the glucose tolerance test (GTT) were analysed for 16 sows that finished their sugar dose within 10 min. Insulin and glucose were analysed using PROC GLM with the following model: $Y = \mu + \text{treatment} + \text{time} + \text{treatment*time} + e$, with time relative to feeding glucose (t=0). The interaction treatment*time was not significant. Peak insulin level and area under the curve (AUC) were analysed in a univariate model with treatment as independent factor. AUC was calculated as the total of insulin concentrations per sow between 10 and 70 min following sugar feeding. Leptin was also analysed using a univariate model. Correlations between insulin and leptin characteristics were analysed with PROC CORR.

3. Outcomes

At allocation, gilts weighed 207 ± 4.2, 205 ± 4.8, and 206 ± 4.4 kg for the 2.5C, 3.5C, and 3.5F treatments, respectively. The different treatments resulted in body weight gains of 809 ± 43, 1141 ± 64, and 1218 ± 51 g per day ($P < 0.05$) for 2.5C, 3.5C, and 3.5F (measured during the second and third week of the dietary treatment period), respectively, reflecting a clear effect of feed/energy level on weight gain and also that feeding the 3.5C and 3.5F treatments isocalorically resulted in a similar weight gain. Around day 110 of gestation (at the time of the GTT), sows weighed 226 ± 3.5, 231 ± 4.7, and 236 ± 4.1 kg, respectively. After farrowing, gilts in the 2.5C, 3.5C and 3.5F treatments weighed 213 ± 4.3 , 215 ± 4.1, and 214 ± 4.1 kg (n.s.), respectively.

Table 2. Performance (Means ± SE) of sows and piglets during 21 days of lactation, after being fed 2.5 kg of a control diet (2.5C), 3.5 kg of a control diet (3.5 C) or 3.5 kg of a high fibre diet (3.5F) during late gestation.

	2.5C	3.5C	3.5F
N	15	17	17
Birth weight, g*	1484 ± 28^{x,y}	1404 ± 44^{x}	1535 ± 48^{y}
Total Born	11.0 ± 0.6	11.4 ± 0.7	11.3 ± 0.6
Litter size at d21	10.4 ± 0.3	10.5 ± 0.2	9.9 ± 0.3
Gain piglets, g per day			
D0-7	155 ± 18	170 ± 15	132 ± 14
D7-14	225 ± 14	216 ± 13	211 ± 14
D14-21	275 ± 34	268 ± 35	241 ± 18
D0-D21	216 ± 7	216 ± 13	194 ± 16
BW piglets, D21**	6059 ± 161	5963 ± 279	5602 ± 354
Feed intake sows, kg			
D0-7	3.4± 0.2^{a}	3.0 ± 0.2^{a,b}	2.6 ± 0.2^{b}
D7-14	5.0 ± 0.3^{a}	4.3 ± 0.3^{a,b}	3.7 ± 0.3^{b}
D14-21	5.4 ± 0.2^{a}	4.8 ± 0.3^{a,b}	4.2 ± 0.4^{b}
Total feed intake D0-	96.8 ± 4.3^{a}	85.0 ± 5.0^{a,b}	73.1 ± 6.2^{b}
BW change sows, kg			
D0-D21	-8.2 ± 3.5^{a}	-12.7 ± 3.4^{a,b}	-20.2 ± 3.4^{b}
D0-7	-2.2 ± 1.3	-4.9 ± 1.3	-6.0 ± 1.6
D7-14	-2.2 ± 1.5^{a}	-2.7 ± 1.3^{a}	-7.6 ± 1.7^{b}
D14-21	-3.6 ± 1.0	-5.7 ± 1.0	-6.7 ± 1.6

*Uncorrected means. Differences between treatments were tested using total born as a covariate. **After birth litter size was standardised to 11 piglets. Litters with heavy scouring not considered in this mean. ^{a,b}different superscripts indicate differences between treatments (P < 0.05). ^{x,y}difference P < 0.10.

