NUTRITIONAL MANIPULATION OF CORPUS LUTEUM DEVELOPMENT DURING EARLY PREGNANCY TO INCREASE EMBRYO SURVIVAL AND LITTER SIZE

Report prepared for the
Co-operative Research Centre for an Internationally Competitive Pork Industry

By

Pieter Langendijk

SARDI Livestock, Roseworthy campus, 5371 SA

June 2011

Established and supported under the Australian Government's Cooperative Research Centres Program

Executive Summary

Embryo mortality during the first month of pregnancy is around 30% in gilts and 40-50% in multiparous sows, and therefore limits litter size and pregnancy rate. One of the key players during this period is the pregnancy hormone progesterone, secreted by the ovaries, and which is positively related to embryo survival. Because high feed levels (> 2.5kg) have consistently been shown to reduce systemic progesterone, the current paradigm says that gilts should be fed a "low" feed level during early pregnancy. However, the evidence on this issue has been equivocal, with some studies not showing an effect of feed level and some studies even showing a positive effect of a high feed level on embryo survival and pregnancy rate. The explanation of this paradox may lie in the fact that the uterus not only relies on the systemic circulation for its progesterone supply, but also receives progesterone "directly" from the ovaries through counter-current transfer systems. Effects of feed level on systemic progesterone may be counteracted by (positive) effects on progesterone secreted by the ovaries. Studies have so far only focused on systemic progesterone.

This project therefore was designed to quantify progesterone secreted by the ovaries under different feed regimes during the <u>first month of gestation</u>, to assess the importance of this "local source" of progesterone for embryo survival, and to revisit the paradigm of how feed level affects embryo survival, pregnancy rate, and ultimately litter size. Also, the effect of using different energy sources as opposed to cereals as main energy ingredient in gilt diets, was assessed.

In an initial trial, a surgical model was used (unilateral ovariectomy) in which one ovary was removed from 30 gilts prior to mating, to assess the effect on embryo survival in the uterine horn attached to this ovary. Removal of the one ovary would make this horn rely solely on systemic progesterone, as opposed to the other, contralateral horn, which had a systemic supply as well as "local" supply of progesterone from the ovary still attached. In the horn with both systemic and local supply of progesterone 1.3 more embryos (6.3 vs. 5) survived at d35 of pregnancy, indicating the significance of local transfer of progesterone (2.6 embryos in total for two horns). Also, gilts on the high feed level had 11.3 embryos as opposed to 10.3 on the low feed level, and a better embryo survival between implantation (d15) and d35 of gestation.

To quantify secretion of progesterone by the ovaries as affected by feed level, 20 gilts were surgically fitted with catheters in the vena cava, close to where the utero-ovarian vein drains into the vena cava, to enable sampling of blood close to the ovarian source. These gilts were fed either a high (2.8 kg) or low (1.5 kg) feed level during early gestation. First of all, this study showed that progesterone is secreted in a pulsatile fashion by the ovaries with concentration varying between 50 to 600 ng/ml in an individual sow, as opposed to a more stable concentration of around 20-30 ng/ml in the systemic concentration at this stage of gestation. At d6 and d9 of gestation, the high feed level resulted in a higher mean concentration and more pulses of progesterone in the vena cava, indicating a higher secretion rate of progesterone by the ovaries. Recovery of embryos at d10 of gestation also showed a higher embryo survival (92% vs 77%) on the high feed level.

In a further study with 98 gilts, two feed levels (1.5 vs. 2.8 kg), and inclusion of a high fat% or fibre% isocaloric to the high feed level were assessed in their effects on embryo survival. Pregnancy rate (92 to 96%) and embryo survival (72 to 77%) was not affected by the treatments, indicating no adverse effect of a high feed level on reproductive performance, and that extra inclusion of fat or fibre in the diet results in similar reproductive performance. The treatments with the high feed level did, however, increase the total mass of luteal tissue on the ovaries, the tissue which is responsible for secretion of progesterone. This implies a positive effect of feed level on secretory capacity of progesterone, since luteal mass was correlated with systemic progesterone.

