Effect of piglet birth weight on weights at weaning and 42 days post weaning

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Summary

Objective: To model the effects of birth weight on preweaning survival and weights at weaning and at 42 days post weaning.

Materials and methods: Individual birth-weight and weaning-weight records of 2467 pigs weaned at 14 to 21 days old were partitioned into nine categories incrementally increasing or decreasing by 0.5 SD (0.16 and 0.68 kg, respectively) from the mean (1.57 and 5.80 kg, respectively). To study the effect of birth weight on weight at subsequent phases, fixed effects of birth-weight category and parity of dam were included in the model for weights at weaning and 42 days post weaning. To evaluate the effect of weaning weight on weight at 42 days post weaning, fixed effects of weaning-weight category and parity of dam were included.

Results: From birth to weaning, maximum piglet survival (93.8% to 97.1%) was attained in birth-weight categories 2, 3, and 4, and poorest survivability (71.2% to 79.6%) was observed in birth-weight categories 1, 5, and 7. Weight at 42 days post weaning increased with heavier birth-weight category ($P < .001$) and with heavier weaning-weight category ($P < .001$). Parity of dam was a source of variation ($P < .01$) for weights at weaning and 42 days post weaning.

Implications: Differences in body weight at birth are perpetuated, so that pigs lighter at birth are still lighter at 42 days post weaning. Pigs of primiparous sows have a growth disadvantage. Producers should consider alternatives for managing underweight pigs on an individual herd basis.

Keywords: swine, birth weight, preweaning mortality, weaning weight, nursery performance

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Resumen - Efectos del peso al nacimiento y al destete en el peso a 42 días post destete

Objetivo: Modelar los efectos del peso al nacimiento sobre la supervivencia antes del destete y en el peso al destete y a los 42 días post destete.

Materiales y métodos: Los registros del peso individual al nacimiento y al destete de 2467 cerdos destetados a los 14 y 21 días de edad se dividieron en nueve categorías aumentando el incremento o decremento por 0.5 SD (0.16 y 0.68 kg, respectivamente) de la media (1.57 y 5.80 kg, respectivamente). Para estudiar el efecto del peso al nacimiento en el peso en fases subsecuentes, se incluyeron efectos fijos de las categorías de peso al nacimiento y la paridad de la hembra en el modelo para peso al destete y a los 42 días post destete. Para evaluar el efecto del peso al destete en el peso a los 42 días post destete, se incluyeron efectos fijos de las categorías de peso al destete y paridad de la hembra.

Resultados: Entre el nacimiento y el destete, la supervivencia máxima de lechón (93.8% a 97.1%) se obtuvo en las categorías de peso al nacimiento 2, 3, y 4, y la peor supervivencia (71.2% a 79.6%) se observó en las categorías de peso al nacimiento 1, 5, y 7. El peso a los 42 días post destete aumentó con las categorías de mayor peso al nacimiento ($P < .001$) y con las categorías de mayor peso al destete ($P < .001$). La paridad de la hembra fue una fuente de variación ($P < .01$) para peso al destete y a los 42 días post destete.

Implicaciones: Las diferencias en el peso corporal al nacimiento se perpetúan, de manera que los cerdos más ligeros al nacimiento siguen siendo los más ligeros a los 42 días post destete. Los lechones de hembras primíparas tienen una desventaja de crecimiento. Los productores deberían buscar alternativas específicas para manejar a los cerdos de bajo peso en su granja.

Résumé - Effet du poids à la naissance et au sevrage sur le poids 42 jours après le sevrage

Objectif: Modéliser les effets du poids à la naissance sur la survie pré-sevrage et le poids au sevrage et à 42 jours post-sevrage

Matériels et méthodes: Les poids à la naissance et au sevrage ont été relevés individuellement pour 2467 porcs sevrés entre 14 et 21 jours d'âge et ont été séparés en neuf catégories augmentant ou diminuant en incrément de 0.5 SD (respectivement 0.16 et 0.68 kg) à partir de la moyenne (respectivement 1.57 et 5.80 kg). Afin d'étudier l'effet du poids à la naissance sur le poids à des phases subséquentes, les effets fixés de la catégorie du poids à la naissance et la parité de la mère ont été inclus dans le modèle pour les poids au sevrage et à 42 jours post-sevrage. Pour évaluer l'effet du poids au sevrage sur le poids 42 jours

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post-sevrage, les effets fixés de la catégorie de poids au sevrage et la parité de la mère ont été inclus.

