THE RESPONSE TO INCREASING DIETARY LYSINE ON LACTATION AND SUBSEQUENT REPRODUCTIVE PERFORMANCE OF FIRST-LITTER SOWS

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

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By

Mr. Rob Smits

Rivalea Australia
PO Box 78 Corowa NSW 2646
rsmits@rivalea.com.au

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Executive Summary

Maximizing the lactation performance in sows provides the foundation from which good quality piglets are weaned and maximizes growth through to finisher. First-litter (gilt litter) sows produce piglets with the lowest birth weight and also have low sow intakes in lactation compared to older multiparous sows. The aim of this experiment was to evaluate the response to increasing levels of dietary lysine and other amino acids in first-litter sows on lactation performance, sow weight loss over lactation and subsequent reproductive performance and sow retention on a commercial farm over summer.

Four hundred and thirty seven first-litter sows were allocated to one of five dietary lysine (total lysine/kg) levels offered *ad libitum* during a 20 day lactation: 6.2 g/kg, 8.7 g/kg, 10.9 g/kg, 13.3 g/kg, 15.6 g/kg. Sows were weighed and backfat P2 thickness was recorded within 24 hours of farrowing and again at weaning. Litters were weighed after initial fostering to an average litter weight within 24 hours of farrowing of 17.6 kg. Litters were re-weighed after 14 days and at 20 days. Subsequent reproductive performance including wean to oestrus interval, farrowing rate and cause of pregnancy failure and subsequent litter size was recorded from herd records. There was no significant linear response to dietary lysine in lactation in piglet weight gain, weaning weight or sow weight and P2 change over lactation. Increasing dietary lysine had a small but significant negative effect on sows' lactation feed intake. Average daily lysine intakes ranged between 31 to 78 g total lysine, however there was no evidence of a higher level of performance in litter weight gain or weaning weight at the higher daily lysine intakes. Litter gains and average piglet gains improved after the second week of lactation, however the response to dietary lysine on litter gain was non-significant. Subsequent reproductive performance was also unaffected by linear increases in dietary lysine intakes, although there was evidence that between 8.7 to 15.6 g lysine/kg subsequent litter size increased. The subsequent litter size of sows treated with the lowest lactation lysine level of 6.2 g/kg was similar to litter size of sows fed 10.9, 13.3 and 15.6 g/kg. Farrowing rates were unaffected by lactation lysine level. There were a high proportion of sows that needed to come off the study due to poor health of their litter, predominantly due to milking failure and scours. There was no significant treatment effect on cause of removal or total removal from the study, however it indicated that there are likely non-nutritional constraints to lactation in this piggery.

The current recommendation to formulate diets based on sow intake to achieve a daily lysine intake of between 50-55 g total lysine remains. Although affected by health and heat stress, the lactation performance data from this herd is not dissimilar from other production herds recorded in the field. The study highlighted that increasing dietary lysine, when other limitations to lactation performance occur, does not result in improved litter gains or weaning weight. The sow maternal reserves at weaning also seemed to adequately ameliorate low lysine intakes during lactation when subsequent reproductive

performance was assessed. At current ingredient costs, an increase of 1 g dietary lysine costs approximately $45/tonne. There is no economic justification to increase dietary lysine in lactation above 11 g/kg when litter gains remain under 2 kg in commercial herds. Maximizing sow feed intake during lactation to increase both energy intake and protein intake remains the most cost-effective way to improve productivity from first-litter sows.

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1. Introduction

It has been widely reported that high sow replacement rates are predominantly caused by poor reproductive performance or reproductive failure (Hughes and Varley, 2003, Levis, 2005, Lucia, et al., 2000). In an analysis of herd production records using PigChamp, Koketsu and Dial (1997) reported that for every 1 kg increase in lactation intake there was 0.80 - 0.9 times less likely to be removed from the herd due to reproductive failure. One of the main causes of low reproduction in the breeder herd is due to body catabolism during lactation in first-litter sows. There have been numerous experiments to investigate the response of the first-litter sow to increased lactation intake, or specific amino acid intake such as lysine. King and Williams (1984) reported that it took first-litter sows longer to resume oestrus when weight loss during lactation was high, however found no effect of lactation intake on ovulation rate and subsequent litter size. King and Dunkin (1986) showed that first-litter sows were able to minimise lactation tissue loss by consuming 63 MJ DE/day and 815 g crude protein (35.5 g lysine/d). Ten years later, Tritton et al (1996) reported that there was a curvilinear response between dietary lysine level and litter gain and a positive correlation between high daily protein and lysine intake and subsequent litter size. Daily lysine intakes for first-litter sows have been recommended at 55 g (Dourmad, et al., 1998, Johnston, et al., 1993, Kim, et al., 1999, Tritton, et al., 1996) and supported findings from Johnston et al (1993) who suggested a daily lysine requirement of 54 g for high-producing mixed parity sows. In the US, Touchette et al (1998) concluded that there was no apparent benefit from feeding first-litter sows beyond a daily intake of 55 g lysine. The current NRC requirements (1998) recommends a dietary lysine level of 8.0 to 9.0 g lysine/kg to achieve a daily intake of 45 to 55 g. They use a predictive equation to adjust dietary requirements for potential litter gains as follows:

Lysine (apparent ileal digestible intake g/d) = -6.39 + 0.022 (litter gain g/d) with an R^2 of 0.88

Given an 80% digestibility of total lysine in cereal based diets, a primiparous sow producing litter gains of 2.0 kg/d would require 49 g total dietary lysine per day, whilst a high producing sow with a litter gain of 2.5 kg/d would require a daily intake of 62 g total lysine. Further dietary responses may be evident on sow protein loss during lactation, subsequent fertility, and longevity.

More recently, data has emerged suggesting a fertility response to higher lysine intakes (Usry et al, unpublished). These studies conducted in the US reported that increasing the dietary lysine (total) level from 9.9 to 12.4 g/kg resulted in linear increases in piglet growth rate. Yang et al (2009) also reported that modern lean genotypes that have low appetites are able to increased their milk production, and milk protein and total solids concentration at higher lysine intakes during lactation. However, increasing the protein content of the lactation diet, particularly in summer, needs to proceed with caution. Smits et al (1998) reported there was a reduction in appetite by gilts and sows fed 12 g total lysine/kg compared to those fed 8 g lysine/kg conducted over the summer months when intakes are historically low (Final Report BMI 8/0987, 1998). The heat increment from feeding high protein diets can place extra stress on sows (Johnston, et al., 1999).

There is a paucity of data published in the scientific literature on the amino acid requirements of lean genotypes under cereal based diets as used in Australian herds since the work by Tritton et al in 1996. Current industry recommendations are for 10 g lysine/kg in gilts or an average daily intake of up to 55 g lysine. Hewitt and van Barneveld recently conducted an experiment as part of the Pork CRC project 2D-104 investigating effects of litter suckling size (7 or 12) at 9.4 or 15.3 g lysine (total)/kg. They reported a significant effect of suckling size on subsequent litter size but found no response to the increased dietary lysine level on lactation performance or subsequent fertility in a commercial herd.