Table 2 shows several performance characteristics for sows and piglets during lactation. There was a difference in birth weight between gilts fed the control diet at 3.5 kg and gilts fed the high fibre diet (3.5F). After correction for number of total born, mean birth weight was 1484 g, 1404 g, and 1535 g for 2.5C, 3.5C, and 3.5F (P < 0.10). The 2.5C treatment was intermediate. At day 7, 14 and 21 litter size did not differ. Litter weight gain was not different between treatments in week 1, 2, or week 3.

Feed intake of the sows during lactation was affected by treatments during gestation. The gilts fed the low feed level (2.5 kg) during gestation had the highest feed intake during lactation (96.8 kg over 21 days), being significantly different from the gilts on the fibre diet (3.5F: 73.1 kg over 21 days). The gilts on the fibre diet (3.5F) did not have a higher feed intake than those on the control diet fed at the same feed level (3.5C: 85.0 kg over 21 days) during gestation; their feed intake was even lower, although not significantly. As a consequence, body weight loss was lowest for gilts on the control diet fed 2.5 kg. Feed intake during lactation was not correlated to body weight at farrowing.

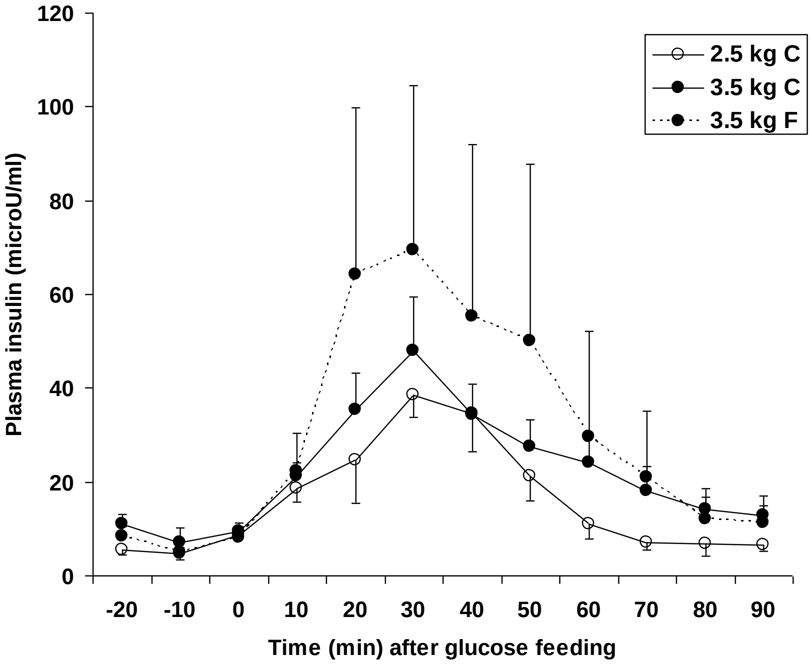


Figure 1. Plasma insulin concentration in an oral glucose tolerance test. Gilts were fed a standardised dose of sugar (3 g/kg $BW^{0.75}$) at t=0 min, around day 110 of gestation. Gilts were on 2.5 kg (2.5C, n = 5) or 3.5 kg (3.5C, n = 6) of a standard gestation diet, or on 3.5 kg of a high fibre diet (3.5F, n = 5) during the last month of gestation. Insulin profile was higher for sows on the fibre diet (3.5F) compared to sows fed the control diet at a low (2.5 kg) feed level (P = 0.03).

Insulin levels (Figure 1) peaked at 30 min following the sugar dose, and the peak was 43.7 ± 6.7, 57.1 ± 9.9, and 93.7 ± 43.5 µU/ml for 2.5C, 3.5C, and 3.5F, respectively (n.s.). In the five sows on the fibre diet there was considerable variation in the insulin peak, with two of the five sows having a peak of over 200 µU/ml, and two sows having a peak as low as 15.1 and 18.6 µU/ml, respectively. Area under the curve was 168 ± 16, 197 ± 30, and 318 ± 132 µU/ml, for the three treatments respectively (n.s.). Insulin profiles were higher for sows on the fibre diet (3.5F) compared to sows fed the control diet at a low (2.5 kg) feed level (P = 0.03). Sows fed the control diet at 2.5 kg or 3.5 kg during gestation did not differ in their insulin profile. Insulin profile characteristics were not related to feed intake during lactation.

