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AUSTRALIAN Pork™

Addressing seasonal effects on piglet birthweight and within litter variation

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Executive Summary

It has been proposed that reduced LH concentrations are a potential mechanism to explain seasonal infertility (for review, see De Rensis et al., 2017). Large follicles contain more LH receptors than smaller ones (Campos *et al.* 2012). So, if LH secretion is reduced in summer months, ovulation from smaller follicles may be more frequent resulting in more variable oocyte, and so eventual piglet quality. There is little published research investigating the effect of season on litter birth weight variability. Dextrose has been linked to improved oocyte development, with the provision of this additional energy source fed to the sow during the insemination period reducing piglet birthweight variation (Van den Brand et al. 2005). In this experiment we proposed two hypotheses: that birth weight variation would be increased in litters from sows bred in summer, and that dextrose supplementation during the wean to mate period would ameliorate this manifestation of seasonal infertility.

Five hundred and ninety one parity 2-5 sows (3.0 ± 0.1) were allocated to one of two diets (Control; standard diet, Dextrose; control + 5% dextrose supplementation) from weaning until insemination during summer (February-March) and winter (August-September) in 2018. Sows were housed in groups of 40 from weaning and fed 3.5kg of the respective diets daily until the second day of estrus. Sows not mated within seven days from weaning were removed from the experiment. Wean to service interval, pregnancy rate and farrowing rate, along with litter size variables (TB, BA and BD) were recorded for each sow. At farrowing, all piglets were weighed to calculate minimum, maximum, standard deviation and co-efficient of variation in birth weight, as well as the % of piglets born < 1.1kg for each sow. Those born alive were tagged and followed throughout lactation for survival and growth to day 21.

The herd in which the experiment was conducted experienced marked seasonal infertility, with pregnancy rate dropping from 92% to 70%, farrowing rate from 89% to 64% and total born from 14.2 to 13.8 in winter and summer matings, respectively ($P < 0.05$). Treatment effects were observed for TB and BA, with Dextrose sows farrowing 1.0 and 1.4 piglets more than Control sows for each of these traits, respectively ($P < 0.05$). There was a tendency for a higher CV birth weight to be observed in summer than winter (16.6 ± 0.4 versus 15.8 ± 0.4; $P = 0.1$), but no main effect of treatment or interaction between treatment and season were observed for minimum, maximum, standard deviation, co-efficient of variation or % piglets < 1.1kg ($P > 0.05$). A higher number of pre-foster deaths and piglet removal events were recorded for sows mated in summer than winter ($P < 0.05$), and piglet removal was lower by 0.29 pigs / litter in Dextrose than Control sows ($P < 0.05$). A tendency for more pigs weaned was observed in sows bred during winter than summer (9.4 ± 0.2 versus 9.0 ± 0.2; $P = 0.1$), but there was no effect of treatment ($P > 0.05$). CV weight at day 21 was higher in winter bred sows than summer (21.4 ± 0.9 versus 19.1 ± 0.7; $P < 0.05$), and in Dextrose than Control (21.4 ± 0.7 versus 19.2 ± 0.8; $P < 0.05$). Piglet average daily gain was unaffected in those born to sows bred in summer (~230 ± 7 g), but when born to sows bred in winter, Dextrose piglets grew at a rate of 202 ± 8 g per day, whilst control piglets only achieved 179 ± 9 g per day ($P < 0.05$).

This experiment identified that there is evidence for increased birth weight CV in sows bred during the summer months despite the reduced litter size, suggesting that this is another way seasonal infertility can manifest. The 5% inclusion of dextrose in the wean-to-mate sow diet increased litter size without compromising litter homogeneity at birth, however higher variation was reported by day 21 irrespective of season. Interestingly, Dextrose resulted in overall less piglet removals, and higher growth rates in those born to sows mated in winter (lactated in summer), which may suggest the applied treatment improved piglet vigour but this remains to be confirmed.

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1. Objectives of the Research Project

This project set out to:

Identify whether seasonal infertility impacts on piglet traits such as birth weight, and within litter weight variation.

Determine the impacts of large within litter weight variation on lactating sow performance.

Reduce the amount of within litter variation through the inclusion of dextrose in a 'wean to mate' diet during summer months.

2. Background to Research

Seasonal infertility can manifest itself in various forms but reports typically concentrate on reductions in farrowing rate and litter size. It is driven by temperature and photoperiods, which directly impact reproductive axes and indirectly act through effects on lactation feed intake. These effects can vary across years and are often site dependent as climatic conditions and management strategies change. In herds that suffer reproductive loss during summer months, either through reduced farrowing rates or pigs born per litter, or a combination of both, management strategies have been adopted to maintain pig flows. As a rule of thumb, producers will mate more sows during the warmer months of the year to counteract this dip in reproduction and maintain pig numbers on the ground. What producers may be less able to deal with is a dip in piglet birth weight, or even more importantly, an increase in litter weight variation, as there are currently very few management strategies that can address this issue. An increased within litter heterogenicity is associated with increased piglet death and increased variation in weaning weights (Milligan *et al.* 2002; Akdag *et al.* 2009). This last point may translate to impacts on time to slaughter, carcass weight variability and even meat quality (Madsen and Bee 2015). Thus, effects on birth weight and birth weight variation are far reaching across the production chain (van Barneveld and Hewitt 2016).

