Pregnancy and lactation interventions to increase progeny birth weight and growth and survival to weaning

2D-119

Report prepared for the

Co-operative Research Centre for an Internationally Competitive Pork Industry

By

Dr Kathryn L Gatford[1], Prof Julie Owens[1], A/Prof Mark Nottle[1], Dr Karen Kind[2], Dr William HEJ van Wettere[2], Dr Miles De Blasio[1], Mr Rob Smits[3], Dr Cherie Collins[3], Mr Rod Hamann[4]

[1]Robinson Institute and Discipline of Obstetrics & Gynaecology, School of Paediatrics and Reproductive Health, University of Adelaide SA 5005

[2]School of Animal & Veterinary Sciences, University of Adelaide, Roseworthy SA 5371

[3]Research & Innovation Unit, Rivalea Pty Ltd, Corowa NSW 2646

[4]Australian Pork Farms Group, Sheaoak SA

December 2010

(revised March 2011)

Executive Summary

Low birth weight and poor pre-weaning growth decrease survival and growth of piglets up to slaughter, and small piglets are born with fewer muscle fibres, limiting potential for lean tissue deposition. In project 2F-103 we showed that treating sows or gilts with pST from early to late pregnancy (day 25 to 100) increased birth, weaning and carcass weights of their progeny, with bigger responses in sow than gilt progeny. A shorter period of maternal pST treatment is preferred from a welfare and labour view, but we had already shown that treatment in early pregnancy only (day 25 to 50) did not increase progeny birthweight or performance in either parity. Increasing maternal pST in late pregnancy increased birth weight in other studies, although with more still births in one study. In Experiment 1 (conducted at Rivalea, Corowa, NSW, 2009-2010), we therefore investigated effects of treating sows and gilts with pST in late pregnancy (day 75 to 100) on birth and weaning weights of progeny, under commercial conditions. Gilts and parity 2/3 sows (n=75/group) were injected daily with pST (2.5 mg/d in gilts, 4.0 mg/d in sows) from day 75 to 100 of pregnancy, and maternal and progeny responses compared to untreated controls. Maternal pST injections increased piglet birth weight (+96g, 6.4%, P=0.034) and weaning weight (+430 g, 5.7%, P=0.038) but ONLY in sows (all parity 2 and 3 in this study), with no effect on progeny weight in gilts. Removal rates of dams in pregnancy, lactation and after weaning, and subsequent litter size were not affected by pST treatment.

The results of Experiment One suggest that pST treatment from day 75 to 100 of pregnancy is an effective strategy to increase birth and weaning weights in sow progeny, but that longer-term increases in maternal pST are required to increase birth and weaning size in gilt progeny. This has welfare and labour cost advantages over the longer injection protocol, at least in sows, whilst ***post-weaning responses remain to be evaluated***. The results of Experiment 1 do, however, mean that longer-term increases in maternal pST are required to increase fetal growth and birth weight in gilts. Exploring non-injection approaches to achieve this may therefore be necessary. ***Increasing weaning weight of sow progeny by 6% is modelled to reduce COP by 1c/kg in the current industry genotype, with a benefit to the Australian Pork Industry of $3 million per annum.***

A second strategy to improve progeny performance is to increase growth rates before weaning. Previous work has shown that arginine supply limits piglet growth, and feeding arginine-supplemented lactation diets to gilts increased weaning weights of progeny. Whether this would be effective in mature sows or under commercial conditions was not known. In Experiment 2 (conducted at Sheaoak Piggery, APFG, South Australia, 2009), we therefore tested whether increased dietary arginine in lactation would increase piglet growth rates and weaning weight in mature sows. Sows (Parities 2-5) were fed a control lactation diet or a diet supplemented with an additional 1% arginine. Maternal arginine supplementation increased piglet weights in early-mid lactation, and average growth rates throughout lactation, but only in male piglets. This was not due to changes to milk yield, which was similar in both groups despite lower feed intake in arginine-supplemented sows. Milk amino acid concentrations were increased in parity 2 and 4 sows, but decreased in parity 3 in arginine-supplemented sows. Weaning-estrous interval was 1 day shorter in arginine-supplemented sows.

The results of Experiment Two further suggest that feeding additional arginine through lactation can improve growth of male piglets in early-mid lactation and has positive effects on subsequent sow reproduction.

Table of Contents

1. Introduction

Background: Experiment One, Late gestation pST in sows and gilts

Birth weight, milk production and pre-weaning survival:

Improving pre-weaning growth rate and survival was identified as a major research priority for the Pork CRC at the September 2008 workshop on "Increasing Lactation Yield". Increased weaning weight and pre-weaning survival directly improve cost of production , as well as producing indirect benefits through improved post-weaning progeny growth and feed efficiency. Birth weight is a strong positive predictor of survival and weight at weaning (1, 4, 9, 20, 21). Furthermore, milk production is largely demand driven as larger piglets remove more milk from the mammary gland and increased litter weight increases sow milk production and the total litter weight gain (13).

Strategies to increase birth weight and milk demand - maternal pST treatment during pregnancy:

Fetal growth in the pregnant pig may be constrained by commercial feed levels, particularly in the gilt, where fetal and maternal growth compete for nutrients. Increased maternal nutrition throughout pregnancy improves birth weight as well as feed efficiency and muscle fibre development of progeny (2), but may decrease lactation feed intake of the sow, so that an alternative approach is needed to improve fetal growth and progeny performance. We and others have shown that daily pST injections of gilts between d25 and 50 of pregnancy increase fetal growth under commercial feeding conditions (8, 16), and improve progeny performance particularly of low birth weight piglets within a litter (7, 17, 18). More sustained treatment with pST (daily injections between d25 and 100 of pregnancy) increase birth weight of progeny, particularly in large litters (6). In our previous Pork CRC project (Gatford et al 2F-103-0607), comparing untreated controls with pST injections from day 25 to 50 or 25 to 100 of gestation in gilts and sows, longer-term pST injections increased average litter birth weights (8%) and weaning weights (5%) compared to controls. Although effective, daily pST injection during pregnancy is labour intensive and may generate consumer acceptance issues, related to ethical concerns about repeated injection as well as use of exogenous hormones.

A shorter period of increased pST during pregnancy may be still be effective in increasing birth weight and pre-weaning survival and growth. A number of studies have shown that increasing maternal pST in late gestation (from ~day 100 to term), either directly (10 mg pST/day) or by administering GHRF to increase endogenous production, did not increase birth weight, but did improve markers of progeny viability including body lipid content and circulating glucose, and weaning weight, as well as feed efficiency (gain:feed) after weaning (3, 5, 14). Injecting gilts with 6 mg/day pST from day 80 of pregnancy until term increased birth weight from 1.3 to 1.4 kg, and increased placental weight by 20%, but also increased the rate of still births from 8% to 17%, and increased piglet losses early in lactation, although survival rates to mid-lactation appeared similar (19). Electroporating pregnant gilts with a plasmid which expresses GHRH at day 85 of pregnancy, to increase endogenous pST production for the remainder of pregnancy, increased piglet weights at birth and weaning, did not alter pre-weaning survival and increased growth rates from birth to 100 kg (10). Together these studies suggest that maternal pST treatment in late gestation, although not necessarily up to term, will increase piglet birth weights, weaning weights and postnatal performance, although high doses may increase still births. We therefore tested the effectiveness of daily pST injections with a lower pST dose (2 mg/day in gilts and 3.5 mg/day in sows) from day 75 to 100 of pregnancy in increasing progeny birth weight, growth and survival to weaning (Study 1).