In two studies at Rivalea, one with 233 gilts and one with 225 first litter sows, the implications of these results were explored in relation to farrowing rate and litter size in a commercial herd. In the gilt study, three feed levels (1.6 vs. 2.4 vs. 3.2 kg) of a conventional diet, and a diet with a high fibre content (10%) were compared. The fibre diet was fed isocaloric to the medium feed level. Pregnancy rate at d28 was not significantly different between treatments, although it was highest (91%) for the high feed level compared to the other treatments (81 to 83%). Farrowing rates were similar across treatments (74 to 83%). Total born (11.8 to 12.5) and born alive (11.2 to 11.5) did not differ across treatments.The high fibre diet had similar reproductive performance to the other treatments. If all gilts were pooled based on their growth rate, the 25% gilts with the highest growth rate (1003 g/d) had a higher pregnancy rate (92 %) than gilts with the 25% lowest growth rate (216 g/d; 85 % pregnant), and medium growth rate (573 g/d; 80 % pregnant), $P<0.09$. Difference in farrowing rate (86 % vs. 72 % vs. 78 %) was similar across gilts with a high, medium, and low growth rate in the first 25 d of gestation but not significant ($P=0.12$).

In the trial with first litter sows, two feed levels (2.0 vs. 3.0 kg) of a conventional diet, and two diets with respectively 9.4% fat and 10.0 % fibre fed isocaloric to the high feed level were tested. Farrowing rate (89 to 98%; corrected for not farrowing for non-reproduction reasons) did not differ across treatments, and total born (13.0 to 13.5) and live born (11.9 to 12.2) were similar across treatments. When pooled across treatments, sows with a high growth rate (25% highest; n=58) had a 100 % farrowing rate compared to 94 % for sows with a medium (n=108) and 92% for sows with a low (25 % lowest; n=59) growth rate ($P=0.09$). The fat and the fibre diets had similar reproductive performance to the other treatments.

The results from this project show that when considering nutritional effects on embryo survival, specifically effects of feeding level, progesterone secretion by the ovaries should be considered, and not only effects on systemic progesterone. A high feed level increases progesterone secretion by the ovaries. High feed levels were shown not to have an adverse effect on embryo survival at all, and some of the data from this project show a positive effect of a high feed level on embryo survival and pregnancy rate, possibly due to increased secretion of progesterone by the ovaries, counteracting a higher clearance from the systemic circulation. The project has also shown that high fibre diets, of interest in the context of group housing, can be used during early pregnancy with similar reproductive performance as conventional diets. In terms of feed allowance during early pregnancy, 2 to 2.4 kg during early pregnancy, 2.2 to 2.6 kg during mid-pregnancy, and 2.5 to 3.0 kg are recommended during late pregnancy for gilts. This allows a balanced maternal body weight gain during pregnancy, avoiding very low feed allowances during early pregnancy and excessively high feed allowances during late pregnancy. During early pregnancy higher feed allowances (than 2 to 2.4 kg) can be fed without compromising reproductive performance, but a balanced development of the gilt would probably require a limited growth rate.

A major part of this project was the subject of the PhD-thesis by Ms Rebecca Athorn, PhD-student with the University of Adelaide. Her thesis is projected to be submitted by September 2011.

Table of Contents

1. Introduction

The main objective of this project was to develop nutritional strategies for early pregnancy, based on feeding level and specific feed ingredients, to enhance embryo survival and litter size.

Sub-objectives

1. Establish effects of feeding level on progesterone secretion by the ovary and whether these effects are different from effects on systemic concentration of progesterone.
2. Establish feeding levels that optimally support luteal development and function for gilts and multiparous sows, in order to maximise embryo survival and potential litter size.
3. Identify the risk of low feed levels (structural) or off-feed incidents in terms of luteal failure and embryo survival.
4. Improve CL function and embryo survival by specific dietary ingredients that stimulate secretion of IGF-1.

Background

The main motivation underlying this project is that embryo mortality in gilts is still around 30% of embryos that result after fertilisation, and in older parity sows this figure is even higher, around 40-50%. Therefore, reducing embryo mortality offers a major opportunity to increase litter size in both gilts and older parities. With regard to the effect of feeding level on embryo mortality, the current paradigm says that a high feeding level in gilts reduces systemic progesterone and may therefore reduce embryo survival, as progesterone is a major determinant of uterine function during early gestation. In older parity sows the relationship between feeding level and embryo mortality has hardly been studied.

Despite the existing paradigm on the effect of feeding level on embryo mortality, literature on this subject is controversial. Almost all studies do find a reduction in systemic progesterone in gilts fed a high feeding level, but not all studies find a reduction in embryo mortality at a high feeding level. Some studies even find an increase in embryo survival and/or pregnancy rate in gilts fed a higher feed level. There is also inconsistency in what is defined as a “low” or “high” feeding level.

