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This article is the 9th in a series highlighting the unique value of soybean meal to swine nutrition and health

The Economic and Environmental Impact of Increasing Soybean Meal Protein and Energy in Swine and Poultry Diets

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Introduction

Soybean meal (SBM) is one of the most commonly used feed ingredients for swine and poultry nutrition. However, variation in SBM composition (both digestible amino acids and energy) impacts the final diet's nutritional value, associated animal performance, and diet cost. This variability arises from different processing plants, times, or regions, and requires ongoing evaluation of SBM. In addition, there has been an increased focus on environmental impact, and on understanding how diet composition influences sustainability metrics such as greenhouse gas (GHG) emissions. It is assumed that improving the environmental impact of formulated animal diets will come at a cost, but the dynamics have not been fully explored.

We recently published two studies (Pope et al., 2023 and 2024) that expand on these issues and propose methods to quantify the economic and environmental impact of increasing SBM crude protein and energy in swine and poultry diets. Higher concentrations of digestible amino acids and energy result in increased SBM market value, and coincide with reduced dietary GHG emissions (gCO2e/kg). Understanding, quantifying, and effectively communicating these benefits requires reliable amino acid and energy values as well as credible, science-based estimates of the environmental impact of feed ingredient production. GHG values for feed ingredients commonly used in U.S. swine and poultry diets are presented here, as well as the environmental impact of SBM composition changes.

Ingredient Evaluation in Practice

Nutritionists may intuitively understand the impact of variable nutrient composition on animal diets, but may underestimate the true economic implications. While accounting for this variation is routine for nutritionists, it is important to think beyond regional SBM crude protein (CP) differences (typically ranging from 45.5 to 47.0%) and utilize more holistic methods to link that variation in ingredient composition to business outcomes. Specifically, quantifying how variation in ingredient quality or composition can and should impact decision-making (e.g. diet cost, diet composition, over- or under-formulating the diet, environmental impact). The value of SBM in the diet is determined by its amino acid concentration, the digestibility of those amino acids, and its current market price relative to other ingredients prices. The interaction of these factors impacts the ideal quantity of SBM in the diet. Methods are needed to quantify true ingredient value when these variables change.

We proposed a framework that can be utilized to complement core business units that need to evaluate SBM value from various processing plants/sources, and determine which is the most valuable in the diet in dollars per ton (Pope et al., 2023). Furthermore, including the latest science-based research on the environmental impact of feed ingredients enables formulations that quantify dietary GHG emissions. While not currently standard practice, consumer- and policy-driven mandates may soon require evaluation of the environmental impact of ingredient inclusion in formulated diets.

Increasing SBM Digestible Amino Acids and Energy

A recent study (Pope et al., 2023) presented a framework to quantify SBM value in swine and poultry diets, using digestible amino acids and energy as the primary determinants of end-user value. SBM samples were analyzed for moisture, CP, and 11 amino acids (AA). These values were regressed to estimate five SBM CP concentrations (44.0, 45.0, 46.0, 47.0, and 48.0% CP) and the corresponding energy, and then used in a formulation exercise. The estimated energy values increased as SBM CP increased. Least cost diet formulation software calculated the cost of diets for swine and poultry for the five SBM CP concentrations. For each scenario, the only change allowed during the least cost optimization was the individual CP concentration (and corresponding energy level) of SBM. Representative diets for four swine production phases were specified: lactation, nursery, grower, and finisher production. Three phases were specified for poultry: layers, broiler grower, and broiler finisher production.

Relative SBM economic value (dollar per metric ton) was determined based on the changes in the nutritional properties of the SBM, primarily digestible amino acids and energy (Boyd et al., 2023). To estimate the relative SBM value in the diet by CP concentration (44.0–48.0%), differences in diet cost were applied to the SBM based on the amount used per metric ton. Diets were formulated using average prices for two different price scenarios: 1) marketing years 2016/2017 through 2018/2019, and 2) marketing years 2020/21 through 2022/2023. For each 1% increase in SBM CP concentration from 44.0 to 48.0%, SBM nutritional or relative value increased (**Figure 1**) as the diet included less of the higher quality soybean meal (**Figure 2**), and lower overall diet costs (**Figure 3**).

