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Effects of Thermo-Mechanically Processed Soybean Meal on Nursery Pig Growth and Fecal Characteristics

Jessica L. Smallfield, Jason C. Woodworth, Joel M. DeRouchey, Mike D. Tokach, Robert D. Goodband, Katelyn N. Gaffield, Jordan T. Gebhardt,[1] Alan J. Warner,[2] Chad W. Hastad,[2] Sabrina T. May,[3] Wesley P. Schweer,[3] and Chad M. Pilcher[3]

Summary

A total of 1,254 mixed-sex pigs (PIC 800 × [Fast York A × PIC L02]; initially 12.4 ± 0.22 lb) were used in a 28-d study to evaluate the effects of thermo-mechanically processed soybean meal (TM-SBM; Provisoy; Cargill; Wayzata, Minnesota) on nursery pig growth and fecal characteristics. Pens of pigs were randomly allotted to one of five dietary treatments in a randomized complete block design with body weight (BW) and nursery entry date as blocking factors. There were 18 to 20 pigs per pen and 12 pens per treatment. The experimental diets were corn-soybean meal-based with increasing TM-SBM replacing soybean meal on a standardized ileal digestible (SID) Lys basis in the diet (0, 25, 50, 75, and 100% in phase 1 and 0, 12.5, 25, 37.5, and 50% in phase 2). Treatment diets were fed in two phases from d 0 to 7 (phase 1) and d 7 to 21 (phase 2) followed by a common diet from d 21 to 28 (phase 3). At the end of phases 1 and 2 (d 7 and 21), fecal samples were collected from three randomly selected pigs in each pen to determine fecal dry matter (DM). Fecal scoring was also conducted on collected fecal material using a 0 to 4 scoring system, with 0 indicating firm feces and 4 indicating diarrhea. From d 0 to 21 (experimental period), ADG and ADFI increased then decreased (quadratic, $P \leq 0.038$) with the best performance observed when TM-SBM replaced 25 to 50% of the SBM in phase 1 and 12.5 to 25% in phase 2. Moreover, feed efficiency improved (quadratic, $P = 0.036$) with TM-SBM replacing 50 and 25% of the SBM in phases 1 and 2, respectively, but worsened thereafter. No differences were observed for ADG, ADFI, and feed efficiency during the common period (d 21 to 28). Overall (d 0 to 28), ADG and ADFI tended to increase then decrease (quadratic, $P \leq 0.089$) with the best performance observed when TM-SBM replaced 25% of the SBM in phase 1 and 12.5% in phase 2. For fecal DM, a treatment × day interaction was observed (quadratic, $P = 0.024$) indicating that the response to added TM-SBM differed across days. On d 7, the greatest increase in fecal DM occurred when TM-SBM replaced 25% of the SBM SID Lys (quadratic, $P = 0.004$) but decreased with 50% replacement of SBM SID Lys and then remained relatively stable. There were no fecal DM treatment

[1] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.
[2] New Fashion Pork, Jackson, MN.
[3] Cargill Animal Nutrition, Wayzata, MN.

differences observed on d 21. In summary, increasing TM-SBM to replace up to 25 to 50% of the SID Lys of SBM in phase 1 and 12.5 to 25% in phase 2 resulted in improved growth performance throughout the experimental period. Fecal DM on d 7 was greatest when 25% of the SID Lys of SBM was replaced with TM-SBM in phase 1. Higher inclusions of TM-SBM above 50% of the SID Lys of SBM in phase 1 and 25% in phase 2 were associated with decreased ADG and worsened feed efficiency.

Introduction

Weaned pigs often face digestive challenges, such as diarrhea, as they adjust from sow's milk to a plant-based diet. This dietary change can increase the risk of morbidity and mortality. Soybean meal is the most economical source of protein for pigs, but the complex carbohydrates (stachyose, raffinose) and storage proteins (glycinin, and beta-conglycinin) can cause hypersensitivity and impact growth performance in nursery pigs. Thus, soybean meal levels need to be limited in diets fed immediately after weaning. Instead, a portion of the soybean meal can be replaced with other specialty protein sources, such as fish meal, spray-dried animal plasma, or further refined specialty soy products. However, specialty soy products can vary in nutrient profile, amounts of complex carbohydrates, and palatability. Most of these factors can be measured in the laboratory; however, palatability and actual feed intake response must be measured in growth studies.