Campos *et al.* (2012) have suggested that higher levels of luteinising hormone (LH) will result in an increase in large follicle populations as they contain more LH receptors than smaller follicles. They then go on to state that that if the follicle population is more uniform, so too will be the oocyte quality, and so conclude that high levels of LH will result in reduced litter weight heterogenicity. It has been proposed that reduced LH concentrations are a potential mechanism to explain seasonal infertility (Peltoniemi *et al.* 2000), with reduced levels reported during the summer months. Logically, if basal LH secretion is reduced in summer months, follicle development with be more variable, and ovulation from smaller follicles may be more frequent resulting in more variable oocyte quality. There is little published research investigating the effect of season on litter birth weight variability. Quesnel *et al.* (2008) reported no significant effect of season at conception on the coefficient of variation (CV) of piglet birth weight (P= 0.068), and because significance was not obtained data was not presented. This study also failed to show any season effect on litter size (conception rate was not reported) which may suggest the experimental herd was less susceptible to the impacts of seasonal infertility.

Birth weight CV appears to be established during the embryonic stage (d35 gestation) (van der Lende *et al.* 1990) suggesting that it is likely that the quality of the follicle and /or oocyte rather than subsequent uterine conditions that contributes most to eventual litter weight variance. To support this, when dietary arginine concentrations were increased to enhance placental growth from d30 gestation, no improvement in piglet weight variation was reported (Mateo *et al.* 2007). Ovulation rate is positively related to birth weight CV (Quesnel *et al.* 2008), but one manifestation of seasonal infertility is a reduction in litter size and so there must be other metabolic influences acting to increase variation from summer breedings. Quesnel *et al.* (2008) discussed the impact of body reserve loss in lactation on birth weight heterogeneity in the subsequent litter with the reasoning that metabolic status influenced follicle and oocyte quality and so embryo development. Heat stress during lactation has been shown to reduce the circulating concentrations of both insulin and IGF-1 (Williams *et al.* 2013), both of which are strongly implicated in embryo quality. Carbohydrate-rich diets fed during the follicular phase appear to increase follicle and oocyte quality most likely due to increases in plasma insulin and IGF-1, and their inclusion in the diet from weaning to oestrus has been shown to reduce birth weight CV of the litter from 21 to 17% (Van den Brand *et al.* 2006). There are several factors in this latter study that lead the investigators to believe effects may be even greater than reported.

Namely, authors state that only sows that had moderate body condition loss in lactation were used, and the effect of season was not investigated.

Variation in litter birth weight can affect pork production from the time of birth through to slaughter. There is little published information on the seasonality of variation in piglet birth weight, but the science would suggest it is plausible. It would appear that oocyte quality is important and so nutritional strategies should target this reproductive phase. Dextrose is successful in reducing litter weight variation and so its effects should be tested during the summer months. The aim of the following experiment was to determine whether CV of birth weight is influenced by season, and to test the effectiveness of dextrose administration at alleviating these effects if evident.

3. Research Methodology

All procedures were carried out with approval from Primary Industries and Regions South Australia. The experimental periods were applied over two season replicates; summer (February-March) and winter (August-September). Climate data for each of the experimental periods are shown in Table 1.

Table 1. Climate data obtained from the Bureau of Meteorology weather station located in Roseworthy approximately 22km SE from the experimental site.

		Avg. Min (°C)	Avg. Max (°C)	Highest temperature (°C)	Days over 30°C	Solar exposure (MJ/(m*m))
Summer	February	16	32.5	43.3	18	22
	March	12.8	28.8	37.7	12	18.5
Winter	August	5.9	16.9	22.5	0	12.4
	September	3.6	19.6	28.6	0	17.3

1.1 Dry sow management

Sow history prior to being recruited to the experiment is outlined in Table 2. The sows were older (parity 3.1 ± 0.0) and lighter (214.2 ± 5.1 kg) in summer than winter (parity 3.0 ± 0.0 and 216.8 ± 4.2 kg; $P < 0.05$). There were no differences in season or treatment for any other variables examined.

*Table 2. Number and previous history of sows allocated to either the Control or Dextrose treatments during the summer and winter replicates. † *P < 0.05 with significant main effect presented in bracket.*

	Summer				Winter				
	Control		Dextrose		Control		Dextrose		
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Significance†
n	148		142		145		151		
Parity	3.1	0	3.1	0	3	0	3	0	* (Season)
Previous TB	13.3	0.4	13.4	0.4	13.6	0.4	12.7	0.3	NS
Previous BA	12.5	0.3	12.7	0.4	12.6	0.3	11.9	0.3	NS
Previous BD	0.7	0.1	0.7	0.1	0.7	0.1	0.6	0.1	NS
Previous Mummified	0.6	0.1	0.5	0.1	0.7	0.1	0.6	0.1	NS
Previous NPW	9.5	0.2	9.8	0.2	9.8	0.2	9.7	0.2	NS
Back fat (mm)	16.5	0.3	16.3	0.3	17.1	0.3	17.5	0.3	NS
Weight (kg)	213.5	5.2	214.9	5.2	214	4.4	219.7	4.4	* (Season)

Over four replicates in summer, and six replicates in winter, sows were weaned in groups of 40 to partially slatted pens with a space allowance of $2m^2$/sow. Sows were hand fed 3.5kg of each of the control and treatment diets daily at 0700. Diet information is presented in Table 3. Sows in the Control and Dextrose treatments received 0% and 5% dextrose (0g/day and 193g/day) respectively.

Table 3. Diet information for Control and Dextrose treatments during the summer and winter replicates.

