The Great Divide: Optimizing Weaning Strategy to Satisfy Both Breeder and Finisher Requirements

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Introduction

Since the dawn of the Leman Era, owners, managers, veterinarians, consultants and bean counters have been at work on optimizing sow herd output and facility utilization. The development of multi-site systems has often resulted in breeder and wean-to-finish units optimizing profit independently, particularly where the different phases of production are independently managed or owned. While breeder units have been pursuing ever more pigs weaned per sow, nursery and finisher units have been doing their best with diminishing quality and performance of weaned pigs. However, weaning is the transaction point between the two factions. How best to get both parties to sing the tune of mutual profitability …?

A lot of attention has been focused on means of increasing weight at weaning, complex starter diets and related aspects of management to improve post-weaning performance. It is clear that pig quality at entry to the nursery predicts much of subsequent pig performance. It is now also clear that in this regard, age is as important as weight at weaning (Dunshea *et al.*, 2003, Main *et al.,* 2004, Main *et al.,* 2005, Wolter and Ellis; 2001). Methods of pricing weaned pigs have been reviewed (Main *et al.,* 2004) for their potential to equitably represent the value of desired specifications. Currently, weaned pig pricing systems and widely used sow herd metrics continue to support weaning at ages that are lower than the work of these authors would suggest is most profitable for the whole enterprise.

System modeling has become a mainstream technique for evaluating and understanding the dynamics of large, complex systems. One important use of such models is optimizing the economic implications of changes to the system. If the breeder unit and the wean-to-sale portion of the pig business are to successfully generate and share profit, it is necessary to clearly distinguish the financial impact of key policy decisions such as weaning age for the whole enterprise. This paper describes a model that optimizes the effect of weaning age on return on assets (ROA) for a multi-site production system viewed from both ends of the spectrum.

The Model and the Method

The ePiggery® model is designed to accomplish the following:

1. Quantify the change in a production variable (e.g. total born) in terms of any other production or finance variable (e.g. earnings before interest & tax)
2. Optimize financial performance through automated variable assignment incorporating the Dupont Model (DiPietre, 1997)

The model is comprised of a deterministic Breeder Model linked at weaning age to a stochastic Progeny Model. Optimization is achieved through the use of evolutionary algorithms. Hereafter, use of the term ‘optimization’ in this paper refers to this process.

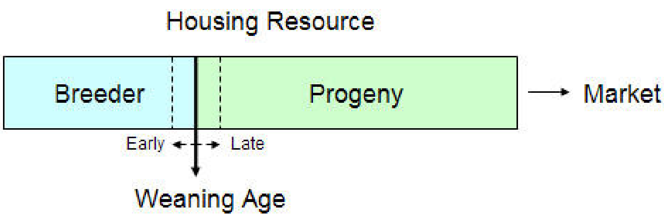
The model was set up for a 1,000 sow farrow-to-finish multi-site enterprise using current Australian benchmark performance data and production operation costs (Australian Pig Annual 2005), including current housing asset replacement costs. A price matrix was employed using a current base price of AU$2.50/kg (US$ 84.50/100lb) that penalizes heavily for fatness, as is common in Australia.

Reproductive relationships used in the model are based on published data (Belstra, 1999, Costa *et al.,* 2004, Levis, 1997,) and are described briefly here. Changes in weaning age will affect:

- breeder and progeny housing requirements
- breeder reproductive efficiency, and
- post-weaning progeny performance

Breeder housing is comprised of different types of accommodation for boars, mated and unmated gilts, weaned, gestating and lactating sows. Of these, gestating and weaned sow accommodation requirements are a function of weaning age via relationships to farrowing rate (FR) and weaning to first service interval (WFSI), respectively. Progeny housing requirements are a function of number of pigs weaned, post-weaning mortality (PWM), stocking rate and sale age (SA).

