Development of Models to Describe the Weekly Response of Ractopamine, When Constant or Variable Dietary Levels of Paylean® are Fed

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Most previous trials have evaluated the response of Paylean® (ractopamine) when constant levels of 4.5 to 18 g/ton were fed for the last 90 lbs of live weight gain. Recently, a trial was conducted to determine whether the response to Paylean could be enhanced or maintained if fed at increasing or decreasing levels compared to pigs fed a similar constant level throughout the finishing stage (Herr et al., 2001).

Experimental Procedures

Data from the Paylean trial of Herr et al. (2001) was used for this analysis. Eighty barrows and 80 gilts were assigned into 32 pens (5 pigs/pen) to four dietary treatments. The dietary treatments were:

1. Control diet containing no Paylean;
2. Step-down diet sequence: 18 g/ton Paylean weeks one and two, 9 g/ton Paylean weeks three and four, and 4.5 g/ton Paylean weeks five and six;
3. Step-up diet sequence: 4.5 g/ton Paylean weeks one and two, 9 g/ton Paylean weeks three and four; and 18 g/ton Paylean weeks five and six;
4. Constant diet containing 10.5 g/ton Paylean.

Gilts were fed a 19.6% CP diet with a 2.9% lysine level while barrows were fed an 18.5% CP diet with a 1.1% lysine level. Pigs were weighed and feed intakes were recorded weekly for the six-week period to determine average daily gain (ADG) and daily feed intake (DFI), from which feed efficiency (gain:feed, G:F) was calculated.

The three Paylean treatments resulted in a substantial variability in weekly growth performance for ADG, DFI, and G:F. The objectives of this research were to model the response of Paylean to (1) describe the response in terms of variables related to underlying biological changes; (2) model the response of alternative Paylean feeding strategies; and (3) provide predicted performance for systems operations research and subsequent economic analyses.

Statistical Analyses

Two approaches were taken to model the weekly response to Paylean. The first method was to subtract the weekly performance of the control pigs of the same sex from the performance of each pen of pigs fed Paylean. This created a dataset with 144 weekly pen mean observations for the Paylean response of ADG, G:F, and DFI. The second approach was to use the growth performance data for all four treatments (192 weekly pen means) in prediction equations which included the fixed effects of sex and week with additional variables to describe the Paylean response.

Regression models included independent variables from three sets of variables: (1) variables to account for the Paylean level (ppm) for that specific week, (2) variables that account for changes in the level of Paylean fed each week, and (3) variables to describe the duration of Paylean feeding.

To describe the current Paylean level, two alternative approaches were taken. The first based on previous analyses was the Paylean level (ppm) to the .5 power (square root). The second approach was to include the linear and quadratic effects of the current Paylean level. Numerous variables were used to account for the changes in the weekly levels of Paylean fed. The initial variables were the current weekly level of Paylean fed minus the level of Paylean (ppm) one, two, or three weeks prior. Based on preliminary correlation and regression analyses, the current Paylean level minus the mean level of Paylean fed two and three weeks prior was elevated as an independent variable. As a final step, separate variables were created in cases where the current level was greater than the prior level (positive values) and less than the prior level (negative levels). Separate negative and positive values were included if the regression coefficients for the positive (step-up) and negative (step-down) were significantly different from each other ($P < .10$) and both significant ($P < .10$) based on their partial sums of squares.

Variables were included to account for the decreased response to Paylean with increased duration of Paylean feeding. These variables included: (1) the cumulative weight gain since initiation of Paylean feeding, (2) the days on test from the initiation of Paylean feeding, (3) the cumulative grams of Paylean fed, which is in actuality the cumulative product of the weekly feed intake times the concentration of Paylean fed, (4) the cumulative product of the weekly Paylean level fed times the weekly weight gain, and (5) the cumulative product of the Paylean level fed times the days on test.

The values assigned weekly to each pen of Paylean pigs were cumulative mid-week values, that is the average of the values at the beginning and end of the week (Table 1). For days of Paylean, the values are identical for all pigs fed Paylean; 3.5 days for week one and 10.5 for week two. The other variables such as cumulative weight gain, Paylean or grams of Paylean intake are specific for each pen.

Regression equations were initially evaluated based on R^2 and RSD. Non-significant variables based on partial sums of squares were deleted ($P > .10$). Equations were further evaluated based on the magnitude of the partial sum of squares for the effect of week in the prediction of the actual performance data. The lower the partial sums of squares due to week overall, the better the prediction equation accounted for the changes in Paylean response with duration of feeding.

