Final Report

to

North Carolina Pork Council

Genetic selection criteria and management practices that improve productivity and pig value of below average birth weight piglets

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This project included three experiments conducted over a two year time frame.

1. Genetic relationship between individual piglet birth weight and performance traits.

2. Effect of piglet birth weight on body weight, growth, backfat, muscle, survival and quality of commercial market swine.

3. Effect of piglet birth weight on efficiency of commercial market swine.

Complete results of these trials can be found in the doctoral dissertation of Dr. Justin Fix located at http://www.lib.ncsu.edu/theses/available/etd-03232010-190436/unrestricted/etd.pdf. At this time two journal articles have also been published in Livestock Science.

1. Genetic relationship between individual piglet birth weight and performance traits.

Large White and Landrace datasets were provided by Smithfield Premium Genetics Group (Rose Hill, NC) from five nucleus farms located in North Carolina and Texas. During farrowing, nursery, and finishing phases all pigs were housed in confinement facilities typical of U.S. swine production and management followed standard U.S. protocol. Variance component estimation was completed using breed specific 6 trait animal models with maternal effects of the birth dam. Estimation of variance components was accomplished using GIBBS2F90 (Mistal et al., 2002). Heritabilities (diagonal) and genetic correlations (off-diagonal) are provided in Tables 1 and 2.

Heritability of individual birth weight is low and therefore potential for genetic selection is likely nominal. Based on the higher maternal heritability compared to direct heritability, it appears the genetic aspects of the uterine environment (nutrition, space, etc.) contribute a larger portion of the phenotypic variation than the fetus' or individual pig's contribution. Consequently, the potential for genetic selection for an individual's increased birth weight due their genetic merit is minimal. Even so, there is still the potential, if desired, to impact individual birth weight through direct selection.

Impacting birth weight through indirect selection on other traits is also possible. Based on the estimated genetic correlations, selection for increased BW measured later in life should lead to heavier birth weights. In addition, selection for reduced backfat would also result in increased birth weight. Backfat and BW or some measures of growth are common selection criteria, particularly in terminal lines.

Even with the potential for direct or indirect genetic selection to reduce or eliminate the incidence of low birth weight pigs, it appears the issue cannot be solved by selection alone, at least in short time period. The potential for increased incidence of light birth weight pigs with continued emphasis on litter size needs to be considered within selection programs. Furthermore, post farrowing management decisions must be considered and further examined to assist in reducing the economic impact of these light birth weight pigs on a production system.

Table 1. Heritability (diagonal) and genetic correlations (off diagonal) for Large White.

	Direct						Maternal					
	BWT	WWT	OTW	OTBF	OTLD	ADFI	BWT	WWT	OTW	OTBF	OTLD	ADFI
BWT	0.064	0.544	0.477	-0.235	-0.188	0.107	-0.296	-0.098	-0.491	0.280	0.328	-0.024
WWT		0.105	0.545	-0.259	-0.342	0.516	-0.104	-0.504	-0.421	0.346	0.500	-0.427
OTW			0.248	0.044	-0.036	0.681	0.036	-0.219	-0.502	0.045	-0.047	-0.315
OTBF				0.524	-0.156	0.166	0.031	0.084	-0.016	-0.587	-0.013	0.038
OTLD					0.329	-0.190	0.036	0.160	0.061	-0.015	-0.597	0.196
ADFI						0.296	-0.063	-0.402	-0.544	0.028	0.133	-0.752
BWT							0.124	0.663	0.543	-0.247	-0.251	0.139
WWT								0.096	0.613	-0.275	-0.340	0.542
OTW									0.086	-0.162	-0.144	0.692
OTBF										0.081	0.116	-0.124
OTLD											0.072	-0.201
ADFI												0.166

BWT = individual BW at birth; WWT = individual BW at weaning; OTW = BW at off-test (Large White: 172.8 ± 4.5 d; Landrace: 171.5 ± 4.6 d); OTBF = real-time ultrasonic backfat depth at off-test; OTLD = real-time ultrasonic loin depth at off-test; ADFI = average daily feed intake.

Table 2. Heritability (diagonal) and genetic correlations (off diagonal) for Landrace.

