Peri-weaning polyamine supplementation: effects on piglet performance pre- and post- weaning

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Executive Summary

This project builds on previous work indicating a beneficial effect on piglet growth to weaning and intestinal function when they were orally dosed with polyamines prior to weaning. This report covers two trials conducted at a commercial facility. The first trial investigated the effect of orally dosing piglets with polyamines prior to and / or after weaning on growth rate to day 36 post-weaning. The second trial investigated the effect of providing polyamines in bowls to piglets prior to and/or after weaning on their growth performance pre and post-weaning.

The first experiment failed to demonstrate any beneficial effects of polyamine supplementation on piglet performance. However, in the second study there was a significant effect of treatment (polyamine versus control) on piglet weight at weaning (6.59 ± 0.04 versus 6.48 ± 0.04 kg), 7 days post-weaning (7.27 ± 0.05 versus 7.11 ± 0.05 kg) and day 36 post weaning (20.1 ± 0.19 versus 19.5 ± 0.19 kg).

It was interesting that while male piglets tended to grow faster prior to weaning, they exhibited a more severe growth check in response to weaning compared with female piglets. Further, a significant, negative correlation between liveweight gain during the last seven days of lactation and the severity of the post-weaning growth check was observed, with higher growth rates immediately pre-weaning resulting in a more severe reduction in growth post-weaning.

While the data from experiment one failed to support the findings of our previous studies, it is possible that stress induced by repeated picking up and gavaging of piglets within a trial of this size may have negated any beneficial effects of the polyamine treatment. In contrast, the data from study two supports our previous evidence of a beneficial effect of polyamine supplementation of developmentally impaired piglets (gilt progeny suckling parity one sows during summer in the current trial and piglets suckling parity one sows in our previous studies).

Based on all our research to date it is clear that polyamine supplementation during the last week of lactation can be beneficial for ‘at risk’ or vulnerable piglets. However, future work should be conducted to determine whether polyamine levels in sows milk can be altered sufficiently by supplementing the sow. Furthermore, strategies to increase polyamine levels in colostrum by sow supplementation should also be investigated, with evidence in other species indicating that higher polyamine ingestion immediately post-partum may be beneficial for intestinal and immune development, and thus growth and survival of the piglet.

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1. Introduction

Piglet growth during the immediate post-weaning period is often compromised as a result of their failure to adapt to the switch from a milk-dominated to a cereal-dominated diet. Commonly referred to as post-weaning growth check, this period of adaptation and resultant decline in growth exerts a significant impact on overall herd feed conversion efficiency, increasing the time taken to attain market weights, and in severe cases resulting in mortality. Structural and functional changes in the small intestine that cause a decrease in digestive and absorptive capacity in the weaned pig and are key contributors to the growth check in weaned piglets. Milk-borne polyamines (putrescine, spermidine and spermine) trigger a series of changes in the gastrointestinal tract of the suckling offspring that help it adapt to the progressive transition from a milk dietary regime to a solid dietary regime. However, early weaning programs designed to increase sow productivity have resulted in a significant portion of piglets being weaned at less than 21 days of age, meaning piglets are likely to have insufficiently matured gastrointestinal tracts.

Previously, we have demonstrated that polyamine supplementation prior to weaning can significantly improve piglet liveweight gain pre-weaning, and increased intestinal absorptive area at weaning. Furthermore, a greater response to polyamine supplementation was observed in piglets suckling parity one sows. Therefore, the current project had three primary aims:

1. to determine whether peri-weaning polyamine supplementation promoted piglet growth and survival pre- and post-weaning.
2. to determine when, relative to weaning, polyamine supplementation has the greatest effect on piglet performance.
3. to investigate the effectiveness of a commercial application of polyamines

2. Methodology

Two experiments were conducted at a large South Australian Piggery. In experiment one, polyamines were delivered directly to each individual piglet using an oral drenching gun. In experiment two, polyamines were added to the water provided in drinker bowls for gilt progeny suckling first lactation sows during summer.

Experiment One: Effect of polyamine supplementation pre- and / or post-weaning on piglet growth.