Further evaluation was conducted by fitting the residual values of the Paylean fed pigs (144 pen week observations) to a model including the effects treatment, week and treatment by week. The equations with the smallest residual sums of squares in such a model would be expected to best describe the changes in the Paylean response. The two best overall equations for ADG, DFI, and G:F Paylean response and actual data were evaluated for their ability to account for the treatment by week variation, magnitude, and type of prediction biases. The predicted and actual mean values, for either the weekly Paylean response or weekly actual and predicted performance values of the three Paylean treatments were compared. The correlation of predicted and actual treatment means (C_R) and variance ratio of the predicted treatment weekly means were calculated.

The portion of the total sums of the total Paylean treatment by week sum of squares accounted by the model was calculated by the equation: $1 - (SS_A / SS_R)$ where SS_R is the remaining residual sums of squares accounted by treatment, week and treatment by week interactions and SS_A are the sums of squares of the actual values accounted by the treatment by week model.

Results

The variables included in the best overall two prediction equations for the Paylean response for ADG, DFI, and G:F are shown in Table 2. The prediction equations for the actual Paylean treatment means also included the fixed effects of sex and week. Five of the six models included the current Paylean level to the .5 power (square root). All models included variables that related the current Paylean level to levels fed three weeks prior or both two and three weeks prior. In four equations, the regression coefficients for the positive and negative values were significantly different such that separate regression coefficients were predicted. This indicates that the impact of increasing or decreasing Paylean levels differ in the absolute magnitude of change in Paylean response.

All equations included have one or two variables that account for the duration of Paylean feeding. The most common variables were the linear or linear-quadratic effects of cumulative weight gain on Paylean or cumulative grams of Paylean intake. The predicted and actual values for the Paylean treatment by week means and the prediction equation summary statistics are presented in Table 3. The best individual prediction equations accounted for 83.9, 61.8 and 82.8% of the sum of squares due to treatment, week and treatment by week effects for ADG, DFI, and G:F. The equations were less precise in predicting the weekly Paylean treatment response for DFI than either G:F or ADG based on the C_R and V_R statistics. The lower V_R for DFI indicated the below average DFI week means were over predicted and above the average means were under predicted. Feed efficiency and ADG had similar C_R values (.896 to .916) however, a greater portion of the true variation of the weekly Paylean treatment means could be accounted for G:F (V_R = .94) than ADG (V_R = .82).

The actual and predicted performance levels for the weekly Paylean treatment means are presented in Table 4. Overall, the summary statistics (C_R and V_R) are higher for the prediction of the actual values than the Paylean response variables (Table 3). There are two reasons for this result. First, the Paylean response was estimated as the weekly Paylean treatment mean minus the sex-week mean for the control pigs (N = 4 pens of 5 pigs). There are two sources of sampling variance in such an estimate, the sampling variance of the specific Paylean treatment by week mean and the sampling variance of the weekly sex mean of the control pigs. This method of accounting for the weekly performance of the control pigs adds additional variation to the estimate of the Paylean response. Second, the model for the actual performance of the weekly Paylean treatment means included the effects of sex and week simultaneously estimated with the continuous variables. The effects of sex and week were estimated using the data from the control pigs and the Paylean fed pigs.

The prediction equations for ADG and G:F accounted for a greater portion of the Paylean treatment by week variation for ADG and G:F than DFI. The variance ratio values greater than unity for DFI (V_R = 1.1) indicated that the predicted Paylean treatment means are more variable than the actual means. With C_R values of approximately .92, this is only possible if some above average weekly Paylean treatment ADFI means are over predicted and below average means under predicted. The summary statistics of ADG and G:F approach unity indicating that the performance of Paylean fed pigs can be modeled from information on the independent variables used in the prediction equations. However, it should be noted that these are within sample analyses. Also, it is likely that an inability to account for the Paylean response in respect to the duration of Paylean feeding were taken into account by the week effect. For this reason, these statistics produced by these equations are the "upper bound" values of the precise in which the weekly Paylean response can be estimated in future pig trials, even if precise estimates of weekly control pig performance is available.

Summary

The results of this research indicates that independent variables from three sets of variables which (1) describe the current Paylean level, (2) contrast current versus prior levels, and (3) duration of Paylean response are needed to account for the Paylean response when Paylean values are changed (step-up or step-down). The Paylean response for DFI could not be predicted as precisely as the Paylean response for ADG and G:F. These models allow the prediction of daily Paylean response for alternative management strategies. Additional research should be completed on alternative Paylean step-up programs with a series of treatments that will allow for further refinement of Paylean response models.

