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ONTARIO PORK RESEARCH PROPOSAL FINAL REPORT

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Project Title: A decision support tool to evaluate the impact of between animal variability and alternative management scenarios for growing-finishing pigs on growth and carcass characteristics, profits and nutrient excretion.

PROVIDE THE FOLLOWING INFORMATION IN NON-TECHNICAL LANGUAGE:

Objectives of the Research Proposal:
The aim of the project is to further develop an existing and well-tested pig growth and nutrient utilization model (biological model), and to develop a simple user-friendly decision support system (DSS). These tools can be used for optimizing profits and nutrient use on individual growing-finishing pig units in Ontario, and to make general management recommendations. Special consideration was given to increasing flexibility in representing alternative shipping strategies.

Summary of Research Results:
A well-tested and full-scale, dynamic, biological pig growth model has been expanded to reflect the pig's response to the use of phytase and Paylean™ in the diet, to represent between animal variability within groups of pigs, and to increase flexibility in defining alternative shipping strategies. The model generates and records growth curves, changes in feed intake, carcass composition, phosphorous and nitrogen retention and economic returns (based on up to 3 carcass grading payment grids) for 1000 individual pigs within a group, and allows weekly sorting of market pigs for shipment. The variance and co-variance values for pig type parameters (e.g. lean tissue growth potential and feed intake) that contribute to between animal variability are determined using an automated calibration technique. The trained user of this rather complex, biological model can manipulate ingredients, formulate feeds, design feeding programs (vary the duration and level of feeding), vary level and duration of feeding phytase and Paylean®, alter pig growth performance potentials, define alternative carcass grading schemes and shipping strategies, set economic parameters, and run the model to assess dynamically their financial and environmental impacts for individual growing-finishing pig unit. A simplified version of the model was developed to function as a decision support system (DSS). The DSS serves as an interface to an extensive data base of previously defined alternative management scenarios. The user can enter situation-specific costs, prices and carcass grading systems, and use the DSS to identify which of the previously defined management scenarios maximizes gross margin per pig or gross margin per pig place per year.

A decision support tool to evaluate the impact of between animal variability and alternative management scenarios for growing-finishing pigs on growth and carcass characteristics, profits and nutrient excretion

Detailed description of research activities, results and implications

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INTRODUCTION AND OBJECTIVES

To assess the financial and environmental impacts of alternative management sccenarios for growing-finishing pigs, interactive effects of feeding schemes, use of Paylean^R, pig lean growth potentials, maintenance energy requirements, carcass grading schemes, pork price and variable costs must be examined integratively. By expanding the scope of an existing biology-based pig growth and nutrient utilization model to account for use of Paylean^R and phytase in the feed, between-pig variability, and alternative shipping strategies, a systems approach can be used to optimize nutrient use and profits for individual growing-finishing pig units in Ontario in which the aforementioned aspects of managing growing-finishing pigs are considered.

The aim of this project was produce two versions of a biology-based dynamic pig growth model that can be used to asses the financial and environmental impact of alternative management scenarios for individual growing-finishing pig units: (1) a rather complex full-scale biology-based stochastic model (biological model), and (2) a simplified and very user-friendly decision support system (DSS). Trained users can use the biological model to optimize management scenarios for individual growing-finishing pigs units, to demonstrate principles of nutrient utilization for growth in the pig and to conduct what-if type analyses. The DSS allows untrained model users to evaluate the financial and environmental impacts of a large number of alternative and previously defined management scenarios.

APPROACH, RESULTS AND DISCUSSION

I. Growth Model Interface

A well-tested and full-scale, dynamic, biological pig growth model (Birkett and de Lange, 2001a,b,c; de lange et al., 2001) has been expanded to reflect the pig's response to the use phytase and Paylean^{TM} in the diet (Schinckel et al., 2003a,b; de Lange et al., 2006), to represent between animal variability within groups of pigs, and to increase flexibility to define alternative shipping strategies for optimizing carcass value and thus profits.

The model, with a 1 day iteration interval, is used to represent utilization of intake of digestible energy (**DE**), protein, fat, non-starch polysaccharides (fiber) and 7 essential amino acids for growth in protein (**PD**) and lipid (**LD**), with water and ash modeled as functions of PD. Based on cumulative PD and LD, live body weight (**BW**) gain, carcass characteristics and efficiencies of nutrient utilization are predicted (Birkett and de Lange, 2001a,b,c. de Lange et al., 2001, 2006).

