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This article is the 8th in a series highlighting the unique value of soybean meal to swine nutrition and health

Strategic Use of Soybean Meal to Prevent the Carcass Weight Dip during the Summer

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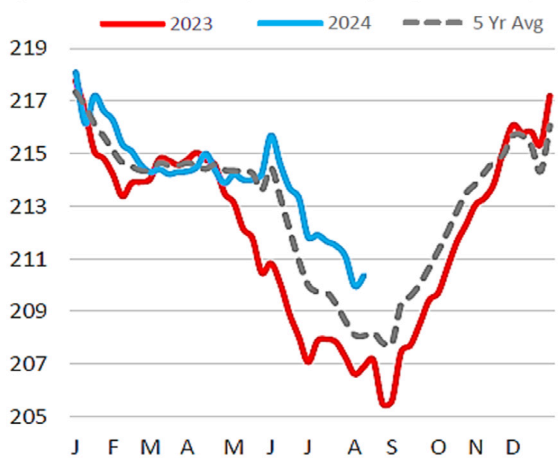
Introduction

The persistent reduction in carcass weight during summer months poses a substantial challenge for the swine industry, limiting its profitability potential. It is estimated that this seasonal carcass weight dip, primarily due to heat stress conditions, costs producers about $450 million annually (Schieck Boelke, 2024). This seasonal decline is observed year after year, resulting in substantial growth reduction. On average, the industry experiences a recurring decline in carcass weight of 6-12 lb/pig during the summer (**Figure 1**; USDA, 2024). It has long been assumed that this reduction in carcass weight is solely related to the effect of heat stress conditions during summer months.

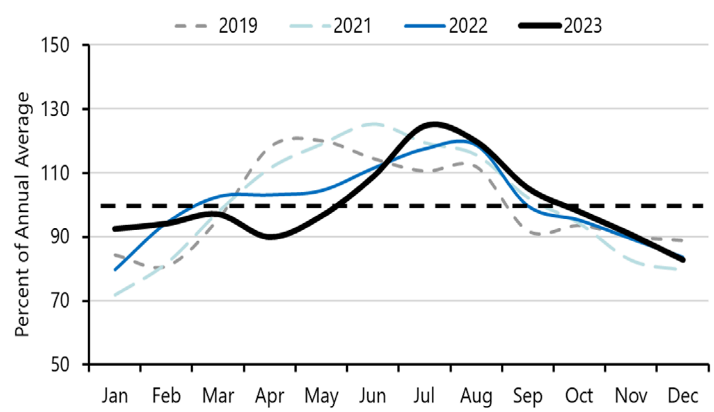
Figure 1. Hog carcass weights consistently drop during summer months when hog prices are typically higher



Indeed, exposing pigs to high ambient temperatures negatively affects their growth performance, as pigs reduce feed intake as a primary adaptation mechanism to lower metabolic heat production (Renaudeau et al., 2011). However, we speculate that, in addition to heat stress, certain nutritional factors can compound the negative impact on feed intake. We have identified that using feed ingredients such as corn DDGS has a feed intake-reducing effect, and when fed to pigs during summer months, it further contributes to the summer carcass weight dip.

This article highlights the importance of using a nutritional strategy that maximizes feed intake and growth to optimize revenue capture. Coincidentally, this summer carcass weight dip phenomenon often aligns with peak market hog prices, with July and August being the most financially consequential (**Figure 2**; Schulz, 2024). The scenario described creates one of the most significant revenue-capture opportunities for swine producers. This article provides evidence of a nutritional program designed to maximize the growth potential of pigs to be sold during peak pricing periods by leveraging the recent learnings of using high levels of soybean meal (SBM). We propose that feeding high levels of SBM has multifunctional roles in growing pig diets, including systemic antiviral and antimicrobial effects (Petry et al., 2024), which may elicit greater nutrient efficiency and improve growth performance of pigs (Boyd and Gaines, 2023).

Figure 2. Relative monthly hog price from 2019 to 2023 (excluding 2020). Relative prices are presented as a percentage of the annual average price. This figure illustrates summarized data from the Iowa State University, Estimated Livestock Return reports (Schulz, 2024)



Summer Carcass Weight Dip: High Cost for Producers

The drastic reduction in carcass weight during summer is costly for producers. Our simple economic model estimates that a 6 lb. lighter carcass reduces the income over feed cost (**IOFC**) by about $6/pig (**Table 1**). This economic model assumes a feed cost of $300/Ton and a relatively modest hog price of $90/CWT. The opportunity cost was much more profound for the summer of 2022 when hog prices peaked at $115.6/CWT (Schulz, 2024).

In addition to the high opportunity cost of inferior carcass weights, we anticipate additional costs during processing. Among others, these costs include: 1) increased processing plant penalties because of the greater proportion of light-weight

Table 1. Economic analysis of the cost of 6 lb. carcass weight reduction using the ISU Optimal Market Tool (Schulz, 2024). The model assumes a 2,400-head finish barn, 4% mortality, 109 days on feed, initial body weight = 49 lb., feed cost of $300/Ton, and hog price of $90/CWT.

Item	Non-Summer	Carcass Weight Dip
Days on feed, days	109	109
Final body weight, lb	297.6	289.4
Weight gain, lb	249.1	240.9
ADG, lb/day	2.29	2.21
ADFI, lb/day	5.89	5.60
Total feed intake, lb	641.5	610.7
FCR	2.575	2.535
Payout (Grid), %	100.4	99.1
Income, $/pig	$247.20	$237.28
Feeding cost, $/pig	$87.30	$83.10
IOFC, $/pig	$160.00	$154.20

pigs at marketing (e.g. < 180 lb. carcass), and 2) increased processing costs per unit of saleable meat because of reduced throughput relative to plant fixed costs (e.g. increased shackle space cost and increased labor cost per unit of saleable meat).