	Direct						Maternal					
	BWT	WWT	OTW	OTBF	OTLD	ADFI	BWT	WWT	OTW	OTBF	OTLD	ADFI
BWT	0.061	0.539	0.546	-0.162	-0.012	0.236	-0.186	-0.170	-0.509	0.135	0.015	-0.369
WWT		0.075	0.489	0.028	-0.204	-0.035	-0.063	-0.344	-0.448	-0.019	0.035	-0.154
OTW			0.292	0.182	-0.068	0.511	-0.096	-0.178	-0.488	0.064	0.016	-0.098
OTBF				0.445	-0.263	0.085	0.127	-0.029	0.120	-0.637	0.106	0.269
OTLD					0.250	-0.187	-0.258	-0.099	-0.050	0.164	-0.486	-0.097
ADFI						0.310	-0.022	0.090	-0.037	0.088	0.188	-0.522
BWT							0.112	0.695	0.660	-0.278	0.142	0.340
WWT								0.082	0.695	-0.089	0.081	0.302
OTW									0.094	-0.176	0.105	0.347
OTBF										0.077	-0.206	-0.225
OTLD											0.075	-0.129
ADFI												0.162

BWT = individual BW at birth; WWT = individual BW at weaning; OTW = BW at off-test (Large White: 172.8 ± 4.5 d; Landrace: 171.5 ± 4.6 d); OTBF = real-time ultrasonic backfat depth at off-test; OTLD = real-time ultrasonic loin depth at off-test; ADFI = average daily feed intake.

2. Effect of piglet birth weight on body weight, growth, backfat, muscle, survival and quality of commercial market swine.

All live born piglets (n = 5,727) used for this study were born from July 6, 2008 to August 3, 2008 from Large White x Landrace (n = 463) females bred to Duroc sires. Pigs were weighed (BIRTHWT) and individually identified within 24 h of birth; immediately following identification 16.7% of pigs were cross fostered to reduce variation among litters for number nursed. Farrowing was not induced for sows used in this trial. Pigs with BIRTHWT < 0.7 kg (n = 132) were not used in the analysis. Within 5 d of age all pigs were processed and male pigs castrated. At approximately 10 d of age pigs were given access to creep feed.

Pigs were tracked from birth until harvest. Differences in number of animals from birth to harvest are accounted for by several factors. First, mortality during the pre-weaning and nursery phases was elevated (n = 1,300) at this commercial facility during the time of the trial. Also, not all pigs with WWT were kept in the trial, as some of the youngest pigs in weaned group were held back at the sow farm to be weaned the following week. Finally it was not possible to collect HCW on all pigs at the plant. Management was typical of commercial U.S. swine production protocol throughout all phases of production. Pigs (n = 4,108) were individually weighed 2 d prior to weaning (WWT) (18.7 ± 2.1 d of age). Pigs used in this trial were weaned once weekly in 4 groups (groups 1, 2, 3, 4) and remained in those groups through nursery and finishing. After weaning, animals were transferred to a commercial nursery facility for a 7 wk nursery phase. Following the nursery phase, animals were transferred to a commercial finishing facility. Within 5 d of finisher placement (FINP) (74.8 ± 1.9 d of age) pigs from all groups were individually weighed (n = 3,439). Pigs were sent to a commercial harvest facility where HCW was collected (n = 1,693) (199.2 ± 12.1 d of age).

Body Weight and Growth

Linear ($P < 0.01$) and quadratic ($P < 0.01$) effects of BWT on WWT and PWADG were observed (Table 3). However, there were linear BWT x cross foster status interactions ($P < 0.01$) for both WWT and PWADG. Regardless of cross foster status, as BWT increased WWT and PWADG increased at a decreasing rate. Therefore, the difference in WWT and PWADG was greater at lower BWT than higher BWT. Based on the interactions, as BWT increased the difference in WWT and PWADG between non-cross fostered pigs and cross fostered pigs became greater. Both linear and quadratic effects of BWT on FINP ($P < 0.01$; $P < 0.01$), FIN7 ($P < 0.01$; $P < 0.01$), FIN16 ($P < 0.01$; $P < 0.01$), and HCW ($P < 0.01$; $P = 0.04$) were observed. Also, linear ($P < 0.01$) and quadratic ($P < 0.01$) effects of BWT on PWADG, NADG, FADG, and TADG were observed (Table 3). In all instances as BWT, increased BW and ADG increased at a decreasing rate.

The difference in WWT between cross fostered vs. non-cross fostered pigs increased as BWT increased. This is likely due to increased variation with increased BWT; the difference in low BWT pigs is small; however, the difference in heavier BWT is greater due to the increased BW of the pigs. Increased BW at weaning due to differences in BWT has been reported in several studies. Light BWT pigs were smaller at weaning compared to heavy BWT pigs. The cross foster status x BWT interaction can likely be explained by, cross fostered pigs gaining less than non-cross fostered pigs during the preweaning phase. Stewart and Diekman (1989) evaluated BW of cross fostered vs. non-cross fostered pigs at 21 d of age in litters of either 6 or 12 pigs and reported regardless of litter size, cross fostered pigs were smaller.

