

Soybean meal mitigates respiratory disease–impaired growth in pigs

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Introduction

Soybean meal (SBM) is a superb amino acid and energy source for pig diets, but another important dimension is emerging in relation to health-promotion in humans and food animals. Soybeans contain an abundance of functional molecules (FM) in the non-nutritive fraction (Sharma et al., 2019), as well as bioactive peptides that arise during digestion of major SBM proteins (Chatterjee et al., 2018). There is considerable information on these in relation to human health, but research with food animals is in the early stages of development (Smith and Dilger, 2018).

To our knowledge, the first illustration of the disease-mitigating effects of SBM in pigs was reported in 2010 by researchers at the Hanor Company (Johnston et al., 2010; Boyd et al., 2010). Swine respiratory disease infection (SRD) was unexpectedly encountered during a study with growing pigs that involved low SBM (typical) and high SBM diets. Pigs fed low SBM diets exhibited a profound loss in growth and feed conversion efficiency (FCE), which is common during periods of high immune stress. However, pigs fed diets with higher SBM content (38-50%) grew as though no active infection was present. These results were confirmed by another group who conducted a similar study design, almost simultaneous with ours, and who also encountered SRD pathogens unexpectedly (*Gene Gourley, M.S., personal communication*).

In effect, the planned experiment at Hanor became decidedly more valuable when pigs encountered a SRD complex of pathogens. This proved to be fortuitous. Our observation that SBM could mitigate SRD–impaired growth was novel for food animals and led to a [new frontier](#) in ingredient science.

This paper describes that work and makes the case for a more balanced use of SBM as compared to extreme displacement by alternative amino acid sources during periods of SRD stress. Results from the Hanor study exposed the hidden cost of SRD and illustrated the effectiveness of SBM in mitigating impaired growth. Our observation that SBM can mitigate the effects of SRD is strengthened by results from a commercial study where the ability of pigs to thrive improved by increasing dietary SBM content (Cemin et al., 2020). We conclude with the proposition that SBM is both a nutritional and [health-promoting](#) ingredient.

Intent of the original Hanor study

The original experiment was designed to determine whether SBM level was a factor in meeting the dietary lysine requirement for pigs fed the metabolic modifier, ractopamine hydrochloride (RAC). In other words, did the level of dietary lysine required to maximize growth and FCE depend on the

amount of SBM used to meet the lysine requirement? The simultaneous investigation of response to dietary lysine and SBM level was a fortunate design feature when SRD infection was unexpectedly encountered. Given this circumstance, the question evolved beyond how amino acid specifications were met to whether the nutraceutical components of SBM could mitigate respiratory disease impaired-growth. In the end, the high SBM (H-SBM) regimen profoundly improved the level of growth and FCE achieved when compared to low SBM (L-SBM) fed pigs.

Study design

Dietary treatments were arranged as a 4 x 2 factorial; having 4 standardized ileal digestible (SID) lysine levels and 2 SBM levels (L-SBM, H-SBM). Pigs in all 8 diet subclasses were fed RAC (5 ppm) with whole-body growth rate (ADG), FCE and carcass gain being the key measures. A total of 420 castrate pigs (PIC terminal genetics) with an average body weight of 217 lbs were used. Data were collected each week for 21 d, after which all pigs were harvested. The commercial research facility that Hanor used was an academic equivalent setting, since pig density (room, pen) was low and environmental stressors normally encountered in commercial sites were reduced. The latter was accurate until we encountered an active infection of SRD complex of pathogens. The experimental framework is shown in **Table 1**.

Table 1. Factorial arrangement of SID lysine¹ and soybean meal (SBM) level diets

| Diet SBM Level | SID Lysine, % ^{1,2} | | | | Total Pens and Pigs | |
|----------------|------------------------------|--------|--------|--------|---------------------|-------------------|
| | 0.65 | 0.75 | 0.85 | 0.95 | EU Pens | Pigs ³ |
| Low | 6 (52) | 6 (53) | 6 (52) | 6 (53) | 24 | 210 |
| High | 6 (52) | 6 (53) | 6 (52) | 6 (53) | 24 | 210 |

¹Standardized ileal digestible, SID.