Table 1. Examples of independent variables in step-up program (lb)[a]

Variables	Definition	Week 1	2	3	4	5	6
Initial Wt.,(lb)	Weekly initial weight	168.81	188.49	211.99	228.20	245.20	258.91
Ending Wt.,(lb)	Weekly ending weight	188.49	211.99	228.20	245.20	258.91	267.20
ADG,(lb/d)	Average daily gain	2.82	3.35	2.31	2.43	1.96	1.19
ADFI,(lb/d)	Average daily feed intake	5.51	7.34	6.70	6.39	6.24	5.89
Gain:Feed	Average daily gain / daily feed intake	0.51	0.46	0.35	0.38	0.31	0.20
Paylean Level	Current weekly Paylean level (ppm)	4.96	4.96	9.92	9.92	19.84	19.84
Paylean-2	Current Paylean level minus the level fed 2 weeks prior, (ppm)	4.96	4.96	4.96	4.96	9.92	9.92
Paylean-3	Current Paylean level minus the level fed 3 weeks prior, (ppm)	4.96	4.96	9.92	4.96	14.88	9.92
PLM23	Current Paylean level minus mean level fed 2 and 3 weeks prior, (ppm)	4.96	4.96	7.44	4.96	12.40	9.92
PLPM23	Positive PLM23 values when Paylean is stepped up, (ppm)	4.96	4.96	7.44	4.96	12.40	9.92
PLNM23	Negative PLM23 values, when Paylean is stepped down	0	0	0	0	0	0
$(PL)^2$	Current Paylean level (ppm) squared	24.61	24.61	98.42	98.42	393.68	393.68
$(PL)^{.5}$	Square root of current Paylean level (ppm)	2.23	2.23	3.15	3.15	4.45	4.45
PLBWT	Paylean level times weight gain for the week (ppm * lb)	97.64	116.55	160.73	168.61	271.03	164.44
APLBWT	Cumulative product of the weekly weight gain times the Paylean level (ppm * lb)	97.64	215.52	376.26	544.87	816.70	981.06
AMPLBWT	Cumulative midweek (mean of initial and ending week values (lb * ppm) for APLBWT	48.81	156.70	295.88	460.58	680.78	1031.15
WTGPAY	Cumulative midweek weight gain on Paylean (lb)	9.85	31.44	51.30	67.90	83.25	94.25
$WTGNPAY^2$	Cumulative weight gain on $Paylean^2$, g	97.11	988.31	2631.85	4610.73	6929.98	8882.61
PLINTAKE	Paylean Intake,(g)	0.086	0.115	0.212	0.201	0.393	0.371
APLI	Cumulative Paylean intake, g	0.086	0.202	0.414	0.615	1.008	1.379
AMPLI	Cumulative midweek Paylean intake, g	0.043	0.144	0.308	0.514	0.811	1.199
$(APLGI)^2$	Cumulative midweek $Paylean\ intake^2$, g	0.002	0.021	0.095	0.265	0.058	1.424

[a]Example is for a pen on the step-up treatment

Table 2. List of independent variables in the prediction equations [a]

Dependent	Model	Independent Variable
ADG	1	Current Paylean level minus the mean levels fed two and three weeks prior (positive values); current Paylean level minus the mean levels fed two and three weeks prior (negative values), weight gain on Paylean, weight gain on Paylean squared.
ADG	2	Current Paylean level to the .5 power, current Paylean level minus the mean level fed two and three weeks prior, weight gain on Paylean, weight gain on Paylean squared.
ADFI	3	Current Paylean level to the .5 power, current Paylean level minus the level fed three weeks prior (positive values), current Paylean level minus the level fed three weeks prior (negative values), cumulative product of Paylean level times weight gain, cumulative product of Paylean level times weight gain squared.
ADFI	4	Current Paylean level to the .5 power, current Paylean level minus the level fed three weeks prior (positive values), current Paylean level minus the level fed three weeks prior (negative values), cumulative grams of Paylean intake, cumulative grams of Paylean fed squared.
G:F	5	Current Paylean level square root, current Paylean level minus the mean level fed two and three weeks prior (positive values), Paylean level minus the mean level fed two and three weeks prior (negative values), cumulative grams of Paylean intake.
G:F	6	Current Paylean level square root, current Paylean level minus the mean of the levels fed two and three weeks prior (positive valued), cumulative grams of Paylean intake.

[a]Prediction equations for actual performance also included the fixed effects of week and sex