The trained user of this rather complex, full-scale model can manipulate ingredients, formulate feeds, design feeding programs (vary the duration and level of feeding), vary level and duration of feeding Paylean[R], alter pig growth performance potentials, define alternative carcass grading schemes and shipping strategies, set economic parameters, and run the model to assess dynamically their financial and environmental impacts for individual growing-finishing pig units (e.g. Moughan et al., 1995; Birkett and de Lange, 2001a,b,c; de Lange et al., 2003, 2006).

For the assessment of alternative shipping strategies, growth performance, carcass characteristics, and carcass value (for three different carcass grading grids) of 1000 individual pigs in a group is estimated and stored in a data base, as described in detail in the next section. Various sorting strategies can then be applied for weekly shipping of pigs. For each weekly shipping of pigs a different grading grid may be used. The model than generates estimates of mean and variability in growth rate, carcass weight, carcass lean yield, carcass value, gross margin per pig and gross margin per pig place per year.

Blue-prints to obtain relevant model inputs for individual pig units have been established and documented (de Lange et al., 2001). Financial performance is calculated based on feed usage, and predicted growth rate, carcass evaluation, and fixed and variable production costs. Estimates of environmental impacts include excretion of nitrogen, phosphorus, and methane (de Lange et al., 2006).

II. Modeling Stochasticity

Sub-routines have been added to the full-scale model to account for between pig variability with respect to key pig type growth parameters that control nutrient utilization and growth performance: (i) the maximum rate of whole body protein deposition (**PDmax,** g/d), (ii) body weight at which PDmax starts to decline (**PDdecl**, kg;), (iii) the minimum body fatness (**minLP**; MJ ME $^{-1}$; linearly related to daily ME intake), and (iv) daily feed intake **(ΔADFI,** kg/d; expressed as the deviation from a reference daily feed intake curve according to NRC, 1998).

PDmax is closely associated with lean tissue growth potential. Up to PDdecl, PDmax is constant, thereafter maximum PD declines as represented by a Gompertz function. MinLP is closely associated with the minimum ratio of body fat tissue deposition and body lean tissue deposition and determines lean tissue growth during the energy dependent phase of lean tissue growth.

For these parameters we have estimated variability and co-variability based on previous experiments conducted at Ridgetown College using the feed intake recording equipment (FIRE) system. The FIRE system allows monitoring of feed intake and BW gain of individual pigs housed in groups. Data were obtained from an experiment that involved pigs from the main terminal sire lines in Ontario and that were fed non-limiting diets (Mandel et al., 2006). Aforementioned individual pig type parameters distribution was determined as a sum of the parameter mean and a product of a normal random deviate and the factors of the Cholesky decomposition of the pig type parameter (co)variance matrix, estimated using an automated inverted modeling technique (vanderVoort and de Lange, 2005). The automated inverted modeling technique involved fitting observed feed intake and growth curves to feed intake and growth curves generated using the model - by varying the aforementioned pig type parameters - and minimizing the difference between observed and model predicted growth curves for each individual pig. Resulting estimates of variability (standard deviation, **SD**; diagonal) and correlations (off-diagonal) are listed in Table 1.

Table 1. Distribution of pig type parameter components with variable standard deviation on the diagonal and correlations on the off-diagonal.

	PDdmax	**PDddecl**	**minL/P**	**∆ADFI**
PDdmax(g/d)	7.62	0.1	-0.54	0.35
PDddecl(kg)		16.27	-0.07	-0.01
minL/P (MJ ME^{-1})			0.002	-0.25
∆ADFI(kg/d)				0.17