²Experimental unit pens of pigs shown prior to parenthesis. Total pigs per treatment subclass is shown in parenthesis.

³Average initial whole-body weight for treatments, 216 ± 1.5 lbs.

Diet formula design

Diets were formulated to provide 0.65, 0.75, 0.85 or 0.95% SID lysine for both SBM regimens. The level of SBM and crude protein (CP) for each diet subclass is shown in **Table 2**. Diet composition is shown in **Table 3a** with calculated nutrient content for diets shown in **Table 3b**. Nutrient level was confirmed by analysis.

Four diets were manufactured and summit blended at the research farm to create the 8 experimental diets using Feed Logic equipment. Diets 1 and 4 were composed for L-SBM

diets with SID lysine levels achieved by increasing SBM and crystalline amino acids. Diet 1 (L-SBM) included corn gluten meal to meet the minimum CP level (16.0%) required for diets containing RAC. Diets 5 and 8 were manufactured for H-SBM diets by increasing SBM content, without the use of crystalline amino acids. This allowed comparison of the growth response to dietary lysine for typical diets (L-SBM) to those with significantly higher SBM content.

The 0.65% SID lysine diet for both SBM levels (diets 1, 5) was equivalent for CP (16.0%) and for each of the 6 most limiting essential amino acids and histidine; their total being 3.46, 3.48% for L-SBM and H-SBM diets, respectively. Both diets were isocaloric (net energy, NE). Nutrient equality was important because a difference in response at that point (0.65% SID lysine) could not be attributed to different levels of CP, essential amino acids or NE. Given the extreme care to achieve nutrient equivalency, this diet pair was the anchor for the response curve with respect to the interpretation of results.

Table 2. Level of dietary soybean meal (SBM) and crude protein (CP) content

| Diet SBM Level | Unit | SID Lysine ¹ , % | | | |
|----------------|---------|-----------------------------|------|------|------|
| | | 0.65 | 0.75 | 0.85 | 0.95 |
| Low | lbs/ton | 273 | 316 | 362 | 406 |
| High | lbs/ton | 374 | 462 | 553 | 637 |
| Low | CP, % | 16.0 | 16.0 | 16.0 | 16.0 |
| High | CP, % | 16.0 | 17.4 | 18.7 | 20.1 |

¹Standardized ileal digestible, SID.

Table 3a. Ingredient composition of summit blend diets¹

| Diet ² | 1 | 4 | 5 | 8 |
|---------------------|-------------|-------------|-------------|-------------|
| SID Lysine, % | 0.65 | 0.95 | 0.65 | 0.95 |
| Ingredient, lbs/ton | Low SBM | | High SBM | |
| Corn ground, 8.5% | 1521 | 1474 | 1482 | 1239 |
| Soybean meal, 47.5% | 273 | 406 | 374 | 637 |
| Corn gluten, 62.0% | 109 | 0 | 39 | 0 |
| L-Lysine.HCl | 2.5 | 7.0 | 0 | 0 |
| L-Threonine | 0 | 3.0 | 0 | 0 |
| DL-Methionine | 0 | 1.5 | 0 | 0 |
| Choice white grease | 46 | 61 | 58 | 80 |
| Mono-calcium Phos. | 21.5 | 20.9 | 21.0 | 19.6 |
| Limestone | 16.7 | 15.8 | 16.0 | 14.2 |
| Salt | 8.0 | 8.0 | 8.0 | 8.0 |
| VTM Premix | 2.0 | 2.0 | 2.0 | 2.0 |
| Ractopamine, 9 g/lb | 0.5 | 0.5 | 0.5 | 0.5 |
| Total | 2000 | 2000 | 2000 | 2000 |

¹Standardized ileal digestible, SID. Digestible coefficients for corn, soybean meal, corn gluten meal was updated based on NRC (2012) which led to slight increases in SID lysine values for diets 1, 4, 5, 8: 0.68, 0.98, 0.68, 0.99%, respectively.