Provisoy is a specialty soy protein product created by thermo-mechanically processing soybean meal in the presence of steam. Through further processing, Provisoy has lower anti-nutritional factors, such as trypsin inhibitors, than conventional soybean meal, without removing oligosaccharides. In previous studies conducted by the supplier, Provisoy has been shown to support gut health[4] and improve protein digestibility.[5] However, more data are needed to demonstrate the effects of Provisoy on nursery pig performance in commercial research barns where pigs are fed diets typically used in the United States. Therefore, the objective of this study was to evaluate the effects of increasing TM-SBM on nursery pig growth and fecal characteristics in a commercial environment.

Materials and Methods

General

The protocol used in this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. This study was conducted at the New Fashion Pork research wean-to-finish facility in Jackson, MN. The facility consisted of two rooms with a total of 62 pens. The facility was completely enclosed, environmentally regulated, and mechanically ventilated. Each pen contained a three-hole, dry self-feeder and a bowl waterer for *ad libitum* access to feed and water.

[4] Hu, Q., M. I. Sardi, S. A. Naqvi, L. Hackenhaar, P. Pluk, J. de Laat, M. D. Newcomb, E. Khafipour. 2023. Effects of different soy protein sources on gut microbiome composition and relationship with performance in pigs in regular nursery and F4 enterotoxigenic *Escherichia coli* (ETEC) challenged conditions. J. Anim. Sci. 101(Suppl. S3):312. (Abstr.).

[5] Hu, Q., L. Hackenhaar, N. Paton, J. de Laat, M. D. Newcomb. 2023. Effect of protein source on piglet performance and dietary protein digestibility in regular nursery and *Escherichia coli* challenged conditions. J. Anim. Sci. 101(Suppl. S2):101. (Abstr.).

Animals and diets

A total of 1,254 mixed-sex pigs (PIC 800 × [Fast York A × PIC L02]; initially 12.4 ± 0.22 lb) were used in a 28-d growth study. Pens of pigs were randomly allotted to one of five dietary treatments in a randomized complete block design with BW and nursery entry date as blocking factors. There were 18 to 20 pigs per pen and 12 pens per treatment. The experimental diets were corn-soybean meal-based with increasing TM-SBM replacing SBM on a standardized ileal digestible (SID) Lys basis in the diet (0, 25, 50, 75, and 100% in phase 1 and 0, 12.5, 25, 37.5, and 50% in phase 2; Table 1). All diets were formulated to the same SID Lys level and were similar in energy content with SBM net energy considered to be 100% of corn net energy. The same amount of L-Lys HCl was used in each diet within phase, but additions of other feed-grade AA were adjusted to equalize Met and Cys, Thr, Trp, and Val concentrations relative to Lys in all diets. Nutrient loading values for TM-SBM were provided by the supplier and values for the other ingredients were obtained from the NRC (2012). Treatment diets were fed in two phases with a feed budget of 6 lb per pig for phase 1 (d 0 to 7) and 10 lb for phase 2 (d 7 to 21) followed by a common diet from d 21 to 28 (phase 3). All diets were fed in meal form and were manufactured at the New Vision Co-op (Worthington, Minnesota).

Measurements and sampling

Pig weights and feed disappearance were measured on d 0, 7, 14, 21, and 28 to determine ADG, ADFI, and F/G. Fecal samples were collected on d 7 and 21 at the end of each phase from three randomly selected pigs per pen to determine percentage dry matter. Samples were dried at 131°F (55°C) in a forced-air oven for 48 h, and the ratio of dried-to-wet fecal weight determined the fecal dry matter. Fecal samples were analyzed separately for each pig and the average of the three samples from each pen was then used for statistical analysis. Fecal scores were also conducted on collected fecal material using a 5-point scoring system, with 0 indicating hard, pellet-like lumps and 4 indicating diarrhea.

