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Regression Analysis to Predict the Impact of High Neutral Detergent Fiber Ingredients on Carcass Yield

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Abstract

Research has shown that carcass yield is reduced when feeding distillers dried grains with solubles (DDGS) or other high fiber ingredients. Considering the financial implications of changing carcass yield, the objective of this project was to develop regression equations to accurately estimate carcass yield from dietary NDF withdrawal strategies. Data from 8 trials originating from 5 journal articles, 2 theses, and 1 technical memo were used to develop a regression equation to predict carcass yield. The regression analysis showed that number of days in the withdrawal period (WP), NDF level in the dietary phase prior to the final phase (NDF1), NDF level in the last dietary phase before marketing (NDF2), and the interaction between NDF2 and WP (NDF2 × WP), were the most important variables in the dataset to predict carcass yield. The resulting regression equation: carcass yield, % = $0.03492 \times \text{WP (d)} - 0.05092 \times \text{NDF1 (\%)} - 0.06897 \times \text{NDF2 (\%)} - 0.00289 (\text{NDF2 (\%)} \times \text{WP (d)}) + 76.0769$ may be used to predict the influence of dietary NDF and NDF withdrawal strategy on carcass yield.

Keywords

neutral detergent fiber, carcass yield, mixed models, regression equations

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Regression Analysis to Predict the Impact of High Neutral Detergent Fiber Ingredients on Carcass Yield¹

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Summary

Research has shown that carcass yield is reduced when feeding distillers dried grains with solubles (DDGS) or other high fiber ingredients. Considering the financial implications of changing carcass yield, the objective of this project was to develop regression equations to accurately estimate carcass yield from dietary NDF withdrawal strategies. Data from 8 trials originating from 5 journal articles, 2 theses, and 1 technical memo were used to develop a regression equation to predict carcass yield. The regression analysis showed that number of days in the withdrawal period (WP), NDF level in the dietary phase prior to the final phase (NDF1), NDF level in the last dietary phase before marketing (NDF2), and the interaction between NDF2 and WP (NDF2 × WP), were the most important variables in the dataset to predict carcass yield. The resulting regression equation: carcass yield, % = $0.03492 \times \text{WP (d)} - 0.05092 \times \text{NDF1 (\%)} - 0.06897 \times \text{NDF2 (\%)} - 0.00289 (\text{NDF2 (\%)} \times \text{WP (d)}) + 76.0769$ may be used to predict the influence of dietary NDF and NDF withdrawal strategy on carcass yield.

Introduction

Multiple studies have investigated the impact of high fiber ingredients on swine growth and carcass characteristics. Reports have indicated that up to 30% distillers dried grains with solubles (DDGS) can be fed without compromising growth performance.^{4,5,6} However, research has also shown that carcass yield is reduced when DDGS or other

¹ The authors thank PIC North America (Hendersonville, TN) for technical and financial support.

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⁴ DeDecker, J. M., M. Ellis, B. F. Wolter, J. Spencer, D. M. Webel, C. R. Bertelsen, and B. A. Peterson. 2005. Effects of dietary level of distiller's dried grains with solubles and fat on the growth performance of growing pigs. *J. Anim. Sci.* 83(Suppl. 2):79. (Abstr.).

⁵ Stein, H. H. and G. C. Shurson. 2009. Board-invited review: The use and application of distillers dried grains with solubles in swine diets. *J. Anim. Sci.* 87:1292-1303.

⁶ Jacela, J. Y., J. M. Benz, S. S. Dritz, M. D. Tokach, J. M. DeRouchey, R. D. Goodband, J. L. Nelssen, and K. J. Prusa. 2009. Effect of dried distillers grains with solubles withdrawal regimens on finishing pig performance and carcass characteristics. In: *Proc. Swine Day, Stn. Rep. Prog.* 1020, Manhattan, KS. p. 181-191.

ingredients containing high concentrations of dietary NDF are fed.⁷ The high NDF levels increase weight of intestinal contents at harvest.^{8,9} One successful strategy to ameliorate the negative effects on carcass yield is withdrawing high NDF ingredients before harvest. Research has reported that pigs transitioned from a high NDF diet to a corn-soybean meal diet before harvest had similar carcass yield compared with pigs fed a corn-soybean meal diet during the entire finishing phase.^{10,11,12} Taking into consideration the financial implications of improving carcass yield, the objective of this project was to develop prediction equations to accurately estimate the change in carcass yield from dietary NDF and NDF withdrawal strategies.

Procedures

A literature review was conducted to compile studies that examined the effects of high insoluble fiber ingredients and withdrawal strategies on carcass yield. The literature search was conducted via the Kansas State University Libraries, using the CABI search engine and the keywords “neutral detergent fiber,” “withdrawal strategies,” and “growing-finishing pigs.” Data were derived from both refereed and non-refereed publications, including theses, technical memos, and university publications. The final database resulted in publications from 2007 to 2015.