Inconsistency in literature may be caused by the fact that a change in feeding level may have differential effects on secretion of progesterone by the ovary as opposed to systemic progesterone. Systemic progesterone seems to be consistently reduced by an increased feeding level, due to the effect that a higher feeding level has on the (increased) clearance of progesterone from the systemic circulation by the liver. However, there is evidence that progesterone supply to the uterus not only relies on progesterone in the systemic circulation, but also on direct supply of progesterone from the ovaries, through counter-current transfer of progesterone from ovarian veins to uterine arteries and through lymphatic pathways. This direct supply may negate effects of feeding level on systemic supply of progesterone to the uterus, and even counteract those effects by increasing secretion of progesterone by the ovaries. In fact, it has been shown that IGF-1 levels, which are positively related to feeding level, are related to secretion of progesterone by the ovaries. Also, a higher feeding level may increase LH secretion from the brain, stimulating the ovaries to secrete more progesterone. These effects may override the effect of a high feeding level on systemic progesterone, and the net result of reducing systemic progesterone and increasing secretion of progesterone by the ovaries would determine the supply of progesterone to the uterus, and consequently influence embryo survival and pregnancy rate.

As outlined in the aims of this project, the studies described below were designed to re-evaluate the effects of feeding level on embryo survival and pregnancy rate, and to establish how important the local supply of progesterone is for embryo survival, and how feeding level influences the local secretion of progesterone. Further, the aim was to establish how specific energy components in the diet (fat, fibre) may affect embryo survival related to their specific effects on local and systemic progesterone.

2. Methodology

Exp 1 Relevance of local progesterone supply - the unilateral ovariectomy model

In this experiment gilts were subjected to unilateral ovariectomy, i.e. one ovary was removed, to establish wether the removal of the local source of progesterone (ovary) would have an effect on the survival or development of embryos in the uterine horn on the side of the removed ovary. Local transfer of progesterone from the ovary to the uterine horn occurs unilaterally, i.e. from the ovary to the horn that the ovary is attached to. Removal of one ovary therefore, would reduce progesterone supply to the uterine horn attached to that ovary to systemic supply only, whereas the opposite horn would still benefit from both systemic supply and local transfer of progesterone directly from the remaining ovary.

Exp 2 Effects of feed level and energy source on embryo survival

In this study, two feeding levels (1.5 kg/d vs. 2.8 kg/d) of a standard diet were compared, as well as substitution of part of the energy sources in the standard diet (cereals) by fat or fibre ingredients, was investigated. The fat and the fibre diet were fed isocalorically to the gilts that were fed a high feed level of the standard diet. The hypothesis was that replacing cereals with fat (to some extent) would make the diet less insulinogenic and therefore reduce IGF-1 levels, which would be less stimulatory to progesterone secretion. Replacing cereals by fibrous ingredients (to some extent) was expected to increase clearance of progesterone from the systemic circulation due to specific effects of fibre on capturing of cholesterol, a precursor for steroids like progesterone, in the gut. Diets with a high fibre content are of interest in group housing systems as they have been reported to increase the welfare of group housed sows and gilts.

Exp 3 Effect of feed level on progesterone in utero-ovarian venous blood

In this study, 20 gilts were fitted with a permanent catheter in the vena cava, to enable frequent blood sampling from the site where the utero-varian vein drains into the vena cava. Progesterone concentration in these blood samples reflects actual output of progesterone by the ovaries, before it enters the systemic circulation and is not subject to dilution by the systemic circulation nor to metabolic clearance (e.g. by the liver). It is therefore a good estimate of local contribution directly from the ovaries to arterial supply of progesterone to the uterus. In contrast to the systemic circulation, progesterone concentraion in the vena cava follows a pulsatile pattern, with pulses varying from 100 to 400 ng/ml, as opposed to concentration of progesterone in the systemic circulation varying around 20 to 30 ng/ml at this stage of gestation, and showing no pulsatile pattern.

Gilts were mated at their second (natural) oestrus and weighed 125 kg at mating. Frequent blood samples were taken at day 6 and 9 of gestation, day 6 representing the phase when ovaries are still independent of LH input; at day 9 ovaries are responsive to LH input. Gilts were fed either 1.5 kg/day (~M+0.2 kg) or 2.8 kg/day (~M+1.5 kg), resulting in weight gain of 0.37 kg/d and 1.28 kg/d, respectively. At day 10 reproductive tracts were recovered to assess embryo development and survival.