Summer Carcass Weight Dip: Contributing Factors

Traditionally, we have attributed the drastic reduction of carcass weight during summer months solely to the impact of heat stress conditions. However, we propose that the summer carcass weight dip results from the compounding effect of exposing pigs to heat stress conditions and the displacement of SBM with feed intake-reducing ingredients in grow-finish diets. Although pigs are sold during the summer months, they gain weight throughout all growing phases, which begin in the colder months for most of these pigs. Therefore, nutrition programs should be designed to maximize the growth potential of pigs in these early phases to minimize the summer carcass weight dip. While compensatory growth may occur in some situations (Menegat et al., 2019), we suspect that heat stress conditions in the later growth phases of pigs will limit any potential for compensatory growth. Thus, it is crucial to prevent any impairment to the pigs' earlier growth, as this will be reflected in their final carcass weight. We propose that the use of feed ingredients that negatively impact the feed intake of pigs will further limit their growth potential under heat stress conditions.

Summer heat stress conditions

It has been well documented that exposing pigs to heat stress conditions negatively impacts their feed intake and growth performance (Mayorga et al., 2019). Due to their low capacity for dissipating body heat, pigs rely more on reducing metabolic heat production to maintain a constant body temperature under heat stress conditions. Heat-stressed pigs reduce voluntary feed intake as their main adaptation to minimize heat production. It has been reported that feed intake declines by about 1% in growing pigs and 2% in finishing pigs for every degree above the upper critical temperature (Patience et al., 2015a). This reduction in feed intake negatively impacts the growth performance of pigs and their carcass weight, with minimum impact to feed efficiency (Renaudeau et al., 2011b). Although heat stress conditions during the summer months are the primary factor for the summer carcass weight dip, we speculate that specific nutritional factors produce a compounding negative effect on feed intake and consequently on growth performance.

Feed intake-reducing feed ingredients and impact on carcass weight gain

Prior to including feed ingredients in diets, nutritionists must have a basic understanding of their nutritional value when fed to pigs and their intrinsic factors able to hamper or stimulate feed intake. At a minimum, there should be knowledge of the ingredient's chemical composition, digestibility of energy and nutrients, and the dose-response to inclusion rates (Stein, 2008; Elsbernd et al., 2019). This latter response is critically important, as this is used to develop dose-response curves or to establish maximum inclusion rates prior to conducting least-cost feed formulation. Response curves for ingredients and nutrients are essential for the mathematical modeling of targeted growth performance and feed efficiency relative to system expectations. Because of varying market conditions, these models should be dynamic as they target optimal growth rate and feed efficiency relative to financial inputs, ultimately maximizing system profitability.

Characterization of the feed intake response to inclusion levels of feed ingredients is critical for their successful use in grow-finish diets. The presence of antinutritional factors intrinsic in seeds and factors generated from processing (e.g. Maillard's reaction) can influence pig's sensorial perception or cause gut disturbances; and thus, negatively impact feed intake (Torrallardona and Roura, 2009). By-products generated from other industries and used as feed ingredients should be carefully studied. These alternative feed ingredients are commonly used in grow-finish diets primarily to reduce feed costs. Of these, corn distillers' dried grains with solubles (corn DDGS) have gained popularity and have been used in grow-finish diets to replace a portion of corn, and a lesser portion of SBM and inorganic phosphorus (Stein and Shurson, 2009).

A recent meta-analysis reviewed 102 growth performance observations from published studies that compared the use of corn DDGS in pig diets with standard corn-SBM diets. Although a high proportion of the observations (>65%) showed no changes in pig performance when diets included corn DDGS, approximately 27% showed a significant reduction in ADG (–1.86%), ADFI (–1.04%), and G:F (–1.18%) when comparing the performance of pigs fed diets including corn DDGS with those fed corn-SBM-based diets (Jang et al., 2021).

Nutritionists should be cautious of the changes in corn DDGS sources, as new technologies are continuously implemented in ethanol plants to improve production efficiency. Although new corn DDGS sources may seem to contain greater nutritional value than conventional corn DDGS sources (Espinosa and Stein, 2018), they have also been reported to decrease pig performance. In a recent study, the impact of a novel high-protein corn DDGS source (HP-DDGS) was investigated in nursery diets (Yang et al., 2019). Researchers reported that increasing levels of HP-DDGS (0, 10, 20, and 30%) in nursery diets linearly decrease the daily feed intake by 14%, daily gain by 20%, and the efficiency of feed utilization by 8%.

Although the price of corn DDGS may seem attractive at times, producers must look beyond feed costs alone. When estimating the overall economic value of feed ingredients, especially those that impact growth performance, pork producers should account for feed efficiency and throughput changes. For these scenarios, the factsheet "Economics in Swine Nutrition" from Kansas State University (Menegat et al., 2019) provides two estimations that can be used to estimate the economic value of these ingredients:

Feed cost per unit of gain:

$$\mathit{Feedcostofgain}(\$/\mathit{lbgain}) = \mathit{feedefficiency} \times \mathit{feedcost}(\$/\mathit{lb})$$

This estimation is useful when comparing nutritional programs that may impact feed efficiency but not growth rate.

*Income over feed cost (**IOFC**):*

$$\mathit{IOFC}(\$/\mathit{pig}) = \mathit{Revenue}(\$/\mathit{pig}) - \mathit{Feedcost}(\$/\mathit{pig})$$

This estimation can be applied to compare nutritional programs that may impact both feed efficiency and growth rate when evaluated on a fixed-time basis. Revenue per pig can be estimated by multiplying hot carcass weight by hot carcass weight price, or total live weight by live weight price.