Similar to insulin, glucose (Figure 2) peaked at 30 min following the sugar dose, and the peak was 6.61 ± 0.31, 6.69 ± 0.41, and 6.35 ± 0.41 mM/ml for 2.5C, 3.5C, and 3.5F, respectively (n.s.). Area under the curve was 40.3 ± 1.9, 37.2 ± 3.4, and 38.8 ± 2.0 mM/ml, for the three treatments respectively (n.s.). There was no difference between treatments in the glucose profile.

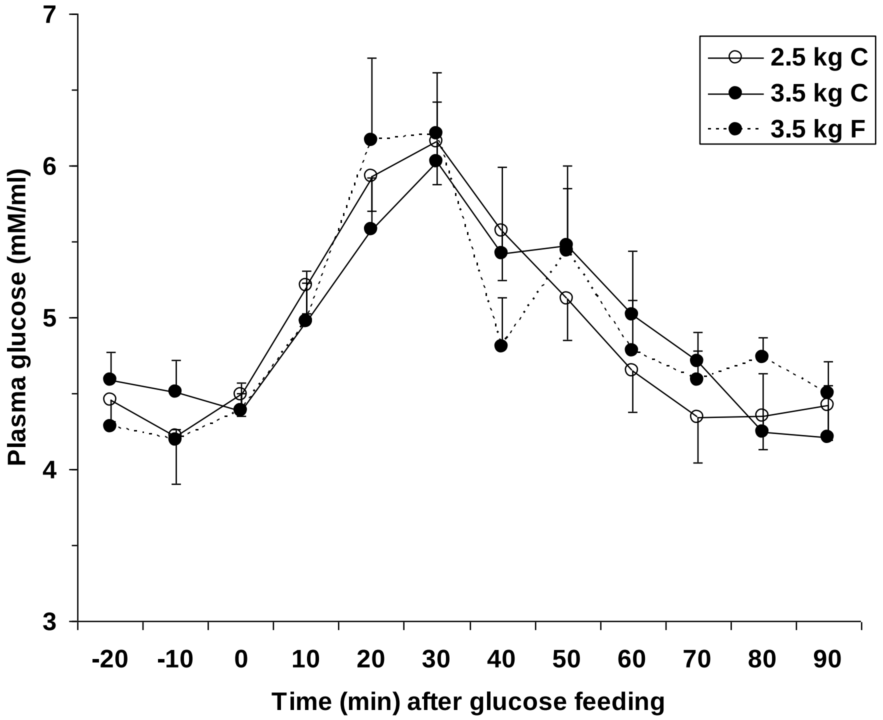
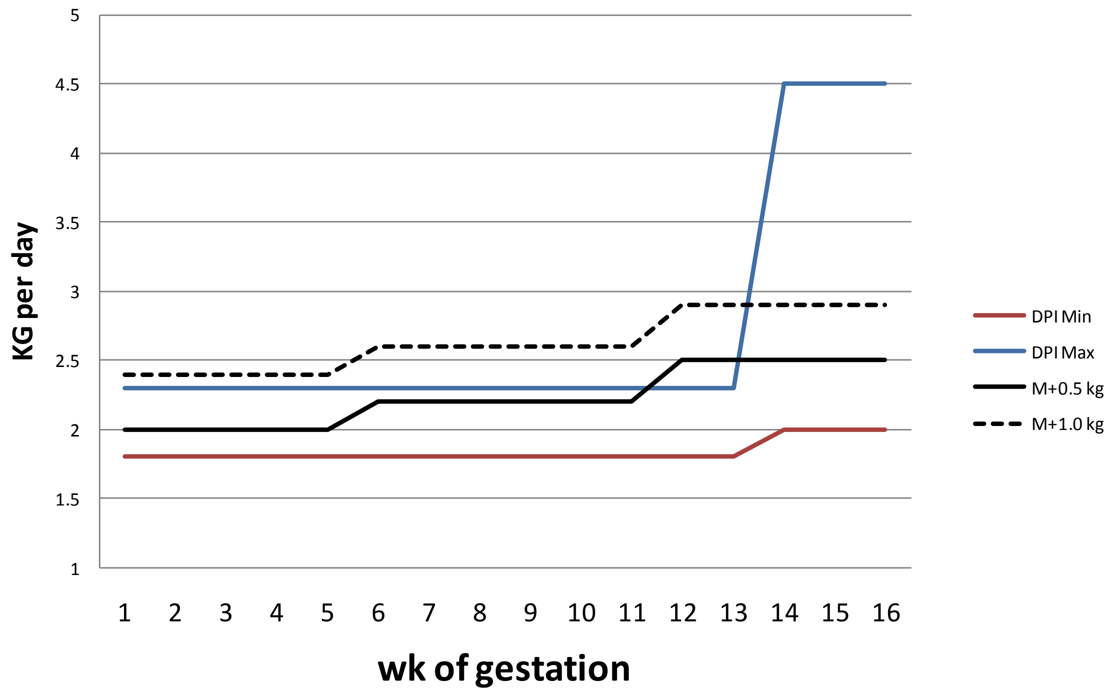