Lactation performance and consequently weaning weight and piglet survivability is a major limitation in current commercial herds. Maximizing lactation performance from first-litter sows is important as they produce piglets that are lower in birth weight and may be more compromised in immune competency (Le Dividich, et al., 2005, Miller, 2006) and eat less than older multiparous sows (Jones and Hermesch, 2007). The optimal level of available lysine and balanced amino acids remains to be evaluated. It is expected that the young lactating sow could also have higher amino acid requirements than established over 10 years ago with genetic selection for lean body mass. The aim of this experiment was to determine the relationship between increased dietary lysine from a combination of protein meals and synthetic amino acid supplementation in a dose response experiment on lactation, sow weight and backfat loss and subsequent reproductive performance and sow retention to second parity. The experiment was designed to test the hypothesis that primiparous sows will increase their lactation performance and subsequent litter size when offered diets with high levels of dietary lysine during lactation.

2. Methodology

The experiment was conducted in the summer of 2009 with the treatment allocations over first lactation occurring between the first week of January to second week of April. The subsequent data was completed in September. The experiment was conducted at a commercial module at Rivalea, Corowa, NSW, where the weekly farrowings consisted of gilt litters and multiparous sows. Four hundred and thirty seven farrowed first-litter sows were allocated in total. The number of primiparous sows allocated each week varied and where possible multiples of five were allocated to allow even treatment replication per week.

Housing and feeding management

Pregnant gilts were transferred from a separate module at Corowa that housed young parity sows (parity 0-2). At approximately 110 days, gilts were transported by truck to the farrowing module and entered the farrowing sheds (Sheds 1-6). After entry, sows were allocated to one of five dietary lysine treatments:

6.2 g lysine/kg
8.7 g lysine/kg
10.9 g lysine/kg
13.3 g lysine/kg or
15.6 g lysine/kg as total lysine in a diet formulated at 14.7 MJ DE/kg.

The diets were formulated to be isoenergetic and used a combination of synthetic amino acids and animal and vegetable protein meals (Table 1). The ratio of essential amino acids to lysine was kept above the minimum recommendations considered as ideal by the NRC (1998) and Kim et al. (2001) and subsequently published as a technical note (Kim, et al., 2005). All diets were manufactured as a mash diet and prepared as 10 kg bags to facilitate feeding. Sows were fed 3 kg of their treatment diet prior to farrowing once a day, and thereafter were offered their dietary treatment up to three times a day to appetite. Recording of sow feed intakes commenced on day of farrowing and ended on the day of weaning.

On the first day of birth, litter size was evened up by fostering piglets of similar age from other gilt litters to average 11, with a range between 8 to 13 piglets. Litters were weighed on electronic scales and litter size recorded. Sows were weighed the day after farrowing to minimize the impact of disturbance and colostrum intake during the first 24 hours of life. Sows were walked onto a set of portable electronic scales and backfat was recorded at the P2 site (65 mm from the midline along the last rib) by real-time ultrasound. Litters were re-weighed on Day 14 and again the day prior to weaning. Sows were weighed and P2 measured on the day of weaning. There was no piglet creep feed provided to the litters during lactation. When necessary, litters were provided with electrolytes in creep drinkers.

During the study, scours were prevalent in most weeks and sows and piglets were treated for non-haemorrhagic Escherichia coli (*E. coli)* and haemolytic *E.coli*. Sows were treated with lincomycin whilst litters were given extra bentonite and electrolyte solution in waterers. If there were more than five piglets removed from the litter after fostering on Day 1 the sow was recorded as removed from trial. Data as to the reasons from sow removal were separately analysed. Following weaning, sows were re-mated at the first observed post-weaning oestrus. All sows were offered a commercial gestation diet post-weaning and mated by artificial insemination (AI) using 3 x 10^9 sperm cells per dose with a mating repeated 24 hours later. Sows were weaned into AI crates and then moved to gestation stalls for the 15 weeks gestation until movement into the farrowing accommodation for their subsequent litter. Sows that were weaned but failed to subsequently mate were recorded. Pregnancy failure, reason and subsequent litter size was recorded. The proportion of sows that were re-bred within 7 days was analysed in addition to the weaning to mating interval (WMI). Subsequent litter size was recorded as the litter born to the first post-weaning oestrus mating of the parity 1 sow. Sows that were re-mated due to a resumption of oestrus (i.e post-weaning matings that were classed as returns, or negative pregnancy tested animal or aborts) were excluded from the subsequent farrowing rate and litter size dataset.

Statistical analyses

Data was analysed by SPSS v 17.0 (SPSS Inc. Chicago, Il.) using General Linear Univariate modelling for continuous variables of weaning age, live weight, litter size and litter weight. Linear relationships between dietary lysine and daily lysine intake were modelled using regression techniques. Differences between treatments or between causes of sow removal, weaning to oestrus within 7 days, and farrowing rate and pregnancy failure were analysed by chi-square.

Of the 437 sows allocated to the experimental diets at farrowing, the number allocated to each treatment at the start of the experiment were 84, 88, 90, 88 and 87 for dietary lysine levels 6.2, 8.7, 10.9, 13.3 and 15.6 g lysine/kg, respectively. Treatment allocation was not equal due to differing numbers of sows being available each week. Each week the number of pregnant gilts allocated to the experiment ranged in number between 19 and 46 sows. When sows were removed from the study during lactation, they were removed from the dietary treatment and placed on a commercial lactation diet (14.7 MJ DE; 10 g lysine/kg).

3. Outcomes

Lactation performance of primiparous sows

The experiment was conducted over one of the hottest periods ever recorded (Figure 1) and a large number of litters had to be removed from the trial data set due to milking failure, scouring litters and as a consequence, poor litter growth rates and number weaned. Table 2 summarizes the weight change over lactation and the removal of sows from the trial due to poor litter gains or excess removal of illthrift piglets (> 5 piglets) during lactation. All sows entered the experiment in good condition. There tended to be a linear increase in post-farrowing weight with dietary lysine, and this may have been due to a short-term dietary response on protein accretion from pre-farrowing treatment feeding (approximately 5 days prior to pre-parturition). Lactation intake of the sow was negatively related to dietary lysine intake (Table 2 and Figure 2). Although on average, the mean intakes were similar, there was a higher distribution of sows with lower intakes in the high lysine diets. Feed intake was highly influenced by the time during lactation when the study was conducted (Figure 5), although there was no significant time x dietary lysine interaction (P=0.410). The proportion of sows that ate less than 5 kg/d on average increased with dietary lysine (19/59 sows on 6.2 g/kg; 21/60 on 8.7g/kg; 22/57 on 10.9 g/kg; 36/62 on 13.3 g/kg; and 29/62 on 15.6 g/kg; χ^2 10.41, P=0.053). In week 4, there were no sows that remained on trial in the lowest lysine group. The daily lysine intake during lactation was significantly increased due to dietary treatment (P<0.001) with the response having an r^2 value of 0.76. There were no other dietary responses to lysine in terms of sow weight or fat loss, sow weaning weight or weaning P2 (Table 2).

The number of sows removed from the dataset was similar between treatments (Table 2). The cause of removal included sow death, litter scours, mixing of litters, lactation failure, illthrift piglets not treated for scours, sows being used as foster sows, and removals due to poor sow condition or lameness. There were no significant differences between treatments for any one cause (Table 3). When combined, scours and piglet illthrift were the major causes of piglets being removed during the study, followed by lactation failure. In total, 130 litters were affected by non-treatment related issues during lactation (30% of the starting population).