Through internal research at The Hanor Company, we learned of the drastic impact on the feed intake of pigs when using corn DDGS, especially during the early-growth phases. In the Hanor Technical Memo 2019-07 (Elsbernd et al., 2019) we determined the impact of increasing levels of corn DDGS on the growth performance of nursery pigs during the last phase (28.9 to 52.9 lb of body weight). This study involved five dietary treatments with increasing levels of corn DDGS: 0, 5, 10, 15 and 20%. The diets used were corn-SBM based with increasing levels of DDGS. All diet treatments were isocaloric and formulated to contain the same nutrient-to-energy ratios. We observed that increasing inclusion of corn DDGS linearly reduced the daily feed intake (Linear P < 0.001; **Figure 3a)** and the daily weight gain of pigs (Linear P < 0.001, **Figure 3b**), but had no effect on FCR (P = 0.741; data not shown). Consequently, increasing inclusion of corn DDGS on late-nursery diets linearly increased the proportion of pigs considered culls at the end of the trial (Linear P = 0.017; **Figure 3c**), negatively affecting the proportion of full-value pigs. The financial evaluation showed a progressive economic disadvantage when increasing the inclusion of DDGS in late-nursery diets (**Table 2**).

Figure 3. Impact of increasing levels of corn DDGS in late-nursery diets on the a) daily feed intake, b) daily gain, and c) full-value pig outcomes (Hanor Technical Memo 2019-07; Elsbernd et al., 2019).

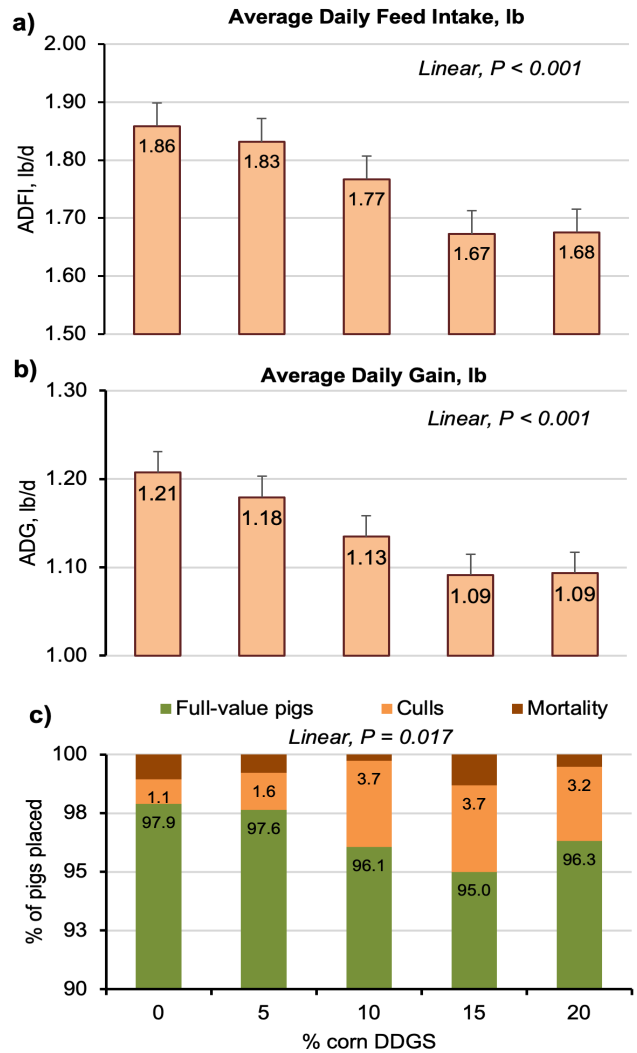


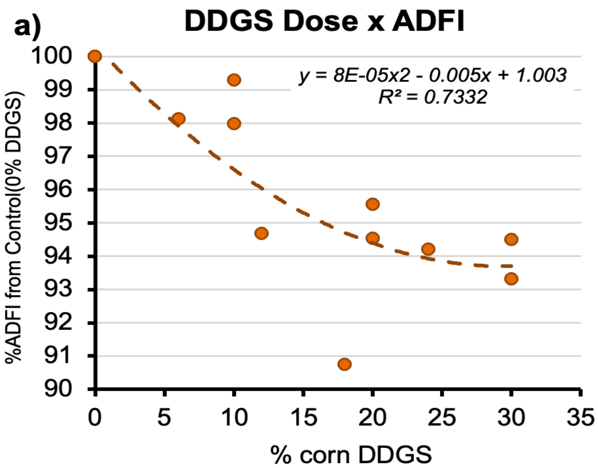
Table 2. Economic evaluation of the increasing inclusion rates of corn DDGS in late-nursery diets. This model is presented as a fixed-time basis, and uses estimations from the response of pigs documented in the Hanor Technical Memo H 2019-07. It assumes a hog price of $80/cwt and feed costs of $240/Ton (corn DDGS: corn price = 120%), relevant for the time the trial was conducted.