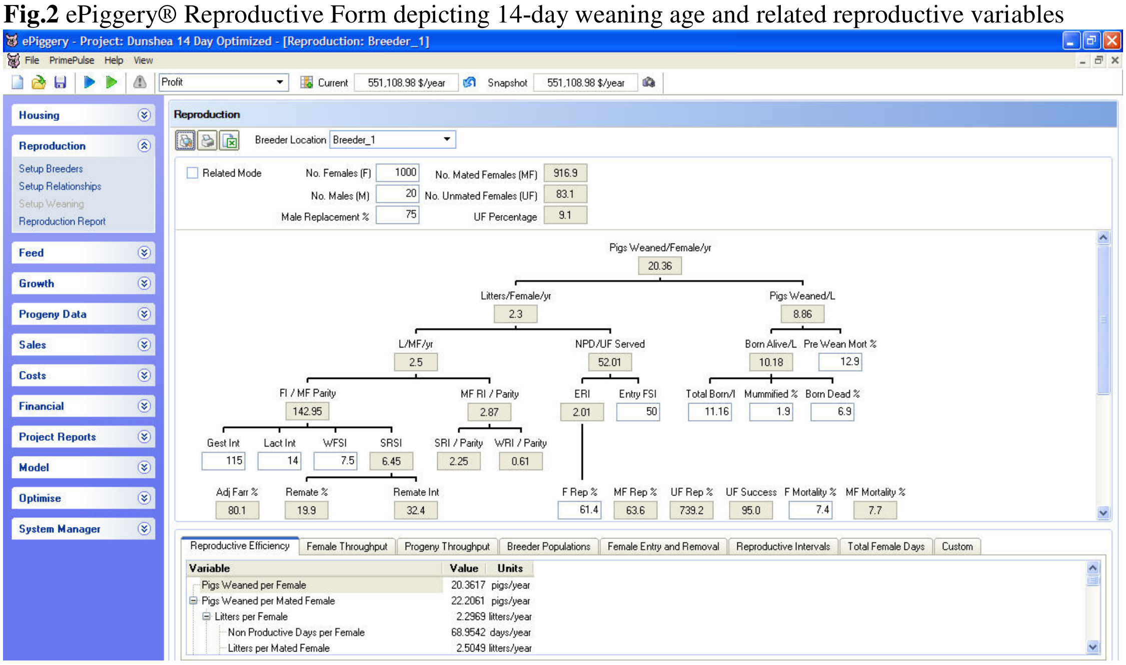
Fig.1 Effect of changes in weaning age on housing resources



From a breeding perspective, changes in weaning age result in exchange of farrowing crates for gestation stalls or group breeder space (Fig.1). From the perspective of progeny housing requirements, changes to weaning age result in exchange of pre-weaning progeny accommodation in farrowing crates to post-weaning accommodation in nursery space.

Three key reproductive efficiencies contributing to the number of pigs weaned are negatively affected by a reduction in weaning age. These are FR, WFSI and total pigs born per litter (TB). However, a common industry viewpoint is that the leverage conferred by litters per sow per year overcomes reduced litter size. This perception and health issues are the drivers of reduced weaning age.

Fig.2 ePiggery® Reproductive Form depicting 14-day weaning age and related reproductive variables



Post-weaning performance has been shown to be affected by reduced weaning age in the following ways:

- Reduced average daily live weight gain (ADG) (Main *et al.* 2004)
- Increased P2 Fat depth (P2) (Dunshea *et al.* 2003)
- Live weight variability (LW CV%) (Main *et al.* 2004)
- Increased post-weaning mortality (PWM) (Main *et al.* 2004 and 2005)
- Heavy-for-age pigs grow faster than light-for-age pigs (Dunshea *et al.* 2003)

The expression of post-weaning ADG effects varies between studies. The intent in the analyses described here was to determine the effect that differences in growth and carcass fatness attributable to changes in weaning age had on whole farm profitability, and then to determine optimum weaning age. The model was therefore constructed using published growth data, and assumptions regarding aspects of mortality based on the observations of Main *et al.* Live weight change was assumed to be linear between reported live weight and age co-ordinates. The model assumes a linear change in FCR from weaning to sale; the same FCR response curve was used for all scenarios.