The relative SBM value increased on average $10 per metric ton for swine and $12 per metric ton for poultry per ton of feed

Figure 1. SBM Relative Value, $/MT for Each 1% Increase in SBM CP

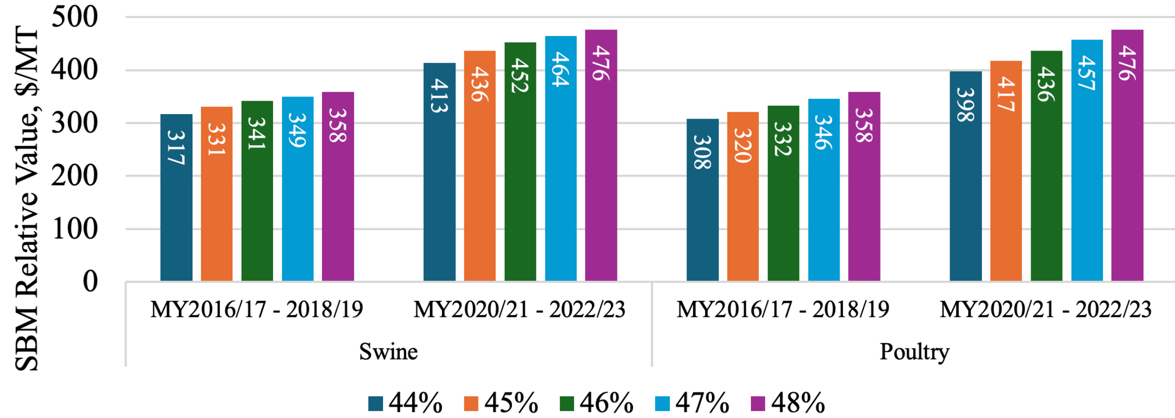


Figure 2. Average SBM Inclusion, kg/MT for Each 1% Increase in SBM CP

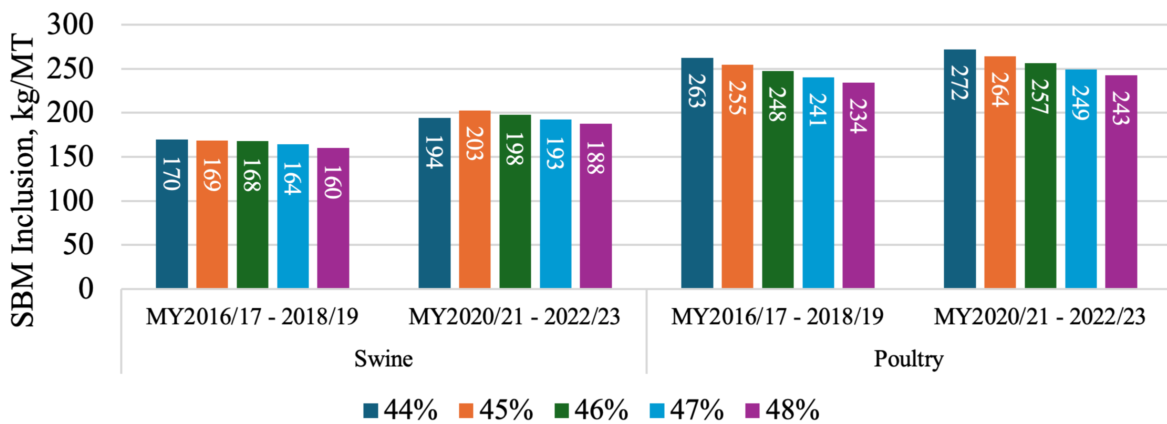
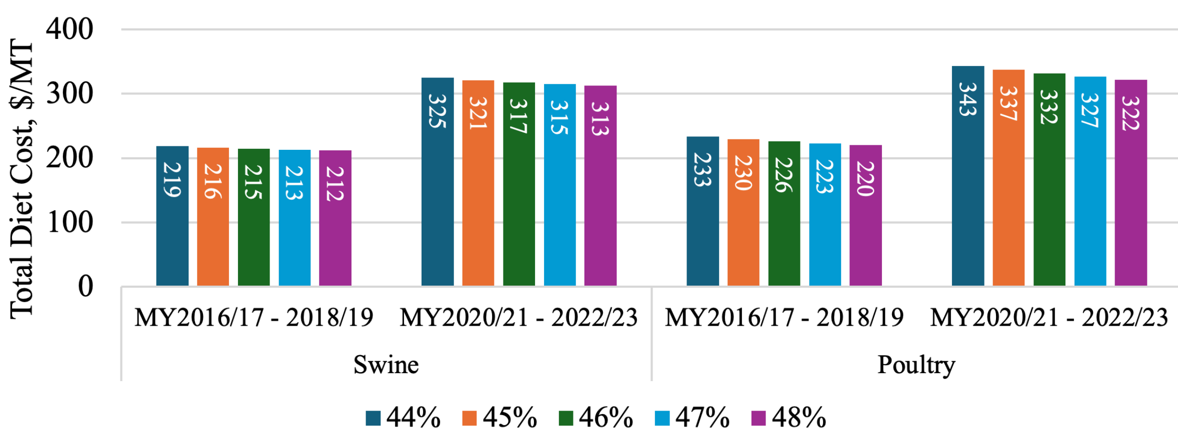
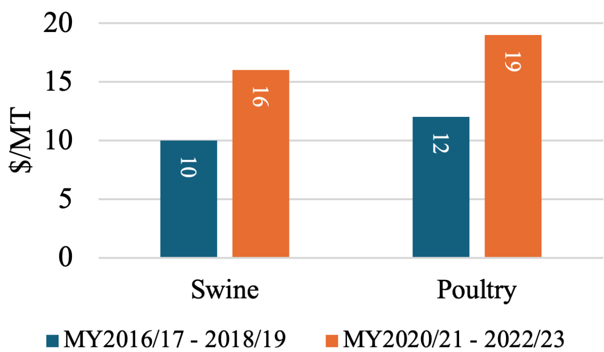