Résultats: De la naissance au sevrage, la survie maximale des porcelets (93.8% à 97.1%) a été obtenue dans les catégories 2, 3, et 4 des poids à la naissance, et la moins bonne survie (71.2% à 79.6%) a été observée dans les catégories 1, 5, et 7 des poids à la naissance. Le poids à 42 jours post-sevrage augmentait avec la catégorie de poids à la naissance plus lourd ($P < .001$) et avec une catégorie de poids au sevrage plus lourd ($P < .001$). La parité de la mère était une source de variation ($P < .01$) pour les poids au sevrage et à 42 jours post-sevrage.

Implications: Des différences dans le poids à la naissance sont perpétuées de sorte que les porcs plus légers à la naissance sont encore plus légers 42 jours post-sevrage. Les porcs issus de truies primipares sont désavantagés dans leur croissance. Les producteurs devraient envisager des alternatives pour gérer les porcs de poids insuffisant sur une base individuelle de troupeau.

Within the swine industry, selecting for number of liveborn pigs rather than total born is increasing the number of pigs weaned per female. Selection for litter size is negatively correlated with birth weight.[1] However, with increased number born alive, average piglet birth weight and birth weight variation have contributed to higher piglet mortality.[2] Additionally, low-birth-weight piglets often experience lower weight gains and survivability in subsequent phases of production.[3] Use of three-phase production and all-in, all-out production systems has made growth rate extremely important from the nursery through the finisher.

At weaning, pigs weighing less than 3.6 kg require a higher level of management (eg, individual pig care, penning lightweight piglets separately from the larger group of newly weaned pigs) and more complex diets, which increases production costs for pork producers.[4] Studies indicate that piglets weighing < 1 kg at birth have very little chance of still being alive at weaning[4] or of producing a standard pig. A standard pig is defined as a pig falling within a target market-weight range and not substantially discounted from an established base price or value.[5] Slow-growing and or substandard pigs interrupt pig flow, as finishing buildings must be emptied and cleaned in time to receive the next group of pigs.[6] Ultimately, light-birth-weight pigs have lower body weights in subsequent phases, are unable to meet ideal market weight demands of the processor, and incur associated monetary penalties. Alternatively, they may be fed longer, incurring additional feed and facility charges, in order to attain a more desirable market weight.[2,7] Both situations reduce profit potential for pork production operations.

Management plays a significant role in survival rates as well, and it is important to determine a threshold for birth weights above which saving piglets is economically feasible. Thus, the objectives of this study were to model the effects of birth weight on survival to weaning, and to assess the effect of piglet birth weight on weaning weight and weight 42 days post weaning.

Materials and methods

Animals

The experiment was conducted using Danbred N.A. (Columbus, Nebraska) maternal-line barrows and gilts from a maternal-line multiplication herd (H and K Enterprises, Nevada, Iowa), including 2467 pigs that survived until weaning. All crossbred pigs in this study were offspring of Landrace dams in their first to eleventh parities and Yorkshire sires. For the purposes of this study, sows of parities ≥ 6 were combined into one parity class. As performance among parties 6, 7, 8, 9, 10, and 11 was similar, combining parities provided a more equal distribution of number of sows in parity categories, and many commercial operations automatically cull at parity 6.[8]

Procedures

At birth, each litter was assigned to one of two weaning-age groups. The first group averaged 15 days of age at weaning and included pigs that were weaned at 14, 15, and 16 days of age. The second group averaged 20 days of age at weaning and included pigs that were weaned at 19, 20, and 21 days of age. Within 24 hours of birth, each piglet was individually identified and weighed, and sex was determined. Neonatal pigs were cross-fostered before 3 days of age to equalize the number of pigs across all litters (mean 10.25 pigs per sow, SD 0.25). By 7 days of age, all males were castrated.