As an ***example*** to illustrate the effectiveness of the stochastic program, a population of 1000 pigs was simulated utilizing (co)variance values presented in Table 1. Average values for the PDmax , PDdecl, minL/P and ∆ADFI were 140 g/d, 80 kg , 0.039 MJ ME $^{-1}$, and 0 kg/d beyond NRC intake level, respectively. Diet DE content was 14.25 MJ/kg fed at a level of 85% of NRC, with Paylean® fed at 5mg/kg feed starting at 85 kg BW and at an average cost of 212 $/ton. Weaner pig (25 kg BW) costs were set at $55 along with variable cost of $15/pig. Base price for carcass was assumed to be $1.40/kg. One of the three marketing schemes included shipping all pigs on the 107th day of the growth phase (Marketing Scheme 1), compared to starting to ship pigs when 50% of the pigs exceeded 110 kg BW and ship all pigs heavier than 110 kg, and ship subsequent weeks pigs that are 110 kg or heavier, with a minimum shipping batch size of 50 pigs (Marketing Scheme 2). The payment grid used for the two marketing schemes was the standard Ontario 1997 grid. Minimum BW at shipping of 110 kg and at day 107 were chosen since on this day and BW economic returns per pig were maximized for the mean pig type parameters listed above. The Marketing Sscheme 2 was repeated using 108 kg as the BW criteria determining shipping strategy (marketing Scheme 3).

Table 2a shows the output report generated for two marketing schemes with an minimum BW at shipping of 110 kg for Marketing Scheme 2. Marketing Scheme 2 shipping batch sizes were 533, 419 and 48 pigs in week 1, 2 and 3, respectively. Marketing Scheme 2 resulted in lower overall SD for both economic and two carcass variables (carcass weight and index) as shown in Table 2a. Gross margins per pig ($/pig**)** and per pig place ($/pig place/year) were $1.17 and $3.97 lower respectively, with higher SD for Marketing Scheme 1 compared to overall returns for Marketing Scheme 2. Compared to Market Scheme 1 carcass index SD was reduced from 9.5 to 6.5, and carcass weight SD was reduced from 3.06 to 1.9 kg.

Table 2a. Impact of shipping strategy[a] on mean and variation (SD) in aspects of pig growth performance and profitability.

	Marketing Scheme 1[a]		**Marketing Scheme 2[a]**							
	All		Group 1 [b]		Group 2 [b]		Group 3 [b]		Overall	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BW(kg)	*112.75*	*3.36*	112.6	1.84	114.2	1.61	112.2	4.3	113.26	2.0
Day	*107*		104		111		118		107	4.1
ADG	*902*	*69*	951.68	37.8	864.9	59	681	97	902	83
F:G	*3.1*	*0.25*	2.92	0.11	3.2	0.23	4.15	0.55	3.1	0.34
$/pig	*9.18*	*9.93*	15.38	5.3	5.2	5.52	-0.6	8.1	10.35	7.8
$/pig place	*27.68*	*29.96*	47.58	16.4	15.14	16.22	-1.7	22.39	31.65	24
Yield	*60.33*	*0.47*	60.75	0.23	59.97	0.23	58.56	0.8	60.32	0.61
Index	*99.76*	*9.52*	103.43	5.55	96.7	5.6	97.11	0.88	100.32	6.5
Cwt(kg)	*92.4*	*3.06*	92.2	1.68	93.8	1.40	92.2	3.8	92.88	1.9
Pdmax	*140*	*7.6*	145.03	5.4	134.5	4.6	131	8.3	140	7.5
PDdecl	*79.6*	*16.3*	84.6	13.3	76.28	16.0	52	15.5	79.6	16.3
minLd/Pd	*0.04*	*0.002*	0.04	0.001	0.04	0.001	0.04	0.001	0.04	0.002
ΔADFI (kg/d)	*0.00*	*0.17*	0.03	0.17	-0.02	0.17	-0.05	0.15	0.00	0.17

[a] Marketing Scheme 1: ship all pig at day 107; Market Scheme 2: start marketing when 50% reach 110 kg BW or greater, ship subsequently at weekly intervals pigs with a BW greater than 110 kg, with a minimum shipping batch size of 50 pigs.
[b] Group 1, 2 and 3 sizes were 533, 419, 48.