Selection for Inclusion and Exclusion Criteria

In order to be included in the final database, experiments had to meet the following criteria: 1) pigs used in experiments had ad libitum access to feed and water; 2) the percentage of dietary ingredients fed throughout the experiment was adequately defined; 3) the experiments withdrew high NDF ingredients, including control treatments; and 4) the experiments provided information including duration of the feeding period, initial BW, final BW, ADG, ADFI, G:F, NDF from the last 2 dietary phases, duration of withdrawal period and carcass yield. The initial search yielded 8 publications. One paper was eliminated from the analysis because a control treatment was not used. The final database resulted in 7 papers and 8 different studies with a total of 43 treatment observations (Table 1).

⁷ Linneen, S. K., J. M. DeRouchey, S. S. Dritz, R. D. Goodband, M. D. Tokach, and J. L. Nelssen. 2008. Effects of dried distiller grains with solubles on growing and finishing pig performance in a commercial environment. *J. Anim. Sci.* 86:1579–1587.

⁸ Turlington, W. H. 1984. Interactive effects of dietary fiber levels and environmental temperature on growing pigs. MS Thesis. University of Kentucky, Lexington.

⁹ Anugwa, F. O. I., V. H. Varel, J. S. Dickson, W. G. Pond, and L. P. Krook. 1989. Effects of dietary fiber and protein concentration on growth, feed efficiency, visceral organ weights, and large intestine microbial populations of swine. *J. Nutr.* 119:879–866.

¹⁰ Asmus, M. D., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, T. A. Houser, J. L. Nelssen, and R. D. Goodband. 2014. Effects of lowering dietary fiber before marketing on finishing pig growth performance, carcass characteristics, carcass fat quality, and intestinal weights. *J. Anim. Sci.* 92:119–128.

¹¹ Graham, A. B., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, and S. Nitikanchana. 2014. The interactive effects of high-fat, high-fiber diets and ractopamine HCl on finishing pig growth performance, carcass characteristics, and carcass fat quality. *J. Anim. Sci.* 92:4585–4597.

¹² Coble, K. F. 2015. Influence of dietary fiber and copper on growth performance and carcass characteristics of finishing pigs and utilizing linear programming to determine pig flow. PhD diss., Kansas State University, Manhattan, KS.

Diet Composition Calculations

Treatment diets of each trial were reformulated using a spreadsheet-based software program (Kansas State University Diet Formulation Program V.8.1) to obtain dietary nutrient content with the NRC¹³ ingredient library. Compositions of experimental diets were used to calculate percentage NDF in the last two dietary phases and NE (kcal/lb) concentrations on an as-fed basis and were recorded in the template for each dietary treatment.

Statistical Analysis

The PROC GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) was used to develop regression equations to predict carcass yield for finishing pigs. The method of restricted maximum likelihood was used in the model selection to evaluate significance of fixed effect terms. The model was determined using a step wise selection procedure starting with manual forward selection through individual predictor variables, with a statistical significance at $P < 0.05$ used to determine inclusion of terms in the model. Throughout the selection process, studentized residuals plots were observed to determine if quadratic or interaction terms needed to be tested in the model. Residual plots were also used to investigate outliers. For development of the statistical model, study was included as a random effect according to procedures suggested by St-Pierre.¹⁴ In addition, observations were weighted across studies according to the within-study pooled standard error. To determine the weighting, the standard error of each mean was inverted and squared, and subsequently divided by the original standard error to express the results on the same scale as the original data. Lastly, the WEIGHT statement in SAS provided a weight for each of these transformed values. Thus, observations with a smaller standard error were weighted more heavily.

Results and Discussion

Prediction Equation for Carcass Yield

The regression analysis revealed that the number of days in the withdrawal period (WP), NDF level in the dietary phase before the final phase (NDF1), NDF level in the withdrawal period before marketing (NDF2), and the interaction between NDF2 and WP (NDF2 \times WP) were significant variables in the dataset to explain changes in carcass yield (Table 2).

As expected, high levels of NDF had a negative impact on carcass yield. Increasing the length of the withdrawal period improved carcass yield; however, the effect of withdrawal period was dependent on the level of NDF2, as indicated by the interaction term. According to Turlington,⁸ the reduction in carcass yield from feeding high-fiber ingredients results from an increase in the weight of intestinal contents in colon and cecum. The increase in gut fill is a result of the type of fiber in the ingredient. Neutral detergent fiber has been shown to cause the digestive contents to swell in the large intestine by absorbing water, thus increasing the fecal volume in the large intestine.¹²

¹³ NRC. 2012. Nutrient Requirements of Swine. 11th ed. Natl. Acad. Press, Washington, DC.