²Diets 1, 4 were manufactured and blended by Feed Logic equipment to derive diets 2, 3. Diets 5, 8 were likewise blended to derive diets 6, 7.

The remaining test diets (0.75, 0.85, 0.95% SID lysine) were equivalent for NE, minerals and vitamins, but not for all essential amino acids or CP. However, each diet met or exceeded the requirement for the 5 most limiting essential amino acids in relation to dietary lysine, based on the current NRC standard (2012). The CP level for each lysine cohort pair was higher for H-SBM diets (**Table 2**), which led to greater amounts of isoleucine, valine and dispensable amino acids. Diets were formulated based on nutrient specifications from the literature at that time, but amino acid and NE levels were recalculated (**Table 3b**) and evaluated based on the 2012 NRC standard for this publication.

Fortunately, estimates for the SBM NE to corn NE ratio that was used for this experiment were in relative agreement with recent estimates for academic-equivalent settings (Boyd and Gaines, 2023). The updated estimates for SBM and corn are reflected in calculated NE values shown in **Table 3b**.

Table 3b. Calculated nutrient composition of summit blend diets¹

| Diet | | 1 | 4 | 5 | 8 |
|--------------------------------------|---------|---------|-------|----------|-------|
| SID Lysine, % | | 0.65 | 0.95 | 0.65 | 0.95 |
| Item | Unit | Low SBM | | High SBM | |
| Hanor NE, 2020 ² | mcal/lb | 1.171 | 1.178 | 1.177 | 1.181 |
| Crude Protein | % | 16.4 | 16.4 | 16.4 | 20.4 |
| SID Lysine ¹ | % | 0.68 | 0.98 | 0.68 | 0.99 |
| SID Lysine:NE | g/mcal | 2.63 | 3.77 | 2.62 | 3.81 |
| SID M+C:Lysine | ratio | 0.79 | 0.56 | 0.74 | 0.59 |
| SID Thr:Lysine | ratio | 0.74 | 0.66 | 0.75 | 0.66 |
| SID Trp:Lysine ³ | ratio | 0.20 | 0.17 | 0.23 | 0.23 |
| SID Ile : Lysine | ratio | 0.83 | 0.57 | 0.85 | 0.76 |
| SID Val : Lysine | ratio | 0.98 | 0.66 | 0.98 | 0.85 |
| SID His : Lysine | ratio | 0.55 | 0.39 | 0.57 | 0.50 |
| Sum, Amino Acids ⁴ | % | 3.46 | 3.93 | 3.49 | 3.55 |
| Calcium Total | % | 0.60 | 0.60 | 0.60 | 0.60 |
| Phosphorus STTD ⁵ | % | 0.28 | 0.28 | 0.28 | 0.28 |
| SBM sourced isoflavones ⁶ | | - | - | - | - |
| Genistein | ppm | 157 | 233 | 214 | 365 |
| Daidzein | ppm | 110 | 164 | 151 | 257 |
| Glycitein | ppm | 22 | 33 | 30 | 51 |
| Total Isoflavones | ppm | 286 | 425 | 392 | 668 |

¹Standardized ileal digestible, SID. Original diet composition was updated for SID level as stated in Table 3a, footnote 1. SID levels for each amino acid shown was also slightly different which is reflected in the ratio of amino acids to lysine.

²Diets were originally formulated to be isocaloric based on internal effective ME, but NE values were recalculated using NRC (2012). NE values for corn, corn gluten meal; SBM NE were based on Boyd and Gaines (2023). SBM, corn gluten meal, fat NE values to NRC corn NE ratio were: 0.843, 0.951, 2.908.

³NRC (2012) model estimated requirement for SID Trp:Lysine ratio as 0.177 (0.18), but the Diet 4 ratio was 0.165 (0.17); bias in performance was expected for diet 4 (see text). The ratio for diets 1-3 exceeded the NRC (2012) minimum, respectively: 0.203, 0.194, 0.184.