Increased BW at future ages or stages of production due to increased BWT appear to be consistent across studies, regardless of the method of analysis. However, it is important to look at the differences in future BW across the BWT distribution and realize an increase in BWT from

0.8 to 1.0 kg does not have the same effect as an increase from 2.0 to 2.2 kg (Figs. 1, 2, 3). From these results, it is apparent BWT affects future BW. The major cause of this appears to be a difference in ADG. Based on the results from the current study, BWT affects ADG during all phases on production; the difference is greatest for the lightest BWT pigs. The findings of differences in ADG are in agreement with Rehfeldt et al. (2008) for birth to harvest and Powell and Aberle (1980) for 26 to 96 kg BW. Not only do heavier pigs begin life with an advantage in weight but pigs at the lower end of the BWT distribution fall further behind in BW over time which appears to be due to reduced ADG.

Several studies have reported at least a minor relationship between BWT and the anterior teat selection (McBride, 1963; Fraser, 1975; Hartsock et al., 1977). Anterior teats have been shown to produce a greater amount of colostrum (Fraser and Lin, 1984) and pigs have reportedly gained more BW when nursing anterior teats (Kim et al., 2000). All of which may explain the increase in preweaning ADG. The increase in preweaning ADG leads to heavier BW at weaning which has been shown to affect postweaning gain. Klindt (2003) reported pigs with greater preweaning ADG also have greater postweaning ADG.

It was concluded that increased BWT is associated with increased BW later in life. However, the relationship between birth weight and growth is not linear. There appears to be a threshold for BWT where once surpassed, further increase in BWT does no result in increased BW or ADG.

Composition

There was no effect ($P > 0.05$) of BWT on BF. However, BWT had linear ($P < 0.01$) and quadratic ($P = 0.04$) effects on LMA. As BWT increased LMA increased at a decreasing rate.

Estimates for WWT, FINP, FIN7, FIN 16, HCW, PWADG, NUR, FADG, TADG, LMA, and BF at five 5 BWT (0.9 kg, 1.2 kg, 1.5 kg, 1.8 kg, 2.1 kg) representative of the BWT distribution (approximate mean, ± 1 SD, ± 2 SD) are displayed in Table 3.

Our study found no effect of BWT on BF and is in agreement with Powell and Aberle (1980), Gondret et al. (2005), and Rehfeldt et al. (2008) who all reported no differences in BF on carcasses at harvest due to differences in BWT categories. Regardless of the type of analysis, it appears differences in BWT do not affect BF deposition on live animals measured by ultrasound prior to harvest or on carcasses at harvest.

Based on these results it can be concluded BWT affects pig BW at later stages in life. It has been reported in numerous studies that BW affects LMA. Because of these relationships the authors felt it most appropriate to adjust LMA to a common age rather than BW by including age as a covariate. By doing this, the total effect of BWT on LMA can be evaluated independent of age. It appears the effect of BWT on LMA is similar to the effect of BWT on BW and ADG. The difference in LMA due to BWT is greatest in lighter BWT pigs and becomes less as BWT increases resulting in heavier BWT pigs having increased muscle mass.

Birth weight of pigs in a commercial U.S. swine facility greatly impacts economically important traits. Pigs with low birth weights begin life smaller, gain less during all phases of production, and as result are lighter at fixed time points. Lighter birth weight pigs also have less longissimus muscle area. The impact on growth and muscling is greatest for pigs at the lighter end of the birth weight distribution; the impact on the heavier end of the distribution in regards to growth, diminishes as pigs become older.

Table 3. Effect of birth weight on BW, ADG, longissimus muscle area, and backfat.