A total of 60 litters suckling first and second parity sows were used in this trial. The experimental design was a 2 x 2 factorial, incorporating two levels of polyamine supplementation for the 6 days prior to weaning (plus or minus oral polyamines) and two levels of polyamine supplementation for the 6 days immediately post-weaning (plus or minus oral polyamines). Weaning occurred on day 23 approximately. Seven days prior to weaning, piglets were weighed and within litters were pair matched according to weight and allocated to one of the following four treatments:

1. (Control): no polyamine supplementation (n = 120 piglets)
2. polyamine supplementation pre-weaning only (n = 120 piglets)
3. polyamine supplementation post-weaning only (n = 120 piglets)
4. polyamine supplementation pre- and post- weaning (n = 120 piglets)

Pre-weaning treatments (Control solution and polyamine solution) commenced 6 days prior to weaning, with treatments given every second day. Post-weaning treatments (Control solution and polyamine solution) commenced on day of weaning and occurred every second day until day 6 post-weaning.

Piglets were weighed individually on the following days: seven days before weaning, day of weaning, seven days after weaning, fourteen days after weaning, thirty-six days after weaning.

Experiment Two: Effect of adding polyamines to drinker bowls pre-and post-weaning on piglet growth and survival pre- and post-weaning

Twenty-four litters of gilt progeny suckling first lactation sows during the summer period were used in this trial, with 12 litters per treatment: treatment one (Control): no polyamine supplementation, treatment two: polyamine supplementation pre- and post- weaning. In treatment two, the polyamine was added to the water provided in bowls pre-and post-weaning. As in the first experiment, pre-weaning treatments (control solution and polyamine solution) commenced 6 days prior to weaning, with treatments given every second day until day 6 post-weaning. Whole litter weights and piglet numbers were recorded on 7 days prior to weaning and post-weaning. Individual piglet weights were recorded on days 7, 14 and 36 post-weaning

Statistical Analysis

All data is presented at Mean ± SEM, unless otherwise stated. In both experiments, treatment effects on all measures were analysed using an analysis of variance (ANOVA) model, with piglet liveweight (LW) on day -7 included as a co-variate. In experiment one, the model was a two-way ANOVA with treatment and piglet gender as fixed effects. In experiment two, a one-way ANOVA was used. All analysis was conducted using Genstat 15th Edition.

3. Outcomes

Experiment One: Effect of polyamine supplementation pre- and / or post-weaning on piglet growth.

There was no effect of treatment on piglet liveweight gain (Table 1) or liveweight (Figure 1) at any of the measurement points.

Table 1 - Effect of polyamine supplementation pre- and / or post- weaning on piglet liveweight gain in experiment one

Treatment		Piglet average daily liveweight gain, kg/day			
Pre-Wean	Post-wean	D-7 to Wean	Wean to d7	D 7 to 14	D14 to 36
Control	Control	0.206	0.057	0.219	0.432
Control	Polyamine	0.209	0.060	0.217	0.436
Polyamine	Control	0.204	0.068	0.210	0.432
Polyamine	Polyamine	0.215	0.055	0.209	0.426
Pooled SEM		0.004	0.005	0.005	0.005
P value	Treatment	0.727	0.736	0.856	0.856
	D – 7 LW	<0.001	0.360	<0.001	<0.001