⁴Sum of most essential amino acid values (%): lysine, methionine+cys, threonine, tryptophan, isoleucine, valine and histidine.

⁵Recalculated from original available phosphorus.

⁶Isoflavones contribution from SBM using values published by Smith and Dilger (2018).

Unexpected infection with respiratory pathogens

Pigs unexpectedly became infected with multiple respiratory pathogens (SRD complex) that triggered systemic inflammation. SRD causes both growth and FCE to plummet compared to unaffected pigs. Upon learning of the infection, all pigs received medication by water and clinical diagnostics and physical inspection of pigs was initiated under the direction of Tara Donovan, DVM (The Hanor Co.). Serology revealed that pigs were PRRSv and porcine circovirus (PCV2) positive. There were PCV2 lesions and *Streptococcus suis* infection was also confirmed. The inflammatory nature of these viruses has been proven by the presence of circulating pro-inflammatory cytokines (Parra et al., 2006).

The study continued as planned because SRD infection is a production reality. In North America, SRD complex is prevalent in many systems during January – April when barns are closed due to cold weather. In addition, SRD is often a problem for weaned pigs that are derived from PRRSv active sow farms. Taken together, SRD infection can span 6-7 months of the year.

SBM mitigated respiratory disease-impaired growth

The overall effect of SBM level on whole-body and carcass growth and FCE is shown in **Table 4**. Since the response to dietary lysine level was similar for both SBM levels (SBM x lysine level, $P > 0.29$, all criteria), the average response to SBM level is shown for the 21 d study. The growth suppressing effects of SRD is illustrated by comparing the response of L-SBM and H-SBM diets; the latter resulted in profound improvements in whole-body (ADG, +9.5%; FCE, -7.7%) and carcass growth (ADG, +12.8%; FCE, -9.7%).

The net result of H-SBM diets, during the infection, was improved carcass weight gain (3.8 lbs/pig) and significant feed savings. If H-SBM fed pigs were harvested on a weight

constant basis to L-SBM pigs (31.5 lbs carcass gain/pig), they would have required 13.2 lbs less feed per pig.

This was the first study to show that SBM can reduce high immune stress-impaired growth. Until this report (Johnston et al., 2010), efforts to reduce disease impaired-growth by nutritional means had been unremarkable. We propose that SBM is a nutritional and 'prescriptive' ingredient when SRD is encountered in commercial practice; prescriptive, meaning that SBM is a credible, tactical option for respiratory disease mitigation in pigs (*term first suggested by Dr. Lisa Weaver, personal communication*).

Growth response was dependent on SBM level

Although the shape of FCE response curves was similar for both SBM regimens, dietary SBM level caused the curves to separate into 2 planes of genetic expression (**Figure 1**). The same pattern was observed for growth rate (**Figure 2**). This suggests an important principle in relation to genetic expression when confronted with disease. SBM content influenced the level of growth permitted, with growth depending next on amino acid intake. To illustrate, when higher lysine levels (amino acids) were fed to improve performance by apparently less healthy pigs (L-SBM), FCE and ADG became worse not better (**Figures 1, 2**).

In the hierarchy of growth regulation, amino acid intake is important but secondary to health status. Physiologically, the body responds to systemic immune stress by prioritizing nutrients for life-sustaining processes over growth (e.g., IGF-1 declines; Johnston, 1997; Spurlock, 1997). Ultimately, amino acid intake provides the building blocks for muscle growth that health status permits.

This research provides an answer to the often asked question, 'can anything be done nutritionally to improve growth' when disease is encountered? Diet SBM content, rather than elevated amino acid (or energy) intake, is a means of profoundly mitigating growth suppression by the SRD complex.

SBM level differences were compared at the point of response maximum for FCE and growth. Pigs fed H-SBM diets achieved a minimum FCE of 2.60, compared to 2.88 for L-SBM fed pigs; a difference of 0.28 units (**Figure 1**). The dietary lysine level required to achieve minimum response also differed. We estimate that 0.94% SID lysine was required for H-SBM fed pigs and that 0.84% was required for L-SBM pigs (asymptote estimates). The 0.28 unit spread in FCE is a key measure in estimating feed cost for unchecked, respiratory disease stress.