Pigs were housed in a mechanically ventilated, heated, thermostatically controlled, totally confined nursery with plastic slatted flooring. On weaning day, piglets within each weaning-age treatment were weighed and randomly assigned to nursery pens, with approximately 50% barrows and 50% gilts in each pen. Pigs were weighed at birth, weaning, and 42 days post weaning, or at removal from the study, on an electronic scale accurate to 0.05 kg. A total of 89 pens (seven to eight pens per replicate and 12 replicates) were utilized in the study, with each pen housing 26 to 28 pigs (N = 2467). The pens were 2.44 × 3.05 m, providing 0.27 to 0.29 m^2 of floor space per pig. Each pen was equipped with a single-sided stainless steel self-feeder (76.2 cm linear trough space per pen; Chore-Time, Milford, Indiana) and two nipple drinkers, which provided pigs ad libitum access to feed and water.

Pigs were fed a four-phase diet regime from weaning to 42 days post weaning, with feed disappearance recorded on a pen basis. A feed budget was developed which provided each pig with 1.25 kg of a 1.70%-lysine pellet, 6.14 kg of a 1.50%-lysine-meal diet, and 12.57 kg of a 1.30%-lysine-meal diet. For the remainder of the nursery phase, a 1.20%-lysine-meal diet was fed. Pigs weaned at 15 and 20 days consumed 3.0 and 6.5 kg of this diet, respectively. Pigs were removed from test pens due to mortality or if a condition existed in which the pig did not respond to medical treatment (nonambulatory). The date of removal from test, body weight at removal, and removal reason were recorded. The experimental protocol followed the commercial production practices of the operation and met or exceeded requirements in *Guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching*.[9]

Statistical procedures

Birth-weight category. Data were analyzed by analysis of variance (ANOVA) using PROC MIXED of SAS (Cary, North Carolina). Analysis included pigs that were born alive and for which a birth weight had been recorded, even if these pigs did not survive until weaning (preweaning mortalities). Individual birth-weight records were partitioned into nine birth-weight categories which incrementally increased (four categories) or decreased (five categories) by 0.5 SD from the birth-weight mean (Table 1). Survival rates from birth to weaning were computed from the birth-weight categories of interest. A chi-square test for proportions (SAS) was utilized to evaluate survival differences among birth-weight categories using mean separation.

In the analysis of weights at weaning and at 42 days post weaning, fixed effects of birth-weight category, parity of dam, and a linear weaning-age covariate were included in the model. Only pigs that were weaned were included in this birth-weight-category analysis. The effect of litter and the two-way interactions between fixed effects were excluded from the final model because they were not significant sources of variation.

Weaning-weight category. Individual weaning-weight records were partitioned into nine weaning-weight categories which incrementally increased or decreased by 0.5 SD from the weaning-weight mean (Table 2). Fixed effects of weaning-weight category, parity of dam, and the linear regression of the pig's age at 42 days post weaning and at weaning age were included in the model used to analyze weight at 42 days post weaning. The effect of litter and the two-way interactions between fixed effects were excluded from the final model because they were not a significant source of variation. Pig was the experimental unit for all traits measured on the individual animal. Least squares means (± SE) and differences among fixed effect levels were obtained using the PDIFF option of SAS.

Results

Birth-weight category

Survival to weaning. Survival patterns across birth-weight categories are shown in Table 1. Maximum piglet survival from birth to weaning (93.8% to 97.1%) was attained in birth-weight categories 2, 3, and 4. Poorest survivability (71.2%, 79.6%, and 78.4%) was observed in birth-weight categories 1, 5, and 7, respectively.

Weaning weight. Birth-weight category was a significant source of variation in the analysis of weaning weight. Without exception, weaning weight increased with heavier birth-weight category (Table 2). A linear weaning-age covariate ($P < .01$) states that for every 1-day increase in weaning age there is a 0.36-kg increase in weaning weight. Parity of dam was a source of variation for weaning weight across birth-weight categories (Table 3).

Weight at 42 days post weaning. Birth-weight category was a source of variation ($P < .01$) in the analysis of weight at 42 days post weaning. Without exception, weight at 42 days post weaning increased with heavier birth-weight category (Table 4). The linear regression of weaning age ($P < .01$) on weight at 42 days post weaning states that for every 1-day increase in weaning age, there is a 0.7-kg increase in weight at 42 days post weaning. Parity of dam was a source of variation in weight at 42 days post weaning (Table 3). Weights at 42 days post weaning varied across parities, and no consistent pattern by parity was observed.