Background: Experiment Two, Lactation arginine supplements in sows

Strategies to increase milk supply, improve composition and increase piglet growth – maternal dietary arginine supplementation:

Supplementing the lactation diets of primiparous sows with L-arginine-HCL can increase milk production, piglet growth rate and weaning weight (15). This may be because the levels of the essential amino acid arginine present in sow's milk are insufficient to meet piglet requirements for maximal growth, since feeding supplementary arginine directly to piglets increases their growth rates (12) (22). Increased maternal circulating arginine may also increase potential milk supply through its effects on angiogenesis and vasodilation in the dam. Arginine is the common substrate for the generation of nitric oxide (NO; a major vasodilator and angiogenic factor) and polyamines (key regulators of protein synthesis). Arginine should therefore enhance vascular growth of mammary tissue and blood flow within mammary vessels via NO, to increase nutrient supply to the mammary tissues for milk synthesis, and increase mammary protein synthesis via polyamines (11). We therefore plan to test the effectiveness of supplementing lactation diets with arginine to increase milk production, progeny growth and survival (Study 2).

Research Objectives, Experiments 1 and 2:

1. Experiment 1, maternal pST injections in late pregnancy (2009-2010 Rivalea):

To assess the effectiveness of daily pST injection from d75 to d100 of pregnancy in gilts and sows (n=75/group) on maternal reproductive (litter size and birth weight) and lactational performance (milk production) and on progeny pre-weaning survival and growth under commercial conditions.

2. Experiment 2, maternal dietary arginine supplement in lactation (2009 Sheaoak Piggery, APFG):

To assess whether additional dietary arginine given to the sow during lactation increases gilt milk production and progeny performance (pre-weaning growth and survival) and the underlying mechanisms for this (milk yield, composition and/or arginine content) under commercial conditions.

2. Methodology

Experiment 1 - maternal pST injections in late pregnancy to increase progeny birth weight, pre-weaning growth and survival

Design:

Experiment 1 was conducted at Rivalea, Corowa in 2009-2010. Gilts and sows were injected daily with pST, from day 75 to 100 of gestation, and compared with a non-treated control group, to verify whether maternal pST treatment from d75 to 100 increases birth weight and progeny growth and survival to weaning, as seen in our previous studies using daily pST injections from day 25 to 100. The design was a 2 x 2 experiment: 2 parities (gilts/parity 2 and 3 sows) x 2 treatments (control/pST injections), n=75/group. The same gestation diet as in 2F-103 Study 2 was given during treatments to allow expression of responses to pST (13.4 MJ DE/kg, 16% protein, 0.8% lysine).

Outcome measures:

* Sow weight and P2 at start and end of treatment, and after weaning; * Sow feed intake during lactation; * Individual birth weights, litter size (numbers born alive, stillborn and mummies) and litter weight at birth; * Piglet deaths and removals and reasons throughout lactation to weaning * Litter size and litter weight at 14 days; * Individual weaning weights, litter size and litter weight at weaning

Experiment 2 - maternal dietary arginine during lactation to increase milk production, piglet growth and survival to weaning

Design:

Experiment 2 was conducted at Sheaoak Piggery (APFG) in 2009 and incorporated a 2009-2010 Honours project (Sarah Knapp). This study evaluated the effectiveness of feeding sows supplementary arginine during lactation, on piglet growth and survivability during lactation and some mechanisms contributing to this (milk yield, composition and arginine content). The aim was to increase circulating arginine in the dam, to increase nitric oxide synthesis, stimulating vascular development and vasodilation and hence milk yield, and/or to increase milk arginine content, which limits piglet growth after ~day 7 of lactation. Design: Multiparous sows (n=75 per treatment) were fed a standard lactation diet or supplemented with additional arginine (at 1% of diet) from entry into the farrowing house until weaning.

Outcome measures:

* Sow weight and P2 at day 1 of lactation & after weaning; * Sow feed intake during lactation; * Total litter weight & number suckled at day 1 (after fostering), day 7 (when arginine starts to limit piglet growth) and weaning. * Piglet deaths and removals and reasons throughout lactation; * Milk production (weigh-suckle-weigh), milk composition and dam plasma arginine & NO and milk arginine contents in 20 litters/treatment at day 4, 14 and 21 of lactation.

3. Outcomes

Experiment 1 - maternal pST injections in late pregnancy to increase progeny birth weight, pre-weaning growth and survival

Summary:

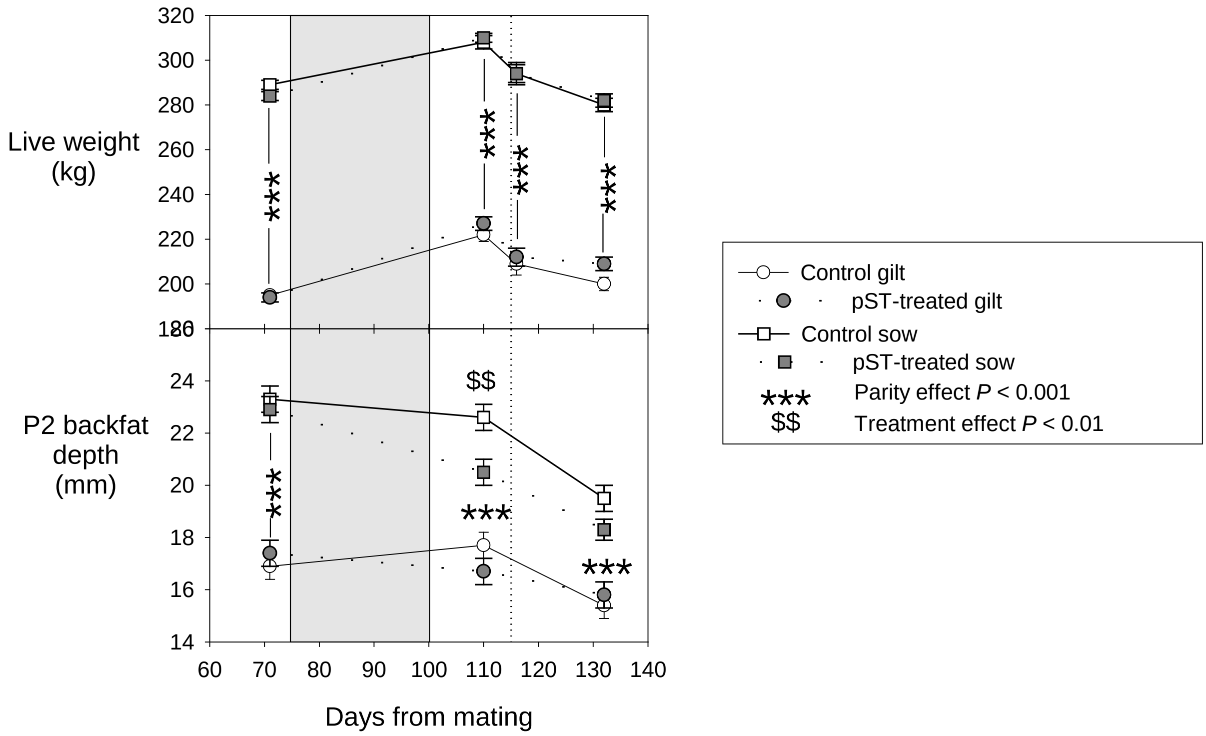
Maternal pST injections increased piglet birth weight (+96g, 6.4%, P=0.034) and weaning weight (+430 g, 5.7%, P=0.038) but ONLY in sows, with no effect on progeny weight in gilts. Removal rates of dams in pregnancy, lactation and after weaning, and subsequent litter size were not affected by pST treatment. Effects on subsequent performance should be evaluated in sow progeny, as this treatment period for maternal pST does not include key periods of fetal muscle development during early-mid pregnancy.