Statistical Analysis

Data were analyzed as a randomized complete block design as a one-way ANOVA using the lmer function from the lme4 package in R Studio (Version 3.5.2, R Core Team. Vienna, Austria) with pen serving as the experimental unit, dietary treatment as a fixed effect, and weight block as a random intercept. Linear and quadratic contrasts were used to test for increasing levels of TM-SBM. Fecal DM samples were analyzed using the fixed effects of day, treatment, and the associated interactions accounting for repeated measures over time. Fecal scores were summarized using the FREQ procedure of SAS OnDemand for Academics (SAS Institute, Inc., Cary, NC) and reported as a percentage of observations within each score category by treatment. Fecal score data were analyzed using the GLIMMIX procedure of SAS. When treatment was a significant source of variation, differences were determined by pairwise comparison using the Tukey-Kramer multiplicity adjustment to control for Type I error. Results were considered significant with $P \leq 0.05$ and were considered marginally significant with $P \leq 0.10$.

Results and Discussion

Growth performance

From d 0 to 7 (phase 1), ADG, ADFI, and d 7 BW increased (quadratic, $P \leq 0.003$) with increasing TM-SBM up to 50% of the SBM replacement and decreased thereafter

(Table 2). Additionally, feed efficiency improved (quadratic, $P < 0.001$) as TM-SBM replacement of SBM increased up to 75% and worsened at 100% replacement of SBM.

From d 7 to 21 (phase 2), ADG decreased (linear, $P = 0.029$) and feed efficiency tended to worsen (linear, $P = 0.072$) with increasing TM-SBM. Day 21 BW increased then decreased (quadratic, $P = 0.020$) with increasing TM-SBM, which was a result of pigs being the heaviest when 25 to 50% of SBM was replaced in phase 1 and 12.5 to 25% replacement in phase 2.

From d 0 to 21 (experimental period), ADG and ADFI increased then decreased (quadratic, $P \leq 0.038$) with the greatest gain and feed intake observed when TM-SBM replaced 25 to 50% of the SBM in phase 1 and 12.5 to 25% in phase 2. Additionally, feed efficiency improved (quadratic, $P = 0.036$) when TM-SBM replaced up to 50% of SBM in phase 1 and 25% in phase 2.

From d 21 to 28 (common period), no significant differences were observed in ADG, ADFI, or feed efficiency. Overall (d 0 to 28), ADG and ADFI tended to increase up to the treatment with 25 and 12.5% SBM replacement in phases 1 and 2, respectively, with performance decreasing (quadratic, $P \leq 0.089$) with further replacement of SBM.

Fecal dry matter analysis and scoring

A significant treatment × day interaction was observed for fecal DM (quadratic, $P = 0.024$) driven by a treatment effect on d 7 but no treatment differences observed on d 21. On d 7, fecal DM increased as TM-SBM increased from 0 to 25% replacement of SBM (quadratic, $P = 0.004$), but then decreased at the 50% replacement level and remaining relatively consistent thereafter.

A treatment × day interaction was observed for fecal scoring (quadratic, $P = 0.017$) driven by a treatment effect on d 7 (quadratic, $P < 0.001$) with the greatest reduction in diarrhea incidence occurring when pigs were fed diets with TM-SBM replacing 25% of the SBM (Figure 1). No treatment difference in fecal score was observed on d 21.

Removals and mortality

Overall, there were no observed treatment differences in mortality; however, the percentage of removals, as well as the combined total of removals and mortality, decreased (linear, $P \leq 0.014$) as the inclusion of TM-SBM increased from d 0 to 21.

In summary, incorporating TM-SBM in diets for the first 21 d post-weaning to replace a portion of the SID Lys provided from SBM (25 to 50% in phase 1 and 12.5 to 25% in phase 2) resulted in improved growth performance. Higher additions of TM-SBM were associated with poorer growth performance. Additionally, TM-SBM inclusion at 25% of SBM SID Lys resulted in fewer incidences of diarrhea and higher fecal DM at d 7 post-weaning. The highest level of TM-SBM decreased the total removals and mortalities.