Weaning-weight category

Weaning-weight category was a source of variation ($P < .01$) in the analysis of weight at 42 days post weaning. Weights at 42 days post weaning increased ($P < .05$) with heavier weaning-weight category (Table 5). The linear regression of weaning age ($P < .01$) on weight at 42 days post weaning indicates that for every 1-day increase in weaning age there is a 0.12-kg increase in weight at 42 days post weaning. The linear regression of age at 42 days post weaning on weight at 42 days post weaning was not significant ($P = .15$).

Parity of dam was a source of variation ($P < .01$) in weight at 42 days post weaning (Table 6). Mean weights at 42 days post weaning varied across parities, and no consistent pattern by parity was observed. Light pigs at birth and weaning had lower body weight at 42 days post weaning.

Discussion

Low-birth-weight pigs continued to be lightweight in subsequent phases of production in this study. The producer was concerned that the lightweight pigs posed a health risk for their contemporaries throughout the production system. Results may be different for other operations, and producers should develop their own threshold levels for determining which pigs should be euthanized or considered substandard depending on the availability of alternative markets to sell lightweight pigs. Alternatively, different facilities could be used to rear lightweight pigs. For example, a hoop building is a lower-cost facility that could be used to raise lightweight pigs in an attempt to increase an operation's income.

Table 1: Effect of birth-weight category on survivability to 42 days post weaning in a maternal line of barrows and gilts

Birth-weight category*	No. of piglets (N = 2893)†	Birth weight (kg)				Survival (%)
		Minimum	Maximum	Mean	SD	
1	59	0.57	0.87	0.77	0.08	71.2[a]
2	139	0.88	1.04	0.98	0.05	97.1[b]
3	259	1.05	1.21	1.14	0.05	93.8[b]
4	405	1.22	1.38	1.30	0.05	95.6[b]
5	617	1.39	1.55	1.47	0.05	79.6[ac]
6	566	1.56	1.72	1.64	0.05	82.5[cd]
7	407	1.73	1.89	1.80	0.05	78.4[ac]
8	273	1.90	2.06	1.96	0.05	87.2[d]
9	168	2.07	2.85	2.24	0.16	86.3[d]

* Each piglet was individually identified and weighed within 24 hours of birth. Birth-weight categories incrementally increased or decreased by 0.5 SD (0.16 kg) from the birth weight mean (1.57 kg). Pigs were weaned at an average of 15 days of age (pigs weaned at 14, 15, or 16 days) or at an average of 20 days of age (pigs weaned at 19, 20, or 21 days).

† Includes all pigs born alive.

[abcd] Means with no common superscript differ ($P < .05$; ANOVA).

Quiniou et al[2] reported that pigs weighing < 1 kg at birth had very little chance of being alive at weaning. Similarly, Gondret et al[3] found that 86% of piglets weighing < 0.80 kg did not survive to weaning. Gardner et al[10] divided birth weights into nine groups ranging from < 601 g to > 2000 g. They reported that increases in birth-weight category were associated with increasing odds of 7-day and 21-day survival, with maximum survival in the highest birth-weight group.

It is possible that outcomes might differ in different operations or genetic lines. Each commercial swine producer should determine whether it is better from an economic standpoint to euthanize lightweight piglets at birth or handle them throughout the subsequent phases of production. Because of higher mortality, higher morbidity, and greater numbers of substandard pigs among pigs categorized as lightweight at birth, it may not be worthwhile to retain lightweight piglets. Variable costs may also be greater than the sales income from lightweight pigs.

In this study, weaning-weight increased with each heavier birth-weight category. These results agree with previous work by Damgaard et al[4] and Quiniou et al,[2] who reported that piglets that are lighter at weaning are lighter throughout the grow-finish phase of production. Both studies utilized maternal-line barrows and gilts, as in this study.

Previous work has demonstrated parity effects for numerous sow reproductive traits. For example, Baas et al[11] reported that the effects of parity on weaning weight increase initially and then decrease in subsequent parities. Similarly, the National Swine Improvement Federation[12] defines parity 4 as the parity in which sows' peak weaning-weight production occurs. However, in the current trial, weaning weights increased until parity 5, and decreased in parity ≥ 6.