Sow weight and backfat depth

Maternal pST treatment did not affect maternal weight (Figure 1a) during pregnancy and tended to increase weight at weaning (P=0.087; control: 240 ± 2 kg; pST-treated: 245 ± 2 kg). During late gestation (day 71 to farrowing house entry, encompassing treatment period), maternal weight gain was greater in gilts than in sows (P<0.001; gilts: 30.4 ± 0.8 kg; sows: 23.8 ± 0.8 kg), and was greater in pST-treated than in control dams (P<0.001; control: 24.6 ± 0.8 kg; pST-treated: 29.6 ± 0.8 kg). Maternal pST treatment did not affect weaning weight loss (P>0.5).

Maternal P2 backfat depth (Figure 1b) was greater in sows than in gilts throughout the study (P<0.001 at each age), and was lower in pST-treated than control dams on entry to the farrowing house in late pregnancy (P=0.003), but did not differ between treatment groups before treatment or at weaning (P>0.4 for each). During late gestation (day 71 to farrowing house entry, encompassing treatment period), sows lost more P2 backfat depth than gilts (P=0.001; gilts: -0.19 ± 0.30 mm; sows: -1.67 ± 0.30 mm), and pST-treated dams lost more P2 backfat depth than control dams (P<0.001; control: -0.10 ± 0.30 mm; pST-treated: -1.76 ± 0.30 mm). Between farrowing house entry and weaning, P2 backfat depth change (overall mean: -1.88 ± 0.29 mm) was similar between parities (P=0.103) and treatment groups (P>0.2).

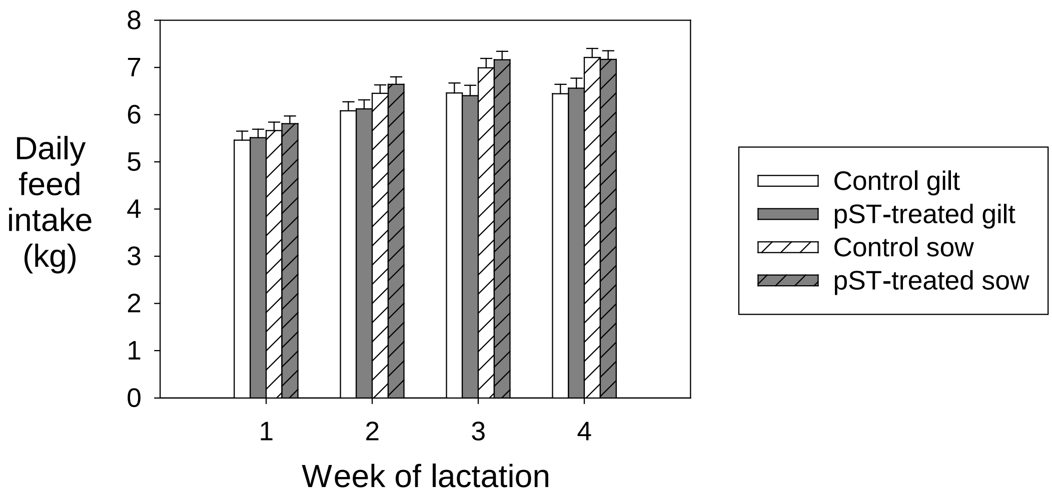
Figure 1 - Effects of maternal pST treatment in late pregnancy (day 75 – 100) and parity on maternal weight and P2 backfat depth. Data are means and SEM at each age; gilts are shown as circles and sows as squares, control dams are in white symbols and pST-treated dams are in shaded symbols.



Lactation

Maternal lactation feed intake (Figure 2) increased more with advancing lactation in sows than in gilts (P=0.011, linear contrast). Daily feed intake did not differ between parities in the first week of lactation (P>0.1), and progressively became higher in sows than in gilts from the second week of lactation (week 2: P=0.015; week 3: P=0.002; week 4: P=0.001). Daily feed intake did not differ between control and pST-treated dams (P>0.7).

Figure 2 - Effects of maternal pST treatment in late pregnancy (day 75 – 100) and parity on maternal feed intake during lactation. Data are means and SEM at each age.



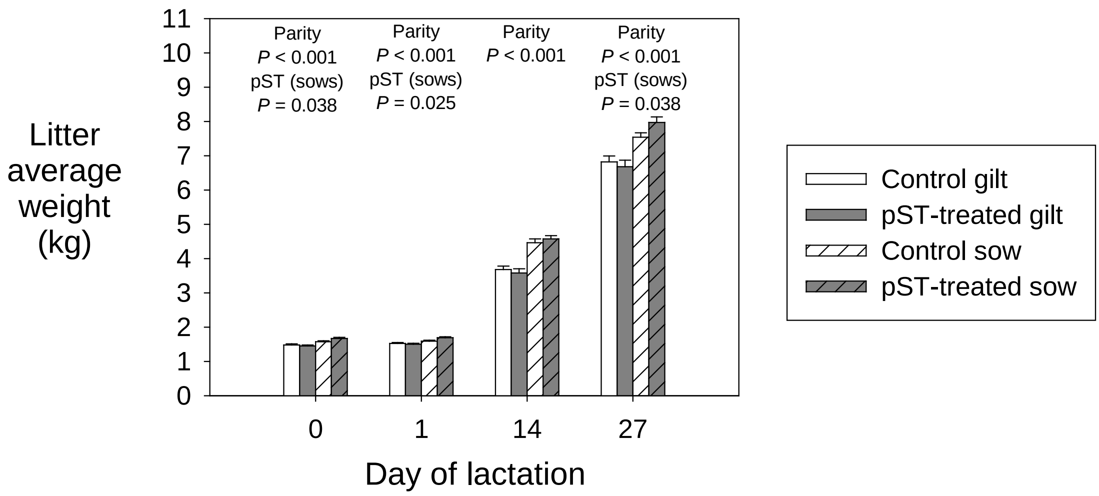
Between day 75 of pregnancy to scheduled farrowing house entry, similar proportions of dams were removed from each treatment group (P=0.594; Control: 5 of 139, 3.6%; pST-treated: 5 of 146, 3.4%). More gilts were removed during pregnancy than sows (P=0.049; Gilts: 8 of 141, 5.7%; Sows: 2 of 143, 1.4%). Similarly, dam removals during lactation were unaffected by maternal treatment (P=0.506; Control: 21 of 139, 15.1%; pST-treated: 23 of 146, 15.8%) and were higher in gilts than in sows (P=0.044; Gilts: 27 of 141, 19.1%; Sows: 16 of 143, 11.2%).