Acknowledgments

Appreciation is expressed to New Fashion Pork (Jackson, MN) for providing the nursery facility and Cargill Animal Nutrition for partial financial support of this trial.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Diet composition (as-fed basis)[1]

	Phase 1					Phase 2					Phase 3
TM-SBM replacement of SBM, %[2]:	**0**	**25**	**50**	**75**	**100**	**0**	**12.5**	**25**	**37.5**	**50**	**Common**
Ingredient, %											
Corn	51.27	51.70	52.09	52.49	52.88	57.80	58.02	58.25	58.48	58.71	65.56
Soybean meal (47% CP)	24.58	18.40	12.22	6.04	---	27.24	23.82	20.40	16.97	13.55	30.43
Thermo-mechanically processed SBM[2]	---	5.79	11.58	17.36	23.02	---	3.21	6.41	9.62	12.82	---
Spray-dried whey	16.65	16.65	16.65	16.65	16.65	10.00	10.00	10.00	10.00	10.00	---
Bovine blood plasma	2.00	2.00	2.00	2.00	2.00	---	---	---	---	---	---
Choice white grease	2.00	2.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	---
Calcium carbonate	0.45	0.45	0.44	0.43	0.43	0.69	0.68	0.68	0.67	0.66	0.68
Monocalcium P (21% P)	0.93	0.90	0.89	0.87	0.85	0.92	0.92	0.90	0.89	0.88	1.00
Salt	0.40	0.40	0.41	0.42	0.43	0.55	0.56	0.56	0.57	0.57	0.60
L-Lys-HCl	0.38	0.38	0.38	0.38	0.38	0.50	0.50	0.50	0.50	0.50	0.50
DL-Met	0.20	0.21	0.21	0.22	0.22	0.22	0.22	0.23	0.23	0.23	0.28
L-Thr	0.18	0.18	0.18	0.19	0.19	0.24	0.24	0.24	0.24	0.24	0.25
L-Trp	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.05
L-Val	0.10	0.09	0.09	0.08	0.07	0.15	0.15	0.14	0.13	0.13	0.20
L-Ile	---	---	---	---	---	---	---	---	---	---	0.03
Zinc oxide	0.40	0.40	0.40	0.40	0.40	0.26	0.26	0.26	0.26	0.26	---
Vitamin premix with phytase[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Choline chloride	0.05	0.05	0.05	0.05	0.05	---	---	---	---	---	---
Total	100	100	100	100	100	100	100	100	100	100	100

continued

Table 1. Diet composition (as-fed basis)[1]

	Phase 1					Phase 2					Phase 3
TM-SBM replacement of SBM, %[2]:	**0**	**25**	**50**	**75**	**100**	**0**	**12.5**	**25**	**37.5**	**50**	**Common**
Calculated analysis											
SID AA, %											
Lys, %	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.25
Ile:Lys	56	57	58	58	59	55	55	55	56	56	55
Leu:Lys	117	117	118	118	119	112	112	113	113	113	111
Met:Lys	36	36	36	36	36	37	37	37	37	37	40
Met and Cys:Lys	59	59	59	59	59	58	58	58	58	58	58
Thr:Lys	65	65	65	65	65	65	65	65	65	65	66
Trp:Lys	20	20	20	20	20	20	20	20	20	20	20.0
Val:Lys	70	70	70	70	70	70	70	70	70	70	73
His:Lys	36	35	35	35	34	35	34	34	34	34	33
NE, kcal/lb	1,160	1,164	1,167	1,171	1,175	1,132	1,134	1,136	1,138	1,140	1,033
SID Lys:NE, g/Mcal	5.08	5.07	5.05	5.04	5.02	5.21	5.20	5.19	5.18	5.17	5.49
CP, %	20.1	19.9	19.7	19.5	19.2	19.8	19.7	19.6	19.5	19.3	19.8
Ca, %	0.65	0.64	0.63	0.62	0.61	0.70	0.70	0.69	0.69	0.68	0.63
STTD P, %	0.44	0.44	0.44	0.44	0.44	0.38	0.38	0.38	0.38	0.38	0.29
Ca:P	1.00	1.00	1.00	1.00	1.00	1.15	1.15	1.15	1.15	1.15	1.04
Na, %	0.40	0.40	0.40	0.40	0.40	0.35	0.35	0.35	0.35	0.35	0.28
Cl, %	0.60	0.60	0.61	0.61	0.62	0.60	0.60	0.61	0.61	0.61	0.50

[1] Phase 1 diets were fed from d 0 to 7. Phase 2 diets were fed from d 7 to 21. Phase 3 was fed from d 21 to 28.
[2] TM-SBM; thermo-mechanically processed soybean meal; Provisoy (Cargill Animal Nutrition, Wayzata, MN).
[3] Empirical Phytase (ADM, Chicago, IL) included at 3,132 FTU/kg provided an estimated release of 0.12% STTD P.