Exp 4 Rivalea: Effect of feed level and energy source on pregnancy and litter size in first litter sows

In this study, performed at Rivalea with 225 first litter sows, two feeding levels (2 vs. 3 kg/d) were compared as well as substitution of cereals as the main energy source in the standard diet with fat (9% vs. 2% fat), or fibrous ingredients (10% vs. 4% fibre). The fat-rich and the fibre-rich diets were fed isocalorically to the sows on the high feeding level. The underlying hypothesis was the same as for exp 2 above.

Exp 5 Rivalea: Effect of high vs med vs low feed level and high fibre diet on litter size and pregnancy rates in gilts.

In this study, a low (1.6 kg/d), a medium (2.3 kg/d) and a high feeding level (3.2 kg/d) were compared in their effects on pregnancy rate and litter size in gilts. Also, a diet high in fibre (10% vs. 4% fibre) was evaluated, fed at an energy level similar to the gilts fed a standard diet at the medium level.

3. Outcomes

Exp 1 Relevance of local progesterone supply - the unilateral ovariectomy model

Table 1 Implantations and embryos per horn in intact and unilaterally ovariectomised gilts.

		Number of implantations per horn			Number of embryos per horn		
		 ovary			 ovary		
Treatment	N	Ipsilateral horn	Contra-lateral horn	Ipsi-cont*	Ipsilateral Horn	Contra-lateral horn	Ipsi-cont
CON, 1.8M	10	6.1 ± 0.4			5.9 ± 0.3		
ULO, 2.4M	15	6.5 ± 0.3	5.3 ± 0.4	1.2 ± 0.5**	6.3 ± 0.4	5.0 ± 0.4	1.3 ± 0.4**
ULO, 1.2M	15	6.3 ± 0.5	5.8 ± 0.4	0.5 ± 0.7	5.3 ± 0.5	4.9 ± 0.5	0.4 ± 0.7

*difference between the ipsilateral (with ovary) and the contralateral (without ovary) horn. The CON treatment had both ovaries intact and therefore the results are average of left and right horn. ** $P<0.05$. The picture of the ovary with CLs indicates the presence of the ovary at one horn.

The table above shows that embryo survival in the uterine horns without an ovary, and therefore relying only on systemic supply of progesterone, was lower (-0.8 embryo) than in the horns that had the ovary still attached.

To simplify the outcome of this study, this would mean that the local supply of progesterone accounted for the survival of 1.6 extra embryos. In this study, half of the gilts subjected to unilateral ovariectomy were fed a high feeding level (2.4 M; around 2.7 kg/day) and the other half a low feeding level (1.2 M; around 1.5 kg/day). In gilts on a high feeding level, the difference in embryo survival between the two horns was even more exaggerated (+1.3 embryos; so 2.6 embryos due to local supply), which is understandable when one considers that systemic progesterone on a high feeding level is lower, and local transfer of progesterone may be higher due to increased secretion of progesterone by the ovaries.

On day 5 of pregnancy, gilts on the low feeding level had a higher concentration of progesterone (+5 ng/ml) in the systemic circulation.

Interestingly, gilts on a high feeding level had a higher overall embryo survival (73% vs. 65%) than gilts on the lower feeding level (not significant), and a higher post-implantation embryo survival (95% vs. 85%, $P<0.05$), despite a lower systemic progesterone level. This contradicts the existing paradigm that a high feeding level has a detrimental effect on embryo survival.

Conclusions from this study

- Local transfer of progesterone directly from the ovary to the uterus contributes significantly to embryo survival and therefore effects of nutrition (feeding level and diet) cannot be considered based on their effects on systemic progesterone only.
- A high feed level reduces systemic progesterone, but embryo survival (after implantation) seems to be improved by a high feed level.

Exp 2 Effects of feed level and energy source on embryo survival

Table 2. Embryo survival in gilts* fed different diets and allowances during the first 25 d of pregnancy.