Table 2b shows the output report generated for two marketing schemes when the minimum shipping BW was reduced to 108 kg for Marketing Scheme 3. Marketing Scheme 3 shipping batch sizes were 555, 407 and 38 pigs in weeks 1, 2, and 3, respectively. Reduction in the minimum shipping BW resulted in a reduction in size of

Group 2 and Group 3 and concurrent increase size of Group 1. When the minimum shipping BW was reduced to 108 kg, Marketing Scheme 3 again resulted in a similar pattern and magnitude of lower overall SD for both economic and two carcass variables (carcass weight and index) compared to Marketing Scheme 1, as shown in Table 2b. However, gross margins per pig ($/pig**)** and per pig place ($/pig place/year) were now $6.65 and $21.17 lower, respectively, with higher SD for Marketing Scheme 1 compared to Marketing Scheme 3. Therefore, as shown by comparing Tables 2a and 2b, reducing target minimum BW at shipping to 108 kg resulted in an increase $5.48/pig and $17.20/pig place/year.

Table 2b. Impact of shipping strategy[a] on mean and variation (SD) in aspects of pig growth performance and profitability.

	Marketing Scheme 1[a]		**Marketing Scheme 3[a]**							
	All		Group 1 [b]		Group 2 [b]		Group 3 [b]		Overall	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BW(kg)	*112.75*	*3.36*	110.6	1.8	112.3	1.61	110.1	4.3	111.26	2.1
Day	*107*		102		109		116		105	4.1
ADG	*902*	*69*	958.1	37.5	871.3	59	667.5	87	911	81
F:G	*3.1*	*0.25*	2.89	0.11	3.2	0.23	4.2	0.52	3.1	0.34
$/pig	*9.18*	*9.93*	19.09	2.08	12.44	2.07	4.45	9.2	15.83	4.8
$/pig place	*27.68*	*29.96*	60.1	6.5	36.9	6.1	12.49	25.9	48.85	15.6
Yield	*60.33*	*0.47*	60.77	0.24	60	0.23	58.53	0.8	60.37	0.59
Index	*99.76*	*9.52*	107.5	3.0	103.3	3.1	102.2	5.9	105.57	3.8
Cwt(kg)	*92.4*	*3.06*	90.3	1.68	92	1.48	90.2	3.8	91	1.9
Pdmax	*140*	*7.6*	144.9	5.4	134.1	4.6	132	8.2	140	7.5
PDdecl	*79.6*	*16.3*	84.2	13.3	76.28	16.0	49	14	79.6	16.3
minLd/Pd	*0.04*	*0.002*	0.04	0.001	0.04	0.001	0.04	0.001	0.04	0.002
ΔADFI (kg/d)	*0.00*	*0.17*	0.03	0.17	-0.03	0.17	-0.03	0.14	0.00	0.17

[a] Marketing Scheme 1: ship all pig at day 107; Market Scheme 3: start marketing when 50% reach 108 kg BW or greater, ship subsequently at weekly intervals pigs with a BW greater than 108 kg, with a minimum shipping batch size of 50 pigs.
[b] Group 1, 2 and 3 sizes were 555, 407, 38 pigs.

Increases in gross margins for Marketing Scheme 3 with a minimum shipping BW of 108 kg (Table 2b) when compared with a minimum shipping BW of 110 kg (Marketing Scheme 2, Table 2ab) are due directly to the reduction in mean carcass weight with a concurrent reduction in carcass index SD and increase in mean carcass index, in particular in Groups 2 and Group 3. Marketing Scheme 3 at BW end-point of 108 kg is the preferable marketing strategy for this group of 1000 pigs. Market Scheme 1 illustrates the high cost of not sorting pigs when carcass value is derived using the 1997 Ontario grading scheme.

This demonstrates the program's suitability for answering "what-if" questions regarding changes in feeding program, pig types, cost inputs and shipping strategy.

III. Decision Support System

The development of a simple and user-friendly decision support system for management of growing-finishing pigs has been completed (PorkMaster DSS).

The computer program has three modules:

1) Analyses of current performance, allowing the generating of feed intake and growth curves from feed intake and BW observations on a sub-sample of representative pigs, and the calculation of average lean growth rate, feed costs per pig, gross margin per pig and gross margin per pig place per year. This is essentially an updated version of the previously produced PorkMaster program.