¹⁴ St-Pierre, N. R. 2001. Integrating quantitative findings from multiple studies using mixed model methodology. J. Dairy Sci. 84:741–755.

Application of Prediction Equations

An example using this equation is presented in Figure 1. In the simulation, pigs were fed with moderate and high NDF1 diets (16 and 21% NDF; equivalent to 35 and 50% DDGS, respectively), and then transitioned to diets with either 9 or 13% NDF during the last dietary phase (NDF2) and fed anywhere from 5 to 40 d before marketing. Predicted carcass yield when pigs were fed a corn-soybean meal (9% NDF) diet during both dietary phases was 75.0%. There is an estimated yield decrease of 0.84 and 1.44% when NDF was 16 and 21% during the last two dietary phases, respectively.

Partial carcass yield recovery is apparent when pigs are fed a 16 or 21% NDF diet and transitioned to a 9% NDF diet, depending on the length of the withdrawal period. However, the model predicted that yield is not continually improved when the diet in the last phase contains 13% NDF. In this situation, the entire benefit is found in the first 5 days of feeding the 13% NDF diet with no further improvement thereafter. The minimal withdrawal period where pigs were switched to a different diet was 5 days in the experiments used to develop the equation. Consequently, the equation should not be used to predict withdrawal times of less than 5 days.

In summary, fiber withdrawal strategies appear to recover carcass yield with the magnitude depending on the NDF level of the last two dietary phases, as well as the fiber withdrawal length.

Table 1. Summary of papers used in the regression analysis to predict carcass yield in finishing pigs

First author, year	Source ¹	NDF1, ² %	NDF2, ³ %	WP, ⁴ d	Initial BW, kg	Final BW, kg	Carcass yield, %
Asmus, ⁵ 2014	J	8.79 - 20.18	8.82 - 20.21	0 - 47	41.0	120.6 - 122.8	71.6 - 73.2
Coble, ⁶ 2015 (exp. 1)	T	8.79 - 20.18	8.82 - 20.20	0-20	38.4	124.6 - 126.0	71.2 - 72.7
Coble, ⁶ 2015 (exp. 2)	T	8.76 - 20.17	8.79 - 20.29	0-24	44.5	128.3 - 132.5	74.3 - 75.4
Gaines, ⁷ 2007	J	8.72 - 15.25	8.75 - 15.28	0-42	66.1	126.9 - 128.5	75.9 - 77.1
Graham, ⁸ 2014	J	8.79 - 20.18	8.83 - 20.20	0-24	55.8	122.9 - 126.8	72.8 - 74.2
Jacela, ⁹ 2009	M	8.53 - 15.00	8.43 - 14.90	0-41	39.0	118.6 - 121.5	75.1 - 75.9
Nemecheck, ¹⁰ 2013	J	8.79 - 20.18	8.82 - 20.20	0-17	49.6	127.5 - 129.0	74.7 - 75.1
Xu, ¹¹ 2010	J	8.76 - 15.26	8.82 - 15.31	0-63	30.0	121.0 - 125.0	75.8 - 77.0

¹ Source type: J = journal, T = thesis, M = technical memo.

² Range of NDF concentration in dietary phase before the final phase.

³ Range of NDF concentration in final dietary phase before marketing.

⁴ Range of withdrawal period.

⁵ Asmus, M. D., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, T. A. Houser, J. L. Nelssen, and R. D. Goodband. 2014. Effects of lowering dietary fiber before marketing on finishing pig growth performance, carcass characteristics, carcass fat quality, and intestinal weights. *J. Anim. Sci.* 92:119-128.

⁶ Coble, K. F. 2015. Influence of dietary fiber and copper on growth performance and carcass characteristics of finishing pigs and utilizing linear programming to determine pig flow. PhD diss., Kansas State University, Manhattan, KS.

⁷ Gaines, A. M., J. D. Spencer, G. I Petersen, and N. R. Augspurger. 2007. Effect of corn distiller's dried grains with solubles (DDGS) withdrawal program on growth performance and carcass yield in grow-finish pigs. *J. Anim. Sci.* 85 (Suppl. 1):438. (Abstr.).

⁸ Graham, A. B., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, and S. Nitikanchna. 2014. The interactive effects of high-fat, high-fiber diets and ractopamine HCl on finishing pig growth performance, carcass characteristics, and carcass fat quality. *J. Anim. Sci.* 92:4585-4597.

⁹ Jacela, J. Y., J. M. Benz, S. S. Dritz, M. D. Tokach, J. M. DeRouchey, R. D. Goodband, J. L. Nelssen, and K. J. Prusa. 2009. Effect of dried distillers grains with solubles withdrawal regimens on finishing pig performance and carcass characteristics. In: *Proc. Swine Day, Stn. Rep. Prog.* 1020, Manhattan, KS. p. 181-191.