The mean fostered piglet weight was 1.63±0.01 kg whilst the mean litter weight was 17.6±0.15 kg. There was no difference between treatments in either the number of piglets from Day 1, nor litter weight or average day 1 weight (P>0.500). The litter and average daily piglet gain during lactation is summarized in Table 4 and Figures 3a and 3b. There was no significant response over the 20 days of lactation to dietary lysine level in either litter gain or average piglet gain. There was a trend towards a lysine response in average piglet gain between day 14 and weaning (Figure 4b; P<0.10), however litter gain between day 14 and weaning was unaffected by dietary lysine (Table 4; Figure 4a). The difference in response between litter gain and average piglet gain is likely due to the litter size weaned which significantly declined when lysine was added at 13.3 g/kg or higher (Table 4). The number of piglets suckling by day 14 tended to influence the magnitude of response to dietary lysine level. When litter size at day 14 was included in the GLM ANOVA as a co-variate factor (P=0.065), the estimated marginal mean values for 6.2, 8.7, 10.9, 13.3 and 15.6 g lysine/kg for day 14-weaning litter gain were 1.49, 1.68, 1.75, 1.74 and 1.66 kg/day (P=0.451). The corresponding average piglet weight gains were 0.177, 0.184, 0.201, 0.204 and 0.202 kg/day. At a lysine level of 10.9 g/kg, there was a tendency for average piglet weight gain to be maximized (P<0.10). Regardless of dietary treatment, the litter gain and average daily piglet growth over the 20 days of lactation was noticeably low compared to litter gains reported in the literature for first-litter sows.

Subsequent reproductive performance

Sows were weaned after 20 days of lactation and mated on the first observed oestrus. There was no significant difference between dietary lysine treatments on the average interval to re-mating, the proportion of sows mated by 7 days or the number re-mated in total (Table 5). The subsequent farrowing rate was not influenced by dietary lysine offered in the previous lactation, although subsequent litter size tended to respond positively to lysine from 8.7 to 10.9 g/kg (Table 5). Using between-treatment post-hoc comparisons, sows offered dietary lysine at 8.7 g/kg in the previous lactation had a significantly lower subsequent total born than the other treatments (P<0.05). There were no significant differences in subsequent litter size between the lowest dietary lysine level and lysine at 10.9, 13.3 and 15.6 g/kg. The regression between dietary lysine level and subsequent litter size was low with an r^2 value of 0.005 and a linear slope coefficient of 0.065±0.057.

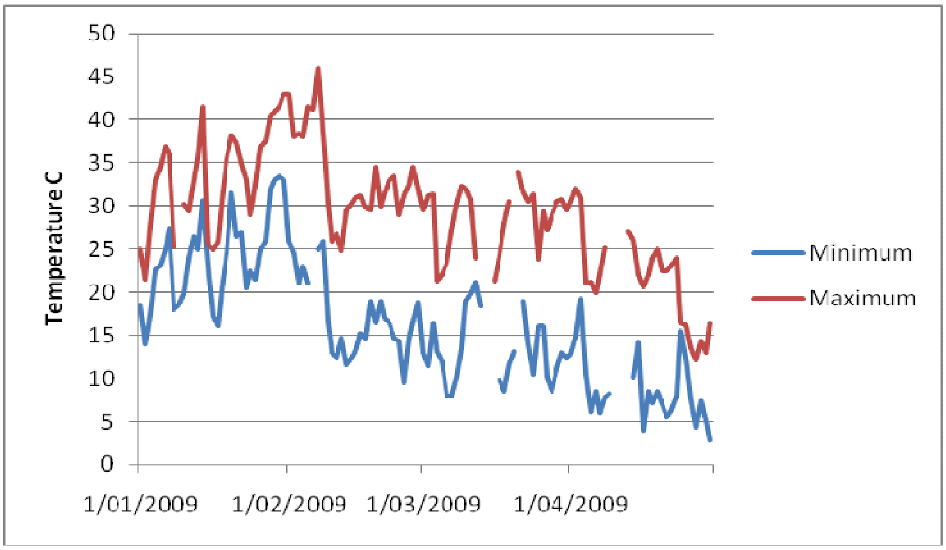

Figure 1. Minimum and maximum daily temperatures recorded at Corowa airport weather station (074034) during the lactating component of the experiment.

Table 1. Ingredient and nutrient composition of experimental lactation diets (on air dry basis).

Treatment diet (g total lysine/kg diet)	6.2	8.7	10.9	13.3	15.6
Ingredient (g/kg)					
Wheat	570	505	440	375.4	313
Barley	120	109	97.5	86.3	75.0
Millmix	120	140	160	180	200
Canola meal	38.3	46.3	52.5	59.0	65.0
Soyabean meal	35.3	61.7	87.7	114.0	140.0
Meat meal	16.7	27.0	47.5	64.0	80.0
Fish meal	10.0	14.0	17.5	21.3	25.0
Blood meal	0	10.0	12.5	19.0	25.0
Tallow	63	62	62	61	60
Salt	3.25	3.25	3.25	3.25	3.25
Limestone	6.3	5.0	5.0	1.6	0
Di-calcium phosphate	14.0	10.7	5.7	3.5	0
Lysine- HCL	0.065	0.65	1.23	1.82	2.43
DL-Methionine	0	0.48	0.78	1.43	1.93
Threonine	0	0.39	0.54	1.20	1.57
L-Leucine	0	0.27	0.53	0.82	1.10
Valine	0	0.26	1.50	0.80	1.07
Arginine	0	0.77	1.50	2.23	3.0
Vitamins and minerals[2,3]	2.1	2.1	2.1	2.1	2.1
Antioxidant	0.2	0.2	0.2	0.2	0.2
Monensin	1.0	1.0	1.0	1.0	1.0
Colour grit	1.0	1.0	1.0	1.0	1.0
Phytase	0.67	0.67	0.67	0.67	0.67
Nutrient (g/kg)[1]					
Digestible energy (MJ /kg)	14.7	14.7	14.7	14.7	14.7
Crude protein	158.7	186.6	211.9	239.3	265.7
Crude fibre	37.8	39.7	41.3	43.1	44.7
Crude fat	77.7	78.8	80.9	82.6	84.0
Calcium	9.1	8.7	9.1	8.8	8.8
Total phosphorus	7.6	7.6	7.6	8.1	8.3
Total lysine	6.2	8.7	10.9	13.3	15.6
Av. lysine (g/MJ DE)	0.34	0.49	0.62	0.76	0.90
methionine:lysine	0.41	0.39	0.39	0.38	0.38
threonine:lysine	0.82	0.76	0.73	0.71	0.70
valine:lysine	1.16	1.05	0.98	0.94	0.91
leucine:lysine	1.67	1.49	1.38	1.31	1.26
isoleucine:lysine	0.89	0.72	0.66	0.61	0.57
Phenylalanine:lysine	1.13	0.96	0.87	0.80	0.76
Phenyl+tyrosine:lysine	1.91	1.64	1.49	1.39	1.32

[1]Nutrient value was based upon Rivalea Australia Pty Ltd proprietary composition data.[2]Premix provided the following nutrients (per kg air-dry diet): copper, 20 mg; iron, 80 mg; manganese, 40 mg; zinc, 100 mg; iodine, 1 mg; selenium inorganic, 0.15 mg; chromium picolinate, 3.2 mg, betaine, 100 mg; antioxidant (Endox®), 100 mg; vitamin A (retinol), 15 m.i.u.; vitamin D (cholecalciferol), 1.5 m.i.u.; vitamin E (α-tocopherol), 60 mg; vitamin B_2 (riboflavin), 3.5 mg; vitamin B_6 (pyridoxine), 2 mg; vitamin B_{12} (cyanocobalamin), 0.02 mg; biotin, 0.2 mg; folic acid, 0.5 mg; niacin, 15 mg; pantothenic acid, 5 mg. [3]Supplementary premix provided following nutrients (per kg air-dry diet): Organic selenium (Selplex®), 0.15 mg; organic iron (Bioplex Iron®), 50 mg; vitamin E (α-tocopherol), 60 mg; niacin, 5 mg.