	Summer		Winter	
	Control	Dextrose	Control	Dextrose
DE MJ/KG	13.4	13.4	13.4	13.4
Protein %	15.2	14.9	15.9	15.7
Crude fibre %	5.1	5.0	5.2	5.0

Dextrose %	0.0	5.5	0.0	5.5

From weaning, sows were moved daily at 0800 from the large pen into detection mating areas in groups of five where fence-line contact with two mature boars was used to detect estrus. If estrus was not detected, sows were moved back to the large group pens, but when standing behaviour was observed, the sows were relocated into mating stations. Once in the mating stations, sows received two post-cervical artificial inseminations 24h apart and were fed treatment diets. After the second insemination, sows were relocated into partially slatted gestation pens in groups of 50 and fed via electronic sow feeder at a space allowance of 1.8m^2/sow. Sows were allocated to gestation pens based on size and mating date and so contained both treatments, as well as commercial sows from outside the experiment. Return rate at 21 days of gestation was determined in the presence of a mature boar, and pregnancy rate confirmed via ultrasonography at approximately 28 days of gestation. All sows were fed a gestation diet (13.0 DE MJ/kg) at 2.1kg/day in summer and 2.4kg/day in winter.

1.2 Lactation sow management

Sows mated during the summer replicate farrowed during winter (June and July), and winter mated sows in summer (December and January). At approximately day 110 of gestation, sows were moved into farrowing accommodation and housed in farrowing crates (1.8 x 2.4m). All sows were fed a lactation diet (14.2 DE MJ/kg) at 2.4kg/day until farrowing, and then *ad libitum* to weaning. On the day of farrowing, the following measurements were recorded; total born (TB), born alive (BA), born dead (BD) and mummified fetuses. Piglets born alive and dead were weighed individually, and those alive were tagged to allow individual identification. Fostering occurred once daily at 1300 and all piglet movement involving tagged piglets was noted. Age and reason for piglet mortalities were recorded, as well as piglet removal for ill thrift. Tagged piglets were weighed again on day 21 of lactation. Individual piglet weights on day 1 and day 21 were used to calculate the total litter weight, minimum and maximum piglet weight, standard deviation (SD), co-efficient of variation (CV) weight, and the percentage of piglets within the litter weighing less than 1.1kg (on day 1; bottom quartile). Piglets were counted at weaning to give number of pigs weaned per sow (NPW).

1.3 Statistics

All data were analysed in SPSS v25 (IBM, USA) and significance established at $P < 0.05$ and tendency at $P = 0.1$. Normally distributed data were analysed using a general linear mixed model, but generalized linear mixed models applied to binary data (bred < 7 days, pregnancy rate, farrowing rate) using binary logistic regression, and to count data (all piglet mortalities) using possion regression. All analyses contained parity, season, treatment and the interaction between season and treatment as fixed effects and mated week as the random term. The number of sows retained for these analyses are outlined in Table 4.

Table 4. Number of sows retained through each stage of the experiment.

	Sample size for analyses			
	Summer		**Winter**	
	Control	**Dextrose**	**Control**	**Dextrose**
Allocated to treatment (n)	151	144	145	151
Mated in experiment (n)	129	122	98	107
Farrowing performance (n)	74	85	86	95

Lactation performance (n)	66	77	68	71

Separate analyses were conducted for 1764 Control and 2076 Dextrose piglets with the individual being the statistical unit. Linear regression was used for weights at day 1 and day 21, and binary logistic regression for survival through birth, fostering and weaning. Survival through birth was treated as a separate trait, but to fostering and weaning was cumulative. The model included birth sow parity, birth litter size group (<12, 12-15 and <15), birth weight group (<1.1kg, 1.11-1.62kg and >1.63kg), CV group (<15%, 15-20%, 20-25% and >25%), sex, season, treatment, and the interaction with main effects and treatment. Birth sow, foster sow and mated week were fit as random terms.

4. Results

Wean to service interval (WSI) was 1.5 days shorter in summer than winter ($P < 0.01$; Table 5) but was unaffected by treatment. These results were mirrored in percent sows bred within seven days. Pregnancy rate was improved by 22% from summer to winter ($P < 0.001$). Similarly, farrowing rate was improved by 25% from summer to winter ($P < 0.001$), and there was a tendency for a 5.9% improvement in Dextrose compared to Control sows ($P = 0.1$).

Table 5. Mean ± SEM mating performance for sows from Control and Dextrose treatments applied during the wean to mate period in summer and winter. Superscripts denote significant difference at P < 0.05. 95% confidence intervals rather than SEM are presented for binary data in brackets.

	Season				**Treatment**				**Summer**				**Winter**						
	Summer		**Winter**		**Control**		**Dextrose**		**Control**		**Dextrose**		**Control**		**Dextrose**		**P-value**		
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Season	Treatment	Interaction
WSI (days)	6.1^a	0.4	7.6^b	0.4	6.6	0.4	7.1	0.4	5.5	0.6	6.6	0.6	7.7	0.6	7.6	0.6	<0.01	NS	NS
Bred < 7 days (%)	90.0^a		74.0^b		83.6		83.9		91		89.9		72.4		75.2		<0.001	NS	NS
	(86.1-93.4)		(68-78.9)		(78.2-87.9)		(78.6-88.0)		(84.8-94.7)		(83.4-94.0)		(63.9-79.5)		(67.3-81.8)				
Pregnancy rate (%)	70.0^a		92.0^b		84.2		84.4		67.4		73.2		93.2		91.5		<0.001	NS	NS
	(61.1-78.3)		(87.1-95.6)		(76.7-89.5)		(77.7-89.4)		(56.0-77.2)		(62.1-82.1)		(85.7-96.9)		(84.0-95.6)				
Farrowing rate (%)	64.0^a		89.0^b		75.7		81.6		56.9		69.7		88.1		89.6		<0.001	=0.1	NS
	(56.2-70.3)		(83.5-92.6)		(68.4-81.8)		(75.3-86.6)		(47.3-66.0)		(60.1-77.8)		(79.8-93.2)		(82.1-94.1)				