Table 2. Effect of thermo-mechanically processed soybean meal (TM-SBM) replacement of SBM on growth performance and fecal dry matter (DM) of nursery pigs [1]

	TM-SBM replacement of SBM, %							
Phase 1:	**0**	**25**	**50**	**75**	**100**		***P* =**	
Phase 2:	**0**	**12.5**	**25**	**37.5**	**50**	**SEM**	**Linear**	**Quadratic**
BW, lb								
d 0	12.4	12.3	12.4	12.4	12.4	0.22	0.791	0.840
d 7	13.5	13.9	14.3	14.1	13.5	0.28	0.533	0.001
d 21	23.7	24.3	24.3	23.6	22.9	0.71	0.071	0.020
d 28	28.5	29.7	29.1	28.7	27.8	1.12	0.165	0.051
Phase 1 (d 0 to 7)								
ADG, lb	0.13	0.20	0.23	0.22	0.14	0.022	0.205	< 0.001
ADFI, lb	0.43	0.45	0.46	0.44	0.40	0.019	0.062	0.003
G:F	0.26	0.43	0.49	0.50	0.35	0.044	0.025	< 0.001
F/G[2]	3.85	2.33	2.04	2.00	2.86	---	----	----
Phase 2 (d 7 to 21)								
ADG, lb	0.70	0.71	0.70	0.66	0.66	0.040	0.029	0.528
ADFI, lb	0.93	0.97	0.95	0.92	0.90	0.038	0.111	0.162
G:F	0.75	0.73	0.73	0.71	0.73	0.020	0.072	0.288
F/G[2]	1.33	1.37	1.37	1.41	1.37	---	----	----
Experimental period (d 0 to 21)								
ADG, lb	0.49	0.52	0.52	0.50	0.47	0.021	0.185	0.011
ADFI, lb	0.75	0.78	0.77	0.74	0.72	0.023	0.069	0.038
G:F	0.66	0.67	0.68	0.67	0.65	0.013	0.753	0.036
F/G[2]	1.52	1.49	1.47	1.49	1.54	---	----	----
Common period (d 21 to 28)								
ADG, lb	0.69	0.77	0.69	0.70	0.71	0.076	0.770	0.736
ADFI, lb	1.26	1.38	1.28	1.28	1.27	0.082	0.692	0.446
G:F	0.53	0.55	0.52	0.52	0.55	0.032	0.925	0.422
F/G[2]	1.89	1.82	1.92	1.92	1.82	---	----	----
Overall (d 0 to 28)								
ADG, lb	0.54	0.58	0.56	0.54	0.53	0.031	0.323	0.059
ADFI, lb	0.87	0.92	0.89	0.87	0.86	0.032	0.205	0.089
G:F	0.62	0.63	0.63	0.62	0.61	0.016	0.632	0.276
F/G[2]	1.61	1.59	1.59	1.61	1.64	---	----	----
Fecal DM,[3] %								
d 7	11.5	21.4	16.1	18.3	17.8	1.31	0.014	0.004
d 21	19.0	19.5	18.9	19.0	19.8	1.31	0.774	0.786
Removals, %	7.2	6.8	4.4	4.4	2.8	1.63	0.014	0.759
Mortality, %	0.0	0.4	0.4	0.4	0.0	0.4	0.999	0.996
Total removals and mortality, %	7.2	7.2	4.8	4.8	2.8	1.63	0.014	0.547

[1] A total of 1,254 mixed-sex pigs (initially 12.4 ± 0.22 lb) were used with 18 to 20 pigs per pen and 12 pens per treatment.
[2] F/G was calculated by taking the inverse of G:F. *P*-values are the same as reported for G:F.
[3] Treatment × day interaction (quadratic, $P = 0.024$).