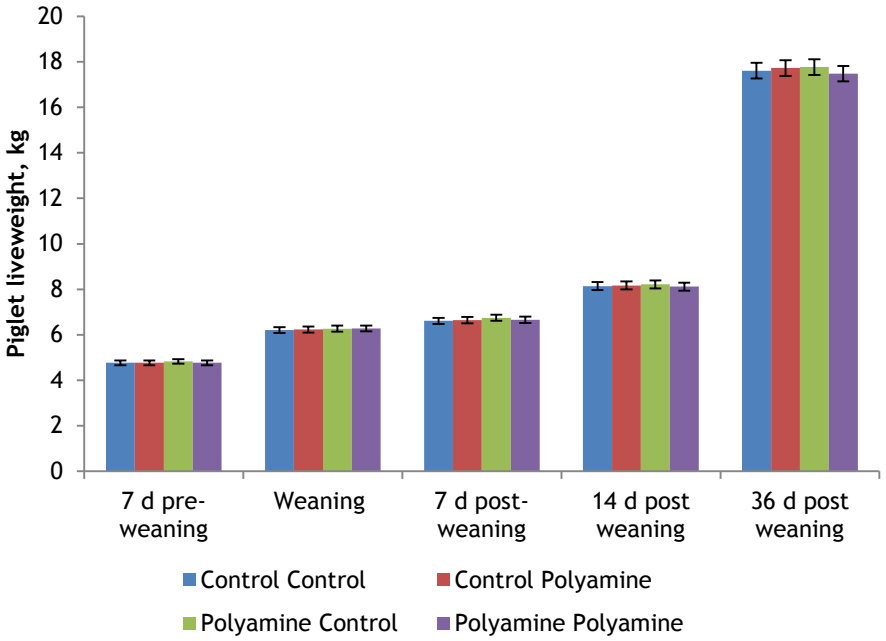

Figure 1 - Effect of polyamine supplementation pre- and post-weaning on piglet liveweight in experiment one

Male pigs were heavier 7 days prior to weaning (P=0.057), at weaning (P < 0.001) and 7 days after weaning (P = 0.051). However, there was no effect of piglet gender on liveweight on days 14 or 36 post-weaning. Male piglets grew faster prior to weaning (P < 0.001), but tended to grow slower during the 7 days post-weaning (P = 0.074), due to a significantly higher post-weaning growth check (P < 0.001). Overall, piglet liveweight on day 7 prior to weaning significantly affected piglet liveweight at all measurement points, as well as piglet liveweight gain, with the exception of the first 7 days post-weaning (Tables 1 and 2).

There was a significant, negative correlation between liveweight gain during the last seven days of lactation and the severity of the post-weaning growth check (r = 0.64; P < 0.001), and between piglet liveweight at weaning and the severity of the post-weaning growth check (r = 0.2; P < 0.001).

Table 2 - Effect of piglet gender on liveweight (LW), LW gain, and change in LW gain pre- and post-weaning in experiment one

	Male	Female	Pooled SEM	P value	
				Gender	D-7 LW
LW, kg					
D - 7	4.890	4.693	0.051	0.057	NA
Weaning	6.374	6.131	0.066	<0.001	<0.001
D 7	6.734	6.605	0.070	0.051	<0.001
D 14	8.251	8.080	0.089	0.126	<0.001
D36	17.780	17.530	0.173	0.353	<0.001
LW gain, kg/d					
D-7 to Wean	0.227	0.192	0.004	<0.001	<0.001
Wean to d7	0.051	0.068	0.005	0.074	0.360
D 7 to 14	0.217	0.211	0.005	0.547	<0.001
D14 to 36	0.433	0.430	0.005	0.686	<0.001
Change in LW gain, pre and post-weaning, kg/d	-0.175	-0.124	0.007	<0.001	<0.001