	Low (1.5 kg/d)	High (2.8 kg/d)	High 13.5% fat	High 7.2% fibre
N	31	21	23	23
Pregnancy rate	94% (31/33)	91% (21/23)	96% (23/24)	96% (23/24)
Weight gain, g/d	320 ± 35[a]	1000 ± 55[b]	919 ± 53[b]	1055 ± 55[b]
Ovulation Rate	15.3 ± 0.4	14.9 ± 0.5	15.3 ± 0.5	16.3 ± 0.4
Progesterone, day 5 (ng/ml)	24.0 ± 1.2[x]	20.0 ± 1.9[y]	25.0 ± 2.7[x]	20.0 ± 1.3[y]
Progesterone, day 15 (ng/ml)	32.0 ± 2.7[a,c]	24.7 ± 2.1[b]	37.4 ± 2.4[a]	30.4 ± 1.5[b,c]
IGF-1 (ng/ml)	55.2 ± 6.2	54.2 ± 6.6	51.7 ± 5.9	52.9 ± 5.7
Total luteal weight, g*	6.7 ± 0.2[x]	7.2 ± 0.2[y]	7.1 ± 0.2[y]	6.8 ± 0.2[x,y]
Luteal weight, g per CL*	0.44 ± 0.01[x]	0.47 ± 0.01[y]	0.46 ± 0.01[y]	0.45 ± 0.01[x,y]
Total embryos*	12.2 ± 0.5	11.9 ± 0.6	11.6 ± 0.6	11.6 ± 0.7
Embryo survival*	80 ± 3%	77 ± 4%	76 ± 4%	76 ± 4%

* Values with asterix are LSmeans corrected for ovulation rate and gilts with embryo survival <30% not included. Viable embryos were those weighing more than 2.17g (2*SD below the mean).

Conclusions from this study

- A higher feeding level (2.8 kg vs. 1.5 kg !!) did not affect (reduce) embryo survival or pregnancy rate, despite reducing progesterone in the systemic circulation at day 5 and day 15 of gestation.
- On a high feeding level, total luteal mass, that is the total weight of the corpora lutea on the ovaries was higher, and progesterone in the circulation was related to luteal mass. This suggests that the progesterone secreting capacity of the ovaries was higher on the high feed level. This may indicate a positive effect of feeding level on formation of corpora lutea after ovulation. This may increase secretion of progesterone by the ovaries and therefore transfer of progesterone from the ovaries to the uterus, despite a lower systemic level of progesterone.
- Progesterone in the systemic circulation was increased in gilts on the fat diet. Fat as a precursor of steroid synthesis may therefore increase progesterone secretion.

- A high feed level, nor a high level of starch in the diet increased IGF-1 levels.
- Replacing cereals to some extent by fibre (7%) does not affect embryo survival or pregnancy rate – therefore high fibre diets can be applied in group housed gilts in early gestation without affecting reproductive performance.

Exp 3 Effect of feed level on progesterone in utero-ovarian venous blood

Table 3. Progesterone in the systemic circulation (VJ: jugular vein) and in the utero-ovarian vein (VC: vena cava) and embryo survival in gilts fed a low or high feed level during early gestation.

	Feed level after mating	
	High (2.8 kg/d)	**Low (1.5 kg/d)**
Day 6		
P4 in VJ (ng/ml)	19.6 ± 1.4	20.9 ± 1.9
P4 mean in VC (ng/ml)	**88 ± 11**[x]	**70 ± 8**[y]
Basal (ng/ml)	38 ± 6	37 ± 6
Pulses per 6 h	3.6 ± 0.6	2.7 ± 0.7
Pulse amplitude (ng/ml)	173 ± 19	149 ± 11
Day 9		
P4 in VJ (ng/ml)	31.4 ± 3.1	35.0 ± 3.4
P4 mean in VC (ng/ml)	**102 ± 14**[x]	**85 ± 11**[y]
Basal (ng/ml)	45 ± 7	45 ± 7
Pulses per 6 h	**5.5 ± 1.2**[a]	**3.8 ± 0.7**[b]
Pulse amplitude (ng/ml)	179 ± 22	174 ± 21
Ovulation rate	15.7 ± 0.8	15.8 ± 0.7
Embryo survival*	92 ± 3[a]	77 ± 3[b]

Sows were approximately 125 kg at mating. *day 10 of pregnancy

Conclusions from this study

- Progesterone in the systemic circulation is by no means reflective of secretion by the ovary, as measured in the vena cava. Progesterone in the vena cava is highly pulsatile and much higher.