TB was higher in Dextrose than Control sows ($P < 0.05$; Table 6). Similarly, BA was higher in Dextrose sows ($P < 0.001$). There was no impact on BD, but mummified was similar between treatment sows in summer, but reduced in Dextrose sows when compared with Control during the winter matings ($P < 0.01$). A tendency for higher day 1 total litter weight was established in Dextrose sows when compared to Control ($P < 0.1$), but no treatment effect was observed in minimum, maximum, SD, CV and percent pigs weighing less than 1.1kg. There was a tendency ($P = 0.1$) for day 1 CV to be higher in summer than winter bred sows.

Pre-foster deaths were reduced in sows mated during winter than summer ($P < 0.05$), no difference was observed in post-foster deaths, but piglet removal was less in the winter bred sows ($P < 0.05$). Piglet removal was also reduced in the Dextrose sows when compared with Control ($P < 0.05$). There was a tendency for NPW to be improved in sows mated in winter than summer ($P = 0.1$).

Total litter weight at day 21 was unaffected by season and treatment. Minimum and maximum day 21 piglet weights were higher in litters born to sows mated in winter ($P < 0.001$). Both the SD and CV at day 21 was increased in litters born to Dextrose treated sows ($P < 0.05$). Season also affected the CV weight at day 21, with sows bred during winter having higher variation than those bred in summer ($P < 0.05$).

Table 6. Farrowing performance for sows from Control and Dextrose treatments applied during the wean to mate period in summer and winter. Superscripts denote significant difference at $P < 0.05$ within effect. † Back-transformed data are presented in brackets.

	Season				**Treatment**				**Summer**				**Winter**						
	Summer		**Winter**		**Control**		**Dextrose**		**Control**		**Dextrose**		**Control**		**Dextrose**		**P-value**		
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Season	Treatment	Interaction
TB	13.8	0.3	14.2	0.3	13.6^{a}	0.3	14.6^{b}	0.3	13.6	0.4	14.1	0.4	13.7	0.4	14.8	0.4	NS	<0.05	NS
BA	12.5	0.3	13.1	0.2	12.3^{a}	0.3	13.7^{b}	0.3	12.3	0.4	12.7	0.4	12.3	0.4	13.9	0.3	<0.1	<0.001	=0.1
BD	1.0	0.1	0.8	0.1	0.9	0.1	0.8	0.1	0.9	0.1	1	0.1	0.9	0.1	0.7	0.1	NS	NS	NS
Mummified	0.8^{a}	0.1	0.6^{b}	0.1	0.7	0.1	0.7	0.1	1.0^{a}	0.1	1.0^{a}	0.1	0.7^{b}	0.1	0.5^{c}	0.1	<0.01	NS	<0.01
Total litter weight	18.4	0.4	19.1	0.4	18.4	0.4	19.3	0.4	18.4	0.5	18.7	0.5	18.3	0.5	19.9	0.5	NS	<0.1	NS
Min D1 weight	0.85	0.03	0.88	0.03	0.88	0.03	0.85	0.03	0.85	0.04	0.85	0.04	0.91	0.04	0.85	0.04	NS	NS	NS
Max D1 weight	1.87	0.03	1.87	0.03	1.89	0.03	1.85	0.03	1.88	0.04	1.86	0.04	1.9	0.04	1.84	0.04	NS	NS	NS
SD D1 weight	0.3	0.01	0.3	0.01	0.31	0.01	0.29	0.01	0.31	0.01	0.29	0.01	0.3	0.01	0.29	0.01	NS	NS	NS
CV D1 weight	16.6	0.4	15.8	0.4	16.3	0.4	16.1	0.4	16.9	0.6	16.4	0.5	15.6	0.5	15.9	0.5	P=0.1	NS	NS
Ln piglets <1.1kg†	3.2	0.7	3.1	0.7	3.1	0.7	3.2	0.7	3.1	0.1	3.3	0.1	3	0.1	3.1	0.1	NS	NS	NS
	(22.8)		(21.4)		(19.6)		(24.5)		(20.8)		(25.8)		(18.5)		(24.3)				
Pre-foster deaths	1.04^{a}	0.09	0.83^{b}	0.08	0.98	0.09	0.88	0.08	1.13	0.13	0.95	0.11	0.84	0.11	0.81	0.10	<0.05	NS	NS
Post-foster deaths	1.0	0.1	1.1	0.1	1.1	0.1	1.1	0.1	1.1	0.1	1.0	0.1	1.1	0.1	1.2	0.1	NS	NS	NS
Piglet removal	1.5^{a}	0.1	1.1^{b}	0.1	1.5^{a}	0.1	1.2^{b}	0.1	1.7	0.2	1.3	0.1	1.3	0.2	1.0	0.1	<0.05	<0.05	NS
NPW	9.0	0.2	9.4	0.2	9.1	0.2	9.3	0.2	8.8	0.2	9.2	0.2	9.4	0.2	9.4	0.2	=0.1	NS	NS
D21 litter weight	54.0	2.5	51.5	2.6	51.2	2.5	54.3	2.4	53.6	2.8	54.4	2.7	48.8	3.2	54.2	3.0	NS	NS	NS
Min D21 weight	4.4^{a}	0.1	3.7^{b}	0.1	4.2	0.1	4.0	0.1	4.6	0.1	4.5	0.1	3.9	0.2	3.6	0.2	<0.001	NS	NS
Max D21 weight	8.0^{a}	0.2	7.4^{b}	0.2	7.6	0.2	7.8	0.2	8.0	0.2	8.1	0.2	7.2	0.3	7.6	0.2	<0.001	NS	NS
SD D21 weight	1.20	0.04	1.21	0.05	1.14^{a}	0.05	1.27^{b}	0.04	1.15	0.06	1.24	0.05	1.12	0.07	1.30	0.07	NS	<0.05	NS
CV D21 weight	19.1^{a}	0.7	21.4^{b}	0.9	19.2^{a}	0.8	21.4^{b}	0.7	18.4	1.0	19.9	0.9	20.0	1.2	22.8	1.1	<0.05	<0.05	NS