Table 3. Weekly actual and predicted Paylean response mean values

		Average daily gain, lb/d			Daily feed intake, lb/d			Gain:Feed		
		Actual	Predicted		Actual	Predicted		Actual	Predicted	
Treatment	Week		Model 1	Model 2		Model 3	Model 4		Model 5	Model 6
2	1	.56	.47	.56	-.10	-.15	-.18	.096	.116	.115
2	2	.60	.59	.65	-.22	-.19	-.22	.100	.074	.075
2	3	.28	.22	.19	-.07	-.04	-.12	.042	.044	.045
2	4	-.14	.00	-.17	-.75	-1.14	-1.21	.041	.030	.024
2	5	-.28	-.17	-.18	-1.03	-.81	-.75	-.032	-.018	-.021
2	6	-.22	-.18	-.13	-.13	-.03	-.04	-.028	-.032	-.031
3	1	.34	.43	.33	-.03	.06	-.08	.081	.089	.090
3	2	.39	.45	.43	-.44	-.18	-.15	.089	.078	.080
3	3	.39	.35	.41	-.35	-.34	-.32	.083	.089	.088
3	4	.25	.33	.27	-.83	-.77	-.74	.098	.074	.074
3	5	.21	.07	.23	-.91	-.53	-.52	.050	.069	.069
3	6	.21	.11	-.01	-.76	-.56	-.47	.048	.034	.034
4	1	.44	.59	.42	.11	-.20	-.23	.099	.107	.107
4	2	.49	.54	.52	.34	-.37	-.33	.099	.082	.083
4	3	.36	.28	.34	.08	-.34	-.32	.036	.071	.071
4	4	.17	.17	.09	-.67	-1.07	-1.11	.065	.059	.059
4	5	.04	-.19	-.03	-1.05	-.84	-.87	.013	.034	.035
4	6	-.12	.01	-.17	-.69	-.57	-.53	.028	.010	.012
C_R[b]			.916	.896		.793	.753		.910	.912
V_R[b]			.829	.823		.809	.819		.943	.945
Portion of SS[b]			.839	.809		.618	.544		.827	.828

[a]Treatment 2 (step-down) = 18 g/ton - weeks one and two; 9 g/ton - weeks three and four; and 4.5 g/ton - weeks five and six. Treatment 3 (step-up) = 4.5 g/ton - weeks one and two; 9 g/ton - weeks three and four; and 18 g/ton - weeks five and six. Treatment 4 (constant level) = 10.5 g/ton - weeks one through six

[b]C_R = correlation of the actual and predicted treatment by week means (N = 18); V_R = the ratio of the variance of the predicted treatment by week means/variance of the actual treatment by week means; Portion of SS = the portion of total sum of squares due to treatment, week and treatment by week effects accounted for by the prediction equation

Table 4. Actual and predicted week growth performance value for Paylean

		Average daily gain, lb/d			Daily feed intake, lb/d			Gain:Feed		
		Actual	Predicted		Actual	Predicted		Actual	Predicted	
Treatment	Week		Model 1	Model 2		Model 3	Model 4		Model 5	Model 6
2	1	2.90	2.99	3.00	5.38	5.47	5.45	.541	.554	.553
2	2	2.69	2.73	2.75	6.68	6.73	6.71	.403	.390	.393
2	3	2.17	2.20	2.13	6.28	6.45	6.39	.354	.344	.348
2	4	2.08	1.99	2.00	6.15	6.10	6.06	.340	.346	.334
2	5	1.36	1.42	1.48	6.04	6.11	6.15	.229	.225	.217
2	6	1.55	1.59	1.66	6.54	6.46	6.40	.241	.235	.234
3	1	2.86	2.78	2.75	5.45	5.35	5.32	.526	.521	.519
3	2	2.55	2.51	2.50	6.46	6.46	6.45	.394	.395	.391
3	3	2.31	2.32	2.36	6.02	6.01	6.02	.394	.390	.385
3	4	2.41	2.41	2.44	6.07	6.19	6.23	.397	.379	.381
3	5	1.89	1.90	1.92	6.17	6.32	6.33	.311	.318	.321
3	6	1.85	1.79	1.79	5.91	6.03	6.16	.315	.313	.316
4	1	3.02	2.89	2.86	5.60	5.34	5.31	.544	.544	.541
4	2	2.64	2.62	2.62	6.56	6.45	6.47	.404	.400	.399
4	3	2.24	2.29	2.29	6.43	6.10	6.16	.348	.371	.371
4	4	2.25	2.32	2.27	6.23	6.07	6.08	.364	.368	.374
4	5	1.62	1.72	1.65	6.02	6.06	6.07	.274	.282	.288
4	6	1.74	1.68	1.62	5.98	6.06	6.06	.295	.288	.292
C_R[b]			.991	.986		.924	.918	.	.994	.993
V_R[b]			1.00	.999		1.098	1.110		1.016	.995
Portion of ss[b]			.980	.971		.838	.823		.988	.987

[a]Treatment 2 (step-down) = 18 g/ton - weeks one and two; 9 g/ton - weeks three and four; and 4.5 g/ton - weeks five and six. Treatment 3 (step-up) = 4.5 g/ton - weeks one and two; 9 g/ton -weeks three and four; and 18 g/ton - weeks five and six. Treatment 4 (constant level) = 10.5 g/ton - weeks one through six

[b]C_R = correlation of the actual and predicted treatment by week means; V_R = the ratio of the variance of the predicted treatment by week means/variance of the actual treatment by week means; Portion of SS = the portion of total sum of squares due to treatment, week and treatment by week effects accounted for by the prediction equation