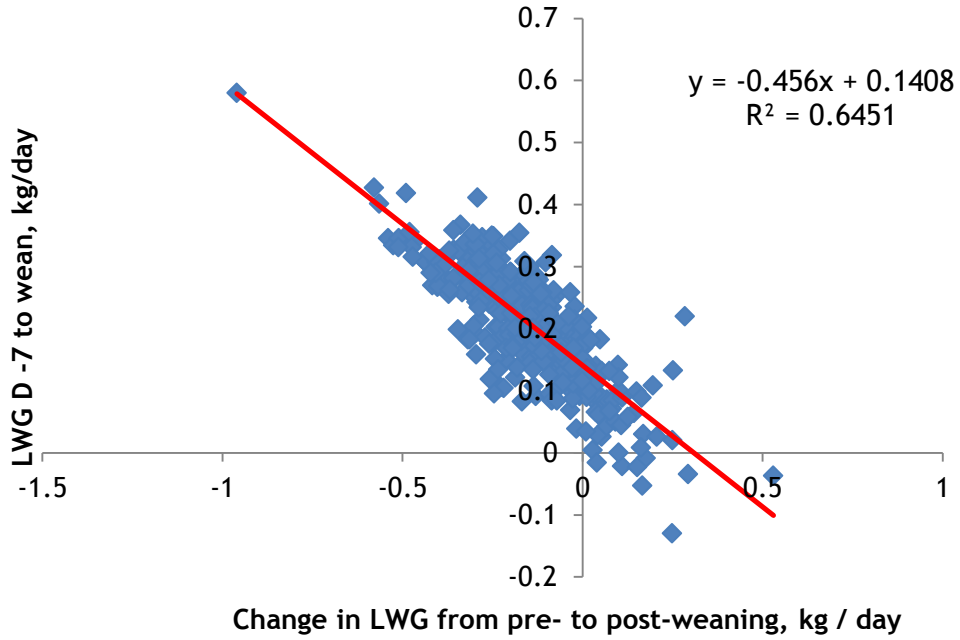

Figure 2 - Relationship between live weight gain during the seven days preceding weaning and the change in liveweight gain during the first seven days post-weaning

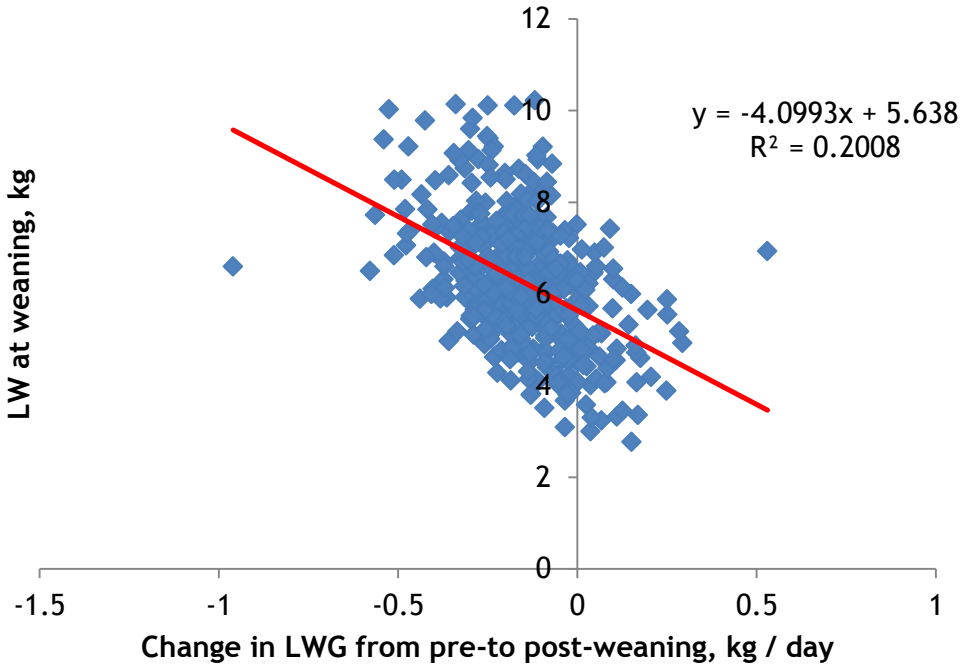

Figure 3 - Relationship between live weight at weaning and the change in liveweight gain during the first seven days post-weaning

Experiment Two: Effect of adding polyamines to drinker bowls pre-and post-weaning on piglet growth and survival pre- and post-weaning

Individual piglet weights were similar at the start of treatment (day 7 pre-weaning) (Figure 4). However, there was a significant effect of treatment (polyamine versus control) on piglet weight at weaning (6.59 ± 0.04 versus 6.48 ± 0.04 kg), 7 days post-weaning (7.27 ± 0.05 versus 7.11 ± 0.05 kg) and day 36 post weaning (20.1 ± 0.19 versus 19.5 ± 0.19 kg). There was a significant effect of treatment (Polyamine versus control) on liveweight gain during the 7 days prior to weaning (1.46 ± 0.04 versus 1.32 ± 0.04 kg), and on liveweight gain from weaning to day 36 post-weaning (13.56 ± 0.20 versus 12.92 ± 0.21 kg).