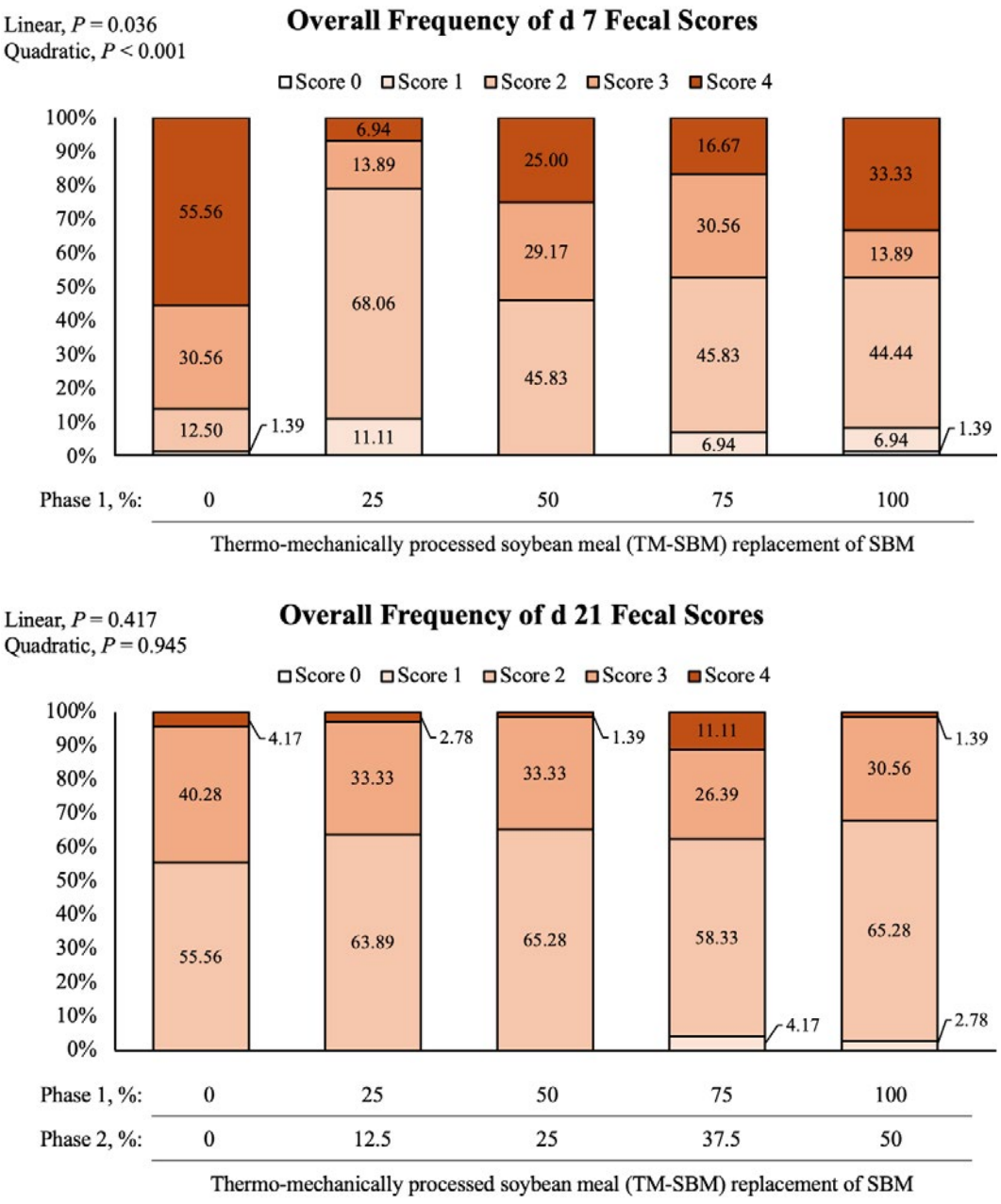

Figure 1. Fecal scores are presented on a 5-point scale: 0 = hard, pellet-like lumps; 1 = firm, formed feces; 2 = normal feces; 3 = mild looseness; and 4 = diarrhea scored by two observers on d 7 and 21. Treatment × day interaction (quadratic, $P = 0.017$). Main effect of treatment (linear, $P = 0.041$; quadratic, $P = 0.014$) and day ($P = 0.004$).