Impressive differences were also observed for maximum ADG. H-SBM fed pigs gained a maximum 2.24 lbs/d compared to 2.07 for L-SBM pigs (0.17 lbs/d change, **Figure 2**). The SID lysine level required to achieve respective maximums was 0.85% for H-SBM fed pigs compared to 0.80% for their counterparts.

Table 4. Main effect of SBM level on whole-body and carcass growth in pigs fed the metabolic modifier, ractopamine for 21 d^{1,2}

| Item | Unit | Low SBM | High SBM | SEM | Statistical Prob. < | % Advantage |
|-----------------------------------|---------|---------|----------|------|---------------------|-------------|
| No. Pens | - | 24 | 24 | - | - | - |
| No. Pigs | - | 210 | 210 | - | - | - |
| Initial Body Weight | lbs/pig | 216.9 | 216.5 | 1.6 | 0.88 | - |
| Whole-body ADG ³ | lbs/d | 1.99 | 2.18 | 0.1 | 0.04 | 9.5 |
| Whole-body FCE ³ | ratio | 2.97 | 2.74 | 0.1 | 0.05 | -7.7 |
| Initial Carcass est. ⁴ | lbs/pig | 160.9 | 160.9 | - | - | - |
| Carcass Yield ⁵ | % | 74.6 | 74.7 | 0.50 | ND | - |
| Carcass Weight | lbs/pig | 192.4 | 196.2 | 1.4 | 0.05 | 2.0 |
| Carcass ADG ³ | lbs/d | 1.33 | 1.50 | 0.1 | 0.09 | 12.8 |
| Carcass FCE ³ | ratio | 4.35 | 3.93 | 0.1 | 0.05 | -9.7 |

¹Dietary SBM levels are shown in Table 2.

²Least squares means calculated using whole-body initial weight as covariate.

³Average daily gain, ADG; Feed conversion efficiency ratio, FCE, calculated as feed/gain.

⁴Initial carcass weight estimated by multiplying initial live body weight x 0.745.

⁵Calculated as carcass weight (head on) at plant/live weight at the research site (<12 h to loading).

Figure 1. Whole-body feed efficiency response for growing pigs receiving Ractopamine (5 ppm) for 21 d: Response to dietary SBM and lysine levels during an active respiratory infection

Dietary level of SBM for each lysine level treatment is shown in Table 2. Arrows show the response maximum (Rmax) feed conversion efficiency (FCE) for both SBM levels. The absolute dietary SID lysine requirement (asymptote) to achieve FCE Rmax is 0.84 and 0.94% for low and high SBM curves respectively.

Quadratic equations: Low SBM, $Y (FCE) = 6.25x^2 - 10.49x + 7.2814$; High SBM, $Y (FCE) = 4x^2 - 7.6x + 6.21$