- In gilts fed a high feed level (2.8 kg), progesterone secretion is slightly higher (P<0.10) on day 6, and higher (P<0.05) on day 9 of gestation. This implies that a high feed level has a stimulatory effect on actual secretion of progesterone by the ovaries, even though it may reduce progesterone in the systemic circulation due to a higher clearance.
- Effects of nutrition on progesterone can therefore not be simply evaluated by its concentration in the systemic circulation; effects on local secretion have to be considered, specifically when nutritional effects on systemic vs. local concentration are differential (e.g. when varying feed level).
- A high feed level increased embryo survival at day 10 of pregnancy.

Exp 4 Rivalea: Effect of feed level and energy source on pregnancy and litter size in first litter sows

Table 4 Effects of treatments on weight gain and reproductive performance in first parity sows

	N*	BW Gain (g/d)	Farrowing rate* (%)	TB	BA
Low (1.0M)	55	320 ± 57[a]	97 (55/57)	13.3 ± 0.4	12.1 ± 0.4
High (1.5M)	51	598 ± 41[b]	95 (51/54)	13.2 ± 0.4	12.2 ± 0.4
High-fat	49	611 ± 50[b]	89 (49/55)	13.0 ± 0.4	12.0 ± 0.4
High-fibre	58	505 ± 46[b]	98 (58/59)	13.2 ± 0.3	11.9 ± 0.3

*at farrowing, excluding sows that did not farrow for non-reproductive reasons, farr rate P=0.14

Table 4 shows that neither feeding level nor replacement of cereals by fat or fibre (to some extent) impacts on farrowing rate or litter size in first parity sows. It is, however, interesting to note that when data were pooled across treatments, sows with a high growth rate (25% highest; n=58) had a 100 % farrowing rate compared to 94 % for sows with a medium (n=108) and 92% for sows with a low (25 % lowest; n=59) growth rate (P=0.09).

Conclusions from this study

- A high feed level is not detrimental for litter size and pregnancy rate in first litter sows.
- Inclusion of fat or fibrous ingredients as energy source does not impact on embryo survival or farrowing rate.
- Therefore, fibre can be included up to 10% in diets for first litter sows during early gestation without affecting reproductive performance.
- Sows with a lower weight gain seem to have a lower farrowing ratel!

Exp 5 Rivalea: Effect of high vs med vs low feed level and high fibre diet on litter size and pregnancy rates in gilts.

Table 5. Effects of treatments on weight gain and reproductive performance in gilts.

	N*	BW Gain (g/d)	Pregnancy rate d28 (%)	TB	BA
Low (21 MJ DE/d)	46	421 ± 41[a]	83 (50/60)	12.5 ± 0.4	11.5 ± 0.4
Medium (31 MJ DE/d)	39	495 ± 45[a]	81 (44/54)	12.2 ± 0.4	11.3 ± 0.4
High (41 MJ DE/d)	45	912 ± 40[b]	91 (53/58)	11.8 ± 0.4	11.2 ± 0.4
Fibre diet (31 MJ DE/d)	42	569 ± 34[a]	82 (50/61)	12.3 ± 0.4	11.3 ± 0.4