Table 2: Effect of birth-weight category and parity on mean weaning weight in a maternal line of barrows and gilts*

Birth-weight category	No. of piglets (N = 2467)†	Average parity of dam	Birth weight (kg)			Weaning weight (kg)‡	SEM
			Minimum	Maximum	Mean		
1	42	2.4	0.66	0.94	0.86	4.15	0.13
2	135	2.6	0.95	1.10	1.03	4.65	0.07
3	243	2.9	1.11	1.26	1.19	5.03	0.05
4	387	2.7	1.27	1.42	1.35	5.38	0.04
5	491	2.8	1.43	1.58	1.51	5.76	0.04
6	467	3.2	1.59	1.74	1.67	6.08	0.04
7	319	3.4	1.75	1.90	1.82	6.39	0.05
8	238	3.7	1.91	2.06	1.97	6.64	0.05
9	145	4.0	2.07	2.85	2.24	7.15	0.07

* Pigs were weaned either at an average of 15 days of age (pigs weaned at 14, 15, or 16 days) or at an average of 20 days of age (pigs weaned at 19, 20, or 21 days). Individual piglet birth weights were partitioned into nine categories which incrementally increased or decreased by 0.5 SD (0.16 kg) from the birth-weight mean (1.57 kg).

† Includes only pigs that survived until weaning.

‡ All weights differ from each other ($P < .001$; ANOVA)

Table 3: Least squares means (± SE) for weights at weaning and 42 days post weaning by parity of dam across birth-weight categories for pigs from a maternal line of sows*

Parity	No. of sows	No. of pigs (N = 2467)†	Weight (kg)	
			Weaning‡	42 days post weaning‡
1	90	726	5.37 ± 0.03[a]	18.91 ± 0.13[a]
2	57	463	5.76 ± 0.04[bc]	20.16 ± 0.15[b]
3	38	317	5.82 ± 0.05[b]	19.79 ± 0.18[b]
4	42	286	5.83 ± 0.05[b]	19.89 ± 0.18[bc]
5	33	201	5.63 ± 0.06[c]	20.41 ± 0.22[bc]
≥ 6	79	474	5.74 ± 0.04[bc]	19.98 ± 0.15[b]

* Pigs were weaned at an average of either 15 or 20 days of age (Table 2). Individual piglet birth weights were partitioned into nine categories (Table 2).

† Includes only pigs that survived until weaning. Pigs were cross-fostered within 3 days of birth to even litter sizes (mean 10.25 ± 0.25 pigs per litter).

‡ Within a column, means with no common superscript differ ($P < .05$; ANOVA).

Parity of dam was a source of variation in age at 42 days post weaning across birth-weight categories. However, it is difficult to explain biologically the results observed, considering the relatively small range of weights at 42 days post weaning (18.9 kg to 20.4 kg) across the six parity classes.

Similar results were observed with weaning-weight categories. It is also difficult to explain biologically the relatively small range of weights at 42 days post weaning (approximately 20 kg to 21 kg) across the six parity classes. The present results differ from those of previous workers.[11,12] Differences are likely due to the relatively small number of sows in each parity subclass compared to the number of records used to develop the National Swine Improvement Federation[12] parity adjustments.

Previous studies support the finding in this study that weights 42 days post weaning increased with heavier birth-weight category. Campbell and Dunkin[13] studied piglets from Large White litters and divided the piglets into heavy and light birth-weight classes. They reported that relative differences in body weight are perpetuated after weaning and result in

Table 4: Effect of birth-weight category and parity on mean weight 42 days post weaning for pigs in a maternal line of barrows and gilts

Birth-weight category *	No. of piglets/category (N = 2391)†	Average parity of dam	Birth weight (kg) Minimum	Birth weight (kg) Maximum	Birth weight (kg) Mean	Weight 42 days post weaning (kg)‡	SEM
1	39	2.4	0.66	0.94	0.86	15.52	0.47
2	125	2.6	0.95	1.10	1.03	17.31	0.27
3	232	2.9	1.11	1.26	1.19	18.05	0.20
4	379	2.7	1.27	1.42	1.35	19.27	0.16
5	475	2.8	1.43	1.58	1.51	20.00	0.14
6	453	3.2	1.59	1.74	1.67	20.76	0.14
7	312	3.4	1.75	1.90	1.82	21.69	0.17
8	233	3.7	1.91	2.06	1.97	22.72	0.19
9	143	4.0	2.07	2.85	2.24	23.41	0.25

* Birth-weight categories defined in Table 2.