	Birth weight[c]				Estimates[d]				
Trait	Linear	*P*-value	Quadratic	*P*-value	0.9 kg	1.2 kg	1.5 kg	1.8 kg	2.1 kg
Body Weight									
WWT[a,b], kg									
Non-cross fostered	3.52	< 0.01	-0.44	< 0.01	3.98	4.76	5.47	6.09	6.64
Cross fostered	3.00	< 0.01	-0.44	< 0.01	3.78	4.41	4.95	5.42	5.82
FINP[a], kg	15.99	< 0.01	-3.19	< 0.01	17.73	20.52	22.74	24.38	25.45
FIN7[a], kg	34.03	< 0.01	-7.51	< 0.01	49.23	54.58	58.58	61.24	62.54
FIN16[a], kg	45.65	< 0.01	-10.45	< 0.01	91.28	98.39	103.62	106.96	108.43
HCW[a], kg	19.45	< 0.01	-3.72	0.04	88.07	91.56	94.38	96.54	98.02
Growth									
PWADG[a,b], g/d									
Non-cross fostered	120.1	< 0.01	-20.7	< 0.01	146.7	169.6	188.9	204.3	216.1
Cross fostered	95.4	< 0.01	-20.7	< 0.01	137.1	152.7	164.5	172.6	176.9
NADG[a], g/d	231.9	< 0.01	-50.4	< 0.01	265.5	303.3	332.0	351.6	362.2
FADG[a], g/d	323.4	< 0.01	-80.9	< 0.01	742.3	788.4	819.9	836.8	839.2
TADG[a], g/d	257.9	< 0.01	-60.4	< 0.01	522.5	561.9	590.3	607.9	614.7
Real-time ultrasound									
LMA[a], cm^2	19.10	< 0.01	-4.69	< 0.01	34.23	36.69	38.30	39.06	38.98
BF[a], cm	0.35	0.21	-0.09	0.32	1.58	1.62	1.66	1.67	1.67

[a]WWT: adjusted 21 d BW (weaning); FINP: adjusted 75 d BW (finisher placement); FIN7: adjusted 121 d BW (7 wks into finishing); FIN16: adjusted 173 d BW (16 wks into finishing); HCW: carcass weight adjusted to 195 d; PWADG: ADG from BWT to WWT; NADG: ADG from WWT to FINP; FADG: ADG from FINP to FIN16; TADG: ADG from BWT to FIN16; LMA: real-time ultrasound longissimus muscle area adjusted to 173 d of age; BF: real-time ultrasound backfat depth adjusted to 173 d.
[b]Cross foster status x birth weight interaction ($P < 0.01$).
[c]Estmates of linear and quadratic effects on traits due to a 1 unit change in birth weight.
[d]Estimated values for traits at 5 birth weights.

Fig. 1. Distribution of all piglet birth weights.

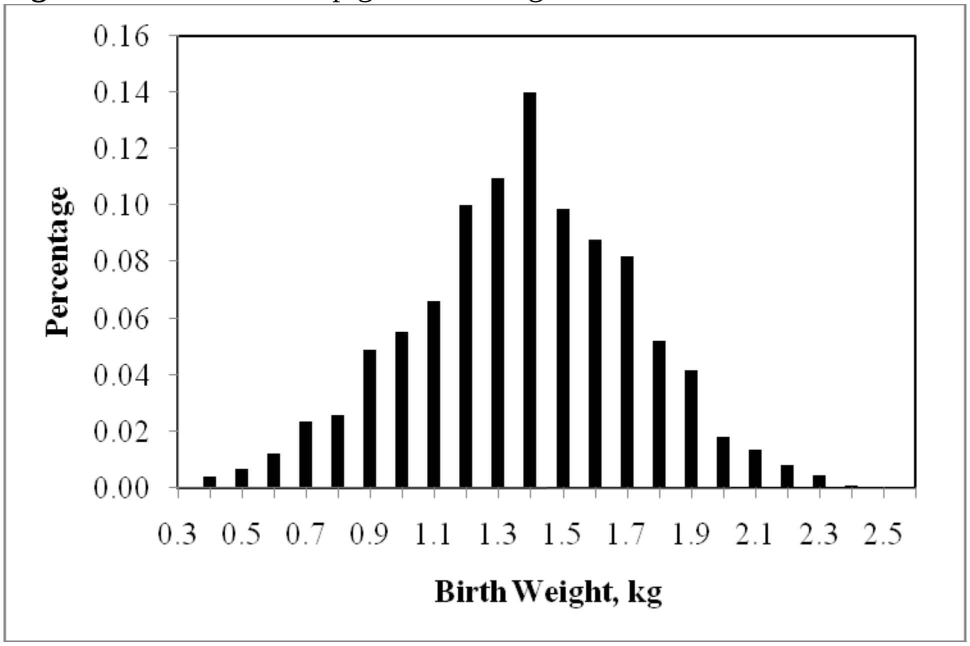


Fig. 2. Effect of birth weight on preweaning average daily gain (PWADG) and BW at weaning (WWT); separated into non-cross fostered pigs and cross fostered pigs.