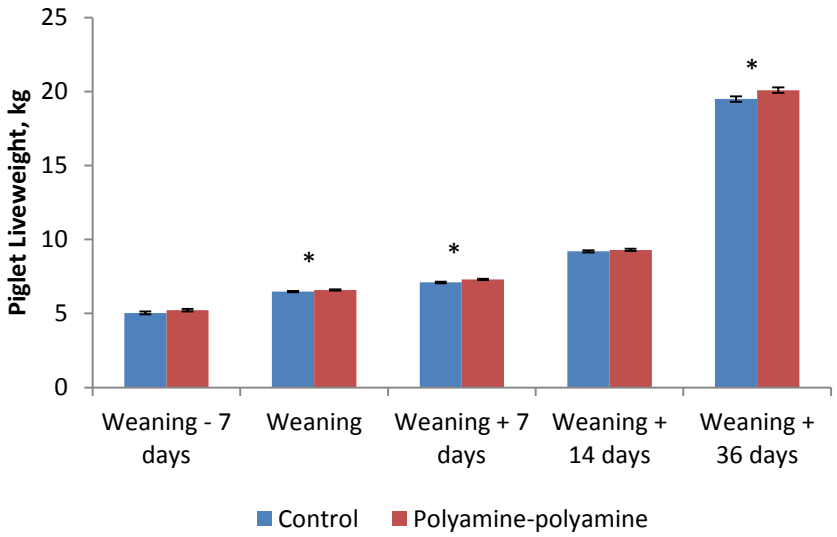

Figure 4 - Effect of adding polyamines to bowls pre- and post- weaning on piglet liveweight

4. Application of Research

The current data build on our previous data demonstrating that polyamine supplementation prior to weaning can increase piglet weight at weaning. The fact that polyamine supplementation only improved piglet performance in runt or fall back piglets could be for two reasons. The first is that the constant picking up and drenching of piglets in experiment one induced a stress response which cancelled out any beneficial effects of the polyamines, and secondly that the impaired development of gilt progeny suckling first lactation sows during summer makes them more likely to benefit from supplements such as polyamines. A positive effect of polyamines on intestinal maturation and immunity has been demonstrated in rats (Perez-Cano et al., 2010), with impaired intestinal development and immunity likely causes of impaired growth and performance in gilt progeny. This might explain the enhanced response to polyamine supplementation in this population of piglets. The theory that polyamine supplementation is beneficial to less developed piglets is supported by our previous evidence that piglets suckling parity one sows benefit the most from polyamine supplementation pre-weaning.

If the outcomes of the current trials are considered in conjunction with those of our previous studies, which clearly demonstrate that polyamine supplementation pre-weaning promotes intestinal development and growth of piglets, in particular piglets suckling first lactation sows, it is evident that polyamine supplementation

is a viable strategy to promote piglet performance. Other work involving the addition of polyamines to milk replacer demonstrated a positive effect on the performance of early weaned piglets (Sabater-Molina et al., 2009) Recent work (Kang et al., 2012) reported a positive effect of high doses of oral polyamine supplementation post-weaning on piglet growth and intestinal development.

Our data suggest that commercial application might involve providing at risk piglets (i.e. fall back/runt piglets, or gilt progeny) with supplementary polyamines pre-weaning. However, the additional labour involved in dosing piglets and the potential stress for the piglet due to excessive handling mean that alternative strategies to increase polyamine ingestion by the piglet need to be explored. A more effective method of increasing polyamine uptake by the piglet is to increase levels in maternal milk. Dietary intake of polyamines significantly alters concentrations in human breast milk (Tya-Ali et al., 2013), with studies in humans, cows, goats and sows demonstrating that polyamine levels vary with the stage of lactation (Motyl et al., 1995; Ptoszaj et al., 1997; Loser, 2000). Spermine concentrations are higher at the start of lactation in sows and humans (Motyl et al., 1995; Plaza-Zamora et al., 2013), with the human data demonstrating markedly higher levels in colostrum compared to transition milk (Plaza-Zamora et al., 2013). Interestingly breed and parity effects on milk polyamine levels have also been reported in goats (Ptoszaj et al., 1997).