Table 2. Sow weight and backfat change during lactation and sow daily intake in response to increasing dietary lysine and offered *ad libitum* during lactation (21.2±0.08 d).

Lysine level (g total/kg) (no. sows)	6.2 (62)	8.7 (61)	10.9 (58)	13.3 (63)	15.6 (62)	SED	Linear Response to Lysine
Post-farrowing							
Sow weight (kg)	205.8	211.4	212.7	209.1	212.0	1.10	0.067
Backfat P2 (mm)	18.4	18.4	18.8	19.2	18.2	0.24	0.288
Weaning							
Sow weight (kg)[1]	192.8	193.8	192.9	194.0	191.8	1.02	0.285
Backfat P2 (mm)[1]	16.3	16.4	15.8	17.4	16.4	0.22	0.235
0 days-weaning							
Weight change (kg)[1]	-17.2	-16.6	-15.8	-16.3	-18.6	0.76	0.211
P2 change (mm)	-2.3	-1.9	-2.8	-1.9	-1.6	0.25	0.880
Sow feed intake (kg/d)	5.0	5.1	5.1	4.9	5.0	0.04	0.014(-ve)
Lysine intake (g tot. lys/d)[1]	31.0	44.8	55.4	65.4	77.7	1.04	<0.001
DE intake (MJ DE/d)	73.6	75.7	74.8	72.3	73.2	0.65	0.014 (-ve)
Prop. of allocated sows removed in lactation	0.26 (22/84)	0.31 (27/88)	0.36 (32/90)	0.28 (25/88)	0.29 (25/87)	$\chi^2$2.03	0.836

Replicate block included as a random factor in GLM model. [1]Post-farrowing sow weight included as a significant co-variate in GLM model.

Table 3. Reasons for sow removal during lactation x treatment and the proportion of the allocated sows removed in brackets ().

Lysine level (g total/kg)	6.2	8.7	10.9	13.3	15.6	Total Removal	P value
No. sows at Day 1	84	88	90	88	87		
Pre-weaned removal							
Scours	9 (0.11)	2 (0.02)	4 (0.04)	6 (0.07)	5 (0.06)	26 (0.06)	χ^2 3.94; P=0.545
Lactation failure	5 (0.06)	11 (0.12)	10 (0.11)	6 (0.07)	7 (0.08)	39 (0.09)	χ^2 2.64 P=0.749
Illthrift	4 (0.05)	7 (0.08)	5 (0.06)	3 (0.03)	5 (0.06)	24 (0.05)	χ^2 7.81 P=0.982
Mixed litter	3 (0.04)	3 (0.03)	6 (0.07)	3 (0.03)	3 (0.03)	18 (0.04)	χ^2 1.77 P=0.867
Sow used as foster dam	1 (0.01)	3 (0.03)	6 (0.07)	6 (0.07)	1 (0.01)	17 (0.04)	χ^2 5.57 P=0.198
Sow death	0 (0)	0 (0)	1 (0.01)	1 (0.01)	1 (0.01)	3 (0.01)	χ^2 1.69 P=0.854
Sow removal (condition or lameness)	0 (0)	1 (0.04)	0 (0)	0 (0)	3 (0.03)	4 (0.01)	χ^2 2.47 P=0.125

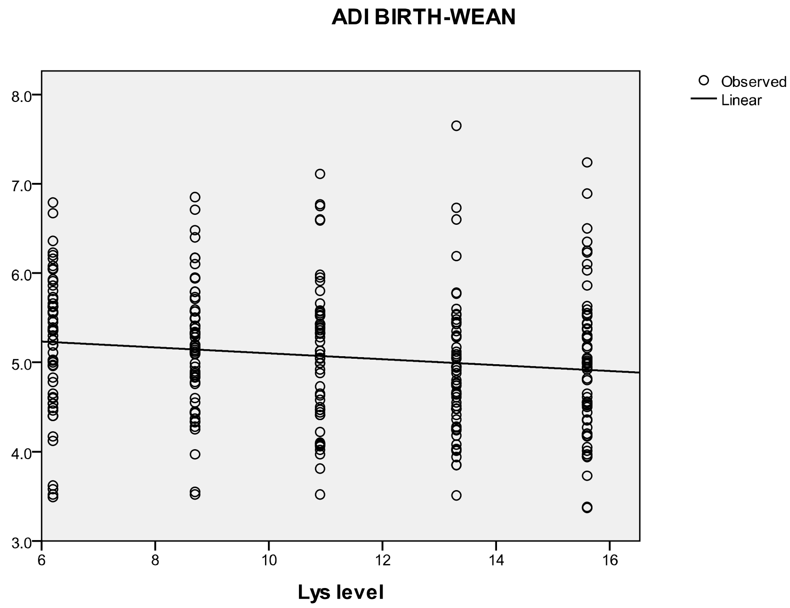

Figure 2. Dietary response on sow lactation feed intake (kg/d) over 21 days (Daily intake = 5.43-0.033±0.013 x lysine daily intake r^2 0.020).

Table 4. Litter response to increasing dietary lysine and offered *ad libitum* during lactation (19.9±0.09 d).

Lysine level (g total/kg) (no. sows)	6.2 (61)	8.7 (61)	10.9 (58)	13.3 (63)	15.6 (61)	SED	Linear Response to dietary Lysine
0-14 days							
Litter daily gain (kg/d)	1.29	1.39	1.35	1.17	1.36	0.03	0.265
Piglet daily gain (kg/d)	0.146	0.156	0.144	0.147	0.156	0.003	0.835
14 days-weaning							
Litter daily gain (kg/d)	1.50	1.68	1.77	1.71	1.65	0.04	0.876
Piglet daily gain (kg/d)	0.176[a]	0.184[ab]	0.199[ab]	0.207[b]	0.202[b]	0.004	0.044
0 days-weaning							
Litter daily gain (kg/d)	1.33	1.46	1.47	1.37	1.45	0.03	0.518
Piglet daily gain (kg/d)	0.155[a]	0.164[ab]	0.162[ab]	0.167[ab]	0.171[b]	0.002	0.387
Litter weaned weight (kg)[1]	43.7	45.8	45.5	42.9	45.5	0.62	0.531
Piglet weaned weight (kg)[1]	4.6[a]	4.7[ab]	4.7[ab]	4.8[ab]	4.9[b]	0.04	0.213
Litter size weaned	9.6[b]	9.6[b]	9.7[b]	9.0[a]	9.2[ab]	0.09	0.021

Replicate block included as a random factor in GLM model. [1]Weaning age included as a significant co-variate in GLM model (WEANAGE=19.9 days).[ab]Mean values within row differ significantly P<0.10.