Figure 2. Plasma glucose concentration in an oral glucose tolerance test. Gilts were fed a standardised dose of sugar (3 g/kg $BW^{0.75}$) at t=0 min, around day 110 of gestation. Gilts were on 2.5 kg (2.5C, n = 5) or 3.5 kg (3.5C, n = 6) of a standard gestation diet, or on 3.5 kg of a high fibre diet (3.5F, n = 5) during the last month of gestation.

Plasma leptin concentration late in gestation was 3.71 ± 0.25, 4.53 ± 0.47, and 4.55 ± 0.42 ng/ml, respectively for the 2.5C, 3.5C, and 3.5F treatments (n.s.). Feed intake during the third week of lactation was negatively correlated (r = -0.28; P = 0.09) with leptin during late gestation. Leptin was not (significantly) correlated to feed intake in the first two weeks or to the average feed intake over the three weeks of lactation.

4. Application of Research

The diagram below shows a conventional recommendation for feed allowance in gilts during pregnancy (minimum allowance in red and maximum in blue). During late pregnancy some recommendations go as far as 3.5 kg and beyond, based on the desire to maximize birth weight. However, data from this project and



literature data show that a feed allowance above 3.0 kg at the end of gestation does not benefit any extra birth weight and compromises feed intake during subsequent lactation.

The recommended feed allowance from this project is indicated by the continuous black line (minimum) and the dotted line (maximum feed allowance). Maximum feed allowance can be higher than the dotted line (except for late pregnancy!), depending on the targeted growth rate of the gilts. Reducing feed allowance at the end of gestation improves feed intake during subsequent lactation and increases herd feed efficiency. Increasing feed allowance during early pregnancy above current recommendations does not compromise reproductive performance (see 2D-112) and still allows a balanced development of the maternal body weight of the gilt.

Ultimately this recommended new feed strategy will allow a balanced development of gilts, maximizing pregnancy and farrowing rates, and also allowing sufficient feed intake during subsequent lactation.

5. Conclusion

In conclusion, a high feeding level (both the standard diet and the high fibre diet) during late gestation clearly reduced feed intake and increased sow body weight loss during lactation. These effects seemed more related to the gestational feed level per se, rather than glucose intolerance, as gilts on the high feed level did not seem to have impaired glucose tolerance compared to gilts on the low feed level. Increased leptin levels may contribute to a reduced feed intake during lactation.

6. Limitations/Risks

When designing a feed strategy for the entire pregnancy period, several factors have to be taken into account. Depending on body weight at mating a targeted weight gain during gestation (40-60 kg) has to be achieved. This ultimately determines the actual feed allowances that are applied, depending on environmental conditions, housing conditions (group vs. individual), feeding system, expected litter size, etc.

7. Recommendations

It is recommended to limit feed allowance during late gestation (last 4-5 wks) to 2.5 to 3.0 kg of a standard gestation diet (32.5-39 MJ DE/d). In regard to maternal body weight gain, it may be worth considering mating at a later age. It is interesting to note that in The Netherlands age at mating has moved from 250 d in 2003 to 260 d (34 wks) at present.

8. References

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