There was no impact of birth sow parity, litter size group, or CV group on piglet survival at birth, to fostering or to weaning ($P < 0.05$). More piglets from sows bred in summer survived to weaning (90.7%) than those bred in winter (82.8%; $P < 0.001$). Birth weight group significantly influenced survival during birth, to fostering and weaning ($P < 0.001$; Figure 1), with a lower proportion of those < 1.1kg surviving, and the highest survival observed at > 1.63kg, at all three timepoints.

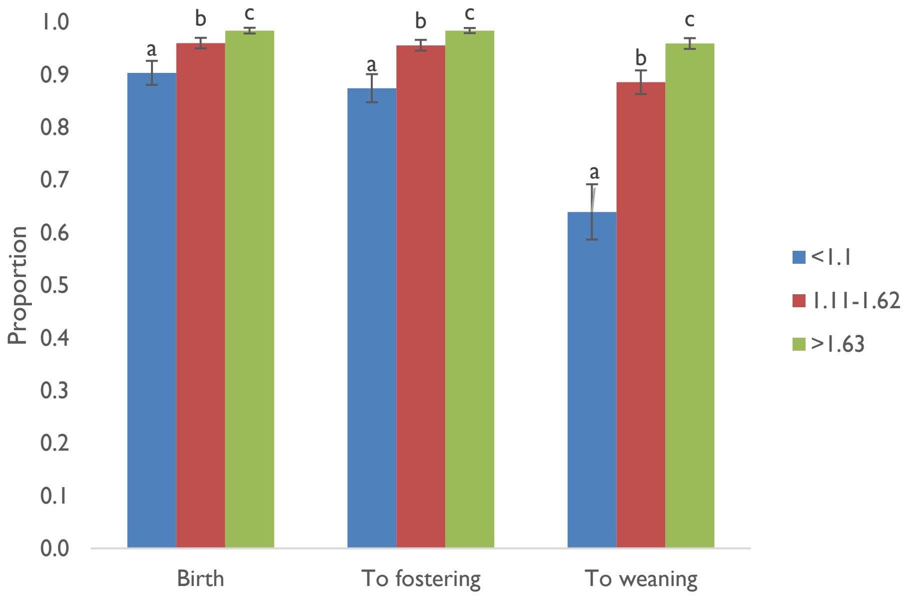

Figure 1. Proportion of piglets surviving birth, to fostering at 12-24h of age, and to weaning at 21d of age weighing < 1.1kg, 1.11-1.62kg and > 1.63kg at birth. Superscripts denote significant difference at P < 0.001 within timepoint.

Piglet gender was also shown to impact survival to fostering and to weaning ($P < 0.01$; Figure 2), with 96.3% of females and 94.4% of males alive at fostering, and 89.2% and 85.1% at weaning respectively.

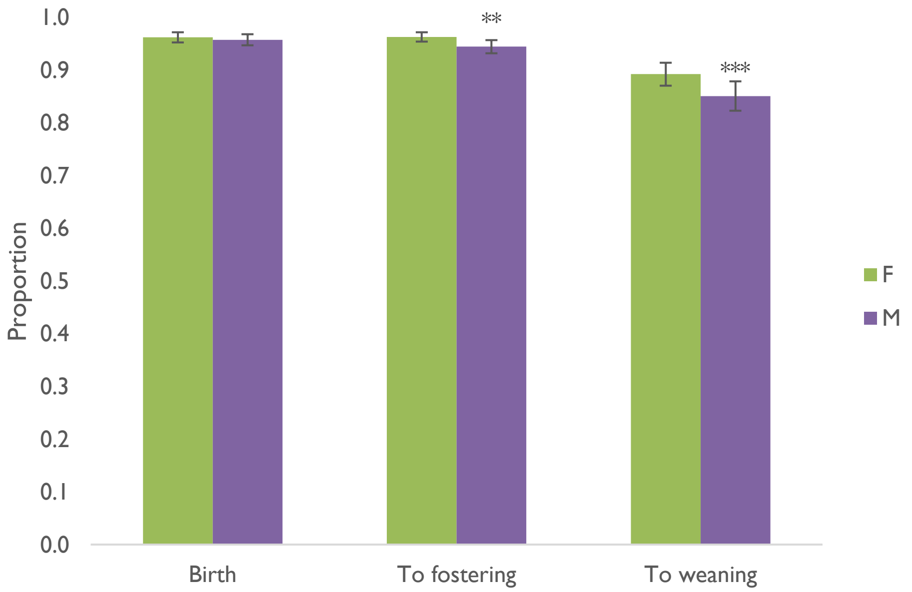

*Figure 2. Proportion of piglets surviving birth, to fostering at 12-24h of age, and to weaning at 21d of age of female (F) and male (M) gender. ** P < 0.01 and *** P < 0.001.*