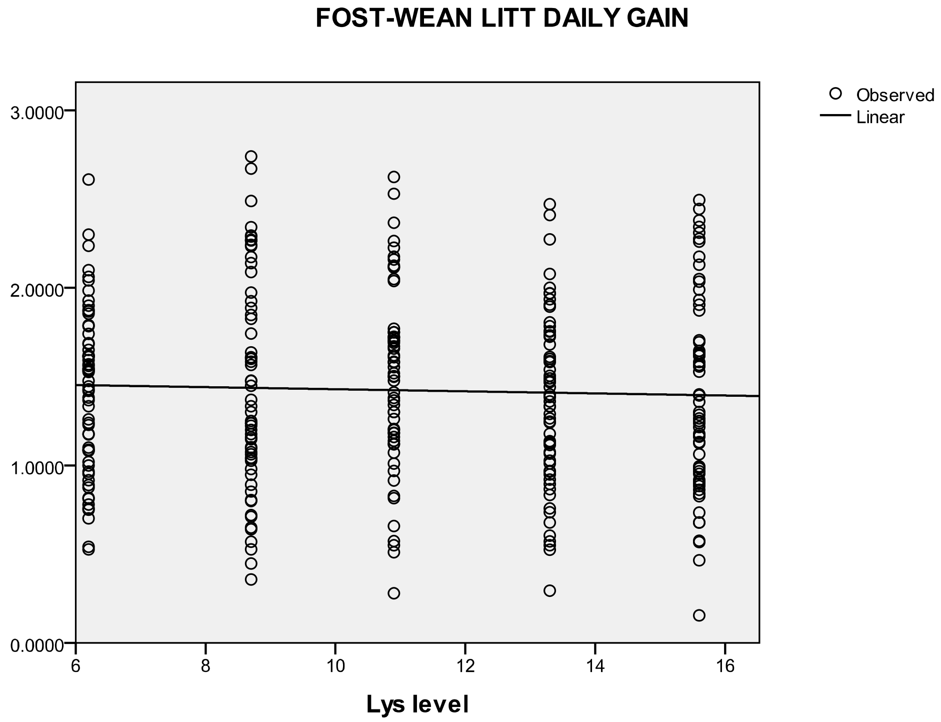

Figure 3a. Linear regression between lysine (total) dietary level and litter gain during lactation (Litter Gain kg/d = 1.488-0.006±0.009 x lysine dietary level g/kg r^2 0.001).

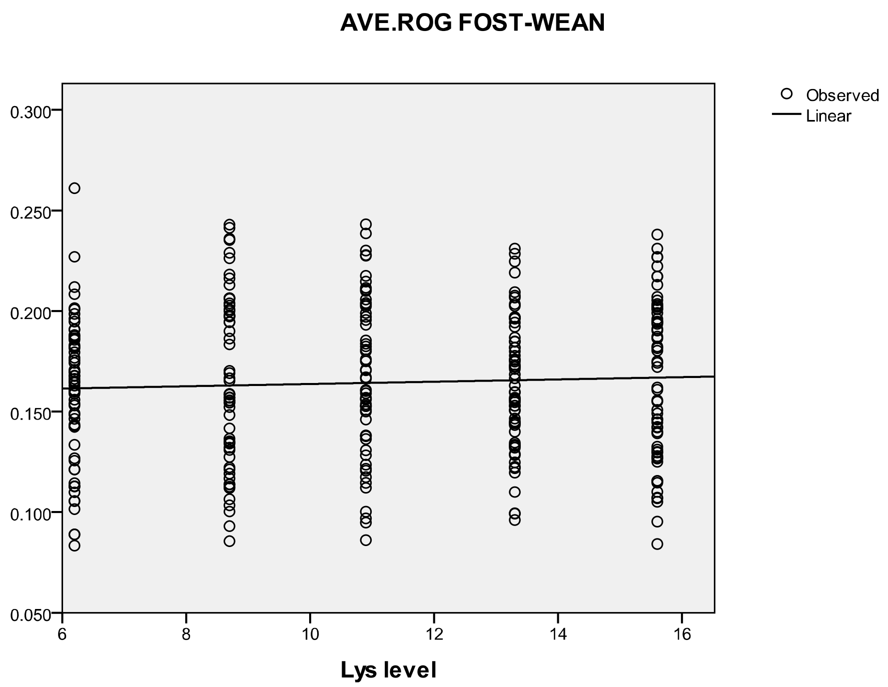

Figure 3b.Linear regression between lysine (total) dietary level and average piglet gain gain between during lactation (Av. piglet gain kg/d = 0.158+0.001±0.001 x lysine daily intake g/d r^2 0.014).

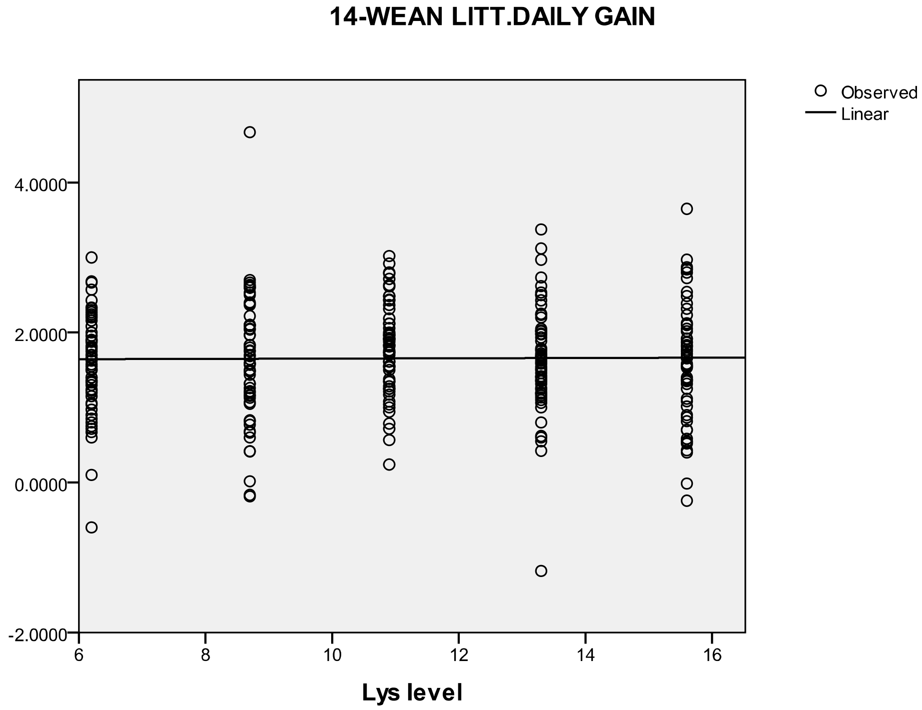

Figure 4a.Linear regression between lysine (total) dietary level and litter gain between day 14 and weaning (Litter Gain kg/d= 1.632+0.002±0.013 x lysine daily intake g/d r^2 0.001).