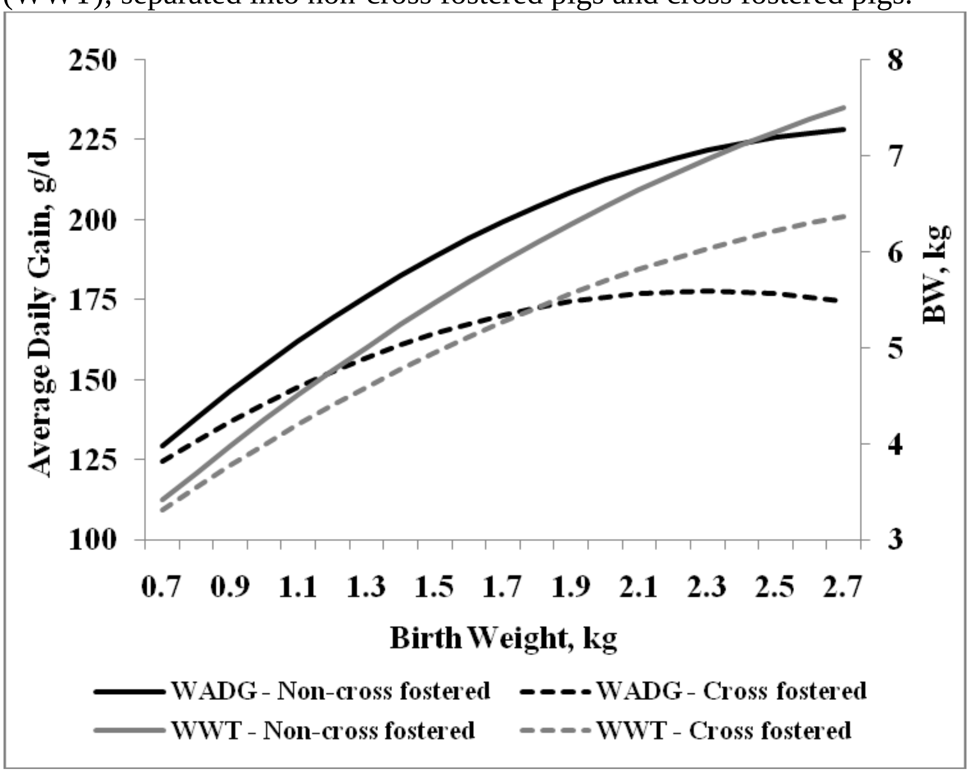


Fig. 3. Effect of birth weight on average daily gain during the nursery phase (NADG) and BW at finisher placement (FINP).