There was a tendency (P < 0.1) for more Dextrose female piglets to survive the birth process than both females and males from Control sows. A trend for reduced survival to fostering in male Control piglets compared with females from the same treatment, and both genders from Dextrose sows was also established (P < 0.1). To weaning, 91.2% of females but 83.9% of males survived in the Control treatment (P < 0.01), but no sex effect was observed in Dextrose litters (86.9% and 86.2% respectively; Figure 3).

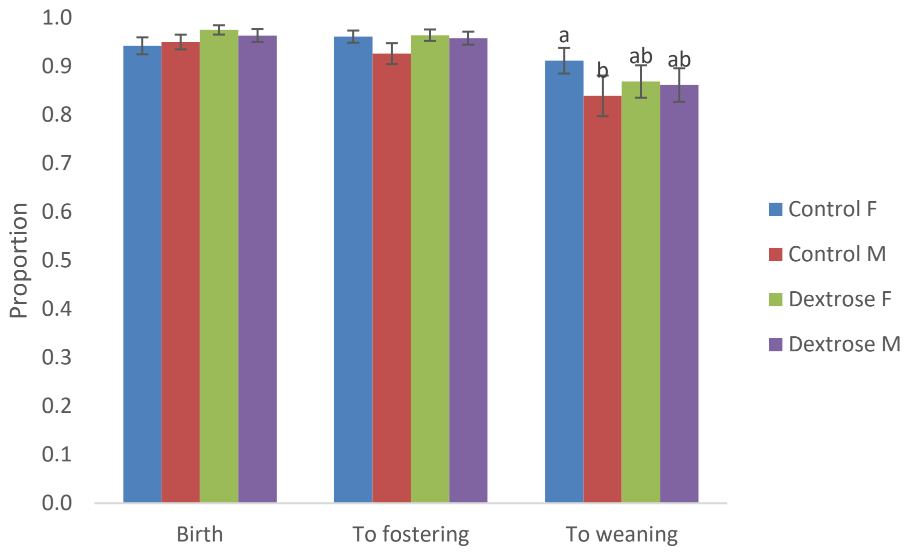

Figure 3. Proportion of piglets surviving birth, to fostering at 12-24h of age, and to weaning at 21d of age from Control and Dextrose treated sows of female (F) and male (M) gender. Superscripts denote significant difference at P < 0.01 within timepoint.

Piglet average birth weight was influenced by litter size, birth weight group and gender (P < 0.01), but was unaffected by birth sow parity, CV group and treatment (P > 0.05; Table 7). Weight at day 21 and ADG was highest in piglets with the heaviest birth weight, and in those born to sows bred in summer (P < 0.001). A significant breeding season by treatment interaction was identified, whereby there was no treatment effect in piglets born to sows bred in summer, but in those bred during winter the weaning weight and growth was improved in the Dextrose piglets (by 0.47kg and 23g respectively; P < 0.05).

Table 7. Mean (SEM) piglet birth weight (kg), day 21 weight (kg) and lactation average daily gain (ADG; g) for treatment and birth environment factors.

		Birth weight (kg)	Day 21 weight (kg)	Lactation ADG (g)
Birth sow parity		*NS*	*NS*	*NS*
	3	1.39 (0.01)	5.92 (0.15)	213 (6)
	4	1.38 (0.01)	5.87 (0.15)	215 (6)
	5	1.39 (0.01)	5.79 (0.15)	208 (6)
	6	1.38 (0.01)	5.77 (0.22)	206 (9)
Litter size		*<0.001*	*NS*	*NS*
	<12	1.45[a] (0.01)	5.95 (0.17)	214 (7)

	12-15	1.37^{b} (0.01)	5.74 (0.13)	207 (6)
	>15	1.34^{c} (0.01)	5.83 (0.15)	211 (6)
CV group		*NS*	*NS*	*NS*
	<15	1.40 (0.01)	5.73 (0.12)	202 (5)
	15-20	1.39 (0.01)	5.82 (0.10)	208 (4)
	21-25	1.36 (0.01	5.61 (0.17)	205 (7)
	>26	1.41 (0.01	6.20 (0.38)	227 (16)
Birth weight quartile		*<0.001*	*<0.001*	*<0.001*
	<1.1kg	*0.93^{a} (0.01)*	*4.67^{a} (0.15)*	*198^{a} (6)*
	1.11-1.62kg	*1.40^{b} (0.01)*	*5.93^{b} (0.13)*	*213^{b} (6)*
	>1.63kg	1.84^{c} (0.01)	6.93^{c} (0.13)	220^{b} (6)
Gender		*<0.01*	*NS*	*NS*
	Male	1.40^{a} (0.01)	5.83 (0.13)	210 (6)
	Female	1.38^{b} (0.01)	5.85 (0.13)	211 (6)
Breeding season		*NS*	*<0.001*	*<0.001*
	Summer	1.39 (0.01)	6.13^{a} (0.14)	231^{a} (6)
	Winter	1.39 (0.01)	5.55^{b} (0.15)	190^{b} (6)
Treatment		*NS*	*NS*	*NS*
	Control	1.40 (0.01)	5.73 (0.18)	204 (8)
	Dextrose	1.38 (0.01)	5.95 (0.16)	217 (7)
*Breeding season * Treatment*		*NS*	*<0.05*	*<0.05*
	Summer Control	1.40 (0.02)	6.13^{a} (0.19)	230^{a} (8)
	Summer Dextrose	1.38 (0.01)	6.13^{a} (0.17)	231^{a} (7)
	Winter Control	1.39 (0.02)	5.33^{c} (0.20)	179^{c} (9)
	Winter Dextrose	1.39 (0.02)	5.80^{b} (0.19)	202^{b} (8)
*Treatment * CV group*		*NS*	*NS*	*NS*
*Treatment * Sex*		*NS*	*NS*	*NS*
*Treatment * Birth weight quartile*		*NS*	*NS*	*NS*
*Treatment * Litter size*		*NS*	*NS*	*NS*