Piglet outcomes

Gestation length did not differ between treatments (P >0.8) and tended to be lower in sows than in gilts (sows: 116.4 ± 0.1 d; gilts: 116.7 ± 0.1 d; P = 0.092). Numbers of live-born and still-born piglets were higher in sows than in gilts (P=0.024 and P=0.004 respectively, Table 1). Maternal pST treatment did not alter the number of live-born piglets (P=0.231 overall and P>0.9 in gilts, P=0.128 in sows when analysed separately, Table 1), and affected numbers of still-born piglets in a parity-dependent manner (treatment x parity interaction P=0.082, Table 1). In gilts, maternal pST treatment did not affect the number of still-born piglets (P > 0.8), but in sows, maternal pST treatment increased the number of still-born piglets by 0.4 piglets per litter (P = 0.034, Table 1). Average piglet birth weights (Table 1) were increased by pST treatment in sows (+96 g, P=0.034), but not in gilts (P>0.5), and were higher in progeny of sows than in progeny of gilts (+157 g, P <0.001), with similar results when birth weight was corrected for total litter size at birth (Table 1).

Sows tended to suckle more piglets than gilts after fostering (P=0.064; gilts: 11.3 ± 0.1; sows: 11.5 ± 0.1), and this parity difference in litter size became very significant at day 14 of lactation (P<0.001; gilts: 8.1 ± 0.2; sows: 9.5 ± 0.2) and remained so at weaning (P<0.001; gilts: 7.7 ± 0.2; sows: 9.1 ± 0.2). Litter size from fostering to weaning was not affected by maternal treatment during the preceding pregnancy (P>0.2 at each age). Despite the greater litter size being suckled by sows, average (Figure 3) as well as total litter weight was greater in sow litters than in gilt litters at each age (P<0.001 for each). In gilts, maternal pST treatment did not affect average progeny weight in their litter post-fostering (P>0.7), at day 14 of lactation (P>0.4), nor at weaning (P>0.5). In sows, average progeny weight was greater in litters of pST-treated mothers post-fostering (+93 g, P=0.025) and at weaning (+430 g, P=0.038), but not different from progeny of control sows at day 14 of lactation (P>0.4, Figure 3).

Figure 3 - Effects of maternal pST treatment in late pregnancy (day 75 – 100) and parity on litter average piglet weights during lactation. Data are means and SEM at each postnatal age (day of lactation).



Subsequent reproduction

Weaning-remating interval did not differ between treatment groups (P>0.4) and tended to be longer in lower parity dams, i.e. those that were gilts during the treatment pregnancy (gilts: 7.44 ± 0.68 d, sows: 5.64 ± 0.68 d, P=0.064). Conception rates were similar in sows that had been controls or that were pST-treated in the previous pregnancy (74% and 78% respectively, P=0.293), and were similar in sows that had been gilts or sows during the treatment pregnancy (73% and 79% respectively, P=0.159). Maternal treatment and parity did not affect numbers of live-born (overall mean: 11.68 ± 0.23 pigs), still-born (0.73 ± 0.08 pigs) or mummified piglets (0.23 ± 0.04 pigs) in the subsequent litter (each P > 0.2).

Table 1 - Effects of maternal late pregnancy pST treatment and parity on treatment pregnancy outcomes[1]

Outcome	Gilts		Sows		Significance		
	Control	Late gestation pST	Control	Late gestation pST	Treatment	Parity	Treatment*parity
Number of litters	62	65	66	73			
Litter size at birth							
Total piglets	11.7 ± 0.4	11.6 ± 0.3	13.1 ± 0.4	12.7 ± 0.4	NS	0.001	NS
Live-born piglets	11.0 ± 0.4	10.9 ± 0.4	12.2 ± 0.4	11.4 ± 0.3	NS	0.024	NS
Still-born piglets	0.7 ± 0.2	0.7 ± 0.1	0.9 ± 0.1	1.3 ± 0.1	NS	0.004	0.082[2]
Mummies	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	NS	NS	NS
Average size at birth							
Average birth weight, kg	1.48 ± 0.03	1.45 ± 0.03	1.57 ± 0.03	1.67 ± 0.03	NS	<0.001	0.053[3]
Average birth weight, kg[4]	1.46 ± 0.03	1.43 ± 0.03	1.60 ± 0.03	1.68 ± 0.03	NS	<0.001	0.050[5]

[1] Landrace x Large White gilts and sows (parities 2 and 3 at mating) were uninjected (controls), or injected daily with pST (gilts: 2.5 mg.d^{-1}, sows: 3.5 mg.d^{-1}) from d 75 to 100 of pregnancy. Litter size and piglet weights were recorded within 24 h of birth.

[2] The number of still-born piglets per litter did not differ between treatments in gilts (P > 0.8), and was higher in pST-treated sows than in control sows (P = 0.034).

[3] The average litter birth weight did not differ between treatments in gilts (P > 0.5), and was higher in pST-treated sows than in control sows (P = 0.038).

[4] Corrected to an average total litter size of 12.29 piglets overall and within each parity (gilts: 11.65 piglets born, sows: 12.88 piglets born) for analyses of the treatment *parity interaction.

[5] The average litter birth weight, corrected for average litter size, did not differ between treatments in gilts (P > 0.5), and was higher in pST-treated sows than in control sows (P = 0.039).

Experiment 2 - maternal dietary arginine during lactation to increase milk production, piglet growth and survival to weaning

Summary:

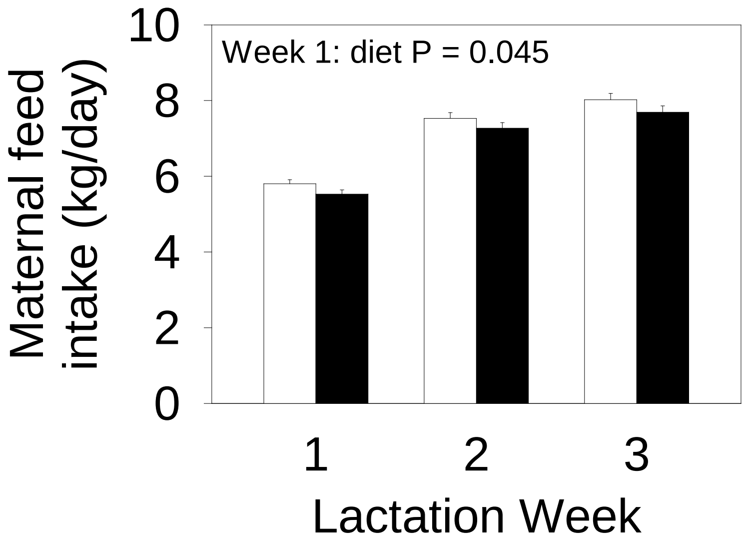
Maternal arginine supplementation increased piglet weights in early-mid lactation, and average growth rates throughout lactation, but only in male piglets. This was not due to changes on milk yield in sows, which was similar in both groups despite lower feed intake in arginine-supplemented sows. Milk amino acid concentrations were increased in parity 2 and 4 sows, but decreased in parity 3 in arginine-supplemented sows. Weaning-estrous interval was 1 day shorter in arginine-supplemented sows.