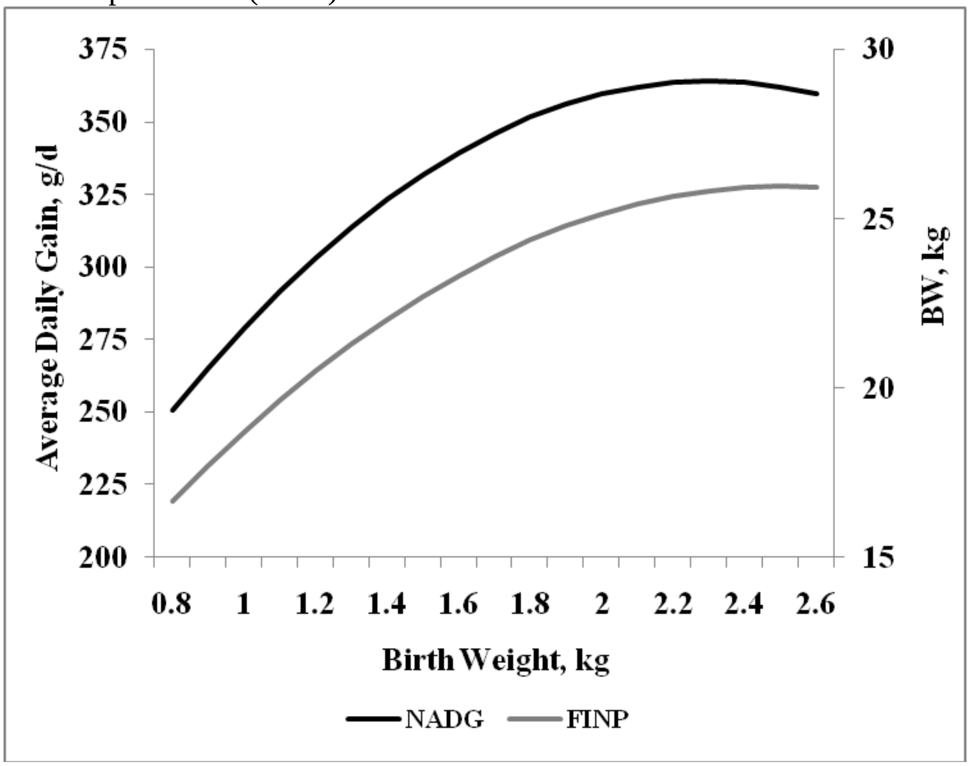
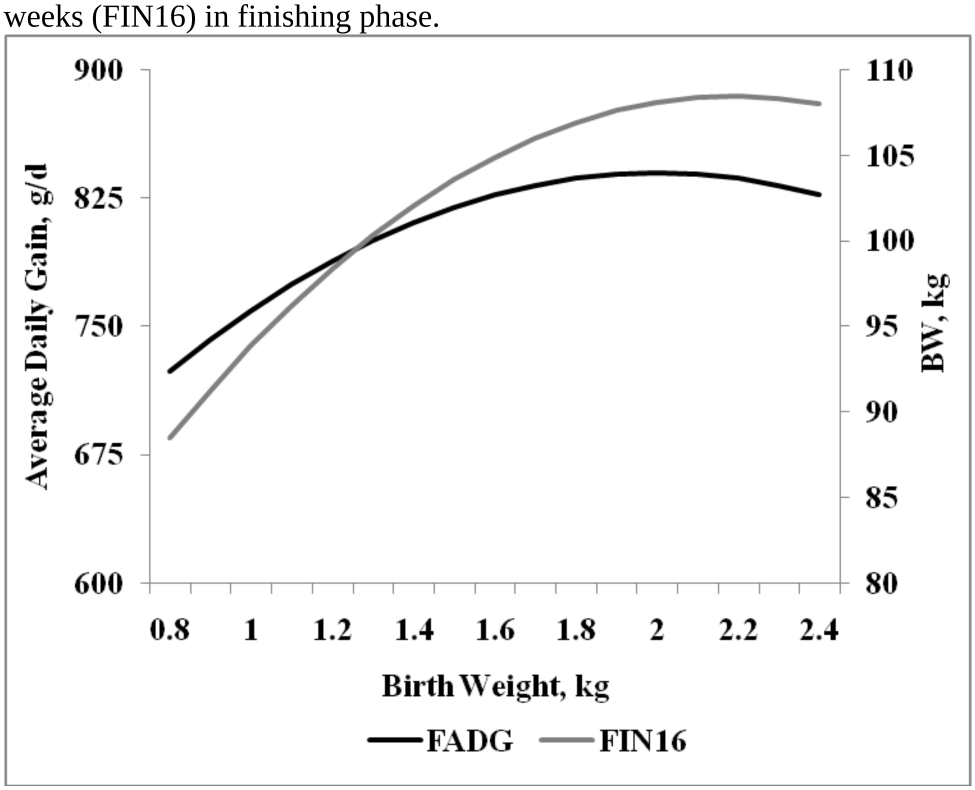


Fig. 4. Effect of birth weight on average daily gain during finishing phase (FADG) and BW 16 weeks (FIN16) in finishing phase.



3. Effect of piglet birth weight on efficiency of commercial market swine.

All pigs born alive (n = 1,052) used for this study were farrowed during May 4, 2009 to May 8, 2009 from Large White x Landrace (n = 82) sows bred to Duroc sires. Within 24 hours of birth all pigs were individually weighed and indentified and cross-fostered to balance the number of pigs nursed per litter. At approximately 5 days of age all pigs were processed and male pigs were castrated. By 12 days of age all litters were provided access to creep feed.

Immediately prior to weaning (20.5 ± 1.1 days of age), individual weaning weights were collected on 440 pigs (220 barrows and 220 gilts). To achieve a balanced number across sex and a complete representation of birth weight; pigs were randomly selected within sex across the entire birth weight distribution of the remaining live pigs at weaning. After weaning pigs were transferred to the North Carolina Swine Evaluation Station (Clayton, NC). All pens at the research facility were 1.52 x 3.66 m with solid concrete flooring.