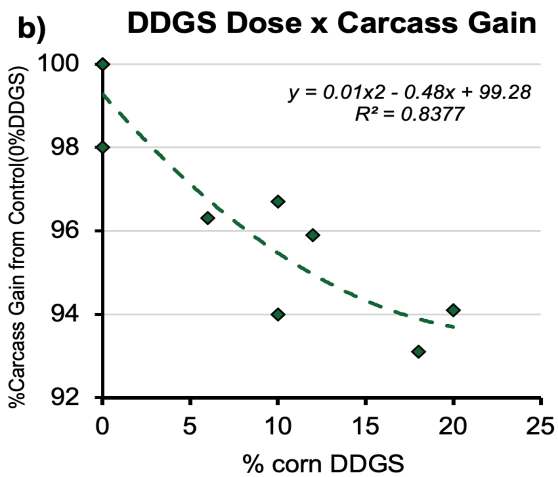
	Corn DDGS Inclusion rate, %				
	0	5	10	15	20
Diet SBM Level					
Gain, lb/pig	25.3	24.6	24.0	23.3	22.7
Revenue, $/pig	20.24	19.71	19.18	18.56	18.12
Feed Cost					
Feed cost, $/pig	4.92	4.78	4.63	4.49	4.34
Economic Evaluation					
Feed cost, $/lb gain	0.194	0.194	0.193	0.192	0.192
Income over Feed Cost, $	15.32	14.93	14.55	14.16	13.78

The economic evaluation in **Table 2** illustrates the need to include revenue estimation for a complete evaluation of the IOFC. Note that feed cost ($/pig) and feed cost per unit of gain ($/lb gain) showed an economic advantage for increasing levels of corn DDGS. However, when potential for revenue is accounted for (live weight by live weight price), the IOFC is reduced by $1.50/pig when late-nursery diets include 20% corn DDGS. This reduction in IOFC is explained by the negative impact of high levels of corn DDGS on weight gain. In this evaluation, IOFC appears to be a superior economic estimation of the profitability of the diet as it captures changes in feed cost and animal performance.

Although the negative impact of corn DDGS was shown for nursery pigs, similar observations have been reported for grow-finish pigs. A data analysis of two other Hanor Technical Memos (Johnston and Boyd, 2003; Johnston et al., 2007) revealed that corn DDGS also impacted feed intake (**Figure 4a**) and carcass gain of grow-finish pigs (**Figure 4b**) in a dose-response manner.

Figure 4. Impact of increasing levels of corn DDGS in grow-finish diets on the a) daily feed intake, and b) carcass gain of pigs (Hanor Technical Memos 2003-02 and 2007-03; Johnston and Boyd, 2003; Johnston et al., 2007).





Mitigating the Seasonal Carcass Weight Dip: Using High Levels of SBM

The value of using SBM in grow-finish diets

Previous articles in this series have reported the apparent extra-nutritional and multifunctional roles of SBM in swine diets, including systemic antiviral and antimicrobial effects (Petry et al., 2024). The positive impact of high levels of SBM in grow-finish diets has been particularly evident when pigs are housed under commercial conditions and health challenged. The use of high inclusion of SBM has been demonstrated to mitigate the negative impact of swine respiratory diseases (**SDR**) on the efficiency of feed utilization and growth rate of pigs (Boyd et al., 2023).

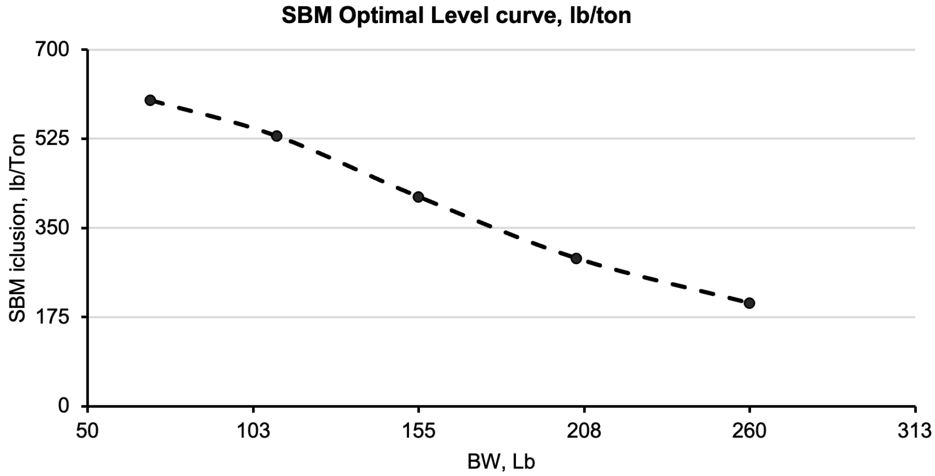
In an internal study conducted at The Hanor Company and described by Body et al. (2023), a simultaneous investigation of the response to increasing dietary lysine (0.65, 0.75, 0.85, or 0.95% SID Lysine) and two SBM levels (Low and High, inclusion rates ranging from 14 to 32%) resulted in unexpected findings when SRD infection occurred. The study used 420 pigs (PIC terminal genetics, initial BW of 217 lb.) over a period of 21 days. During the study, pigs became infected with multiple respiratory pathogens (SRD complex) that triggered systemic inflammation. The diseases caused both growth and feed efficiency to reduce by 8 and 10%, respectively, compared to the performance of pigs prior to the infection. Serology revealed that pigs were PRRSv and porcine circovirus (**PCV2**) positive. PCV2 lesions and *Streptococcus suis* infection were also confirmed. Following veterinary guidance, pigs received medication by water. At the end of the study, diets containing high SBM levels significantly improved pigs' performance compared to those fed low SBM levels. The researchers concluded that high SBM inclusion was an effective strategy that mitigated the severe growth-impairing effects of the SRD complex.

Although SBM is typically used in swine diets as a high-quality protein source, nutritionists should also consider the non-protein fraction that is rich in polyphenols, terpenoids, bioactive peptides, fiber, functional lipids, and other functional compounds. These compounds seem to play a critical role in modulating the immune response and disease resilience in pigs (Petry et al., 2024). These functional effects of SBM may explain, at least partially, recent reports of the greater productive energy of SBM than previously thought (Boyd & Gaines, 2023), especially for pigs housed under commercial conditions. Considering the potential nutraceutical value of SBM, it can be applied during periods of compromised growth, such as health-challenged conditions and during summer months.