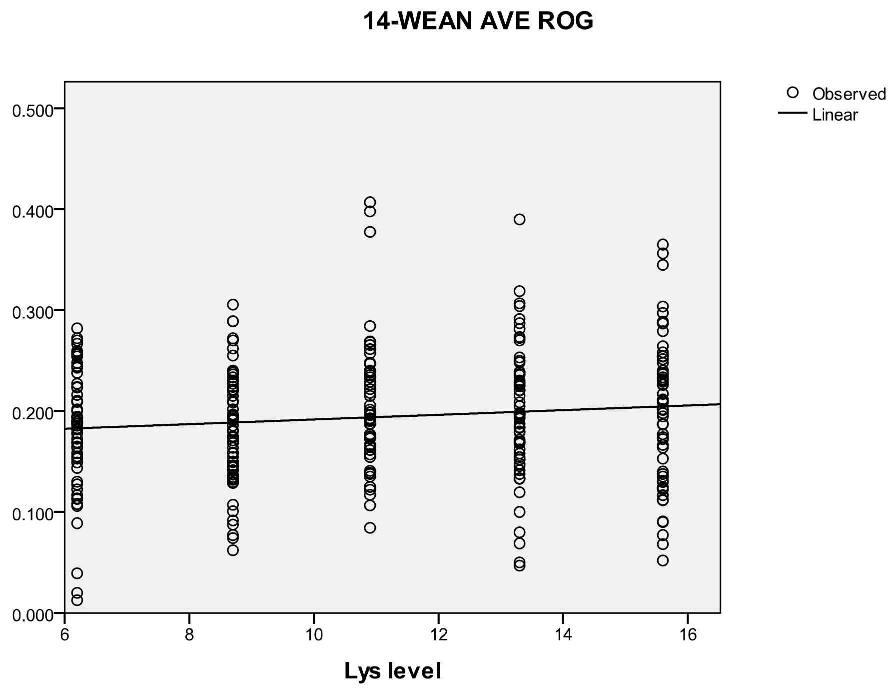

Figure 4b.Linear regression between lysine (total) dietary level and average piglet gain gain between day 14 and weaning (Av. piglet gain kg/d = 0.169+0.002±0.001 x lysine daily intake g/d r^2 0.014).

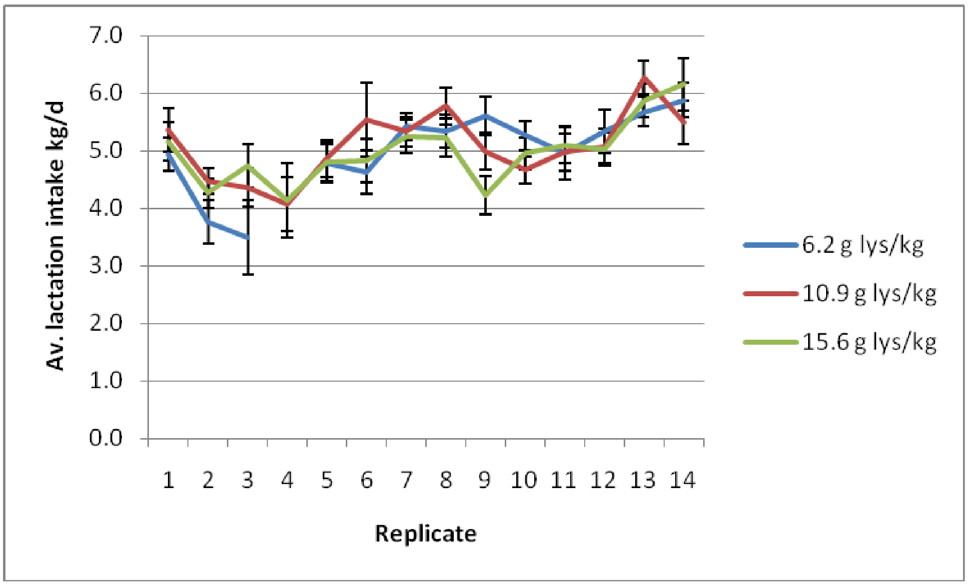

Figure 5. Mean±SE daily sow feed intakes over 20 days lactation of the lowest lysine level, medium level and highest dietary lysine levels during the lactation period of the experiment from January to April.

Table 5. Post-weaning reproductive performance and subsequent litter size of sows offered different dietary lysine levels during primiparous lactation.

Lysine level (g total/kg)	6.2	8.7	10.9	13.3	15.6	SED	P value
No. sows weaned	62	61	58	63	62		
No. re-mated total (% of weaned)	57 (0.92)	55 (0.90)	56 (0.97)	61 (0.97)	58 (0.94)		χ^2 3.50; P=0.622
No. re-mated by 7 d (% of re-mated)	45 (0.79)	52 (0.94)	49 (0.88)	48 (0.79)	47 (0.94)		χ^2 7.42; P=0.168
Av. days to re-mating	8.9	5.7	7.0	7.3	8.3	0.47	P=0.258
No. sows farrowed (% farrowing rate)	50 (0.88)	43 (0.78)	52 (0.93)	50 (0.82)	48 (0.83)		χ^2 5.43; P=0.348
Subsequent parity							Linear lys response
Litter size born live[1]	11.2	10.1	11.2	10.9	11.4	0.18	P=0.103
Litter size still born[1]	0.76	0.34	0.80	0.86	0.38	0.06	P=0.349
Total litter size born[1]	12.2	10.5	12.0	11.9	11.8	0.19	P=0.253

[1]Replicate block included as a random factor in GLM model.

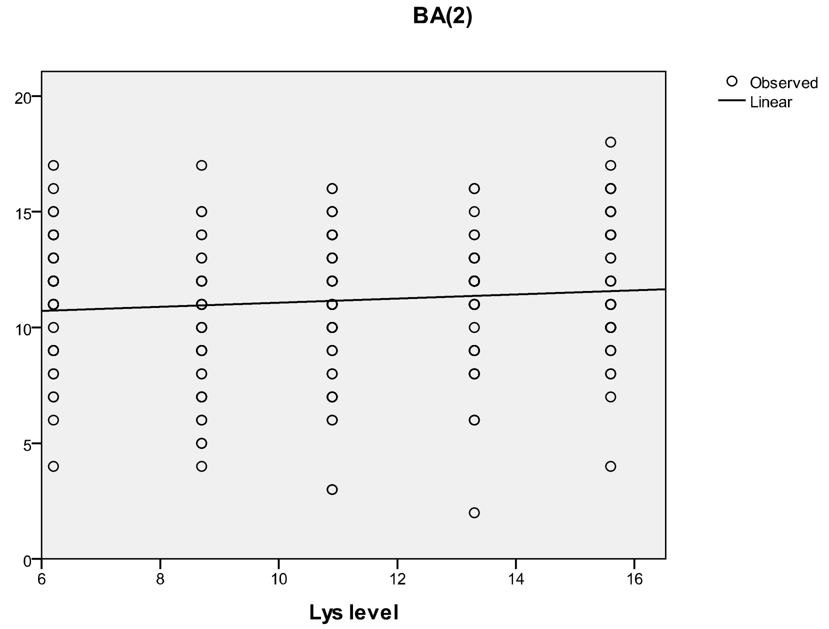

Figure 6. Dietary lysine response of subsequent litter size born live and distribution of litter size.