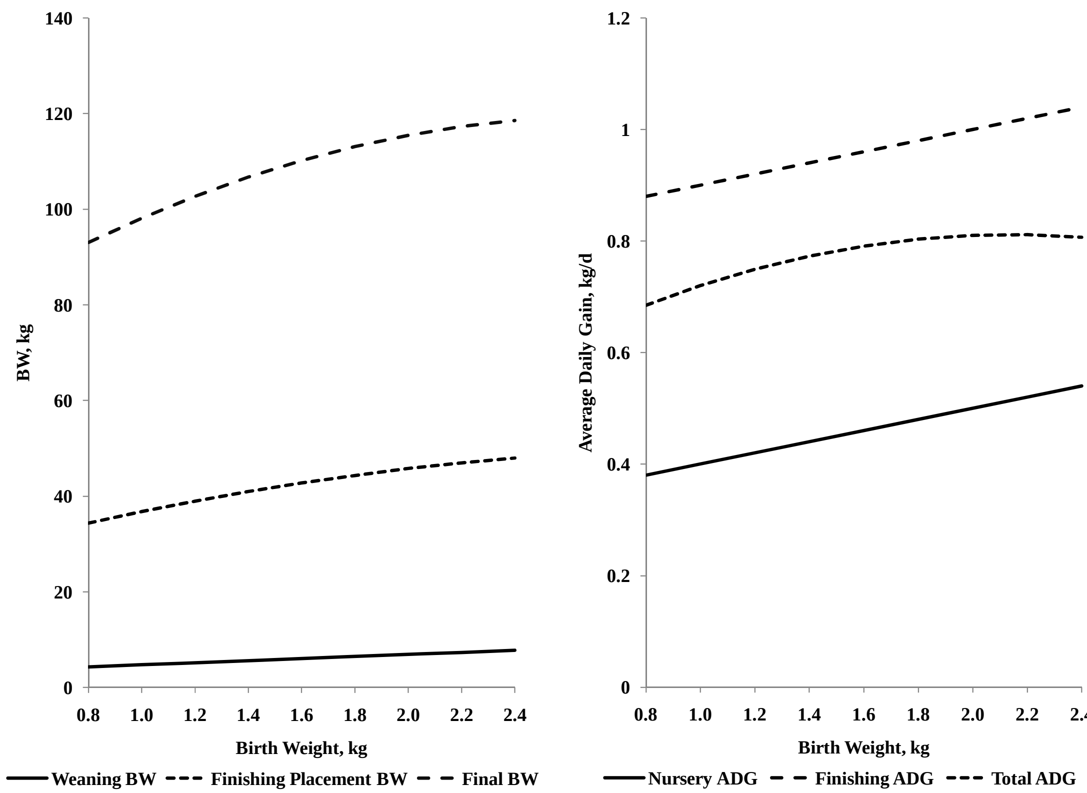
Pigs were assigned to pens of 10 (0.56 m2/pig) within sex from the lightest to heaviest birth weight. Individual BW collections and feed weigh backs were conducted at 3 weeks and 6 weeks into nursery phase. Finishing phase began after week 6 BW collection; immediately following week 6 BW collection all pens were divided into 2 pens of 5 pigs (1.12 m2/pig) from lightest to heaviest birth weights. During the finishing phase individual BW and feed weigh backs were collected every 3 weeks except for the final (off-test) BW collection which was conducted 26 d after previous BW collection. Individual BW were collected all pigs that died or were removed from test during the trial.

During the final 3 BW collections (104.5 ± 1.1, 125.5 ± 1.1, 150.5 ± 1.1 days of age) all pigs were individually measured for 10th rib backfat depth and longissimus muscle area using real-time ultrasound (Aloka 500; Corometrics Medical Systems, Wallingford, CT). Estimated percent lean was calculated using the NPPC (2000) equation. Lean gain and lean gain to feed were calculated from 104.5 to 150.5 days of age.