Sow lactation performance

Control (CON) and arginine-supplemented (ARG) sows lost similar amounts of weight (CON: -7.2 ± 2.2 kg; ARG: -8.9 ± 2.2 kg; P>0.5) and P2 backfat depth (CON: -2.3 ± 0.7 mm; ARG: -2.0 ± 0.7 mm; P>0.3) during lactation.

Maternal arginine supplementation decreased feed intake (measured as feed offered to meet demand) by ~270 g per day in the first week of lactation, but did not alter feed intake in week 2 or 3 of lactation (Figure 4). Daily feed consumption increased from the first to the second week of lactation and remained similar in the final week of lactation (Figure 4).

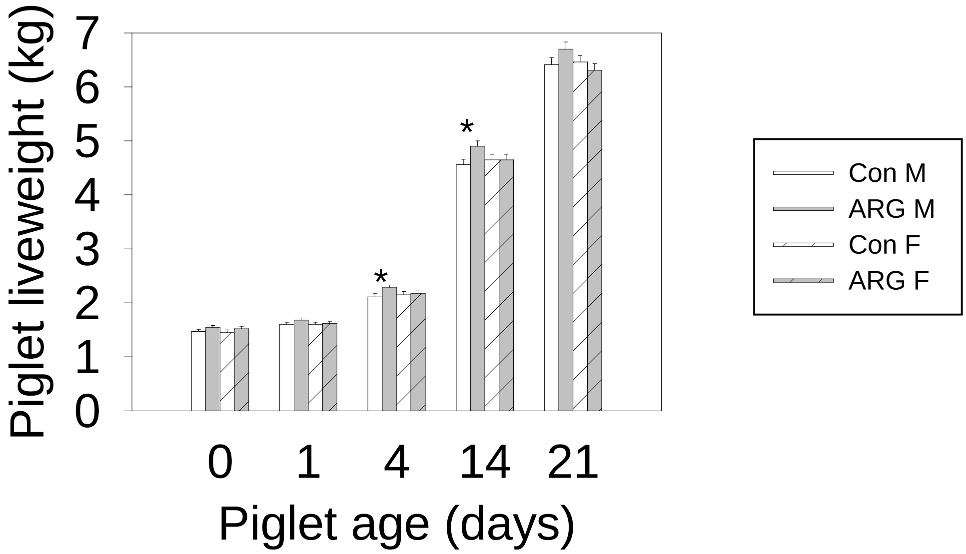
Figure 4 - Effects of lactation diet and week of lactation on maternal feed intake. Estimated means and SEM for control sows are shown in white bars, and arginine-supplemented sows in black bars. Data are corrected for litter size in each week of lactation.



Piglet growth

Maternal arginine supplementation did not affect piglet weight (Figure 5) at day 0, 1 or 21 of lactation, and affected piglet weights differently in male and female piglets at day 4 (interaction P=0.038) and day 14 of lactation (interaction P=0.005). Maternal arginine supplementation increased weight of male, but not female, piglets at day 4 (+170 g) and day 14 (+340 g) of lactation (each P<0.05). Similarly, effects of lactation diet on piglet growth rates over the whole of lactation varied with sex (P=0.013), being higher in male piglets from arginine-supplemented sows than in male piglets from control sows, but not different between diets in females.

Figure 5 - Effects of lactation diet and parity (left-hand panels) on piglet live weight. Means and SEM for control piglets are shown in white bars, and arginine-supplemented litters in shaded bars; males are in plain bars and females in striped bars.

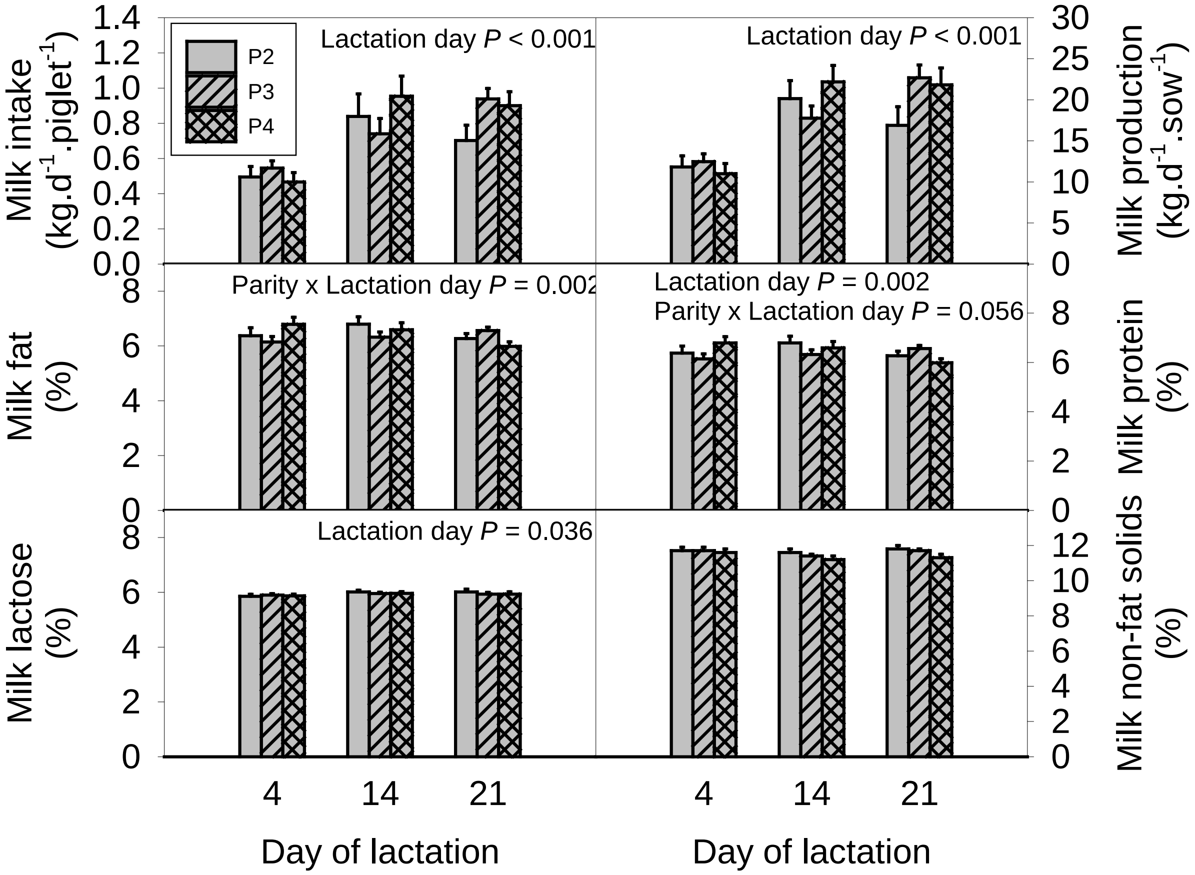


Milk yield and composition

Sow milk production and piglet intake each increased during lactation (each P<0.001) and differed between blocks of the study (milk intake P=0.014; milk production P=0.002), but did not differ between parities or lactation diets (all P > 0.1). Milk intake and production increased between day 4 and day 14 of lactation (each P<0.001) and then remained similar at day 21 (Figure 6).