*N at farrowing

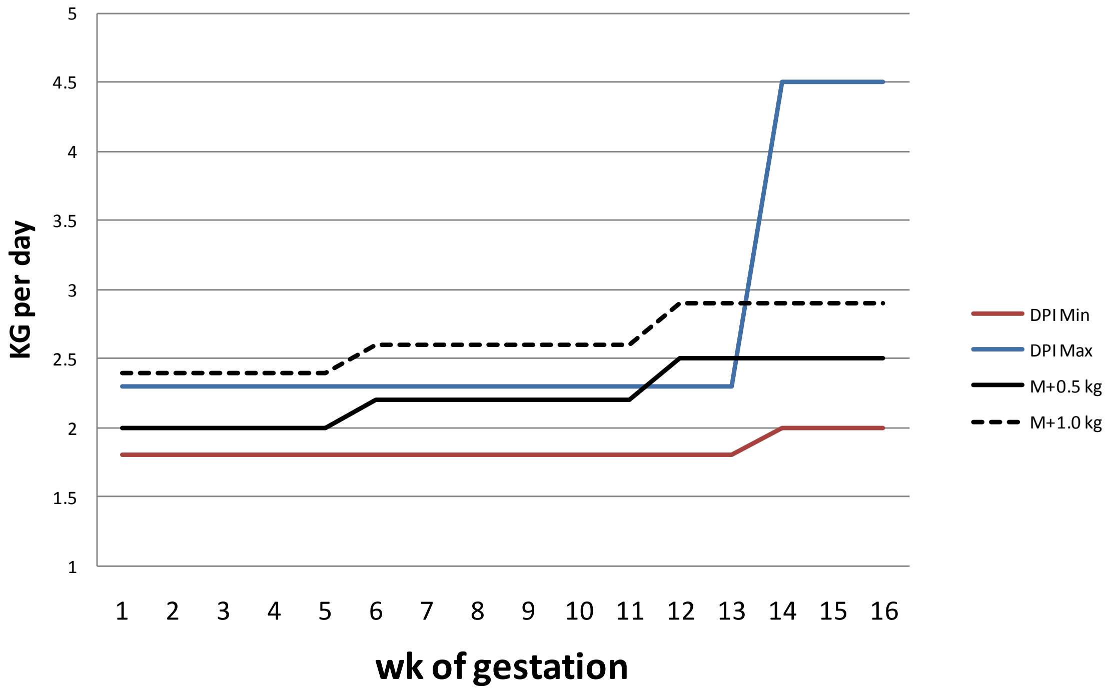
Feeding level and replacement of cereals by a fibrous ingredient to some extent, did not affect pregnancy rate or litter size in gilts. However, when all gilts were pooled based on their growth rate, the 25% gilts with the highest growth rate (1003 g/d) had a higher pregnancy rate (92 %) than gilts with the 25% lowest growth rate (216 g/d; 85 % pregnant), and medium growth rate (573 g/d; 80 % pregnant), P<0.09. Difference in farrowing rate (86 % vs. 72 % vs. 78 %) was similar across gilts with a high, medium, and low growth rate in the first 25 d of gestation but not significant (P=0.12). This mirrors the effect of feeding level on pregnancy rate in first litter sows (Exp 4).

Conclusions from this study

- Feeding level does not impact on pregnancy rate and litter size in gilts, although the results seem to indicate that gilts that have a higher weight gain (and maybe therefore a higher real feed intake?) have a higher chance of maintaining pregnancy,
- Inclusion of fibre in the diets up to 10% does not affect reproductive performance in gilts and therefore fibre can be included in diets to increase welfare in gilts during gestation.

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 early pregnancy some recommendations are more extreme and will actually recommend around 1.5 kg. Such a low feed allowance will compromise growth of the developing gilt and this project has shown that it may even impact negatively



on pregnancy rate and embryo survival. The current project results indicate that a feed allowance between 2 to 2.5 kg is more justified as it does not compromise the development of the gilt and certainly does not compromise reproductive performance, and may even benefit embryo survival and pregnancy rate. 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, depending on the targeted growth rate of the gilts, without compromising reproductive performance. The high feed allowance (blue line) at the end of gestation is based on the desire to maximize birth weight. However, data from a different CRC project (2D-116) 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. Increasing feed allowance during early pregnancy allows a balanced development of the maternal body weight of the gilt and removes the necessity of high feed levels during late gestation.

Ultimately the 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

Progesterone secretion by the ovaries, and therefore contribution of progesterone by local transfer to the uterine blood circulation is different from progesterone measured in the systemic circulation. A high feed level increases progesterone secretion by the ovaries and at the same time reduces systemic progesterone. Contribution of local transfer of progesterone to uterine arterial supply of progesterone and to embryo survival is significant. (aim 1)

Effects of feed level on progesterone and embryo survival should therefore not only consider effects on systemic progesterone, but also on secretion of progesterone by the ovaries. (aim 1)

A high feed level during early gestation increases the total luteal mass and therefore the secretory capacity for progesterone. A high feed level increases ovarian output output of progesterone. (aim 1)

A high feed level did not reduce pregnancy rate or litter size in the above studies. Gilts and first litter sows that achieved a high weight gain seemed to have a higher pregnancy rate, which may reflect that a high actual feed intake promotes the chance of maintaining pregnancy. (aim 2)

A high feed level increased embryo survival in two of three studies that looked at embryo development during early pregnancy. In the third study there was no effect on embryo survival (aim 2)

Inclusion of fibre in the diet at 7-10% did not affect pregnancy rate or litter size, or embryo survival. Fibre can therefore be included in diets for group housed gilts and primiparous sows without necessarily affecting reproductive performance. (aim 4)

Inclusion of fat at a high level (13%) in the diet may increase progesterone secretion. (aim 4)

A surgical model has been developed to study progesterone secretion by the ovaries under different nutritional strategies. This model is now being used to test effects of unintentional feed intake incidents (feed intake drops) such as during high ambient temperature, on function of the ovaries and maintenance of pregnancy. (aim 3)

6. Limitations/Risks

The first body of evidence that resulted in recommending low feed levels for gilts during early pregnancy in gilts was a study by Jindal et al. (1996). That study actually pointed out that a low feed level only during the first 3 d following mating may be beneficial to embryo survival. This aspect has not been studied in this project. It may therefore be interesting to evaluate the effects of feed level during the first few days early post mating.