2) Evaluation of the financial and environmental impact of a large number of previously defined management scenarios. To define management scenarios, the user can choose any combination of alternative predetermined values for:

- (a) initial body weight (i.e. 24 or 28 kg),
- (b) operational lean tissue growth potentials (i.e. 130, 150 or 170 g/d protein deposition, representing unimproved, medium and high, respectively),
- (c) final body weight (i.e. 110, 114, 118 or 122 kg),
- (d) diets in each of 2 or 3 phases (i.e. up to four different diets for phase I and II, and 10 diets for phase III; diets can vary in levels of energy, ideal protein, Paylean^{TM} and added phytase), and
- (e) feeding levels within each of 2 or three phases (i.e. 75, 85 or 95% of NRC, representing low, medium and high feeding levels, respectively).

By combining the previously generated estimates of pig growth performance, carcass quality and nutrient utilization efficiency (using the full-sale model) for each of these scenarios with 'economic' parameters the financial (gross margin per pig or gross margin per pig place per year) and environmental impacts of each alternative management scenarios can be estimated. The 'economic' parameters are:

- (f) alternative carcass grading schemes (schemes can be altered and stored in a separate data base),
- (g) estimates of variability in carcass weight and carcass lean yield (these can be obtained from the full-scaly stochastic and dynamic pig growth model),
- (h) estimates of feed wastage and mortality,
- (i) open days on pig places between lots of pigs
- (j) costs of each of the diets,
- (k) weaner pig price and variable cost per pig, and
- (l) pork price,

The users of this simple DSS will require minimal training and can identify the ‘best’ management scenario for individual pig units among the thousands of alternative management scenarios that are stored in the data base. For example, this routine can be used to determine what management scenario best fits each of the main pig types at different pork prices and carcass grading schemes, to demonstrate the value of reducing variability in carcass weight for the different carcass grading schemes and pork prices, or to assess the value of Paylean^{TM} in the finisher diets. This simple program also allows simple ‘what-if’ analyses, by monitoring the response to changes in values for one or more aspects of management scenarios (parameters (a) to (l)). Up to four different scenarios can be stored in a summary report that can be saved as a pdf file. ***A sample results report is presented in the appendix, illustrating the importance of controlling variation in carcass weights, improving lean tissue growth potentials, and the interactive effects of pork prices and optimum management strategies.***

3) Simulation of user-defined management strategies. This is module provides access to a simplified version of dynamic based dynamic pig growth model. This model is not stochastic – it represents the average pig in a group - and uses only one carcass grading scheme for each model run. However, the model user can directly define all aspects of management scenarios that are listed in the previous section, and is no longer bound by the predetermined values that are stored in the data base of management scenarios. Obviously, more expertise is required to properly estimate the value for each of the model inputs and to characterize diet compositions.

Detailed results can be analyzed and presented in graphic forms. Up to four different scenarios can be stored in a summary report that can be saved as a pdf file, that is similar in layout to the summery reports generated using the second module (evaluation of previously defined management scenarios).

CONCLUSIONS AND IMPLICATIONS

A well-tested and full-scale, dynamic, biological pig growth model has been expanded to reflect the pig’s response to the use of phytase and Paylean^{TM} in the diet, to represent between animal variability within groups of pigs, and to increase flexibility in defining alternative shipping strategies. The model generates and records growth curves, changes in feed intake, carcass composition, phosphorous and nitrogen retention and economic returns (based on up to 3 carcass grading payment grids) for 1000 individual pigs within a group, and allows weekly sorting of market pigs for shipment. The variance and co-variance values for pig type parameters (e.g. lean tissue growth potential and feed intake) that contribute to between animal variability are determined using an automated calibration technique. The trained user of this rather complex, biological model can manipulate ingredients, formulate feeds, design feeding programs (vary the duration and level of feeding), vary level and duration of feeding phytase and Paylean^{R}, alter pig growth performance potentials, define alternative carcass grading schemes and shipping strategies, set economic parameters, and run the model to assess dynamically their financial and environmental impacts for individual growing-finishing pig unit. A simplified version of the model was developed to function as a decision support system

(DSS). The DSS serves as an interface to an extensive data base of previously defined alternative management scenarios. The user can enter situation-specific costs, prices and carcass grading systems, and use the DSS to identify which of the previously defined management scenarios maximizes gross margin per pig or margin per pig place per year.

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Appendix 1. Example summary report of the decision support system demonstrating the interactive effects of the pig's operational lean tissue growth potential, diet composition and variability in carcass traits on gross margins*.