Developing a strategy to mitigate the carcass weight dip

Carcass weight dip as a result of heat stress conditions during summer months is one of the most critical financial challenges for swine producers. This is a phenomenon that substantially affects the whole industry, reporting reductions

Figure 5. Soybean meal Optimal Level curve (lb/ton of feed) that aims to maximize weight gain during summer months. The curve was developed using SBM dose-titration studies. The studies included: Johnston et al., 2010 and Hanor Research Memos 2013-14 and 2018-08 (Johnston et al., 2010; Zier-Rush et al., 2013; Elsbernd et al., 2018). The primary outcome of this optimal curve was the maximum carcass weight.



in carcass weight of 6-12 lbs. per pig sold during this period (May – September; USDA, 2024). Given the high cost of this challenge, many strategies have been proposed. Higher energy density diets were commonly used until a few years ago when the increasing prices of supplemental fat sources made them cost-prohibitive. Moreover, microminerals and other feed additives have been proposed, resulting only in marginal outcomes (Espinosa and Stein, 2021).

Traditionally, high protein diets have not been fed during summer months due to increased metabolic heat production. Excess heat generated by pigs can reduce feed intake as they attempt to lower their body temperature (Patience et al., 2015b). However, a recent study conducted at Iowa State University challenges this notion. The study found that feeding high levels of SBM (41% SBM vs 19% SBM) to pigs (initial BW = 120 lb.) did not exacerbate the negative effects of heat stress conditions (cyclical temperatures were set to 32.8ºC from 8 AM to 8 PM and 29.4ºC from 8 PM to 8 AM). Additionally, feeding pigs high levels of SBM (48% in phase 1 and 29% in phase 4) throughout the grow-finish period did not negatively impact pig overall performance (Swanstrom et al., 2023).

Furthermore, considering the findings from Iowa State University and the functional properties of SBM, we propose a nutritional strategy for pigs to be sold during summer months. This strategy involves using high levels of SBM in finishing diets while excluding feed intake-reducing ingredients. This strategy should be fed to pigs throughout their entire growing period, starting in February for pigs to be sold in May to June, to mitigate the carcass weight dip during summer months. We speculated that this strategy would prevent the reduction of feed intake and enhance early growth potential during non-summer months (February to May). To test this hypothesis, we analyzed data from three studies conducted at The Hanor Company that used high levels of SBM and were conducted under commercial conditions (Johnston et al., 2010; Zier-Rush et al., 2013; Elsbernd et al., 2018). The results were used to develop a SBM Optimal Level Curve, which aims to maximize growth rate and carcass weight gain (**Figure 5**).

After developing an initial SBM curve, a separate study was conducted to validate this curve in the finishing phases of pigs (Boyd et al., 2020). This study used four dietary treatments that compared a previously used high energy diet (Hi Fat) to low energy diets with minimum inclusion rates of SBM (SBM Low, Med, High). All diets were corn-SBM based, with inclusion of synthetic amino acids and formulated to meet or exceed NRC 2012 requirements for growing pigs. SBM diets were isocaloric and formulated to contain the same nutrient to energy ratios. Pigs (PIC terminal pigs) were fed these dietary treatments from 97.5 lb to about 295 lbs. Overall, pigs fed diets with the SBM Low and Med diets were heavier at processing by 3.2 lb/carcass than those fed the Hi Fat diets ($P < 0.10$). Pigs fed Hi Fat diets were more efficient in utilizing the feed (Carcass FCR = 3.83; $P < 0.001$) than those fed the SBM Low and Med diets (Carcass FCR = 3.96), but not those that were fed the SBM High diet (Carcass FCR = 3.70). The greater inclusion rates of SBM resulted in better growth performance during earlier phases than later phases.

Mitigation proof from an integrated swine producer

This study confirmed that DDGS reduced carcass weight and validated the SBM curve for maximum growth during the summer period. The estimated minimum for SBM for each feeding phase was implemented across the entire Hanor system. This program intended to maximize carcass weight of pigs to be sold during late spring through the summer months. The 'prescriptive' use of SBM began in February for pigs that would be sold in June, to avoid the decline in carcass weight that our system sometimes observes, prior to summer. A leading-edge to carcass weight dip may be expected when swine respiratory disease is encountered (Yeske et al., 2024). The Finish 5 summer diet was introduced to the system June 01 and was removed from the diet library by September 30. Pigs that are sold during July, August or September began the seasonal diet program as early as March (**Figure 6**). This 'roll-in, roll-out' process of seasonal diets confined the marginal cost to the period of greatest profit opportunity.

Compared to the typical high-energy diet program, which included added fat and corn DDGS and was used until the summer of 2019, this SBM-based strategy reduced the feed cost by approximately $4 per pig (using the reference ingredient prices from 2020-2023; Pope et al., 2024). More importantly, it improved carcass weight by an average of 5.5 lb. during May to August 2022 (**Figure 7**). Notably, carcass weights trended higher and contrary to historical outcomes during the months of May through July.

Considering the 2022 hog market prices, the SBM-based diet program generated an additional $14 per pig revenue during summer months (June and July) compared to the previous high-energy diet program (**Figure 8**). The practical application of our proposed strategy, utilizing high SBM levels and excluding feed intake-reducing ingredients, offers profound financial benefits for producers aiming to maximize profitability.