Figure 3. Average Total Diet Costs, $/MT for Each 1% Increase in SBM CP



for each 1% increase in CP concentration from 44.0 to 48.0% (**Figure 4**). As SBM CP increased, formulated diets included more corn, less distillers dried grains with solubles (DDGs), less fat and less synthetic amino acids. Higher corn inclusion and lower fat and synthetic amino acid inclusion resulted in lower diet costs. Updating the ingredient prices to reflect changing market conditions (marketing years 2020/2021 through 2022/2023) resulted in an increase in SBM relative value to $16 per metric ton for swine and $19 per metric ton in poultry diets (Pope et al., 2024).

Figure 4. Relative SBM Value for Each 1% Increase in SBM CP, $/MT



Ingredient prices significantly increased between these two periods (**Table 1**). Despite that, the increase in value as SBM amino acid and energy levels increase demonstrates that the relationship is resilient under different market price scenarios. These SBM relative values represent the additional amount that swine and poultry end users could pay for a higher SBM concentration without increasing overall diet costs. For example, assuming a relative SBM value of $10/MT for each 1% increase in CP concentration, if a swine feeder was offered 46% CP SBM at a market price of $350/MT, they could pay up to $360/MT for 47% CP (a $10/MT premium for 1% more CP) and reduce overall diet costs due the improvement in the nutritional value of the SBM. This analysis can be used to understand the economic value of SBM based on intrinsic product and compositional characteristics.

Environmental Impact of Improving SBM composition

Consumers are increasingly focused on shifting their purchasing power toward products that enhance environmental sustainability. This has led to governments and private industry developing strategic goals that aim to improve environmental sustainability. Changing consumer preferences and policy mandates may lead to changing the mindset on how diets are formulated. In animal production, this could include evaluating ingredients based on metrics that link to sustainability goals, including reducing greenhouse gases (GHG) (e.g., carbon dioxide, methane, and nitrous oxide), water consumption, and energy use.