¹⁰ Nemecheck, J. E., M. D. Tokach, J. M. DeRouchey, S. S. Dritz, R. D. Goodband, and J. L. Nelssen. 2013. Effects of diet form and fiber level before marketing on growth performance, carcass yield, and iodine value of finishing pigs. *J. Anim. Sci.* 91 (Suppl. 2):24. (Abstr.).

¹¹ Xu, G., S. K. Baidoo, L. J. Johnston, D. Bibus, J. E. Cannon, and G. C. Shurson. 2010. The effects of feeding diets containing corn distillers dried grains with solubles, and withdrawal period of distillers dried grains with solubles, on growth performance and pork quality in grower-finisher pigs. *J. Anim. Sci.* 88:1388-1397.

Table 2. Regression equation to predict carcass yield from dietary NDF and withdrawal strategies¹

$$\text{Yield, \%} = 0.03492 \times \text{WP (d)} - 0.05092 \times \text{NDF1 (\%)} - 0.06897 \times \text{NDF2 (\%)} - 0.00289 \times (\text{NDF2 (\%)} \times \text{WP (d)}) + 76.0769$$

¹ Data from 8 trials were used as a database for the statistical analysis to develop the model.

NDF1 (%) = NDF concentration in dietary phase before final dietary phase.

NDF2 (%) = NDF concentration in final dietary phase before marketing.

WP (d) = withdrawal period.

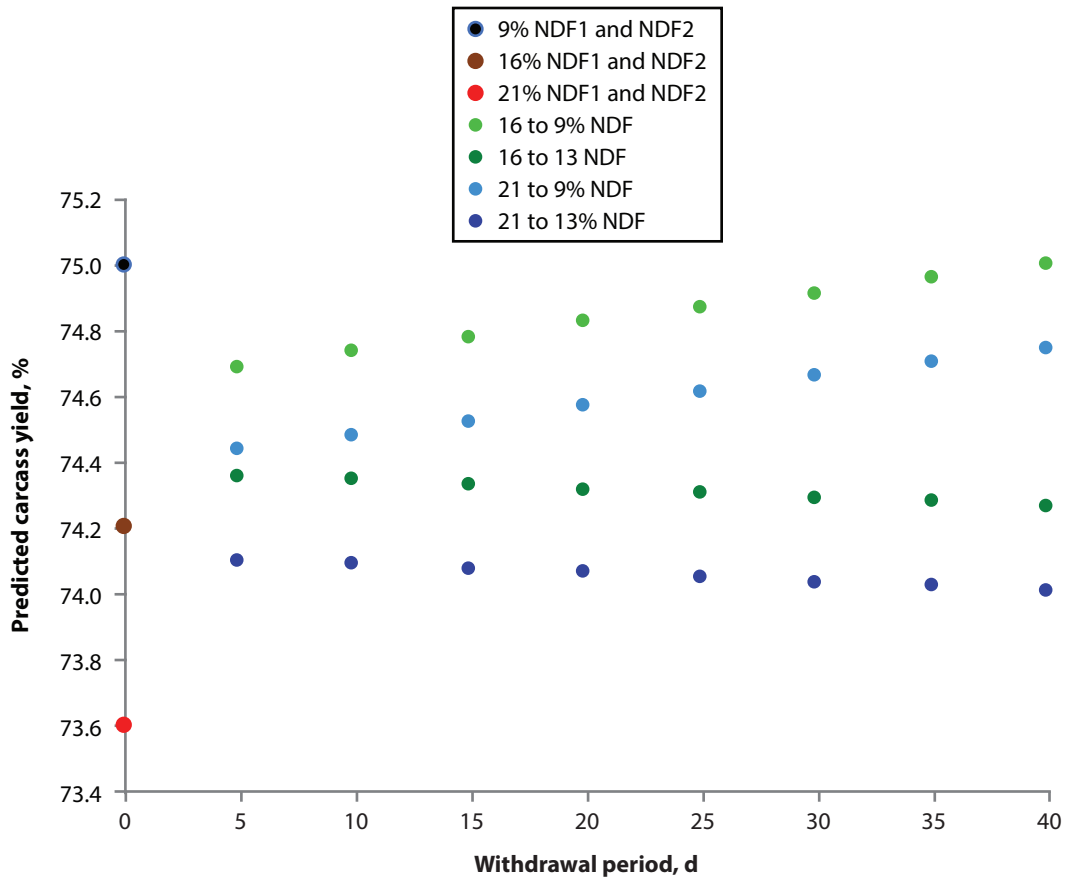


Figure 1. Predicted carcass yield of pigs fed varying NDF levels (9, 16, or 21%) in the last dietary phase before marketing (NDF2), and for pigs transitioned from a 21 or 16% NDF diet (NDF1) to a 9 or 13% NDF diet (NDF2).