Maximizing revenue capture and optimizing profit

We evaluated the financial impact of three nutritional strategies for use during the summer of 2024. In a dynamic market, the decision to implement a specific program should be based on maximizing profitability. This analysis assumed a diet cost of $220 per Ton and a hog price of $90 per carcass CWT. We compared a high-energy program (Hi Energy, including added fat and corn DDGS), our proposed SBM-based program

Figure 6. Illustration of a seasonal 5-phase grow-finish feeding program designed to maximize weight gain during summer months. In this example, our proposed SBM-minimum summer diet program starts in February with a phase 1 diet (Finish 1-S, 50 to 90 lbs BW). This first group of pigs, intended for sale during summer, completes the program in June with a phase 5 diet (Finish 5-S, 220 to 300 lbs BW).

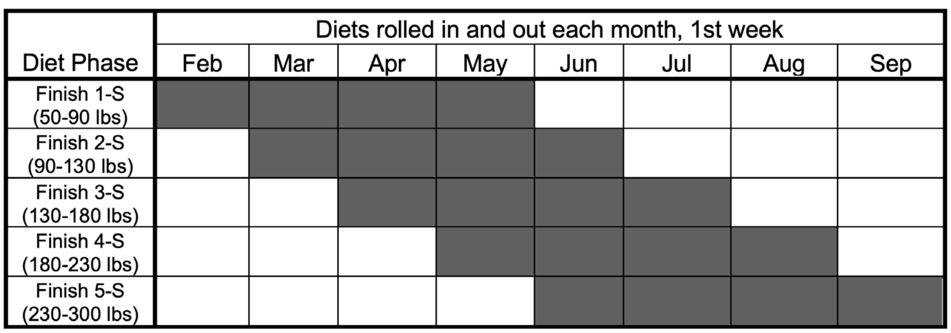


Figure 7. Monthly average carcass weight of pigs sold during 2019 and 2022. Pigs sold during summer months of 2019 were fed a high energy diet that included added fat and corn DDGS (Hi Energy, 2019). Pigs sold during summer months of 2022 were fed a SBM-based summer diet program.

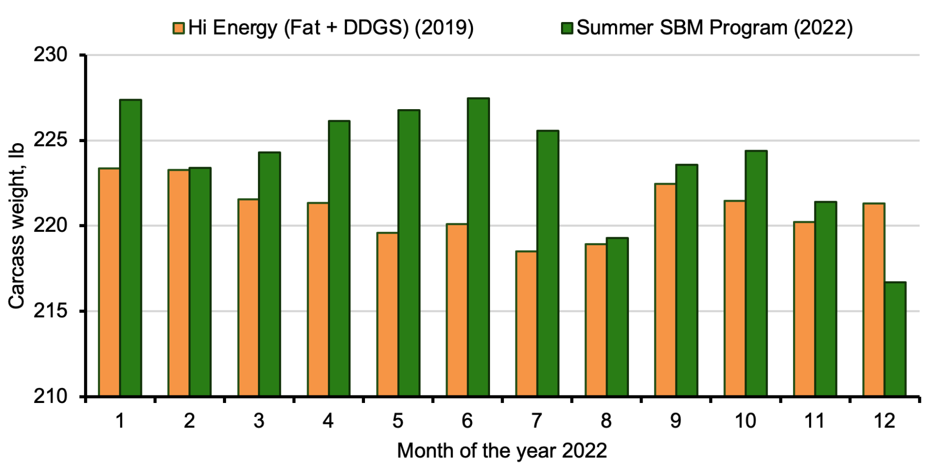


Figure 8. Estimated monthly revenue (carcass weight x hog price 2022) during 2019 and 2022. Pigs sold during summer months of 2019 were fed a high energy diet that included added fat and corn DDGS (Hi Energy, 2019). Pigs sold during summer months of 2022 were fed a SBM based summer diet program.

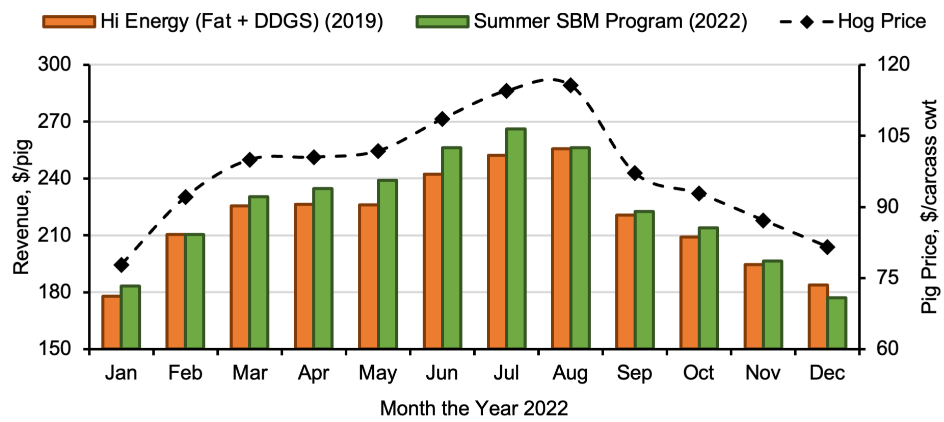
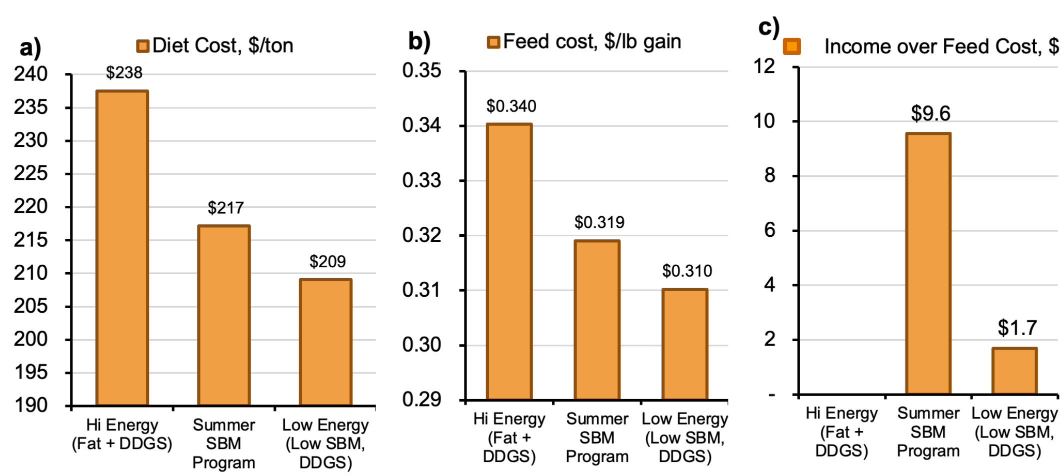