'What if…? Analysis of Weaning Age

Two post-weaning growth 'What if…?' scenarios were modeled to contrast the findings of Dunshea *et al.* (2003) with Main *et al.* (2005). Dunshea *et al.* reported a P2 fat response of 13.1 mm vs. 10.9 mm at 23 weeks of age for 14-day and 28-day weaning, respectively (P = 0.009) with no significant difference in ADG. FCR was recorded for only the first 3 weeks post-weaning during which time no difference was reported between early and late weaned pigs. Mortality was not reported. Main *et al.* reported a linear improvement in ADG (580 to 687 g/d, P < 0.001) and reduced mortality (9.39 to 3.68%, P < 0.001) when weaning age increased from 12 to 21 days. FCR was reported only for the nursery phase, during which time no difference was reported between early and late weaned pigs. Earlier work by Main *et al.* (2002) reported improvements in 10^{th} rib fatness, loin depth and lean percentage with increased weaning age, but these results were complicated by other factors and were therefore excluded in our analysis and comparison. Both light and heavy progeny groups were modeled within the Dunshea scenarios whereas a single population representing Main's reported results was used in those scenarios.

The model was based on the following assumptions: all in, all out production, mortalities were not replaced in the progeny space allocation, and all diets were fed to fixed age limits. Post-weaning mortality was calculated and apportioned separately to the nursery and finisher such that one third of deaths were applied at the nursery stage. Sow numbers were held constant at 1,000 for each scenario.

First, performance was modeled after Dunshea *et al.* (2003) to include the reported effects of post-weaning compensatory gain and accelerated fat deposition. It was hypothesized that 28-day weaning is more profitable than weaning at 14 days of age. Thus, 28-day weaning was used as the comparative benchmark for the range of weaning ages, weights and subsequent growth data included in the model.

In the configuration of the 28-day weaning age scenario, the model was optimized as follows:

1. Sow numbers, weaning age and associated reproductive efficiencies were fixed to quantify breeder housing requirements
2. Excessive housing was allowed for all classes of progeny to allow optimization of sale age without the constraint of housing limitations
3. Market requirements were quantified via the characteristics of the Australian price matrix
4. Earnings Before Interest and Tax (EBIT) was optimized over a range of sale ages
5. Progeny housing resources required for optimum EBIT were then quantified
6. Total housing assets (THA) were derived from the livestock populations required and their respective individual housing class replacement costs

7. EBIT and ROA were then captured for the 28-day weaning age scenario and are summarized in Table 1

The 14-day weaning age scenario was derived by reconfiguring the first scenario as follows:

1. Reduce weaning age, and then adjust FR, WFSI, TB and other relevant reproductive relationships according to published values as described
2. Reassign breeder housing to accommodate the 1,000 sow population (i.e. with adjusted housing class proportions)
3. Optimize EBIT using progeny sale age based on the younger weaning age, related growth data and market requirements
4. Adjust nursery housing to preserve the same entry age to the finisher location as used in the 28-day weaning age model (as depicted in Fig.1 representing the exchange of housing assets)
5. Finisher housing assets were allocated to calculate THA
6. EBIT and ROA were then captured for the 14-day weaning age scenario and are summarized in Table 1

The analysis was then repeated using results reported by Main *et al.* showing lifelong reduction in ADG with earlier weaning. Data representing the 14-day weaning age were deduced by interpolating linearly between results reported for 12- and 15-day weaning ages. Results are shown in Table 1.