The high levels of spermine in colostrum and early milk suggest a strong role during early intestinal maturation of the neonate, as well as a potentially beneficial effect on immune function. Furthermore, the stimulatory effects of spermine on glucocorticoid secretion in rats (Kaouass et al., 1994 and 1997) suggest that maternal polyamine supplementation may promote final visceral maturation during the last days of gestation. In addition, the high levels in colostrum suggest that spermine supplementation immediately pre-farrowing may increase levels in colostrum, potentially benefitting the piglet.

Considering the data available from other species, as well as our own studies in piglets it is evident that spermine supplementation pre- and post- weaning improves intestinal development and growth in piglets. It is also evident that diet can alter polyamine levels in milk, and that increasing maternal polyamine ingestion in late gestation may promote intestinal maturation pre-parturition as well as increase spermine levels in colostrum and promote intestinal maturation and immune function in that way. Finally, it is clear that piglets suckling first lactation sows appear to receive greater benefit from direct spermine supplementation, suggesting levels may be insufficient in first lactation milk. It is, therefore, suggested that future work should determine the effect of maternal parity on polyamine concentrations in milk and determine whether maternal supplementation with polyamines pre- and / or post-parturition can promote piglet growth and survival.

5. Conclusion

Overall, the current data demonstrated that pre- and post-weaning growth of at risk or growth impaired piglets is improved by polyamine supplementation during that time. These data build on, and extend, our previous finding that polyamine supplementation prior to weaning improved the pre-weaning growth and intestinal development of piglets, with the greatest benefits observed in piglets suckling first lactation sows. It is, therefore, suggested that future work should focus on the effect of parity on polyamine levels in sow milk, and development of strategies to increase levels in sow milk.

6. Limitations/Risks

The cost of polyamine supplementation is minimal (1.5 c per day); however the labour involved in dosing piglets individually is high.

Polyamine supplementation only worked on the impaired piglets.

7. Recommendations

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

- Future work should determine the effect of parity on polyamine levels in sow milk
- Future work should determine whether maternal supplementation with polyamines can increase levels in sow milk, thus improving piglet performance and survival
- The impact of polyamine supplementation immediately post-parturition, either by increasing levels in colostrum or by direct dosing of 'at risk' piglets should be investigated
- A commercialization project should be conducted to create a product for the industry

8. References

Atiya-Ali M, Strndvik B, Sabel K-G, Kilander P, Stromberg R, Yngve A. (2013) Polyamine levels in breast milk are associated with mothers' dietary intake and are higher in preterm than full-term human milk and formulas. J. Human Nutrition and Dietetics; 1 – 9.

Kang P, Wang M, Hou Y, Yin, Y, ing B, Zhu H, Liu Y, Qiu Y, Yi D, Wang L, Gong J. (2012). Effects of oral administration of spermine on the development of small intestine and growth performance of weaned pigs. J. Anim. Vet. Advances 11; 2782 – 2787.

Kaouass M, Sulon J, Deloyer P, Dandrifosse G. (1994). Spermine-induced precocious intestinal maturation in suckling rats: possible involvement of glucocorticoids. J. Endocrinology 141; 279 – 283.

Kaouass M, Deloyer P, Dandrifosse G (1997). Involvement of bombesin in spermine-induced corticosterone secretion and intestinal maturation in suckling rats. J. Endocrinology 153; 429 – 436.

Loser C. (2000). Polyamines in human and animal milk. Brit. J. Nutrition 84; S55 – S58.

Motyl T, Ploszaj T, Wojtasik A, Kukulska W, Podgurniak M. Polyamines in cow's and sows' milk. Comp. Biochem. Physiol. 111B; 427 – 433.

Perez-Cano FJ, Gonzalez-Castro A, Castellote C, Franch A, Castell M. (2010). Influence of breast milk polyamines on suckling rat immune system maturation. Dev. Comp. Immuno. 34; 210 – 218.

Ploszaj T, Ryniewicz Z, Motyl T. (1997). Polyamines in goat's colostrum and milk. Comp. Biochem. Physiol 118B; 45 - 52

Sabater-Molina M, Larque E, Torrella F, Plaza J, Lozano T, Munoz A, Zamora S. (2009). Effects of dietary polyamines at physiological doses in early weaned piglets. Nutrition 25; 940 – 946.