Life cycle assessment (LCA) models quantify the environmental effects of individual feed ingredients used in swine and poultry production. LCA takes into consideration environmental

Table 1. Feed Ingredient Price Scenarios, $/MT

Feed Ingredient	MY2016/17 – 2018/19	MY2020/21 – 2022/23	% Change
Energy Grains			
DDGs, 27.4% CP	148	253	42%
Corn germ meal, 23.2% CP	112	180	38%
Corn, 8% CP	140	225	38%
Wheat Midds, 16.3% CP	143	213	33%
Protein			
Canola meal, 36.7% CP	305	453	33%
Soybean meal, 48.0% CP	358	432	17%
Fat			
Fat - Animal vegetable blend	617	1,199	49%
Fat – Tallow- Porcine	656	1,256	48%
Synthetic Amino Acids			
L-lysine HCl, 78.6% lysine	1,565	1,918	18%
DL-methionine, 98.5%	2,756	2,987	8%
L-tryptophan, 98.5%	7,496	8,411	11%
L-threonine, 98.5%	1,896	1,984	4%
L-valine, 98.5%	8,686	5,930	-46%
Minerals			
Calcium carbonate	46	46	0%
Monocalcium phosphate, 21%	465	465	0%
Salt	80	80	0%
Vitamins/Enzymes			
Phytase, 2,500 FTU/g	3,674	3,674	0%
Phytase, 5,000 FTU/g	4,899	4,899	0%
Vitamin & trace mineral pack	2,205	2,205	0%

Adapted from Pope et al., 2023 and 2024. For nutrient specifications, including minimum and maximum inclusions for each ingredient, see Pope et al., 2023.

impacts across the whole supply chain of livestock production to quantify the total environmental impact associated with a product. While methods for developing environmental models that account for these practices are still evolving, the LCA methodology is currently driving policy and company-driven mandates. To account for environmental impact in the formulation analysis, current science-based estimates of GHG emissions (gCO2e/kg) for each ingredient in the diet can be specified (**Table 2**). These estimates account for emissions attributed to supply chain activities through the production of the feed ingredient, but before its utilization as a feed ingredient in animal production.

In a follow up study (Pope et al., 2024), these ingredient-specific GHG emission coefficients were used in formulation to understand how changes in SBM composition (digestible amino acids and energy) relate to GHG emissions. Dietary GHG emissions (gCO2e/kg) decreased as SBM CP (and corresponding amino acids and energy concentrations) increased. For each 1% increase in SBM CP, GHG emissions decreased 4.8% in swine diets and 5.5% in poultry diets (**Figure 5**). Note that values presented are an average of the production phases in both swine (lactation, nursery, grower, finisher) and poultry (broiler grower, broiler finisher, layer). Each production phase resulted in the same trend, with decreasing emissions as SBM CP level increased (individual data not shown).

As previously discussed, when SBM CP increased, formulated diets included more corn, but less DDGs, fat, and synthetic amino acids. Corn had the lowest estimated GHG emissions coefficient of all energy grains and protein ingredients (see **Table 2**). Fat and synthetic amino acids had the highest GHG emission coefficients. Higher corn inclusion and lower fat and synthetic amino acid inclusion in the diets resulted in lower estimated GHG emissions overall.

In addition to reducing dietary GHG emissions, increasing SBM amino acid and energy levels does not appear to increase dietary CP. As SBM nutritional composition improved (higher digestible amino acids and energy), dietary CP level was not affected when formulating to minimize diet cost (**Table 3**). Excess dietary CP is the level above what is required to

Table 2. Greenhouse Gas (GHG) Emissions by Feed Ingredient

Feed Ingredient	gCO_2e/kg
Energy Grains	
Corn Distillers – Ethanol[1]	880
Corn Germ Meal[2]	1,213
Corn Grain[1]	340
Wheat Midds[2]	487
Protein	
Canola Meal[1]	463
SBM[1]	463
Fat	
Fat - Animal Vegetable Blend[2]	13,281
Fat - Tallow – Porcine[2]	14,652
Synthetic Amino Acids	
L-Lysine [1]	6,695
DL-Methionine[1]	2,138
L-Threonine[1]	6,695
L-Tryptophan[3]	4,206
L-Valine[3]	8,997
Minerals	
Calcium Carbonate[3]	62
Monocalcium Phosphate 21%[3]	1,122
Salt (Bulk) [3]	110
Vitamins/Enzymes	
Phytase, 2,500 FTU/gm[3]	1,949
Phytase, 5,000 FTU/gm[3]	1,949
Vitamin & trace mineral pack[3]	3,113

Adapted from Pope et al., 2024.