Figure 9. Financial analysis of a) Diet cost ($/Ton), b) feed cost ($/lb gain), and c) Income over Feed Cost (IOFC, $) of a high energy program (Hi Energy, Fat + corn DDGS), SBM based program (summer SBM program, high levels of SBM, no added fat, not including corn DDGS), and a regular diet program typical of non-summer months (Low Energy, low SBM, including corn DDGS).



(summer SBM program, with high levels of SBM, no added fat, and no corn DDGS), and a regular diet program typical of non-summer months (Low Energy, with low SBM and including corn DDGS) (**Figure 9**).

Our analysis demonstrated that the summer SBM program reduced diet cost by $21 per Ton and feed cost by $0.21/lb gain compared to the Hi Energy program. Although the Low Energy program resulted in the lowest diet cost and feed cost, the IOFC analysis showed that the summer SBM program was superior, generating $9.60 per pig more than the Hi Energy program and $1.70 per pig more than the Low Energy program. This analysis highlights the importance of calculating IOFC when animal performance is impacted by the nutritional programs. As the summer SBM program is expected to improve growth performance, the correct financial analysis should focus on IOFC.

Key Summary

1. The persistent reduction in carcass weight during the summer months ranges from 6 to 12 lbs.
2. This is primarily due to heat stress combined with the inclusion of feed intake-reducing ingredients, such as corn DDGS, corn germ meal, and wheat midds, which displace SBM from diets.
3. The Hanor Company developed developed a seasonal diet program that excludes these feed-intake reducing ingredients and incorporated higher levels of SBM to enhance feed intake and maximize carcass weight during spring and summer months. 4. Use of an ingredient-based maximum intake program across the across The Hanor Company system, compared to the high-energy diet used until the summer of 2019,

reduced feed costs by approximately $4 per pig and increased carcass weight by an average of 5.5 lbs. from May to August 2022.

5. Based on 2022 hog market prices, this program generated an additional $14 per pig in revenue compared to the traditional high-energy diet.

The practical application of our nutritional strategy, which utilizes high SBM levels and excludes feed intake-reducing ingredients, offers substantial financial benefits for producers aiming to maximize profitability. Successful implementation requires defining the optimal SBM dose by phase and ensuring these diets are fed from the initial growing phases of the pig. This is one of the most important illustrations of where lowest diet cost leads to significant profit loss.

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Dr. Rosero presented this paper at the 2024 Iowa Swine Day Pre-Conference Symposium (https://www.youtube.com/watch?v=x7oF696Wy3g&list=PL0ykX2Ev_kLbtZDplcFnKAVdgKfgiwPRW&index=6).