PorkMaster

Management Strategies Report

November 9, 2007

John Farmer

Ontario

Strategy nr		1	2	3	4
Scenario		CANADA ALTERNATIVES	CANADA ALTERNATIVES	CANADA ALTERNATIVES	CANADA ALTERNATIVES
		Base	Carc Wt sd 2.5	Lean growth HIGH	Price 1.50
Initial body weight (kg)		24	24	24	24
Final body weight (kg)		110.5	110.5	110.9	114.3
Oper. lean tissue growth potential (g/d)		150	150	170	170
Carcass grading scheme		ONTARIO	ONTARIO	ONTARIO	ONTARIO
Average daily gain (g/day)		840	840	878	894
Feed conversion ratio (kg feed/kg gain)		2.66	2.66	2.53	2.53
		Carcass Lean Yield (%)	Carcass Lean Yield (%)	Carcass Lean Yield (%)	Carcass Lean Yield (%)
		60.6	60.6	61.4	61.5
Feeding program - details					
Number of phases		3	3	3	3
Diet switches at (kg):	1	55	55	55	55
	2	90	90	90	90
	3	110	110	110	114
Diet names:	1	Lys_0.8%	Lys_0.8%	Lys_0.8%	Lys_0.9%
	2	Lys_0.7%	Lys_0.7%	Lys_0.75%	Lys_0.75%
	3	Lys_0.6%	Lys_0.6%	Lys_0.7%	Lys_0.7%
Feed intake levels (% of NRC):	1	85	85	85	85
	2	85	85	85	85
	3	85	85	85	85
Feed budget (kg/pig; incl. waste):	1	72	72	70	67
	2	95	95	89	92
	3	63	63	60	70
	Total:	230	230	220	228
Value of average carcass ($/pig)		109.03	109.03	109.17	152.7
Carcass value ($/pig)		105.57	107.67	108.54	150.93
Average carcass weight (kg/pig)		88.5	88.5	88.61	91.71
Feed cost ($/pig)		52.56	52.56	51.22	53.88
Cost N disposal ($/pig)		0	0	0	0
Cost P disposal ($/pig)		0	0	0	0
Margin ($/pig)		-7.52	-5.42	-3.21	36.52
Margin ($/pigplace/year)		-23.47	-16.9	-10.37	115.9

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economic data				
Weaner pig price ($/pig)	45	45	45	45
Variable cost ($/pig)	15	15	15	15
Porkprice ($/kg)	1.1	1.1	1.1	1.5
Feed wastage (%)	5	5	5	5
Mortality (%)	1	1	1	1
Variation in carcass yield (sd, kg)	5	2.5	2.5	2.5
variation in lean yield (sd, %)	2	2	2	2
Correlation between carcass weight and lean yield	-0.4	-0.4	-0.4	-0.4
Open days	14	14	14	14

Diet prices ($/ton)	
System Lys_1.1%	272.5
System Lys_1.0%	260.9
System Lys_0.9%	249.6
System Lys_0.8%	237.7
System Lys_0.75%	232.75
System Lys_0.7%	227.8
System Lys_0.65%	223.25
System Lys_0.6%	218.7
System Lys_PL_0.9%	1263.6
System Lys_PL_0.85%	1257.7
System Lys_PL_0.75%	1246.75
System Lys_PL_0.70%	1241.8
System Lys_0.5%	214
System Lys_PL_0.65%	1236.85

* The program was used to choose the 'best' final BW weight and diet lysine levels to maximize profit per pig. Initial BW, BW at which diets were switched and feeding level for each of the three phases were kept constant across the various strategies. Prices of the Paylean^{R} containing diets (PL) have been increased artificially to avoid the use of these diets.

Interpretation:

- The value of reducing variability in carcass weight at shipping is illustrated bv comparing strategy 1 versus 2.

- The value of increasing the animals lean tissue growth potential – through breeding strategies or improve health management - is illustrated bv comparing strategy 2 versus 3.

- The interactive effect of pork price and feeding strategy on margins are illustrated by comparing strategy 3 versus 4. This shows that at poor pork prices the optimum shipping weight should be reduced and that diet protein levels should be reduced in the phase 1 diet.