5. Discussion

The first objective of this project was to identify whether seasonal infertility impacted on piglet traits such as birth weight, and within litter weight variation. The experimental site was appropriate for the project as the traditional indicators of seasonal infertility were observed; farrowing rate was 25% lower and litter size reduced by 0.4 pigs during summer in comparison to the winter matings. Whilst no difference in average birth weight was identified, there was some evidence that day one litter weight CV was increased in sows bred during summer which is in support of our hypothesis. Reviewed by De Rensis *et al.* (2017), reduced lactation nutrient intake in summer alters both the basal and surge release of LH. Only large follicles contain LH receptors, thus when LH levels are high, the growth of these large follicles is encouraged resulting in a more uniform oocyte release. But when LH levels are reduced, both large and small follicles develop, resulting in a more heterogenous oocyte quality and so potentially embryonic population. Our findings would suggest that birth weight heterogeneity is increased in sows bred during summer months and so is another way seasonal infertility can present itself. Interestingly, by weaning, it was the winter bred litters that exhibited the highest variation. These litters would have farrowed in summer, and with the experimental site utilising naturally ventilated farrowing sheds, it is likely the conditions the sow experienced during farrowing and lactation rather than at breeding that resulted in this finding. Indeed, the CV litter weight the piglet was born in to had no impact on ADG, whilst there was a significant 40g/day difference between season.

Interestingly litter weight variation at birth had no impact on piglet survival and growth, which contrasts previous work (Akdag *et al.* 2009). It is however, the smaller piglets that are at a greater risk of mortality in litters with high variation (Milligan *et al.* 2002). We were unable to replicate these findings (data not shown), in that the survival of piglets < 1.1kg was low (54-64%), but consistently low across all CV weight groups. Perhaps it is the management of low birth weight pigs on the experimental site that contributed to this result. Low birth weight pigs born into high CV litters are disadvantaged with regards to colostrum intake as they are often out-completed at the udder by larger conspecifics. Split suckling involves removing the largest piglets from the sow after farrowing when weight disparities are evident, and successfully increases the survival of small piglets presumably through improved colostrum intake (Huser *et al.* 2015). This practice is performed routinely on the experimental site, and so whilst survival of the small piglets was low overall, split suckling may have acted to dilute any impacts of high litter weight CV. Irrespective of litter weight variation, low birth weight piglets (<1.1kg) were significantly disadvantaged with regards to survival and growth, which is not a novel finding.

Dextrose appears to be a more effective energy source in dietary induced insulin enhancement than starch or fat (Van den Brand *et al.* 1998). This was a significant finding as insulin and IGF-1 are important regulators of ovarian function. Subsequent work by these authors showed that litter weight variation was reduced by ~4% when sows were supplemented with dextrose from weaning to breeding (Van den Brand *et al.* 2006). The present findings do not agree with this previous work as CV litter weight was not reduced in the Dextrose treatment both across and within seasons. Thus, the objective to reduce the amount of within litter variation through the inclusion of dextrose in a 'wean to mate' diet during summer months was not achieved. Quesnel *et al.* (2014) also failed to replicate these earlier findings when dextrose in the wean to mate period was combined with arginine from day 77 of gestation. However, dextrose supplementation did improve litter size, with total pigs born being 1.0 higher and pigs born alive 1.4 higher in this treatment compared to the control. Given the positive correlation between litter size and CV litter weight ($r^2 = 0.394$, Milligan *et al.* (2002)), this increase in litter size should have been accompanied by an increase in birth weight variation, but this was not the case. Thus, dextrose supplementation fed from weaning to mating improves litters size whilst maintaining litter weight variation.

Perhaps one of the most interesting findings was that pigs conceived in winter and so suckled in summer grew 23g/day faster in Dextrose than Control litters, and as such were half a kilogram heavier at weaning. Lactation growth rates are supressed during warmer months by poor sow feed intake and this would be exacerbated under the natural ventilation farrowing shed conditions of this experiment. Given there was no improvement in any of the birth weight characteristics, this is a difficult finding to explain. We can only surmise that the size of effect of treatment on litter size across seasons altered mammary tissue activation in the winter bred, summer suckled Dextrose litters. Litter size is a main contributor to milk production; with more piglets ensuring adequate gland drainage and so improvement in milk output (Hurley 2001). In summer bred sows, Dextrose improved piglets born alive by 0.4 piglets per litter but in winter bred sows, this improvement was increased to 1.6 piglets per litter. Thus, before the fostering event at 24h post-farrowing, Dextrose sows bred in winter but suckled in summer nursed an extra 1.2 piglets. In the same review, Hurley (2001) stated the most important time for mammary development is in the first few days following farrowing. So the improvement in litter size, which was largest in winter bred, summer suckled sows from the Dextrose treatment may have resulted in better mammary activation, and so helped to alleviate poor piglet lactation growth rates in summer.