Reference Information

1. Boyd, R. D., Rosero, D. S. and Elsbernd, A. (2022). Increasing dietary soybean meal level improves growth and feed conversion efficiency in healthy pigs and reduces GHG emissions. In *J. Anim. Sci* (Vol. 100, Issue S3, Page 122). https://doi: 10.1093/jas/skac247.233
2. Boyd, R. D. and Gaines, A. (2023). Soybean meal NE value for growing pigs is greater in commercial environments. *Feedstuffs* August Digital Edition, page 1. https://informamarkets.turtl.co/story/feedstuffs-august-2023/page/1.
3. Boyd, R. D., Johnston, M., Usry, J., Yeske, P. and Gaines, A. (2023). Soybean meal mitigates respiratory disease-impaired growth in pigs. *Feedstuffs* October Digital Edition, page 2. https://informamarkets.turtl.co/story/feedstuffs-october-2023/page/2.
4. Elsbernd, A., Boyd, R. D., Hatcher, M., Smith, T., Paz, X. and Rosero, D. (2018). Re-evaluating the maximum constraints of synthetic lysine used to reduce diet cost on finishing 1 to 5 diets. Hanor Tech. Memo 2018-08
5. Elsbernd, A., Boyd, R. D., Smith, S., Picou, J., Andersen, O., Paz, X. and Rosero, D. (2019). Impact of increasing DDGS level on nursery pig performance. Hanor Tech. Memo 2019-07
6. Espinosa, C. D., & Stein, H. H. (2018). High-protein distillers dried grains with solubles produced using a novel front-end–back-end fractionation technology has greater nutritional value than conventional distillers dried grains with solubles when fed to growing pigs. J*ournal of Animal Science*, 96(5), 1869–1876. https://doi.org/10.1093/jas/sky052
7. Espinosa, C. D., & Stein, H. H. (2021). Digestibility and metabolism of copper in diets for pigs and influence of dietary copper on growth performance, intestinal health, and overall immune status: a review. In *Journal of Animal Science and Biotechnology* (Vol. 12, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s40104-020-00533-3
8. Jang, J. C., Zeng, Z., Urriola, P. E., & Shurson, G. C. (2021). Effects of feeding corn distillers dried grains with solubles diets without or with supplemental enzymes on growth performance of pigs: A meta-analysis. *Translational Animal Science*, 5(2). https://doi.org/10.1093/tas/txab029
9. Johnston, M., & Boyd, R. D. (2003). Impact of including corn DDGS in grow-finish diets. Hanor Tech. Memo 2003-02
10. Johnston, M., Fralick, C., & Boyd, R. D. (2007). Titration of the DDGS Level in Paylean Diets. Hanor Tech. Memo 2007-03
11. Johnston, M., Boyd, R. D., Zier-Rush, C., & Fralick, C. (2010). Soybean meal level modifies the impact of high immune stress on growth and feed efficiency in pigs. *J. Anim. Sci*, (Vol. 100, Issue E-Suppl.3, Page 122).
12. Mayorga, E. J., Renaudeau, D., Ramirez, B. C., Ross, J. W., & Baumgard, L. H. (2019). Heat stress adaptations in pigs. Animal Frontiers: *The Review Magazine of Animal Agriculture*, 9(1), 54. https://doi.org/10.1093/AF/VFY035
13. Menegat, M. B., Dritz, S. S., Tokach, M. D., Woodworth, J. C., Derouchey, J. M., & Goodband, R. D. (2019). A review of compensatory growth following lysine restriction in grow-finish pigs. *Translational Animal Science*, 4(2). https://doi.org/10.1093/tas/txaa014
14. Menegat, M., Goodband, R., DeRouchey, J., Tokach, M., Woodworth, J., & Dritz, S. (2019). *Kansas State University Swine Nutrition Guide: Economics in Swine Nutrition*.
15. Patience, J. F., Rossoni-Serão, M. C., & Gutiérrez, N. A. (2015a). A review of feed efficiency in swine: Biology and application. In *Journal of Animal Science and Biotechnology* (Vol. 6, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s40104-015-0031-2
16. Patience, J. F., Rossoni-Serão, M. C., & Gutiérrez, N. A. (2015b). A review of feed efficiency in swine: Biology and application. *Journal of Animal Science and Biotechnology*, 6(1). https://doi.org/10.1186/S40104-015-0031-2
17. Petry, A., Bowen, B., Weaver, L., & Boyd, R. D. (2024). Functional compounds in soybean meal: implications for pig health and physiology. *Feedstuffs*, February digital edition, page 1. https://informamarkets.turtl.co/story/feedstuffs-february-2024/page/5/1
18. Renaudeau, D., Gourdine, J. L., & St-Pierre, N. R. (2011a). Meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. *Journal of Animal Science*, 89(7), 2220–2230. https://doi.org/10.2527/jas.2010-3329
19. Renaudeau, D., Gourdine, J. L., & St-Pierre, N. R. (2011b). Meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. *Journal of Animal Science*, 89(7), 2220–2230. https://doi.org/10.2527/jas.2010-3329
20. Schieck Boelke, S. (2024). *Heat stress in swine affects production*. https://extension.umn.edu/swine-production-management/heat-stress-swine-affects-production
21. Schulz, L. (2024). *Estimated Livestock Returns*. https://estimatedreturns.econ.iastate.edu/
22. Stein, H. H. (2008). *Determination of net energy in U.S. soybean meal fed to group-housed growing pigs*. https://nutrition.ansci.illinois.edu/node/1717
23. Stein, H. H., & Shurson, G. C. (2009). Board-invited review: The use and application of distillers dried grains with solubles in swine diets. In J*ournal of Animal Science* (Vol. 87, Issue 4, pp. 1292–1303). https://doi.org/10.2527/jas.2008-1290
24. Swanstrom, J. A., Humphrey, D. C., Elefson, S., Miller, K. A., Becker, S., Hagen, C. S., Nisley, M. J., Greiner, L., & Gabler, N. (2023). Effect of soybean meal inclusion on grow-finish pig performance and nitrogen balance. In *J. Anim. Sci* (Vol. 101 Issue S2, Pages 251-252). https://doi.org/10.1093/jas/skad341.285
25. Torrallardona, David., & Roura, Eugeni. (2009). *Voluntary feed intake in pigs.* Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-689-2
26. USDA. (2024). *Weekly average weight of barrows and gilts.* https://mymarketnews.ams.usda.gov/filerepo/sites/default/files/2705/2024-08-14/857323/ams_2705_00234.pdf
27. Yang, Z., Urriola, P. E., Hilbrands, A. M., Johnston, L. J., & Shurson, G. C. (2019). Growth performance of nursery pigs fed diets containing increasing levels of a novel high-protein corn distillers dried grains with solubles. *Translational Animal Science*, 3(1), 38–47. https://doi.org/10.1093/tas/txy101
28. Yeske, P., A. Gaines, J. Garrett and R.D. Boyd. 2024. SBM: Tactical option for swine respiratory disease mitigation – DVM perspective. Proc. Amer. Assoc. Swine Vet. Feb. 215-219. https://doi.org/10.54846/am2024/75
29. Zier-Rush, C., McGrath, M., McCulley, M., Palan, R., Picou, J., Touchette, K., & Boyd, R. D. (2013). Performance response for increasing crystalline lysine in finish pig diets: most profitable maximums by phase differ from best FCR maximums. Hanor Tech. Memo 2013-07

Acknowledgments:

This research was conducted at The Hanor Company. Data presented were adapted from internal technical reports appearing on Research Gate under R. Dean Boyd and published ASAS Abstracts.