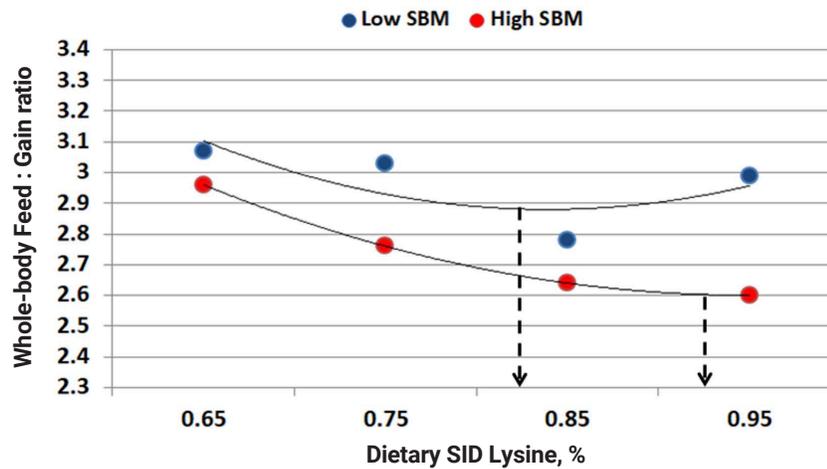
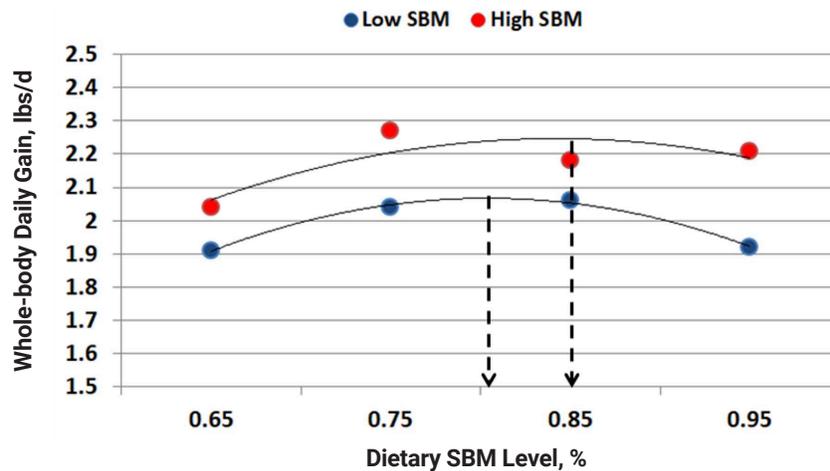


Figure 2. Whole-body daily gain response for growing pigs receiving Ractopamine (5 ppm) for 21 d: Response to dietary SBM and lysine level during an active respiratory disease infection

Dietary level of SBM for each for lysine level treatment is shown in Table 2. Arrows show the response maximum (Rmax) growth rate (ADG) for both SBM levels. The absolute dietary SID lysine requirement (asymptote) to achieve ADG Rmax is 0.80 and 0.85% for low and high SBM curves respectively.

Quadratic equations: Low SBM, $Y (ADG) = -6.75x^2 + 10.85x - 2.2931$; High SBM, $Y (ADG) = -5x^2 + 8.42x - 1.2985$



Is SBM mitigation of SRD effects nutritional?

The biological basis for the mitigating effects of SBM on SRD impaired-growth is unclear, but it is unlikely to be nutritional. This position is based on NE and nutrient equivalency of cohort diets that anchor (0.65% SID lysine) the growth response curves (Figures 1, 2). SBM level is the variable in play and the difference in SBM FM intake is markedly different. These components are most likely involved in mitigating mechanisms.

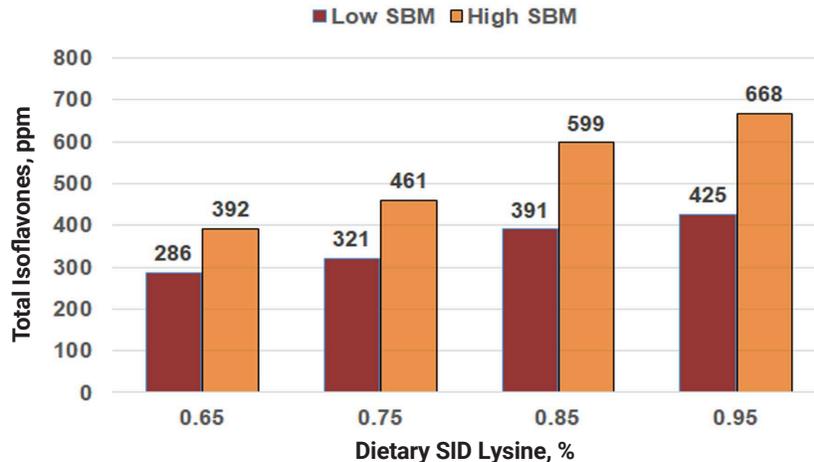
Functional molecules in SBM are remarkably diverse and abundant. The isoflavone (ISF) class of FM was used as a

'marker' to track relative FM differences between SBM levels over the lysine response curve. The H-SBM anchor diet (0.65% SID lysine) provided 37% more ISF than the L-SBM counterpart (Table 3b; diets 1, 5). The disparity in ISF content between diet cohorts increased as lysine level increased (Figure 3).