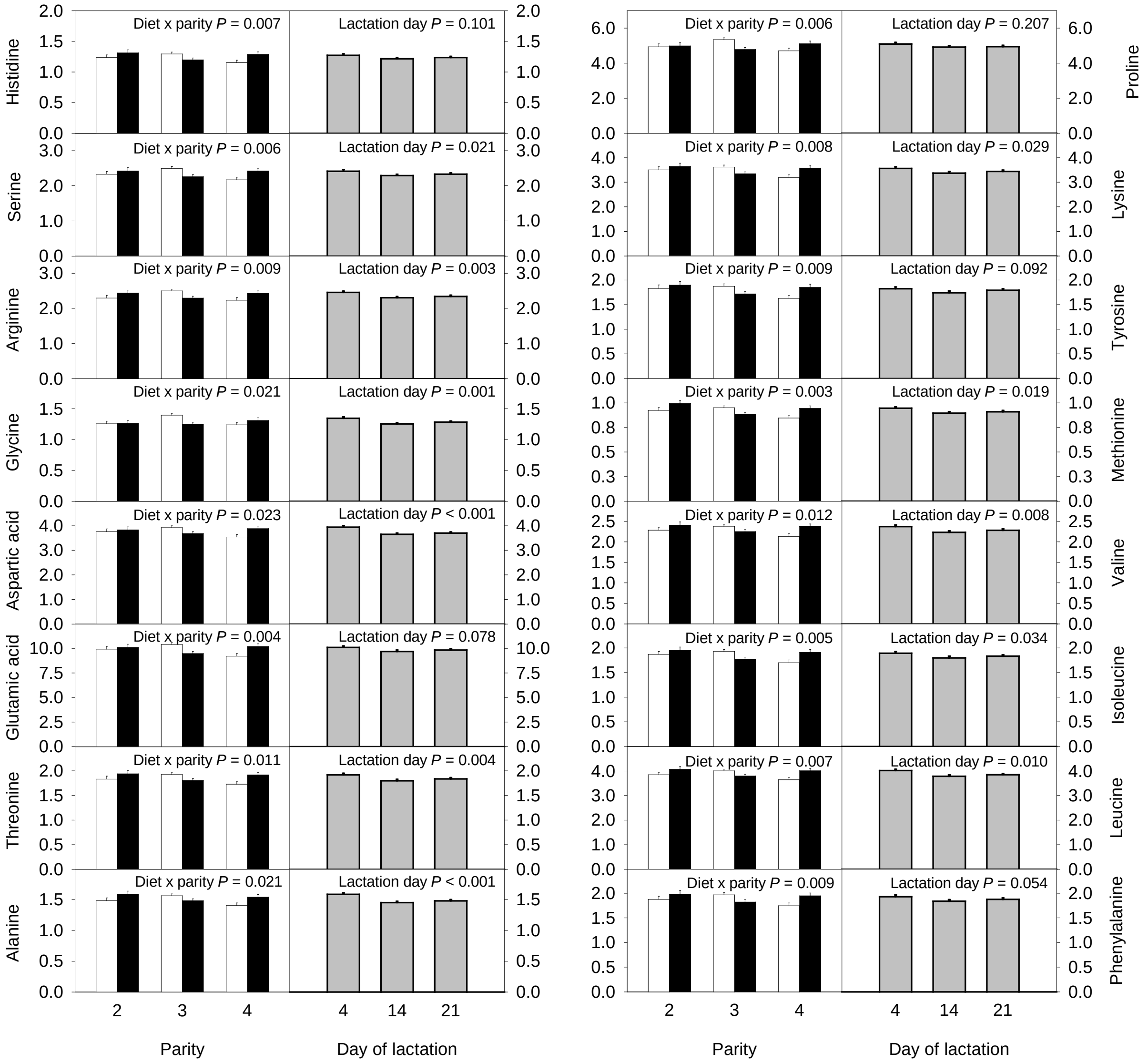
Milk fat and protein contents changed differently through lactation in each parity (each P=0.002), decreasing with time in Parity 4 sows, increasing in mid-lactation in parity 2 sows are remaining fairly constant in parity 3 sows (Figure 6). Milk lactose increased during lactation (P=0.036), although milk lactose contents at each day were not significantly different (each P>0.1, Figure 6). Milk non-fat solids did not change with parity or lactation day (each P>0.1, Figure 5). Maternal lactation diet did not alter these measures of milk composition.

Figure 6 - Effects of lactation day and parity on milk intake, production and composition. Estimated means and SEM for parity 2 sows are shown in grey bars, parity 3 sows in diagonal striped bars and parity 4 sows in cross-hashed bars. Data are corrected to an average litter size of 10.2 piglets suckled.



Milk amino acid contents were affected differently by diet depending on parity (P<0.05 for each amino acid), such that these were consistently increased by arginine-supplementation in parity 2 & 4 sows but decreased by arginine-supplementation in parity 3 sows (Figure 7). Milk amino acid concentrations also decreased with advancing lactation, in general decreasing between day 4 and day 14 of lactation and remaining at similar concentrations from day 14 to day 21 of lactation (Figure 7).

Figure 7 - Effects of lactation diet and parity (left-hand panels) and lactation day (right-hand panels) on milk amino acid contents. Amino acid concentrations are given in mg.mL[-1], based on molecular weights of amino acids in protein. Estimated means and SEM for control sows are shown in white bars, arginine supplemented sows in black bars, and combined means across treatments for each lactation day are shown in grey bars. Data are corrected to an average litter size of 10.2 piglets suckled.



4. Application of Research

Experiment One, Late gestation pST in sows and gilts

Under commercial conditions and with modern geneotypes, AusPig predicts that use of pST in late gestation will reduce COP by 1c/kg, based on improvements in growth for SOW progeny only. Achieving this benefit requires a change in marketing strategy to slaughter animals at maximum weight. Confirmation of improved postnatal performance is needed, given that the present study only followed progeny to weaning and this late pregnancy treatment period does not include the period when muscle fibres are being laid down in the fetus.

Ease of adoption of late gestation pST injections may be limited by labour availability (see under section 6 – limitations/risks). Together with results of project 2F-103, the present results show that:

- Late gestation pST injections (day 75 to 100) increase birth and weaning weights in sow progeny, but not in gilts.
- Sustained pST injections (day 25 to100) increase birth, weaning and carcass weights in progeny of gilts as well as sows, with bigger improvements in sow progeny.
- A longer period of elevated maternal circulating pST during pregnancy is needed to improve birth weight and performance of gilt progeny than in sows

Experiment Two, Lactation arginine supplements in sows

Feeding additional arginine to mature sows during lactation did not increase progeny growth consistently as has previously been reported in gilts, but did improve growth rates in male progeny. This increased arginine in the lactation diet also decreased weaning-estrus interval in sows by 1 day, and may be of benefit where sow housing is limiting in particular production systems. The variation we observed between maternal parities suggest that further evaluation of lactational arginine supplements are warranted within groups of dams of the same parity and genotype, as benefits may be seen in dams at particular ages/parities where maternal nutrient stores are limited. Positive effects on weaning weight have been noted in previous studies in gilts overseas (no previous studies had investigated this intervention in older parities, which was the focus of this study) and we suggest that this intervention should be evaluated within an Australian commercial setting in gilts.