Table 1. Influence of weaning age on ROA

Variable	Units	Dunshea 14 Day	Dunshea 28 Day	Main 14 Day	Main 21 Day
Number of Females	females	1,000	1,000	1,000	1,000
Lactation Length	days	14	28	14	21
Total Born per Litter	pigs / litter	11.16	11.89	11.16	11.50
Preweaning Mortality	%	12.9	12.9	12.9	12.9
Pigs Weaned per Litter	pigs / litter	8.86	9.44	8.86	9.14
Litters per Female per Year	litters / female / year	2.30	2.15	2.30	2.20
Pigs Weaned per Female per year	pigs / female / year	20.36	20.27	20.36	20.13
Pigs Weaned per Annum	pigs/year	20,362	20,273	20,362	20,129
Weaner Cost of Production	$ / pig weaned	47.52	49.43	47.52	48.87
Effective Post Weaning Mortality	%	5.97	3.08	5.97	4.50
Progeny Mortalities	pigs / year	1,215	624	1,215	907
Progeny Feed Costs per Progeny Sold	$ / pig sold	63.12	69.24	62.78	72.20
Progeny Feed Consumed	tonne / year	4,324	4,690	4,201	4,806
Progeny FCR Over Life (LW basis)	ratio	2.37	2.38	2.41	2.58
Progeny Cost of Production	$ / pig sold	143.78	152.87	143.48	154.42
Progeny Sold per Annum	pigs / year	19,146	19,649	19,146	19,223
Days to Market	days	140	133	141	134
Sale Age	days	154	161	155	155
Average Sale Live Weight	kg	95.41	100.67	91.12	97.09
Average Sale Dress Weight	kg	72.16	76.13	68.93	73.43
Average Sale Lean Meat Yield	kg	38.81	40.63	37.02	39.49
Average DW Price	$ / kg	2.39	2.44	2.40	2.39
Average Sale Value	$ / pig sold	172.15	185.5	165.17	175.14
Progeny Revenue	$ / year	3,296,025.76	3,644,954.62	3,162,310.87	3,366,717.27
Breeder Revenue	$ / year	86,907	86,907	86,907	86,907
Total Revenue	$ / year	3,382,932.76	3,731,861.62	3,249,217.87	3,453,624.27
Breeder Costs	$ / year	966,293.26	1,000,882.37	966,293.26	982,428.83
Progeny Costs	$ / year	1,923,845.93	2,091,226.40	1,917,317.03	2,105,547.27
Total Costs	$ / year	2,890,139.19	3,092,108.77	2,883,610.29	3,087,976.11
EBIT	$ / year	492,793.57	639,752.85	365,607.58	365,648.16
Total Assets	$	6,010,244.49	6,363,627.45	6,004,616.55	6,102,519.62
Return On Assets	%	8.20	10.05	6.09	5.99

Weaning age exerted a greater effect on ROA in Dunshea's scenario due to carcass quality. Later weaned pigs generated more revenue per kg sold through a 5¢ / kg price advantage due to carcass leanness. Later weaned pigs were also sold at heavier weights because sale could be delayed (154 vs. 161 days) before fatness and associated penalties limited sale age in the model.

Differences in carcass composition reported by Main *et al.* (2002) were confounded and were therefore not applied in the model. However, this was required to determine carcass value. It was therefore assumed in this analysis that there was a linear fat response for both weaning ages such that both early and late weaned pigs achieved 12 mm fatness at 23 weeks of age. This figure was derived from the average P2 value generated in the Dunshea scenario to approximate a comparable sale population. Thus fast growing late weaned pigs in the Main scenario were relatively leaner. Late weaned pigs could likewise also be sold at heavier weights before incurring penalties, resulting in $10 more revenue per pig sold.

Once the effect of differences in mortality are taken into account, then pattern of growth and corresponding feed use to produce pigs at the optimum sale age were the main drivers of the differences in ROA between the Dunshea and Main scenarios. Thus, if post weaning performance is predictable and housing assets are not limiting, then EBIT can be protected through strategic marketing practices.