Results

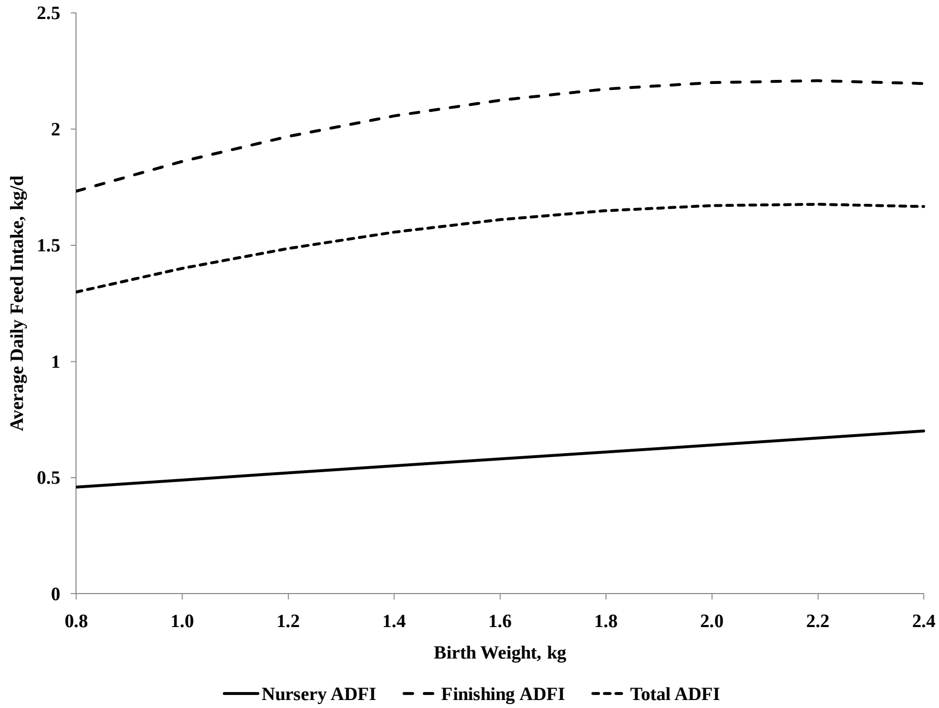
As birth weight increased, pig weights at weaning and beginning of finishing increased in a linear fashion; however, final weight increased at a decreasing weight. As would be expected similar associations were identified between birth weight and average daily gain during the nursery and finishing phases along with the overall test period (Figure 5).

Figure 5. Effect of birth weight on body weights and average daily gain.



Increased birth weight was associated with increased average daily feed intake during the nursery phase. Also, linear and quadratic effects of birth weight on finishing and overall average daily feed intake was estimated; as birth weight increased feed intake increased at a decreasing rate (Figure 6).

Figure 6. Effect of birth weight on average daily feed intake.



Significant Linear effects of birth weight (P < 0.05) on gain to feed during the nursery and finishing periods were estimated. In both instances increased birth weight was associated with reduced gain to feed. Over the entire test period, significant linear (P < 0.01) and quadratic (P < 0.01) effects of birth weight on gain to feed were estimated. As birth weight increased, gain to feed decreased at a decreasing rate (Figure 7). Recall from previous discussion on the impact of birth weight on BW later in life; heavier birth weight pigs were heavier throughout the trial. Increased BW requires more energy for maintenance (NRC, 1998); consequently, heavier birth weight pigs required more energy or feed to maintain their heavier BW. This likely led to the reduced gain to feed of heavier birth weight pigs. This nonlinear association between birth weight and gain to feed mirrored that of birth weight and total average daily gain; incremental changes for the lightest birth weight pigs were associated with a greater differences compared to their heavier contemporaries.

In this study the conclusion of the testing period was based on age not weight of pigs; however, if gain to feed was adjusted for the BW at the conclusion of the test period, there was no longer a significant ($P > 0.05$) association between birth weight and gain to feed. This would seem to agree with the discussion concerning the relationship between birth weight and average daily feed intake; the heavier birth weight pigs consumed more feed due to their additional energy requirements.

Birth weight was associated with lean average daily gain (linear) and lean gain to feed (linear and quadratic). Heavier birth weight pigs had greater lean average daily gain. As birth weight increased, lean gain to feed decreased at decreasing rate. When estimated composition is taken into account, it appears the impact of birth weight on average daily gain and average daily feed intake plays a larger role; as the associations are quite similar for birth weight with average daily gain and gain to feed. As with gain to feed, if lean gain to feed is adjusted for the BW at the end of the test period, birth weight is was no longer associated with lean gain to feed.

Birth weight has dramatic impacts on the growth of pigs from weaning till harvest, over the entire nursery to finishing time period this relationship is not linear. There appears to be a threshold where an increase in birth weight does not result any improvement in gain. Birth weight also impacts the composition, feed intake, efficiency of commercial market hogs; however, much of this appears to be due to the association between birth weight and gain. Heavier birth weight pigs are heavier at a given age which translates to increased muscling, fat, feed intake, and reduced gain to feed. If the difference in BW is accounted for in a covariate analysis many of these effects are no longer significant. If light birth weight pigs are allowed to reach a final BW similar to heavier birth weight pigs, it appears that advantage in efficiency is lost and based on other studies, and may in fact become a disadvantage through the extra days required to reach market. However, in this study we assume that pigs are given a defined period of time to reach market weights rather than sold at a constant pre-determined market weight.

Figure 7. Impact of birth weight on gain to feed and lean gain to feed.