5. Conclusion

We have now shown that a shorter period of increased maternal pST during late pregnancy increases progeny birth and weaning weight in sows but not in gilts, and more sustained increases in maternal circulating pST during pregnancy are needed to increase birth weight in gilt progeny. Further studies are warranted to develop non-injection approaches to increase maternal pST during pregnancy, due to labour availability limitations and potential consumer acceptability concerns/risks related to use of exogenous growth promotants and repeated injections. This is detailed under section 7, Recommendations.

Effects of lactation arginine supplements on milk composition varied between parities, and increased growth was only seen in male piglets, which anectdotal evidence suggests are more prone to growth impairment in early life than their sisters. Further investigation of efficacy of lactation arginine supplements in sows of gilts and on gut function or immune function in progeny might therefore be warranted.

6. Limitations/Risks

Use of pST in late gestation in sows is predicted (AusPig) to decrease COP by 1c/kg, with a value to the Australian Pork Industry of $3.2 million pa. Total and live born litter sizes were numerically similar in control and pST-treated gilts (live-born litter size, control gilts 11.0 ± 0.4 pigs, pST-treated gilt 10.9 ± 0.4 pigs, P>0.9). Although not statistically significant, the risk to litter size in sows (live-born litter size, control sows 12.2 ± 0.4 pigs, pST-treated sows 11.4 ± 0.3 pigs, P=0.128) could be commercially significant and is similar to that seen after long-term pST treatment in pregnant sows (-0.6 live-born pigs/litter), although better survival in heavier piglets may offset this risk. Current adoption is likely to be limited by availability of labour for injection of sows. Although effective in sows, daily pST injection during pregnancy is labour intensive and may generate consumer acceptance issues, related to ethical concerns about repeated injection as well as use of exogenous hormones. Potential concerns therefore also exist regarding consumer attitudes and moves by large purchasers away from use of growth promotants. Exploring non-injection approaches to achieve this increase in maternal circulating pST by increasing endogenous secretion may therefore be preferable. A longer (sustained) increase in maternal circulating pST levels is needed to increase progeny birth and weaning weights in gilt progeny, and non-injection approaches are likely to be of even more benefit in this situation because of the greater labour implications.

7. Recommendations

The results of Experiment 1 imply that elevated levels of maternal pST are required throughout the majority of pregnancy in order to increase birth weight of GILT progeny, although elevated maternal pST only in late gestation is sufficient to increase birth weight of SOW progeny. Labour costs and potential adverse consumer sentiments on ethical grounds make use of daily maternal pST injections unattractive as an option to increase birth weight of progeny, despite the demonstrated efficacy. ***We therefore wish to conduct trials of dietary additives to increase endogenous maternal pST production and circulating levels during pregnancy.***

In our 2009 study, Ms Kate Taylor (Pork CRC 2009 Honours student) showed that endogenous maternal pST (GH) is secreted in a pulsatile manner throughout pregnancy, whilst the mothers endogenous levels of pulsatile pST predict birth weight of progeny. This suggests that selecting for maternal GH in single blood samples will not be a useful selection tool (due to variation in pST in the short-term), but confirms that increasing maternal PULSATILE circulating GH levels in the normal range may increase birth weight. Since birth weight of gilt progeny has been identified as a particular concern of the Australian Pork Industry, we propose to focus on gilts in the subsequent experiment. Our experience to date suggests that responses in sows will be greater than those we expect in gilts. ***Our proposed strategy is to feed gilts with a gestation diet supplemented with 5% medium chain fatty acids (MCFA) during days 25-100 of gestation, and compare outcomes with untreated gilts (controls) and gilts treated with pST injections (positive control).***

Feeding dietary MCFA increases activation of the gut hormone ghrelin, which is stimulatory for endogenous GH secretion. This approach increases circulating GH levels in growing pigs (Dr David Miller, Pork CRC project), whilst direct ghrelin injections increase birth weight in the rat (Nakahara et al, 2006 Endocrinology 147:1333-1342), but dietary MCFA feeding has not been evaluated in pregnancy in any species. We will collect serial blood samples to assess changes in circulating GH profiles in response to these treatments at day 50 and day 100 of pregnancy (after 25 and after 75 days supplementation). We will be seeking Pork CRC funding and a future Honours student to pursue this project in 2011.

The results of Experiment Two confirm that feeding mature sows with additional arginine during lactation improves piglet growth, at least in male progeny, and decreases the weaning-estrus interval by ~1 day. Cost-benefit analyses are required to determine whether this strategy is currently cost-effective for use in industry, as the financial impact will depend ***. We wish to conduct further intensive studies to investigate the mechanisms underlying the decreased weaning-estrus interval, including responses in follicle growth and LH secretion.***

8. References

1. **Campbell RG and Dunkin AC.** The effect of birth weight on the estimated milk intake, growth and body composition of sow-reared piglets. *Anim Prod* 35: 193-197, 1982.

2. **Dwyer CM, Stickland NC, and Fletcher JM.** 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, 1994.

3. **Etienne M, Bonneau M, Kann G, and Deletang F.** Effects of administration of growth hormone-releasing factor to sows during late gestation on growth hormone secretion, reproductive traits, and performance of progeny from birth to 100 kilograms live weight. *J Anim Sci* 70: 2212-2220, 1992.

4. **Fahmy MH and Bernard C.** Causes of mortality in Yorkshire pigs from birth to 20 weeks of age. *Can J Anim Sci* 51: 351-359, 1971.

5. **Farmer C, Petitclerc D, Pelletier G, and Brazeau P.** Lactation performance of sows injected with growth hormone-releasing factor during gestation and(or) lactation. *J Anim Sci* 70: 2636-2642, 1992.

6. **Gatford KL, Boyce JM, Blackmore K, Smits RJ, Campbell RG, and Owens PC.** Long-term, but not short-term, treatment with somatotropin during pregnancy in underfed pigs increases the body size of progeny at birth. *J Anim Sci* 82: 93-101, 2004.

7. **Gatford KL, Ekert JE, Blackmore K, De Blasio MJ, Boyce JM, Owens JA, Campbell RG, and Owens PC.** 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, 2003.

8. **Gatford KL, Owens JA, Campbell RG, Boyce JM, Grant PA, De Blasio MJ, and Owens PC.** Treatment of underfed pigs with GH throughout the second quarter of pregnancy increases fetal growth. *J Endocrinol* 166: 227-234, 2000.

9. **Hemsworth PH, Winfield CG, and Mullaney PD.** Within-litter variation in the performance of piglets to three weeks of age. *Anim Prod* 22: 351-357, 1976.