Optimizing Breeder Only Weaned Pig Production Using a Fixed Weaned Pig Price

The objective of the next analysis was to quantify the financial incentive to sustain younger weaning ages in breeder-only production systems using the breeder data generated in the Dunshea 28-day weaning scenario shown in Table 1. A fixed sale price per weaned pig was used in the model so that the cascading effects of weaning age upon post weaning performance were ignored.

The 28-day Dunshea scenario was reconfigured by removing progeny locations and progeny housing assets from the model, and inserting a sale transfer at weaning. The value of weaned pigs at transfer was calculated as: [(Breeder and Progeny EBIT x Breeder Assets ÷ Total Assets) + Breeder Costs] ÷ No. pigs weaned per year. The rest of the model was constructed as follows:

1. Total sow numbers were fixed at 1,000
2. The number of farrowing crates was initially fixed
3. All other breeder accommodation was increased to be non-limiting
4. EBIT was optimized via weaning age and WFSI, FR & TB were adjusted accordingly
5. Breeder housing assets were re-allocated to livestock populations

Table 2. Optimization of Breeder only EBIT (fixed weaned pig price) via weaning age iteration

Variable	Units	7 Day Wean	14 Day Wean	21 Day Wean	28 Day Wean
Number of Females	females	1,000	1,000	1,000	1,000
Number of Farrowing Crates	crates	57	111	161	208
Lactation Length	days	7	14	21	28
Weaning to First Service Interval	days	10.2	7.6	6.7	5.7
Farrowing Rate	%	74.2	78.3	82.3	84.5
Total Born per Litter	pigs / litter	10.67	11.16	11.50	11.89
Pigs Weaned per Litter	pigs / litter	8.48	8.86	9.14	9.44
Litters per Female per Year	litters / female / year	2.37	2.32	2.24	2.17
Pigs Weaned per Female per year	pigs / female / year	20.07	20.56	20.49	20.47
EBIT	$ / year	364,714.64	379,336.98	360,354.22	345,078.50
EBIT per female	$ / year	365	379	360	345
Breeder Housing Assets	$	1,450,426.75	1,629,919.34	1,789,500.27	1,938,236.36
Return on Breeder Housing Assets	%	25.15	23.27	20.14	17.80

The optimization process tested daily weaning age decrements from 28 to 7 days. Return on breeder housing assets peaks at 7 day weaning indicating a linear financial incentive to replace farrowing crates with group breeder space. Thus, if a fixed weaned price contract could be secured and maintained for the life of the investment, then new enterprise investment clearly favors younger weaning ages.

Conversely, EBIT per sow peaks at 14 day weaning indicating that reproductive inefficiencies provide a natural disincentive to contemplate very young weaning ages. Thus, if assets are currently allocated within a going concern, then there is little incentive to considering weaning less than 14 days of age.

As pigs weaned per female per year varies by only 0.09 between 14 and 28 day weaning, the underlying reproductive efficiencies tend to nullify one another. The counteractive effects of pigs per litter and litters per year appear to balance each other fairly equally with increasing weaning age. The difference in EBIT per female is small compared to the post-weaning effects of changes in weaning age. This invites consideration of later weaning in response to post weaning performance issues.

Weaned Pig Price System Analysis

The objective was to design a weaned pig price system in terms of weaning weight *and* age that shares EBIT equitably between breeder only enterprises supplying weaned pigs to progeny only enterprises. The assumption was that EBIT could be allotted to the respective enterprise based on the proportion of assets employed to support joint EBIT generation.

The Dunshea weaning scenarios were used in the analysis because they encompassed both a wider range of weaning ages and included the perspective of segregation into light and heavy subgroups. A 3 x 3 price matrix was generated by interpolating medium weaning weights from light and heavy subgroups reported, and 21 day weaning age from 14 and 28 day replicates. Post-weaning growth responses were interpolated likewise. Thus the "diagonal" categories presented in Table 3 are supported by reported data whereas the adjacent categories are interpolated from that data.

Table 3. Weaned pig subgroups used in the analysis

Weaning Weight Category	Weaning Age Category		
	14 day	21 day	28 day
Heavy	5.52 kg / 12.16 lb	7.38 kg / 16.27 lb	9.25 kg / 20.39 lb
Medium	4.49 kg / 9.89 lb	6.02 kg / 13.26 lb	7.54 kg / 16.63 lb
Light	3.46 kg / 7.63 lb	4.65 kg / 10.25 lb	5.84 kg / 12.88 lb

Nine scenarios were modeled to quantify weaned pig value as follows: (Breeder Housing Assets ÷ Total Housing Assets) x (Progeny EBIT + Breeder Costs) ÷ No. pigs weaned, where Progeny EBIT was generated initially using a $0 weaned pig purchase price per head. Progeny EBIT was optimized for the weaning age category and then breeder costs and housing assets were determined for the respective lactation length for that level of progeny EBIT.

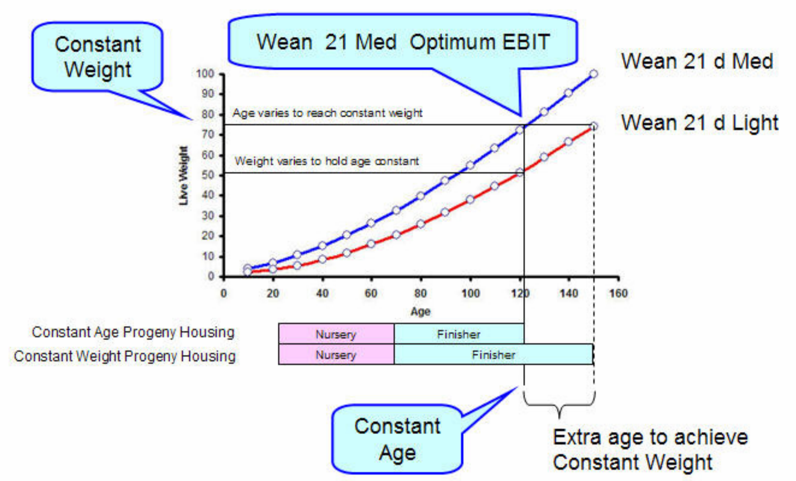
The medium age and weight category was selected to optimize progeny EBIT via sale age. This sale age was then applied to all other weaning age categories to simulate constant sale age and variable sale weight (i.e. limited housing). All analyses were then repeated to simulate constant sale weight and variable sale age (i.e. unlimited housing). The results were averaged and are reported in Table 4.

Table 4. Weaned Pig Value Grid ($ / pig weaned)

Weaning Weight Category	Weaning Age Category			
	14 day	21 day	28 day	Average
Heavy	$60.38	$64.77	$68.13	$64.43
Medium	$57.56	$62.42	$65.06	$61.68
Light	$55.15	$59.06	$62.01	$58.74
Average	$57.70	$62.08	$65.07	$61.61

Fig. 3 depicts the way in which limited (short) and unlimited (long) housing was simulated in the model. The intent was to simulate the circumstances of a going concern in the face of seasonally variable throughput. The results of both sets of analyses were therefore combined in a single table of weaned pig values.

Fig. 3. Model of short vs. long housing



The value gradient presented in Table 4 is similar in response to age and weight vectors ($7.37 vs. $5.69, respectively), with age predominating as the driver of weaned pig value.

In large production systems designed to support segregated management and sale of pigs with different characteristics, opportunity exists to ameliorate the post-weaning effects of age and weight at weaning. As only the 21-day wean age, medium weight scenario was optimized in this analysis, it is speculated that such independent control of marketing strategy of different classes of weaned pig could reduce these gradients. This is particularly true where there are pronounced differences in post-weaning performance between light and heavy pigs, e.g. due to disease, parity of dam, etc.

Market price is the key determinant of pig value, and structure of the price grid profoundly affects the value of weaned pigs to the wean-to-sale enterprise. Furthermore, diet, health, environment and genetics will all influence the expression of post-weaning growth. These factors are specific to particular production systems. Interpretation of this data is therefore intended to be general.

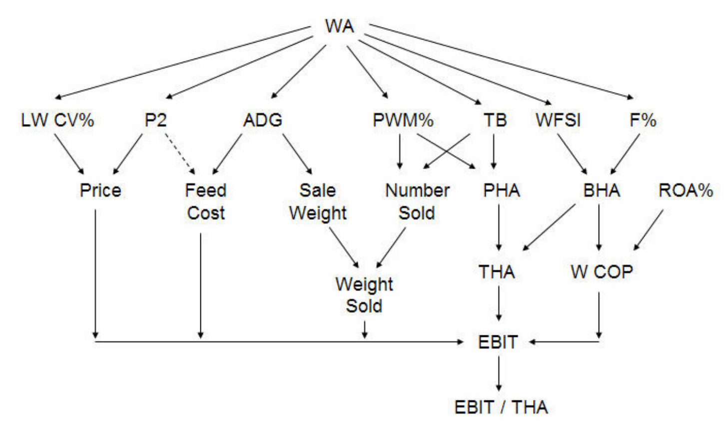
In comparing the weaned pig price grid with the effect of weaning age on EBIT per female depicted in Table 2, it is clear that post-weaning effects are more important financially than pre-weaning effects in the determination of optimum weaning age.

Conclusion

The output of the model described here supports the observations of Dunshea *et al.*, 2003, Main *et al.* 2005, and others that weaning age has a significant impact on the value of a weaned pig. Once the interaction between age, weight and other factors influencing post-weaning performance are more clearly distinguished, further optimization can be carried out to ensure that the entire production process is as efficient and profitable as possible. Viewed from the hypothesis that weaning at 28 days of age is more profitable than 14-day weaning, results of the scenarios described here support the benefits of returning to older weaning ages.

Where to from here in the pursuit of optimum age at weaning, equitable pricing of weaned pigs and optimum market weight and age? The ePiggery® model employed in the analysis enables weaning age to be optimized in terms of EBIT/THA, ROA, ROE (return on equity) or any other variable of interest or importance. For example, both weaning age and variation in weaning age within and between batches of pigs will affect post-weaning performance. These relationships and cascading interactions can be explored using the model. As described here, such tools are invaluable for understanding the nature of the system, in particular linking performance with financial data and exposing urban myths about how they interact.

Fig. 4 Model depicting relationships between age at weaning and factors affecting EBIT / THA



W COP: Weaner Cost of Production

As the facility for progeny data capture becomes more mainstream through the use of RFIDs, autosort gear and electronic slaughter data, the ability to link this information with decision support tools becomes realistically achievable. User-friendly access to these technologies will enable the decision-making process to be customized, and to then move into a real-time environment.

Implications

- It is possible to create a system-specific price grid based on weight and age at weaning that rewards the producer equally in terms of ROA for a pig at weaning as for a pig at market
- It is also possible to deliver this outcome to industry in the form of computer decision support tools as opposed to a paper-based generic weaner value grid
- In this model, while age and weight had a similar effect on weaned pig value, age predominated
- The post-weaning effects of changes in weaning age can be mitigated through segregated management and selective marketing of subgroups of pigs
- Any improvement in carcass fatness, lean protein deposition and lean meat yield with increased weaning age can exert a significant effect on ROA
- Market price and factors such as health, genetics and environment all have a profound influence on post-weaning effects attributable to age at weaning. The magnitude of these factors is farm-specific; any calculation of weaner value must include such measures
- Fixed-price weaned pig contracts encourage weaning at ages far below the optimum for grow-out
- The effect of weaning age on EBIT per female is small
- The counteractive effects of pigs per litter and litters per year tend to balance each other with increasing weaning age
- The post-weaning effects attributable to age at weaning are more important financially than the reproductive effects in the determination of optimum weaning age

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