In conclusion, supplementing dextrose at a 5% inclusion rate to sows in the ‘wean to mate’ period increases litter size without increasing litter weight variation. An additional benefit of the dietary treatment was an improvement in suckling piglet growth rate during the warmer, summer months.

6. Implications & Recommendations

Dextrose is an easy to handle, relatively cheap dietary inclusion. At ~$1000 per tonne and 5% inclusion, the cost is $55 per tonne of feed milled. With a wean to service interval of five days, and feed consumption of 3.5kg per day, the application cost is less than $1 per sow.

Using the reported farrowing rate and piglets born alive, the benefits far out-weight the costs as long as farrowing house management is adequate. Per 100 sows bred, the number of piglets born alive is improved from 931 to 1118 using dextrose during the wean to mate period.

There are other factors that should be taken in to consideration when trying to implement this nutritional strategy. Small farms may struggle to order and store such a feed as volumes will be low and silo space limiting. In order to exploit the advantages identified by this project, we would recommend that the sows daily feed allowance is top-dressed with ~190g of dextrose until breeding. This is easy to achieve in systems that wean into breeding stations, but becomes more complex in group-weaned farms.

7. Intellectual Property

NA

8. Technical Summary

When dextrose in supplemented in a wean to mate diet for sows at a rate of 5%, subsequent litter size is improved, litter weight variation maintained, and piglet growth increased when suckled in summer.

9. Publications arising

One abstract has been submitted for publication in the 2019 Australasian Pig Science Association Conference (Manipulating Pig Production).

We aim to submit the full publication to Animal after this report has been accepted by Australian Pork Limited.

10. Literature cited

Akdag, F, Arslan, S, Demir, H (2009) The effect of parity and litter size on birth weight and the effect of birth weight variations on weaning weight and pre-weaning survival in piglet. *Journal of Animal and Veterinary Advances* **8**, 2133-2138.

Campos, P, Silva, BAN, Donzele, JL, Oliveira, RFM, Knol, EF (2012) Effects of sow nutrition during gestation on within-litter birth weight variation: a review. *animal* **6**, 797-806.

De Rensis, F, Ziecik, AJ, Kirkwood, RN (2017) Seasonal infertility in gilts and sows: Aetiology, clinical implications and treatments. *Theriogenology* **96**, 111-117.

Hurley, WL (2001) Mammary gland growth in the lactating sow. *Livestock Production Science* **70**, 149-157.

Huser, JS, Plush, KJ, Pitchford, WS, Kennett, TE, Lines, DS (2015) Neonatal split suckling improves survival of small piglets. *Animal Production Science* **55**, 1477-1477.

Madsen, JG, Bee, G (2015) Compensatory growth feeding strategy does not overcome negative effects on growth and carcass composition of low birth weight pigs. *animal* **9**, 427-436.

Mateo, RD, Wu, GY, Bazer, FW, Park, JC, Shinzato, I, Kim, SW (2007) Dietary L-arginine supplementation enhances the reproductive performance of gilts. *Journal of Nutrition* **137**, 652-656.

Milligan, BN, Fraser, D, Kramer, DL (2002) Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. *Livestock Production Science* **76**, 181-191.

Peltoniemi, OAT, Tast, A, Love, RJ (2000) Factors effecting reproduction in the pig: seasonal effects and restricted feeding of the pregnant gilt and sow. *Animal Reproduction Science* **60**, 173-184.

Quesnel, H, Brossard, L, Valancogne, A, Quiniou, N (2008) Influence of some sow characteristics on within-litter variation of piglet birth weight. *animal* **2**, 1842-1849.

Quesnel, H, Quiniou, N, Roy, H, Lottin, A, Boulot, S, Gondret, F (2014) Supplying dextrose before insemination and L-arginine during the last third of pregnancy in sow diets: Effects on within-litter variation of piglet birth weight. *Journal of Animal Science* **92**, 1445-1450.

van Barneveld, RJ, Hewitt, RJE (2016) Reducing variation in pork production systems through maternal and pre- and post-weaning nutrition strategies. *Animal Production Science* **56**, 1248-1253.

Van den Brand, H, Soede, NM, Kemp, B (2006) Supplementation of dextrose to the diet during the weaning to estrus interval affects subsequent variation in within-litter piglet birth weight. *Animal Reproduction Science* **91**, 353-358.

Van den Brand, H, Soede, NM, Schrama, JW, Kemp, B (1998) Effects of dietary energy source on plasma glucose and insulin concentration in gilts. *Journal of Animal Physiology and Animal Nutrition* **79**, 27-32.

van der Lende, T, Hazeleger, W, de Jager, D (1990) Weight distribution within litters at the early foetal stage and at birth in relation to embryonic mortality in the pig. *Livestock Production Science* **26**, 53-65.

Williams, AM, Safranski, TJ, Spiers, DE, Eichen, PA, Coate, EA, Lucy, MC (2013) Effects of a controlled heat stress during late gestation, lactation, and after weaning on thermoregulation, metabolism, and reproduction of primiparous sows. *Journal of Animal Science* **91**, 2700-2714.