10. **Khan AS, Fiorotto ML, Cummings KK, Pope MA, Brown PA, and Draghia-Akli R.** Maternal GHRH plasmid administration changes pituitary cell lineage and improves progeny growth of pigs. *Am J Physiol* 285: E224-E231, 2003.

11. **Kim S and Wu G.** Regulatory role for amino acids in mammary gland growth and milk synthesis. *Amino Acids* 37: 89-95, 2009.

12. **Kim SW and Wu G.** Dietary Arginine Supplementation Enhances the Growth of Milk-Fed Young Pigs. *J Nutr* 134: 625-630, 2004.

13. **King RH, Mullan BP, Dunshea FR, and Dove H.** The influence of piglet body weight on milk production of sows. *Livestock Production Science* 47: 169-174, 1997.

14. **Kveragas CL, Seerley RW, Martin RJ, and Vandergrift WL.** Influence of exogenous growth hormone and gestational diet on sow blood and milk characteristics and on baby pig blood, body composition and performance. *J Anim Sci* 63: 1877-1887, 1986.

15. **Mateo RD, Wu G, Moon HK, Carroll JA, and Kim SW.** Effects of dietary arginine supplementation during gestation and lactation on the performance of lactating primiparous sows and nursing piglets. *J Anim Sci* 86: 827-835, 2008.

16. **Rehfeldt C, Kuhn G, Nürnberg G, Kanitz E, Schneider F, Beyer M, Nürnberg K, and Ender K.** Effects of exogenous somatotropin during early gestation on maternal performance, fetal growth, and compositional traits in pigs. *J Anim Sci* 79: 1789-1799, 2001.

17. **Rehfeldt C, Kuhn G, Vanselow J, Furbass R, Fiedler I, Nürnberg G, Clelland AK, Stickland NC, and Ender K.** Maternal treatment with somatotropin during early gestation affects basic events of myogenesis in pigs. *Cell Tissue Res* 306: 429-440, 2001.

18. **Rehfeldt C, Nissen PM, Kuhn G, Vestergaard M, Ender K, and Oksbjerg N.** Effects of maternal nutrition and porcine growth hormone (pGH) treatment during gestation on endocrine and metabolic factors in sows, fetuses and pigs, skeletal muscle development, and postnatal growth. *Domest Anim Endocrinol* 27: 267-285, 2004.

19. **Trujillo-Ortega ME, Mota-Rojas D, Hernandez-Gonzalez R, Velazquez-Armenta EY, Nava-Ocampo AA, Ramirez-Necoechea R, Becerril-Herrera M, and Alonso-Spilsbury M.** Obstetric and neonatal outcomes to recombinant porcine somatotropin administered in the last third of pregnancy to primiparous sows. *J Endocrinol* 189: 575-582, 2006.

20. **van der Lende T and de Jager D.** Death risk and preweaning growth of piglets in relation to the within-litter weight distribution at birth. *Livestock Production Science* 28: 73-84, 1991.

21. **Winters LM, Cummings JN, and Stewart HA.** A study of factors affecting survival from birth to weaning and total weaning weight of the litter in swine. *J Anim Sci* 6: 288-296, 1947.

22. **Wu G, Knabe DA, and Kim SW.** Arginine Nutrition in Neonatal Pigs. *The Journal of Nutrition* 134: 2783S-2790S, 2004.

9. Appendices

Appendix 1: Publications

Peer-reviewed publications to date from this project:

- **KL Gatford**, RJ Smits, CL Collins, C Argent, MJ De Blasio, CT Roberts, MB Nottle, WHEJ van Wettere, KL Kind, JA Owens 2010 Maternal pST treatment in late gestation increases progeny weight at birth and weaning in sows but not in gilts. *Journal of Animal Science* submitted 16 October 2010.

Other peer-reviewed publications published in 2009 and 2010 from Pork CRC and PRDC-funded projects:

- **KL Gatford***, CG Grupen*, RG Campbell, BJ Luxford, RJ Smits, MB Nottle 2010 Reproductive responses to daily injections with porcine somatotropin before mating in gilts. *Journal of Reproduction and Development* (MS 10-060T, accepted 11 June 2010)
- **KL Gatford**, RJ Smits, CL Collins, C Argent, MJ De Blasio, CT Roberts, MB Nottle, KL Kind, JA Owens 2010 Maternal responses to daily maternal porcine somatotropin injections during early-mid or early-late pregnancy in sows and gilts. *Journal of Animal Science* 88: 1365-78 (from Project 2D-103)
- **KL Gatford**, MJ De Blasio, CT Roberts, MB Nottle, KL Kind, WHEJ van Wettere, RJ Smits, JA Owens 2009 Responses to maternal growth hormone or ractopamine during early-mid pregnancy are similar in primiparous and multiparous pregnant pigs. *Journal of Endocrinology* 203: 143-154 (from Project 2D-103)

Conference presentations 2009-2010 from Pork CRC-funded projects:

- **KL Gatford**, K Taylor, KL Kind, WHEJ van Wettere, JA Owens 2010 Circulating growth hormone profiles remain pulsatile during pregnancy in pigs. *Endocrine Society of Australia Annual Meeting, Sydney, Australia, August 2010.* [poster presentation KL Gatford]
- **KL Gatford,** RJ Smits, CL Collins, C Argente, MJ De Blasio, CT Roberts, MB Nottle, KL Kind, JA Owens 2009 Progeny outcomes following maternal treatment with porcine somatotropin during pregnancy *Australasian Pork Science Association Biannual Scientific Meeting, Cairns, Australia, November 2009.* [oral presentation KL Gatford]
- **KL Gatford,** RJ Smits, CL Collins, C Argente, MJ De Blasio, CT Roberts, MB Nottle, KL Kind, WHEJ van Wettere, JA Owens 2009 Maternal outcomes following treatment with porcine somatotropin during pregnancy: reproduction and longevity *Australasian Pork Science Association Biannual Scientific Meeting, Cairns, Australia, November 2009.* [poster presentation KL Gatford]

Appendix 2: Student training

Supervision of Honours students working on this and related Pork CRC-funded projects:

- **2009-2010:** Paul Herde, Bachelor of Sciences (Animal Sciences) Honours student in Animal Sciences (part-time), Principal supervisor Dr Will van Wettere, Co-supervisors Dr KL Gatford and Dr Karen Kind, H2A.
- **2009-2010:** Sarah Knapp, Bachelor of Sciences (Animal Sciences) Honours student in Animal Sciences, Principal supervisor Dr Will van Wettere, Co-supervisors Dr KL Gatford and Dr Karen Kind, H2A. Sarah was a Pork CRC-supported student working on Experiment 2 of this project.
- **2009-2010:** Tai Pham, Bachelor of Biomedical Science, Honours student in Obstetrics & Gynaecology, Principal supervisor Prof Ray Rodgers, Co-supervisors Dr H Irving-Rodgers, Dr KL Gatford, Dr J Trahair, H2A
- **2009:** Kate Taylor, Bachelor of Sciences (Animal Sciences) Honours student in Animal Sciences, Principal supervisor Dr KL Gatford, Co-supervisors Dr Karen Kind and Dr Will van Wettere, H2A. Kate was a Pork CRC-supported student investigating how average and circulating patterns of endogenous pST concentrations change during pregnancy and how these predict birth weight of progeny.