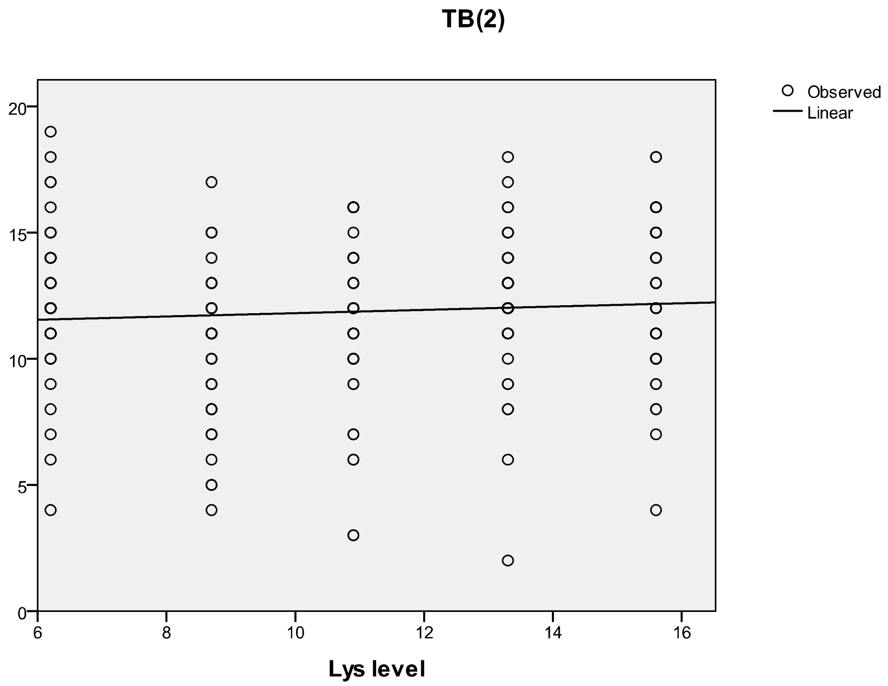

Figure 7. Dietary lysine response of subsequent litter size born total born and distribution of litter size.

Discussion

Increasing the level of dietary lysine during the sows' first lactation did not improve lactation performance or subsequent litter size, rejecting the experimental hypothesis. The negative effect of increasing dietary lysine, through the use of synthetic amino acids and protein sources on lactation feed intake was observed and supports our previous work where we reported a reduced intake over a longer lactation (26 days) when high protein diets were fed to primiparous sows during summer (Smits, 1998). During the first six weeks of the experiment in the farrowing house, the weather was extremely hot (culminating in the Black Saturday Victoria bushfires) and the lactating gilts were substantially affected as recorded by the decline in feed intake. The farrowing houses were also affected by an outbreak of *e.coli* scours which combined with the heat resulted in a high proportion of allocated sows to be removed from the experiment due to piglet swapping and removal and early weaning of affected sows. Nevertheless, there was little evidence of any positive response to dietary lysine when daily intakes were reduced due to heat.

Tritton et al (1996) reported that lactation performance as measured by litter gain responded to dietary lysine levels in a quadratic relationship. However there was not a clear linear relationship between dietary lysine treatments in their experiment. The authors found a significant positive correlation using calculated daily lysine intake values. We observed an increase in average piglet weight gain between day 14 and weaning at 20 days of age, though not litter gain. The difference is likely due to fewer piglets remaining in the litter in the high lysine treatment groups, though the cause of any adverse effect of dietary lysine on sow or litter health was inconclusive. There were other notable differences between the study by Tritton et al and our own. The experimental diets used by Tritton et al (1996) were formulated with a lower dietary energy level (14.3 MJ DE/kg) than our high energy diet (14.9 MJ DE/kg). Their study was conducted outside of the summer heat stress period (Tritton *pers comm.*) and was conducted in a different unit where the weaning age was older at 23 days. Our results demonstrated that litter weight gain and average piglet weight gain increased in the second half of lactation and this was when some response to dietary lysine on lactation performance was noted in the average piglet weight gain.

The lack of a lactation response in commercial sows of modern genotype with increasing dietary lysine is supported by several other studies. Milk production is relatively unaffected by modest dietary protein restriction with sows mobilizing their own body reserves to support the needs of their litter (Revell, et al., 1998). Most commercial nutritional recommendations follow the NRC levels of formulating lactation diets to achieve an average daily intake of 55 g total lysine intake in first-litter sows (NRC, 1998). Hewitt and van Barneveld did not observe any response to increased dietary lysine on lactation performance when they fed either a standard level of dietary lysine (9 g total lysine/kg) or a high level (15 g total lysine/kg) to first-litter sows (Pork CRC project 2D-114 Study 3). They also observed that sows on the high lysine diets had a lower feed intake during lactation. In our experiment, the average sow feed intake was low (5 kg/d) due to the heat, with treatment lysine intakes covering the range from 31 to 77 g/day (total lysine intake). Piglet gain and litter gains were also similar when lactation diets formulated with either 8 or 12 g/lysine/kg were fed to primiparous sows during their first lactation in a previous experiment conducted at the Corowa R&I unit over a 27 day lactation (Smits, 1998).

According to the NRC requirement equation, and given the litter gains observed, the second lowest level of dietary lysine at 8.7 g total lysine/kg would have provided the average litter with adequate intakes of lysine (45 g lysine/d>(-6.39+(0.022 x 1450 g/d))/0.80 digestibility co-efficient. The greater lactation demand observed after 14 days showed that when litter gains increased, the response to dietary lysine also tended to increase to a maximum of 10.9 g lysine/kg. The results have highlighted that non-nutritional limitations to lactation can occur in commercial environments, and when this occurs, increasing nutrient supply does not improve performance.

Litter demand, such as the number of piglets suckling the sow has been identified as a factor determining milk production (Auldist and King, 1995, Kim and Easter, 2001). The litter size at the start of lactation averaged 11 piglets and 17.6 kg, however the suckling demand may have been reduced due to the prevalence of scours and illthrift in the shed over the experimental period. So even though litter size at the commencement of lactation may have been adequately managed by fostering to maximize milk production, the poor quality of the litter especially during the first 10 days may have prevented the sow reaching her lactation potential. There was no clear evidence of a dietary effect on lactation failure or piglet health, however overall a large proportion of litters (almost one third) were affected in some way that caused them to perform below their potential. The balance of other amino acids in relation to lysine was considered during the formulation of the diets according to the information reviewed by Kim et al (2005). The second and third most-limiting amino acids threonine and valine were formulated to be above the ratio relative to lysine identified by Kim et al for all diets.

Unpublished data from the US show evidence of lactation responses to dietary lysine. Usry et al (unpublished) investigated the standardized ileal digestible (SID, equivalent of available amino acid) response to first-litter sows in a high producing genotype on corn-soybean diets (energy values not provided, but estimated at 14-5-14.7 MJ DE/kg). Their treatment diets ranged from 9.9 g/total lysine to 12.4 g total lysine/kg. An increase in litter gain from 2.3 to 2.5 kg and piglet gain from 260 to 288 g/day were achieved at the highest dietary lysine level in a linear response. These are very high producing sows, and well above what have been reported in commercial sow studies from different herds and genotypes in Australia. The maximum lactation response occurred at a dietary lysine level of 1.12 % SID (equivalent to 12 g total lysine/kg). They found there was no response to dietary lysine on subsequent reproductive performance. Yang et al (Yang, et al., 2009) reported that primiparous and multiparous sows responded to higher dietary lysine in corn-soybean diets formulated between 10 to 13.4 g/kg. In gilt litters, they reported litter gains increased from 1.90 to 2.07 kg/d assessed over a 25 day lactation period. They also reported changes in milk composition which is generally unaffected by diet unless extreme formulations are used (Revell, et al., 1998). Sow weight loss (23-28 kg) was much higher than we reported in our study, which suggests that the litter demands were much greater, and hence a response to dietary lysine is more likely. Knabe et al (1996) showed that dietary supplementation with synthetic lysine to sows nursing large litters (10.9 piglets; equivalent to 16 kg litter weight) responded in litter weight gain and 21 day weight to 9 g lysine/kg compared to 6 g/kg. In our experiment, the litter weight after fostering was completed within 24 hours of farrowing was higher at 17.6 kg. The lack of response to dietary lysine was therefore unlikely to be due to insufficient litter demand at the start of lactation.