† Includes only pigs that survived until 42 days post weaning.

‡ All weights differ from each other ($P < .001$; ANOVA).

Table 5: Effect of weaning-weight category and parity on mean weight 42 days post weaning in a maternal line of barrows and gilts*

Weaning-weight category†	No. of piglets/category (N = 2467)‡	Average parity of dam	Weaning weight (kg) Minimum	Weaning weight (kg) Maximum	Weaning weight (kg) Mean	Weight 42 days post weaning (kg)§	SEM
1	15	1.8	1.85	3.08	2.83	13.16	0.76
2	400	2.6	3.09	4.43	3.98	16.28	0.15
3	413	2.9	4.44	5.10	4.78	18.05	0.15
4	444	2.9	5.11	5.78	5.44	19.67	0.14
5	442	3.1	5.79	6.46	6.10	21.07	0.14
6	328	3.2	6.47	7.13	6.77	22.53	0.16
7	208	3.5	7.14	7.81	7.43	23.45	0.30
8	125	3.8	7.82	8.40	8.07	24.17	0.26
9	92	4.3	8.41	10.48	8.98	25.28	0.30

* Pigs were weaned at an average of either 15 or 20 days of age (Table 2).

† Individual weaning weights were partitioned into nine categories which incrementally increased or decreased by 0.5 SD (0.68 kg) from the weaning-weight mean (5.80 kg).

‡ Includes only pigs that survived until weaning.

§ All weights differ from each other ($P < .001$; ANOVA).

Table 6: Least squares means (± SE) of body weight 42 days post weaning by parity of dam across weaning-weight categories* in pigs from a maternal line of sows

Parity	No. of sows	No. of pigs/category (N = 2467)†	Weight 42 days post weaning (kg)
1	90	726	19.95 ± 0.14[a]
2	57	463	20.57 ± 0.16[b]
3	38	317	20.02 ± 0.19[a]
4	42	286	20.24 ± 0.19[ab]
5	33	201	21.03 ± 0.22[c]
≥ 6	79	474	20.62 ± 0.16[ab]

* Weaning-weight categories defined in Table 5.

† Includes only pigs that survived until weaning.

[abc] Means with no common superscript differ (*P* < .05; ANOVA).

light-birth-weight pigs being considerably older or lighter at slaughter than their heavier birth-weight littermates. Powell and Aberle[7] also reported similar results. They studied crossbred piglets divided into three birth-weight groups and reported that low-birth-weight piglets grew more slowly from birth until slaughter. Whether purebred or crossbred pigs were evaluated, growth-performance relationships from birth until end of the nursery phase produced similar results.

Weaning weight appears to be a better predictor of weight at 42 days post weaning than birth weight, as the effect of 0.5 SD of weaning weight was greater than the effect of 0.5 SD of birth weight on weight at 42 days post weaning. However, birth weight and weaning weight have a positive relationship with pig weight at the end of the nursery phase. Wolter et al[14] studied the effect of birth weight on growth performance using crossbred pigs, reporting that the impact of birth weight on growth performance after weaning was greater than that of increasing nutrient intake during lactation. Other studies have reported that pigs that are lightweight at birth[3,14,15] or at weaning[16] require a greater number of days to reach the same market weight than do their heavier littermates.

The results of the current study focused on the initial 42 days post weaning mainly because previous research[17] indicated that improvements in growth and mortality largely occurred in the initial 42 days post weaning. Previous work[3] demonstrated that when lightweight pigs were placed in pens with heavyweight pigs during the postweaning period, they competed less effectively for feed than did heavier pigs. These findings may explain why lightweight pigs at the end of the nursery phase of production continue to be lightweight in subsequent production phases.

Implications

- Producers should further evaluate pigs having the lowest weights at birth, weaning, and 42 days post weaning and consider different alternatives for managing underweight pigs on an individual herd basis.
- Under the conditions of this study, relative differences in body weight at birth are perpetuated at weaning, so that light-birth-weight pigs are lighter at 42 days post weaning than pigs that were heavier at birth.
- Pigs that are heavier at birth are worth more money because they are likely to be heavier at the end of the nursery phase.
- Parity of dam influences piglet weight in subsequent phases of production, with pigs born to primiparous sows having a growth disadvantage.

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