7. Recommendations

- When considering nutritional effects on embryo survival in gilts (and sows), effects on secretion of progesterone by the ovary, besides effects on systemic progesterone have to be taken into account.
- Field studies have to follow up results from this project to study effects of feed level on farrowing rate and litter size in gilts, but also in first litter sows and multiparous sows.
- The previous point is particularly of interest in group housing, where the tendency is to increase feed level for welfare reasons. In that regard, also the inclusion of a high fibre content in diets should be followed up in commercial settings.
- See 4. Application of research for recommendations regarding feeding strategies during early gestation.

8. References

Dyck GW and Strain JH (1983) Postmating feeding level effects on conception rate and embryonic survival in gilts. Can J Anim sci 63: 579-585.

Dziuk PJ (1985) Effect of migration, distribution, and spacing of pig embryos on pregnancy and fetal survival. J Reprod Fertil Suppl 33: 57-63.

Foxcroft GR (1997) Mechanisms mediating nutritional effects on embryonic survival in pigs. J Reprod Fertil Suppl. 52: 47-61.

Gadsby J, Rose L, Sriperumbudur R, Ge Z. (2006) The role of intraluteal factors in the control of the porcine corpus lteum. Reproduction Suppl 62: 69-84.

Jindal R, Cosgrove JR, Aherne FX, Foxcroft GR (1996) Effect of nutrition on embryonal mortality in gilts: association with progesterone. J Anim Sci 74: 620-4.

Krzymowski T, Kotwica J, Stefanczyk-Krzymowska S (1990). Uterine and ovarian countercurrent pathways in the control of ovarian function in the pig. J Reprod Fertil Suppl 40:179–191.

Langendijk P, Dieleman SJ, Gerritsen R, Hazeleger W, Mainsant M-L, Soede NM, Kemp B. (2007) Pulsatile release of luteinising hormone during the luteal phase in lactating and weaned sows. Reprod Fertil Dev 19, 961-966.

Langendijk P, van den Brand H, Gerritsen R, Quesnel H, Soede NM and B Kemp (2008) Porcine Luteal Function in Relation to IGF-1 Levels Following Ovulation During Lactation or After Weaning. Reprod Dom Anim 43, 131–136.

Miller EA, Ge Z, Hedgpeth V, Gadsby JE (2003) Steroidogenic responses of pig corpora lutea to insulin-like growth factor I (IGF-I) throughout the oestrous cycle. Reproduction 125 241-249.

Miller, H.M., Foxcroft, G.R., Squires, J., Aherne, F.X., 1999. The effects of feed intake and body fatness on progesterone metabolism in ovariectomized gilts. Journal of Animal Science 77, 3253-3261.

Pharazyn, A., Foxcroft, G.R., Aherne, F.X., 1991. Temporal relationship between plasma progesterone concentrations in the utero-ovarian and jugular veins during early pregnancy in the pig. Animal Reproduction Science 26, 323-332.

Prime GR and Symonds HW (1993) Influence of plane of nutrition on portal blood flow and the metaboloic clearance rate of progesterone in ovariectomized gilts. J Agric Sci 121: 389-397.

Quesnel H, Boulot S, S Serriere S, Venturi E, Martinat-Botte M. (2010) Post-insemination level of feeding does not influence embryonic survival and growth in highly prolific gilts. Anim reprod Scie 120: 120-124.

Town SC, Putman CT, Turchinsky NJ, Dixon WT and G R Foxcroft (2004) Number of conceptuses in utero affects porcine fetal muscle development. Reproduction 128: 443–454.

Virolainen JV, Tast A, Sorsa A, Love RJ, Peltoniemi OAT (2004) Changes in feeding level during early pregnancy affect fertility in gilts. Anim Reprod Sci 80: 341–352.

Virolainen JV, Love R J, Tast A, and Peltoniemi O AT (2005) Plasma progesterone concentration depends on sampling site in pigs. Anim. Reprod. Sci. 86, 305–316.