1 Greet Model – Mass (ANL 2018)

2 GFLI Database – Mass (GFLI 2022)

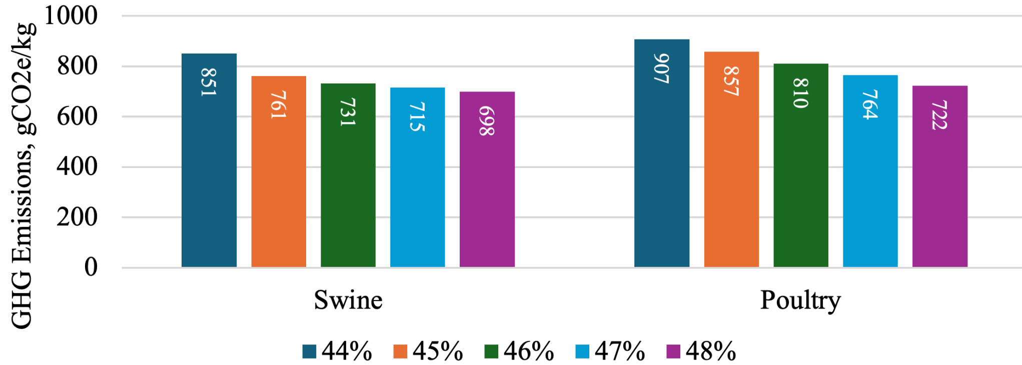
3 ECOALIM Database – Economic (ECOALIM 2023)

Table 3. Total Diet Protein (%) Comparing Diets Optimized for Minimum Diet Cost

Diet	44% CP	45% CP	46% CP	47% CP	48% CP	48% CP – 44% CP
Poultry						
Broiler Grower	19.11	19.12	19.11	19.12	19.11	0
Broiler Finisher	17.51	17.51	17.48	17.5	17.53	0.02
Layer	15.34	15.34	15.33	15.35	15.35	0.01
Swine						
Lactation	17.15	16.48	16.48	16.5	16.46	-0.69
Nursery	20.04	20.08	20.11	20.14	20.17	0.13
Grower	16.07	15.68	15.69	15.67	15.65	-0.42
Finisher	12.95	12.92	12.89	12.88	12.91	-0.03

Adapted from Pope et al., 2024.

Figure 5. Average GHG Emissions, gCO2e/kg for Each 1% Increase in SBM CP



precisely meet amino acid needs for animal production and maintenance. Excess CP is the source of excreted nitrogen (N) (feces and urine). In North America, reduction of N excretion is often not an objective in swine and poultry production because the manure is collected, safely held and then spread as an organic fertilizer, reducing the need for inorganic N sources. However, this finding is critical to other regions that formulate to control dietary CP and corresponding levels of N excretion.

Implications

Improving SBM nutrient composition (higher digestible amino acids and energy) leads to economic and environmental benefits. Higher digestible amino acids and energy result in increased SBM market value and coincides with reduced dietary GHG emissions (gCO2e/kg). Understanding, quantifying and communicating these dynamic benefits in practice require reliable amino acid and energy values and science-based estimates of the environmental impact of ingredients. Improved nutritive quality of SBM coincided with increased corn grain demand in diets, which may create additional demand for corn, influencing crop producer decisions when optimizing crop rotation to maximize profit. Higher SBM value benefits end users and enables additional value to be shared with participants in the value chain. Significant ingredient cost differences showed that the outcome of improved SBM amino and energy levels is resilient, even with changing market conditions.

Conclusion

1. Using SBM with increased amino acid and energy concentrations is a means to reduce diet cost and diet impact on the environment (GHG emissions).
2. Increasing SBM amino acid and energy concentrations can allow reductions in total SBM inclusion in the diet, but a higher nutrient value as SBM quality improves enables users to pay more for higher CP SBM and still reduce diet costs overall.
3. While standardized methods for estimating emissions are evolving, competent GHG emission coefficients for ingredients based on best scientific estimates are presented here; these values can be used by swine and poultry producers who are monitoring the environmental impact of diets.
4. GHG reduction can be achieved without imposing added diet cost.
5. As SBM CP increases (higher digestible amino acid and energy concentrations) corn usage increases, which is a key driver for reduced dietary GHG emissions.
6. Increasing SBM amino acid and energy levels does not appear to increase dietary CP and the corresponding nitrogen excretion.
7. This publication provides a methodology for evaluating the economic and environmental impact of feed ingredients used in animal nutrition.

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