There was a significant decrease in lactation intake as dietary lysine levels increased. Although the average changed little, the distribution of litters that had a low intake was greater as dietary lysine increased. The effect of heat stress on sow voluntary feed intake is well known and first-litter sows are often more affected than older parities (Jones and Hermesch, 2007). We have previously reported that high dietary levels of lysine and overall crude protein reduces feed intake in primiparous sows (Smits, 1998), and these findings are supported by others (Johnston, et al., 1999, Yang, et al., 2000) and more recently in Australia by Hewitt et al (2009). We found there was no effect on sow weight loss or fat loss during lactation, however this is not surprising given that litter growth was not related to dietary lysine response. Tritton et al (1996) did not observe a response to dietary lysine in tissue mobilization from the sow, whereas they did report effects when dietary energy was increased in the lactation diet, which was supported by our own studies increasing lactation energy level in the Pork CRC project 2G-102 (Smits, et al., 2007). The amount of maternal weight lost during lactation was within expectations for the herd.

The subsequent litter size of sows allocated to the dietary lysine level of 6.2 g/kg in the previous lactation was equal to levels of 10.9, 13.3 and 15.6 g/kg. This non-linear response may have been due to a higher proportion of these sows having lactation feed intake of greater than 5 kg and hence a higher energy intake. We have previously reported that energy intake tends to increase subsequent litter size (Smits et al, 2008, Project 2G-102). Subsequent litter size has been reported to increase with previous lactation lysine intake (Tritton, et al., 1996), whereas others have failed to observe a benefit to increased dietary lysine in the previous lactation in first-litter sows (Knabe, et al., 1996, Richert, et al., 1997, Touchette, et al., 1998); Smits, 1998; Hewitt and van Barneveld, 2009, Project 2D-104 Study 3).

Sows with inadequate dietary or endogenous circulatory amino acid levels have a reduced luteinizing hormone (LH) secretion and increased weaning to re-mating interval (Jones and Stahly, 1999). In circumstances where body protein reserves are low, or dietary amino acids are formulated to be inadequate, there has been evidence for a delayed onset of oestrus post-weaning (King and Dunkin, 1986, King and Martin, 1989, King, et al., 1993, Mullan and Williams, 1989). However in circumstances where body reserves are large, this can negate the effect of low lactation intake on onset of oestrus and subsequent litter size (Smits, et al., 1997). The high subsequent performance level of sows at the lowest level of lactation lysine tested was surprising, and doesn't ft a linear response as we expected. Interestingly, a similar response was reported by Tritton et al (Tritton, et al., 1996) at their lowest dietary lysine level (6.2 g/kg). In our current experiment, farrowing rate and litter size in sows fed diets with 6.2 g lysine/kg were similar to those sows fed a lactation diet up to 15.6 g lysine/kg. In some cases, a high subsequent litter size can be associated with lower farrowing rates, if very small embryo litter sizes fail to successfully implant in early pregnancy. However, the distribution of litter size was even for the lowest lysine treatment. When the distribution of subsequent litter size was analysed in Figure 7, there were some sows that farrowed with small litters in treatments fed 109, 13.3 and 15.6 g lysine/kg in lactation. However, even without these litters included, the treatment responses do not markedly increase compared to the lowest level of treatment lysine. All sows were weaned with large body reserves, some 20 kg more than we reported in 1997 (Smits, et al., 1997), and calculated to be 35-40 kg more than weaned in the experiment reported by Tritton et al (1996). Lactation weight loss in our experiment was also considerably lower than observed by Tritton et al who reported an average sow weight loss of 25 kg. This is expected as lower lactation output by the sows on the current experiment would have conserved body reserves.

In conclusion, the response to increasing dietary lysine during a 20 day lactation had no significant benefit to lactation performance, subsequent reproductive performance of sow retention. First-litter sows that were not producing particularly high litter gains during lactation (i.e were <2 kg/d) were not improved when dietary lysine in lactation was increased. During summer, increasing the dietary lysine content through a combination of protein meals and synthetic amino acids reduced lactation intake. There are likely to be other factors that are non-nutritional that limited the lactation performance of this commercial herd.

4. Application of Research

These results highlight the difficulties facing the commercial producer in achieving maximum lactation performance in the field. The experiment concluded that although there was no significant response in lactation performance or subsequent reproductive performance in lactation diets formulated to 6.2 g lysine/kg or 15.6 g lysine/kg, we would recommend that first-litter sows be fed a lactation diet formulated between 10 to 11 g total lysine/kg. This would target daily lysine intakes of 50 to 55 g lysine. The cost of increasing dietary lysine at current (May 2010) prices i $45/tonne per g lysine formulated (g/kg). We recognize that conserving body reserves and body protein during lactation is a long-term strategy for lifetime performance. Formulating to the lowest level of lysine tested would have limitations in herds that are performing at a higher level than we have recorded in this experiment. Unless sows are recording litter gains of 2.2-2.5 kg/day, feeding first-litter sows with higher lysine levels is an unnecessary economic cost.

5. Conclusion

The response to increasing dietary lysine during a 20 day lactation had no significant benefit to lactation performance, subsequent reproductive performance or sow retention. During summer, increasing the dietary lysine content through a combination of protein meals and synthetic amino acids can reduce lactation intake, which ultimately results in no net gain of daily lysine intake, but more importantly can reduce energy intake. The cost of increasing dietary lysine in lactation diets is high ($45 per g formulated lysine). We maintain that the recommendation of achieving a daily intake on average of 50-55 g total lysine is adequate for most commercial herds. When milk production was limited by factors other than nutrient supply, such as health or heat stress, increasing dietary supply of lysine and other amino acids did not improve performance. Overcoming limitations (practical, health or dietary) to sow intake during summer would allow an increase in both energy and protein in first-litter sows and should remain a high priority.

6. Limitations/Risks

The data from the experiment was constrained by non-nutritional factors, primarily health of the litter in the first two weeks of lactation. Whilst we were not able to test the response to dietary lysine in the highest performing litters, the litter and average piglet weight gains are not dissimilar to other commercially recorded weight gains and sow lactation intakes. We therefore feel justified in our recommendations from the research for the majority of Australian producers.

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

- Formulating diets to provide daily lysine intakes of 50-55 g total lysine is adequate and cost-effective for the majority of commercial herds. With the lactation intakes of 5 kg recorded in this experiment, this equates to a dietary lysine level of 11 g lysine/kg (9.2 g available lysine/kg).
- Producers should continue to focus on maximizing lactation intake to first-litter sows especially over summer through improved housing design, feeding management and sow health.
- In some herds that have a high health status and already achieving birth to weaning litter gains of over 2.2 kg/d, a response to higher lysine in a balanced protein diet may be warranted to determine cost-effective changes to their own nutritional program.

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Appendix 1 - Notes

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Appendices

Appendix 1: