MANAGEMENT OF PIGS IN THE PORK PRODUCTION CHAIN

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ABSTRACT

The pork industry has the objective to produce high quality lean pork products. The pig's genetic potential for lean growth and the environment both affect the pig's rate of growth, carcass composition and feed efficiency. Exposure to disease or other stressors reduces carcass muscle growth to a greater extent than fat tissue growth such that at the same feed intake, stressed pigs have decreased carcass lean percentages. Variation in the growth of pigs is in conflict with the pork processors demand to produce pork products which are uniform in both weight and composition. Farms with higher levels of stressors present and large litter sizes with greater numbers of light birth weight pigs will have greater variation in pig growth. Cost effective methods to reduce variation in pig growth should be evaluated. A stochastic model has been developed which allows for the optimization of marketing strategy, Paylean use and barn turn-over. Future models will predict the amount and form of nutrients excreted by pigs and evaluate for specific producers, the most profitable, sustainable nutrient management plan relative to both the pork production and cropping systems. These models currently evaluate the use of alternative diets to reduce the excretion of N and P. In the future they may predict the relative production of other compounds and compounds released as gases.

INTRODUCTION

The goal of the pork industry is to provide high quality pork products to the consumer at the lowest possible cost. Pork processors sell numerous highly trimmed pork products and receive premiums for products that meet specific weight, quality, trim and compositional standards. This has resulted in the development of "value–based" marketing systems in which a premium or discount is received for each pig based on predicted lean content and carcass weight. To remain profitable pork producers must consider a number of alternative genetics, management and marketing decisions to strive to produce pigs with the optimal predicted lean content and carcass weight.

While many criteria (e.g. feed cost/pig or lb of pork) can be used, the ultimate objective is to maximize the daily returns to the facility (pig space-investment) above daily feed and variable costs. A model may take into account optimal pig growth performance, carcass characteristics, nutrient requirements, packer grids, prices of ingredients, replacement animals (feeder pigs), current meat prices, fixed and variable facility costs all being optimized simultaneously.

Economic modeling has become more complex given the current environmental regulations. Producers not only have to try to maximize their profit/pig space/day but also need to balance that with environmental regulations. The new phosphorus based standards go into effect in the US in 2006. The swine manure by-products will need to be land applied on a phosphorus basis depending on phosphorus soil tests and planned crop removals. Traditional manure applications will need to be spread over 2 to 4 times more land base depending on soil and manure phosphorus levels, drastically increasing nutrient management costs. This requires the modeling of the amount, composition and cost benefits of the nutrient excretion and resultant manure applications.

The objectives of this paper are: (1) to review some of the key factors affecting pig performance, (2) to discuss the interactions between pig to pig variation in growth, marketing and scheduling on profitability, and (3) to explore the future use of ractopamine (Paylean^{TM}) and (4) the future of pork production systems analyses.

GENETIC POTENTIAL FOR LEAN GROWTH

Swine growth models require estimates of the protein accretion potential, partitioning of energy and daily energy intakes for each genetic source–sex population. The relative differences in feed intake, feed efficiency and nutrient requirements of barrows and gilts also differ amongst different genetic populations (Schinckel, 1994). Genetic selection for increased carcass leanness and, more recently, increased carcass lean growth rate has resulted in pigs with increased protein accretion rates, increased partitioning of energy to carcass lean growth from fat tissue growth and reduced feed intakes (Schinckel and de Lange, 1996).

ENVIRONMENTAL LIMITATIONS ON PIG GROWTH

Substantial differences in performance exist between different environments and health management strategies. Environmental stressors including pathogen exposure, social stress, and less than optimal stocking density limit growth, such that pigs managed under commercial conditions do not express their maximum potential protein accretion even when allowed ad libitum access to nutrient dense diets (Holck et al., 1998; Schinckel et al., 2003a).

Genetic populations with different genetic potentials for lean growth and fat accretion are different physiologically. From a modeling perspective, lean, low feed intake pigs are expected to be more sensitive to any environmental stressor that reduces feed intake. In addition, selection for increased carcass lean growth and decreased fat tissue growth has likely resulted in changes in immune response (Spurlock, 1997; Spurlock et al., 2003).

EFFECT OF HEALTH STATUS ON PIG GROWTH

In a past experiment, pigs with minimal disease via segregated early weaning (SEW), which were fed a series of non-limiting diets and reared in pens of three pigs (2.23 m^2/pig), achieved

104 kg at 136 days of age and 120 kg at 151 days of age (Schinckel and de Lange, 1996). Pigs raised on the original commercial farm, conventionally weaned with all-in, all-out (AIAO) production, required 184 days to attain 104 kg live weight.

Research conducted in two health status environments, medicated early weaning and continuous flow (CF) commercial conditions, indicated that disease status affects lean growth to a greater extent than fat growth (Williams et al., 1997). The pigs reared via continuous flow management averaged over three diets (.75, .90, and 1.05% lysine) consumed less feed from 27 to 112 kg (2.43 vs. 2.69 kg/d), grew slower (743 vs. 947 g/d), had poorer feed efficiency (.307 vs. .352), and lower muscle growth (263 vs. 342 g/d). At 112 kg, the conventional health status pigs had greater backfat depth (29.8 vs. 26 mm) and smaller loin muscle area (32.1 vs. 36.7 cm^2) than the high health pigs. The visceral organ weight to carcass muscle weight was substantially greater for the conventional health status pigs (57% vs. 49.7%).

GENERAL ENVIRONMENTAL EFFECTS ON PIG GROWTH

The compositional growth of the same genetic population of pigs has been evaluated on two US commercial production units (Schinckel et al., 2002). Pigs reared on farm 1 were reared via AIAO management with 1 week age groups. Pigs on farm 2 were reared in two week groups and were not maintained as a group. Pigs of different age groups were present in the nursery and finish at the same time. The barrows from farm 2 required 6.3 more days to achieve 115 kg body weight (BW) (194.2 vs. 187.9 d, $p<.01$), had .97 cm greater backfat (3.22 vs. 2.25 cm, $p<.01$) and smaller loin muscle area (37.5 vs. 42.4 cm^2, $p<.01$). Gilts on farm 2 required 11.6 additional days (200.5 vs. 188.9, $p<.01$) to achieve 115 kg BW, had .57 cm greater backfat (2.42 vs. 1.85 cm, $p<.01$) and 2.6 cm^2 smaller loin muscle area (42.0 vs. 45.5 cm^2, $p<.01$). The predicted protein accretion rates were 20 g/d lower for farm 2 and predicted daily lipid accretion rates were higher than farm 1.

In a nutrition trial (Carroll et al., 1999), lean gilts sired by lean European sires on the same Landrace by Large White-Duroc dams were reared in the west and east wing of a grow-finish facility. In the west wing, the lean gilts grew faster (934 vs. 798 g/d ADG) and had higher daily feed intakes (2.42 vs. 2.24 kg/d), but were leaner (13.7 vs. 15.8 mm backfat) and had larger loin eye areas (49.1 vs. 47.7 cm^2). The ventilation of the east wing did not provide the air quality of the west wing. In this project, few animals were treated for signs of infectious disease. The results of this trial suggest that the environmental stressors (air quality) reduce muscle growth to a greater extent than fat growth, such that at lower feed intakes percent lean is reduced.

GENETIC BY ENVIRONMENTAL INTERACTION TRIALS

To document and quantify genetic by environmental interactions, three genetic by environmental trials were conducted (Schinckel et al., 2003a). In each trial, two or three genetic populations of pigs (288 to 320 pigs per trial) were reared under two health status environments. Significant genetic by environmental interactions were found for average daily gain, daily feed intake, days to 112 kg live weight, death loss, feed efficiency and predicted percent lean. These results indicate that the increased performance produced by changes in health status differs amongst genetic populations. To make correct decisions concerning any environmental change (health status, air quality, pen density, etc.), the pork producer must have information concerning the expected response of their specific population of pigs to the specific environmental change.

FARM-GENETIC POPULATION NUTRIENT REQUIREMENTS

Because the environment limits pig growth, farm-production system specific essential amino acid: energy ratio and available P to calorie ratio requirements need to be estimated (Schinckel and de Lange, 1996; Schinckel et al., 1998; Tokach and de Lange, 2001). The three alternate methods to set target nutrient requirements are (1) conduct full scale nutrition experiments, (2) develop farm specific compositional growth curves using serial ultrasound and, (3) to utilize mean predicted lean growth rates over the grow finish period (Schinckel et al., 1996).

MODELING VARIATION IN BODY WEIGHT GROWTH FROM BIRTH TO MARKET WEIGHT

Several researchers have realized that variation in growth rates amongst pigs has a cost and should be reduced when cost effective means can be identified (Deen, 1999; King, 1999; Le Dividich, 1999; Dewey et al., 2001; Patience et al., 2004; Tokach, 2004). Some of the variation in body weight growth is caused by differences in birth weight (Foxcroft and Town, 2004). Increasing the birth weight of the lightest 20% of the pigs could substantially increase subsequent BW's and potentially reduce variation in BW (Schinckel et al., 2004). Increasing the birth weight of the heaviest pigs will result in only small increases in subsequent BW's (Figure 1). One reason for this curvilinear relationship is the fact that ADG increases rapidly as BW increases. Heavier pigs at the same age are able to grow faster than average pigs, achieve even greater BW at the same age than average pigs, and thus increasingly grow at faster rates (Figures 2 and 3).

One alternative is to have a separate production system, including nutrition, health program, and facility management for the lightest pigs at weaning. The reduced variation observed in the remaining 80% of the pigs will improve utilization of the larger grow-finish facilities. This reduced variation could result in more precise phase feeding, use of ractopamine, and marketing at specific target weights.

The modeling of the mean and variance of subsequent BW's from birth to market weight is complex because of the curvilinear relationships between birth weight and subsequent BW. Statistical analyses, which assume or only account for linear relationships amongst the serial BW's, would likely not reproduce the actual relationships and variation amongst the serial BW's.

Figure 1. **Relationship of body weight to age for five percentile groups of pigs based on birth weight.**

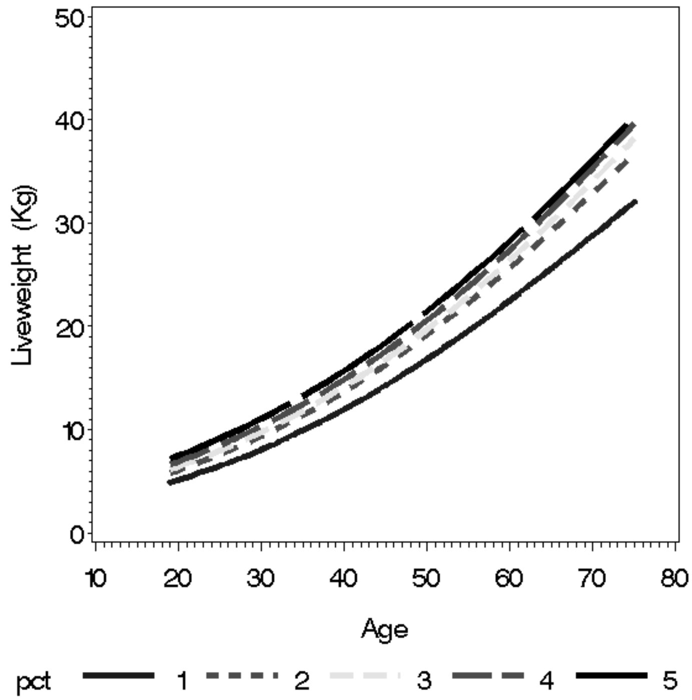


Figure 2. **Relationship of ADG to age for five percentile groups of pigs based on birth weight.**

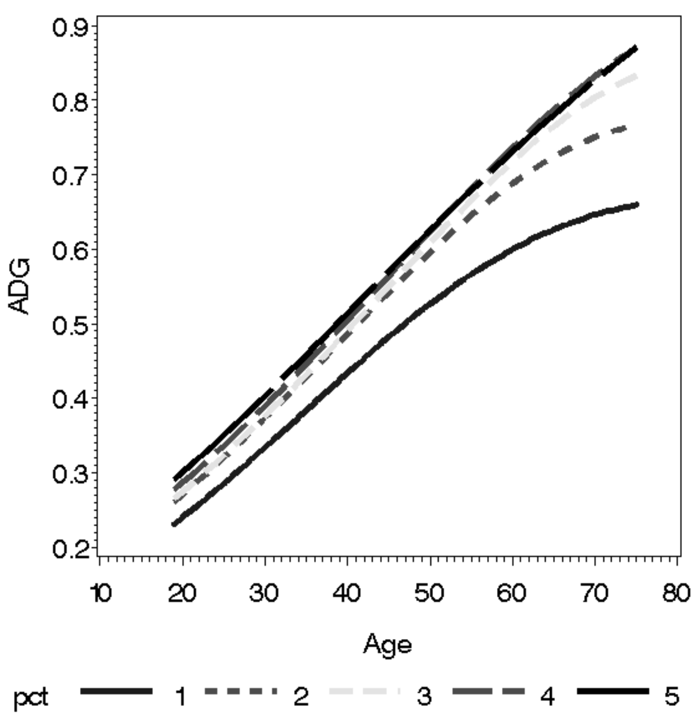
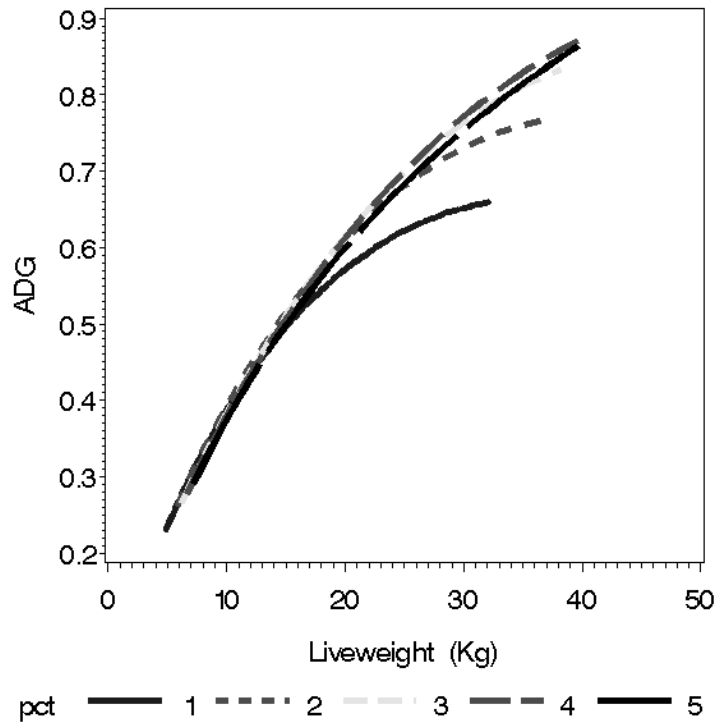


Figure 3. Relationship of ADG to live weight for five percentile groups of pigs based on birth weight.



Health status impacts the amount of variation in BW at each age and the days to reach a specific target BW (Tables 1 and 2). The day of age to reach specific target weights was predicted for the five fastest gaining and five slowest gaining percentiles of gilts in each environment (Table 2). The difference in age predicted to achieve 120 kg between the fastest and slowest growing gilts increased to 61 days in the CF environment and 53 days in the SEW environment. This difference grew to 62 days for the AIAO system and 104 days for the CF pigs to reach 130 kg, making it impractical to market CF pigs at 130 kg BW.

The increased variation in days required to achieve specific market weights has an economic cost as most pork processors discount pigs below their specified target market weight. The economic evaluation of rearing pigs under AIAO or CF management must include both the impact of the differences in the mean performance and differences in the variation in growth.

DEVELOPMENT OF A STOCHASTIC MODEL FOR EVALUATING MARKETING ALTERNATIVES

Pork processors have the objective to market lean pork products which are uniform in weight and composition and receive premium pricing for their product. The evaluation of alternative management and marketing strategies, requires knowledge of the between pig variation in BW and carcass composition.

Table 1. Means and standard deviations for live weight, kg.

	All-in, all-out				Continuous flow			
Age	N	Mean	SD	CV	N	Mean	SD	CV
49	96	28.88	2.34	11.2	96	20.74	2.26	10.9
70	96	36.85	3.76	10.2	96	36.72	3.18	8.7
104	96	67.28	5.34	7.9	96	67.88	5.32	7.8
132	96	93.00	7.99	8.6	96	90.05	8.10	9.0
153	96	115.14	8.52	7.4	96	106.08	9.05	8.5
174	42	120.29	9.03	7.5	96	113.65	9.96	8.8

Schinckel et al., 2002

Table 2. Overall means and means for the pigs of the fastest and slowest five percentile groups for predicted age to achieve specific body weight.

	All-in, all-out: Age				Continuous flow: Age			
Target body weight, kg	Mean	Upper 5	Lower 5	SD	Mean	Upper 5	Lower 5	SD
100	138.1	121.0	159.8	8.4	144.4	123.2	159.8	10.9
110	149.5	130.4	175.2	9.7	160.9	134.4	180.0	16.5
120	161.5	139.4	192.4	11.3	177.4	146.4	207.4	19.3
130	174.2	149.2	211.8	13.4	199.3	154.8	258.9	22.9

Schinckel et al., 2002

The random effects produced by mixed model nonlinear equations could be used to evaluate the growth of individual pigs or specific groups of pigs. Farm-specific BW, empty body composition, and carcass composition can be predicted from serial live BW and real-time measurements. Data from a Purdue University research trial were used as the example data set. High-lean gain gilts (N=96) were reared via AIAO procedures.

The stochastic model predicts daily BW growth, empty body protein accretion, and empty body lipid accretion for each individual pig. For this reason, the stochastic model can be used to predict the BW and carcass composition of groups of barrows and gilts marketed at different ages. The marketing strategy that maximizes the daily return for the grow-finish facility above daily feed costs can be identified. Stochastic models can be used to develop optimal sorting and marketing strategies and to evaluate the costs and returns of specific management decisions that affect variation.

The predicted standard deviation (SD) for carcass weight, fat-free lean mass, total carcass fat tissue mass, and all carcass measurements increased as the age at marketing increased (Table 3). Variables associated with carcass fat mass or backfat thickness increased more rapidly than measures associated with lean mass including longissimus muscle area or optical probe muscle depth.

Table 3. Means and standard deviations for live BW and carcass measurements at alternative marketing ages[a].

	146 d		160		174	
Item	Mean	SD	Mean	SD	Mean	SD
Age						
Live BW, kg	107.4	8.1	119.4	9.1	130.8	9.9
Hot carcass wt, kg	80.6	6.8	90.8	7.7	95.6	8.4
Fat-free lean, kg	42.2	3.7	46.3	4.1	50.0	4.5
Percent fat-free lean	52.5	3.2	51.0	3.2	49.9	3.3
Total carcass fat, kg	24.3	3.8	27.9	4.7	31.6	5.5
Fat thickness, 10th rib, mm	20.9	2.7	22.3	3.3	23.8	3.8
10th rib longissimus area, cm^2	10.8	2.8	43.4	3.1	46.3	3.5
Optical probe fat depth, mm	20.3	2.4	21.2	2.8	22.3	3.2
Optical probe muscle depth, mm	52.2	2.7	54.0	3.0	55.8	3.1

[a]Mean and standard deviations were predicted by simulating 1000 pigs with the means, variances, and relationships predicted by an original sample of 96 gilts.

Four alternative marketing strategies were evaluated. The first strategy was to market all pigs at 160 days of age with a mean BW of 119.4 kg. The second strategy was to market all pigs above 113.8 kg BW at 146 days (21.2%; mean = 118.6 kg) and 160 days (53.5%; mean = 119.9 kg) of age and all remaining pigs (25.3%; mean = 118.8 kg) at 174 days of age. The third strategy was to market pigs above 112.3 kg at 146 days (25.8%; mean = 117.6 kg) and 160 days (53.0%; mean = 118.9 kg) of age and all remaining pigs at 181 days of age (21.2%; mean = 122.6 kg). The fourth strategy resulted in pigs above 116.4 kg being marketed on a weekly basis (13.0, 21.9, 28.8, 19.6, and 9.6% with mean BW's of 120.9, 119.8, 119.6, 120.1, and 120.0 kg, at 146, 153, 160, 167, and 174 days of age) with the remaining pigs (7.1%; mean = 116.6 kg) marketed at 181 days of age.

The three multi-day marketing strategies reduced the SD for BW and carcass weight (Table 4). The SD of carcass fat-free lean and fat mass were reduced to a lesser extent. This is due to the fact that each carcass component mass has two sources of variation: variation in carcass weight and variation in the carcass percentage of the specified carcass component. The weekly marketing strategy resulted in further reductions of the SD for BW and carcass weight in comparison to the two 3-time marketing strategies. However, the weekly marketing strategy had little impact to further reduce the SD of any carcass component or measurement. The multi-day marketing strategies resulted in BW, carcass weight, and to a lesser extent, carcass component mass to not be normally distributed.

Table 4. Means and standard deviations for live weight and carcass measurements with alternative marketing strategies.[a]

	160 d		146, 160, 174		146, 160, 181		146-181 weekly	
Item	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Live BW	119.4	9.1	119.3	4.3	119.4	4.7	119.4	3.0
Carcass weight	90.8	7.7	90.6	3.8	90.6	4.1	90.8	2.7
Fat-free lean, kg	46.3	4.1	46.3	3.3	46.3	3.4	46.4	3.2
Percent fat-free lean	51.0	3.2	51.1	3.1	51.1	3.1	51.0	3.0
Total carcass fat, kg	27.9	4.7	27.8	3.6	27.8	3.6	27.8	3.5
Fat thickness 10^{th} rib, mm	22.3	3.3	22.2	2.8	22.2	2.8	22.1	2.8
10^{th} rib longissimus area, cm^2	43.4	3.1	43.3	2.6	43.3	2.6	43.3	2.5
Optical probe fat depth, mm	21.2	2.8	21.1	2.5	21.1	2.5	21.1	2.5
Optical probe muscle depth, mm	54.0	3.0	54.0	2.8	54.0	2.8	54.1	2.8

[a]Strategies included: 1) all pigs marketed at 160 days of age; 2) pigs above 113.8 kg marketed at 146 and 160 days and the remaining pigs at 174 days of age; 3) pigs above 112.3 kg marketed at 146 and 160 days and the remaining at 181 d; and 4) weekly marketing of pigs above 116.4 kg from 146 to 174 days with marketing of the remaining pigs at 181 days of age. Data based on simulation of 1000 pigs.

The predicted age at 110 kg was normally distributed ($P > 0.10$) for the AIAO gilts. Predicted age to 110 kg was not normally distributed for the CF gilts ($P < 0.02$). Pigs reared under CF management have been previously found to have a greater than expected percentage of slow growing pigs (Patrick et al., 1993).

USE OF A STOCHASTIC MODEL TO OPTIMIZE MARKETING AND BARN CLOSE OUT TIMES

A bio-economic model was developed based on a stochastic growth model (Li et al., 2003a, b, c; Schinckel et al., 2003b), which incorporated the economic optimization principles of livestock replacement, swine growth under limited dietary lysine intake, and growth response to Paylean (Schinckel et al., 2003c). This stochastic model was used to derive the optimal production and marketing decisions for grow-finish swine production.

The objective function of the model was set as maximizing daily return for a 1000-head grow-finish barn managed all-in/ all-out. Model parameters were estimated for modern high lean genetic populations. The return was optimized under 10-year average prices and costs. The optimal management was derived for four payment schemes, simulating producers with various marketing channels and market structures. They were: (1) carcass payment with discounts on underweight and overweight carcasses; (2) carcass merit payment system adopted from Hormel's Carcass Value Program; (3) lean to fat price ratio of 2:1; and (4) lean to fat price ratio of 4:1. The carcass weight discount grid for payment schemes 1, 3 and 4 were also adopted from Hormel's Carcass Value Program. Payment scheme 3 simulated the producers under limited coordination with packers, while payment scheme 4 reflected vertically integrated producers, which capture the full benefit of the increase in carcass value. The model optimized the return for 50-day-old feeder pigs to market.

Pigs were marketed by semi-truck with a capacity of 170 head. Thus, the 1000 pigs were marketed in six truckloads. One or more truckloads can be marketed on the same day. Pigs were marketed when the number of pigs heavier than the sort weight (also a variable to be optimized in the model) exceeded one truckload, except that pigs can be marketed in the last batch regardless of the weights.

It was optimal to market the pigs in three batches under payment schemes 2, 3 and 4, while under payment scheme 1 pigs were marketed as 4 batches (Table 5). The optimal marketing age for the last batches ranged from 162 to 166 days of age, with the earliest age associated with scheme 4. The marketing day for the first batch was in a close range of day 153 to 155 across marketing schemes. For batches other than the last one, the number of pigs to be marketed was 170 head (i.e. one truckload). Thus, there were always multiple truckloads for the last batch.

The optimal return/day/barn ranged from \$230 to \$302 under the assumed average economic conditions (Table 5). Because the SEW gilts are relatively lean, the returns were higher with higher lean to fat price ratios. Numbers of underweight carcasses were calculated to be from 41 to 75 head, with the highest number associated with scheme 4 and lowest number with scheme 1. The numbers of overweight carcasses ranged from 42 to 92 head with the highest number belonging to payment scheme 1 and lowest to scheme 4. The amount of sort loss received were $938, $1327, $774, $929 under payment schemes 1 to 4, respectively.

Table 5. Predicted optimal return and management for SEW gilts with control diets (1000 head/barn).

Payment system	Scheme 1	Scheme 2	Scheme 3	Scheme 4
Return, $/barn-day	230.19	258.45	287.06	301.81
%lysine in diet 1	0.80	0.83	0.82	0.82
%lysine in diet 2	0.74	0.76	0.75	0.75
%lysine in diet 3	0.64	0.67	0.67	0.67
Diet 2 start day	114	115	114	117
Diet 3 start day	128	130	129	131
Marketing age for 1st batch, d	155	153	153	153
Marketing age for 2nd batch, d	161	159	159	159
Marketing age for 3rd batch, d	165	163	164	162
Marketing age for 4th batch, d	166	-	-	-
Avg. slaughter age, day	163.1	160.6	161.3	160.0
Sort weight, lbs	271	268	268	268
Under-weight carcasses, head	41	68	59	75
Sort loss from under-weight, $/barn	299.14	708.24	432.54	600.03
Over-weight carcass, head	92	46	45	42
Sort loss from over-weight, $/barn	638.99	618.73	341.70	328.92

Swine producers often face a fixed schedule for barn closeout, either due to a contracted date for delivering market hogs or the arrival of a new group of feeder pigs. With a fixed schedule, producers have to adjust their management strategies in order to shift the growth rate of the animals and raise the hogs to the packer's desired weight range. The alternative fixed schedule environments were simulated as restricted marketing dates for the last batch of pigs. Fixed schedules investigated here ranged from day 137 to 177, with a step size of 4 days. The optimal return and management of control pigs are displayed in Table 6, where day 164 yielded the highest average daily return. Thus, the restricted marketing days before day 164 were tight schedules and those after were loose schedules. When pigs were marketed at their optimal weight or age, the number of underweight and overweight pigs was both small, close to 7-8%. However, in tight or loose schedules, either the underweight or the overweight pigs were higher than the optimal level. The total amount of sort loss was the least when there was no fixed schedule restriction.

Table 6. Optimal marketing management for fixed schedules (SEW gilts without Paylean and marketed under payment scheme 3; 1,000 head/group).

Fixed schedule day [a]	137	141	145	149	153	157	161	165	169	173	177
Return, $/barn,day	47.05	131.93	178.52	238.58	266.05	279.78	286.43	286.74	282.93	277.95	271.48
Marketing batches	1	1	1	1	1	2	3	4	4	5	5
Sort weight, lbs	-	-	-	-	-	269	269	269	271	271	271
Avg. slaughter wt, lbs	220	228	235	243	251	257	263	268	272	274	276
% underweight carcasses	90.4%	78.0%	62.9%	44.4%	27.8%	16.1%	9.2%	4.5%	2.6%	1.4%	0.7%
% overweight carcasses	0.1%	0.1%	0.5%	1.2%	3.0%	3.2%	3.9%	4.8%	9.7%	10.7%	13.0%
Sort loss due to under-weight carcasses ($/1,000 head)	21,039	14,303	9,302	5,383	2,874	1551	710	342	211	109	59
Sort loss due to over-weight carcasses ($/1,000 head)	10	31	47	101	284	291	319	353	702	720	907

MODELING RACTOPAMINE USE

Nearly 50% of all U.S. grow-finish pigs are now being fed ractopamine (Paylean^{TM}) prior to market. The management of pig production with Paylean was investigated for a group of pigs using a stochastic growth model. This stochastic model was used to derive the optimal production and marketing decisions for grow-finish swine production with Paylean, which include both dietary lysine management and Paylean management (Li et al., 2001 a, b, c). To summarize, the variables to be optimized in the model were dietary lysine concentrations for three diets, the optimal starting days for diets 2 and 3, six optimal marketing days for each truckload, and an optimal sort weight.

The stochastic model indicated that pigs fed Paylean should be marketed at younger ages (5-7 days) than pigs without Paylean, as well as marketed in less batches. The returns were higher for the Paylean-fed pigs than for control pigs (Table 7).

Paylean had higher economic returns under tight marketing schedules than when pigs were marketed under the optimal marketing age or under loose schedules. With extremely tight schedules, the dietary concentration of Paylean should be increased to 13.2 ppm, while with loose schedules, the Paylean concentration should be decreased to 5.0 ppm. Under all fixed environments examined, Paylean fed pigs produced a higher return than control pigs.

MODELING NUTRIENT EXCRETION AS PART OF THE PORK PRODUCTION SYSTEM

Some new technologies provide opportunities for pork producers to mitigate some of the regulatory constraints for application of manure on a limited land base (Prince et al., 2000; Allee et al., 2001; Sutton et al., 2001). The inclusion of phytase in a swine diet greatly reduces the amount of dicalcium phosphate required in the diet and the pig utilizes much of the P that would normally have been excreted. Similarly, the cost of synthetic amino acids has declined, and their availability has increased which is an avenue to reduce N excretion in manure.

Howard (1999) developed a model for whole farm profit maximization. The model allows choice of diet composition, use of phytase, synthetic amino acids, manure disposal as well as crop mix. The model addressed the interactions between manure disposal regulations, pig diet and crop production decisions allowing the farm to mitigate some of the compliance cost while retaining the constraint on availability of resources between crop and livestock production at crucial times of the production cycles.

Yap et al. (2004) further developed the model of Howard to specifically investigate the economic impacts of a phosphorus land application policy. The impact depended primarily on the degree to which the farm was constrained in land suitable for P application, application alternatives, and the use of alternative diets. For example, for a 1500 acre crop farm with capacity to raise 12,000 grow-finish hogs per year, the cost of compliance with the phosphorus policy was as low as $0.56 per pig space but if custom application and alternative diets were not available to the farm the estimated compliance cost was $21.74 per pig space. Phytase diets and diets with synthetic amino acids were optimal under various scenarios in all three (Howard, 1999; Yap et al, 2004 and Echarnier, 2003) studies.

Table 7. Predicted Optimal Return and Management for SEW Gilts with ractopamine (RAC; 1000 head/barn).

Payment system	Scheme 1	Scheme 2	Scheme 3	Scheme 4
Return, $/barn-day	245.60	281.89	314.96	346.65
RAC, g/ton	4.5	5.0	5.9	8.6
%lysine in diet 1	0.77	0.83	0.79	0.82
%lysine in diet 2	0.91	0.97	0.95	1.01
%lysine in diet 3	0.79	0.81	0.79	0.83
Diet 2 and Paylean start day	134	129	128	125
Diet 3 start day	146	144	144	141
Marketing age for 1st batch, d	152	152	152	149
Marketing age for 2nd batch, d	158	157	157	155
Marketing age for 3rd batch, d	160	-	-	-
Sort weight, lbs	271	271	271	266
Avg. slaughter age, day	158.3	156.2	156.2	154.0
Avg. days on RAC	24.3	27.2	28.2	29.0
Days on RAC (last batch)	26	28	29	30
Return over control, $/pig [a]	1.77	2.62	3.12	4.93
Under-weight carcasses, head	45	73	75	98
Sort loss from under-weight, $/barn	355.60	676.55	578.08	1164.42
Over-weight carcass, head	118	104	108	55
Sort loss from over-weight, $/barn	717.28	1291.08	833.74	498.77

[a] Return over control is calculated as the daily return of RAC-treated pigs minus that for control pigs under the same payment scheme, then the difference is multiplied by the number of days on feed for RAC pigs from a feeder pig of 50 days of age.

In recent research (DeCamp, et. al., 2001; Hankins, et al., 2001), pigs fed a 16.1% CP-ractopamine diet (18 g/ton) excreted 14.9% less total N compared to the 13.8% CP diet. A majority of the N reduction was from reduced urinary N excretion. In a 30-d feeding period and 4 less days to market, N excretion would be reduced 206 g per pig marketed. Slurry pH was reduced 0.5 units and ammonia was reduced 8-21% from pigs fed ractopamine. Of the limited research studies completed, ractopamine decreased N excretion, decreased manure output and could result in additional environmental benefits that have not been thoroughly investigated under practical situations (Sutton et al., 2001).

FUTURE OF PIG GROWTH MODELING AND PRODUCTION SYSTEMS ANALYSES

Additional development of models to evaluate the alternatives of manure treatment systems, feeding technologies and management technologies on lean growth requirements of genetic lines of pigs, nutrient excretion, and balance of nutrients in the operation is essential for profitable pork production that is compatible with environmental sustainability. A holistic economic model to determine the critical control points and factors influencing profitability, costs, nutrient flows and pollution potential is needed. This data can be used by producers, technology providers, educators and regulators to implement new technologies and develop effective regulatory policies for sustainable environment and profitable animal agriculture.

CONCLUSIONS

The most profitable production of pigs for the pork processors demand for uniform products requires several items to be evaluated. The current economic objective for pork producers is to maximize daily returns above feed and other variable costs. The management of the pigs including health status and other stressors, the feeding program, the marketing strategy and use of Paylean must all be evaluated. In the future, the costs and benefits of alternative diets, nutrient excretion, alternative manure handling systems and nutrient utilization by plants will also need to be evaluated. Systems analyses of pork production and nutrient excretion which combine pig growth models and economic optimization will be increasingly used by the pork industry.

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