The performance advantage of H-SBM fed pigs was compared across the lysine response curve. Regression-predicted means for FCE and growth response for anchor diets exhibited a 0.14 FCE unit advantage for H-SBM pigs (Figure 1). Growth rate was improved by 0.15 lbs/d over L-SBM counterparts (Figure 2). These differences are nearly twice their respective SEM (Table 4), despite being nutritionally equivalent.

Figure 3. Total isoflavone content for experimental diets based solely on the contribution by SBM

Total isoflavone (ISF) content of diets is based on the contribution by SBM. This value is the sum of genistein, daidzein and glycitein, which are shown in Table 3b. Level of each ISF was derived from the review by Smith and Dilger (2018). Total ISF content for high SBM diets was 37, 44, 53 and 57% greater than for low SBM diets (0.65, 0.75, 0.85, 0.95% SID lysine), respectively.



Response variance for SBM level was also compared for 0.75 and 0.85% SID lysine cohort diets. The relative advantage for H-SBM fed pigs at each lysine level was similar to the difference for anchor diets, with some exception. Whole-body FCE differed by -0.15 and -0.25 units (Figure 1) and growth rate improved by 0.15 and 0.19 lbs/d for 0.75% and 0.85% SID lysine diets, respectively (Figure 2).

Comparisons were not made at the 0.95% level because it exceeded the lysine requirement of L-SBM for FCE and ADG. In addition, the L-SBM diet appeared to be slightly deficient in tryptophan based on the NRC 2012 standard (Table 3b), which could introduce nutrition bias into the response. Each of the other L-SBM diets (0.65, 0.75, 0.85%) exceeded the minimum SID ratio of tryptophan to lysine (0.18).

Classic health – amino acid nutrition principle

Our research confirms that the rate and efficiency of growth is governed by health status; healthier pigs grow faster and more efficiently than unhealthy pigs. It confirmed that the lysine (amino acids) requirement is higher for healthier than for unhealthy pigs. In addition, increasing lysine intake beyond the requirement for unhealthy pigs does not over-ride disease impaired-growth (Figures 1, 2). These landmark principles were established by Noel Williams and his PhD advisor, Dr. Tim Stahly (Williams et al., 1997).

Our study extended concepts beyond their classic work, but in line with their hypothesis that FM in a product such as SBM may play a role in disease mitigation (*personal communication, Dr. Stahly, 1998*). The seemingly ‘inopportune’ infection by the SRD complex (*co-infection with multiple respiratory pathogens*) that we encountered created high-immune stressed pigs with profoundly impaired-growth. The observation that SBM (FM abundant source) had mitigating effects to counter the SRD complex is original and unusual; unusual in that the magnitude

of response tends to be extraordinary for nutrition research.

Since SBM proved to have mitigating effects against SRD, it has dual and complementary functions as an ingredient: nutritional and tactical.

SBM improved nursery pigs’ ability to thrive

There are other examples of SBM improving the health status of pigs reared under commercial conditions (e.g., improved viability, reduced medical treatment). The report by Cemin and co-workers (2020) is especially noteworthy. Their collaboration with 2 production companies (JBS Pork, New Horizon Farms) afforded them access to 2 commercial farms and more than 6000 nursery pigs. Their primary objective was to observe the FCE response to increasing dietary SBM content (corn-SBM diet phase). Despite the narrow time frame of the test (21 d) and with pigs being in relatively good health, SBM reduced mortality and cull pigs (disqualified, extreme low weight or condition) in a dose-dependent manner (Figure 4). In other words, the ability of pigs to thrive in late nursery and early grower periods was positively related to SBM level.

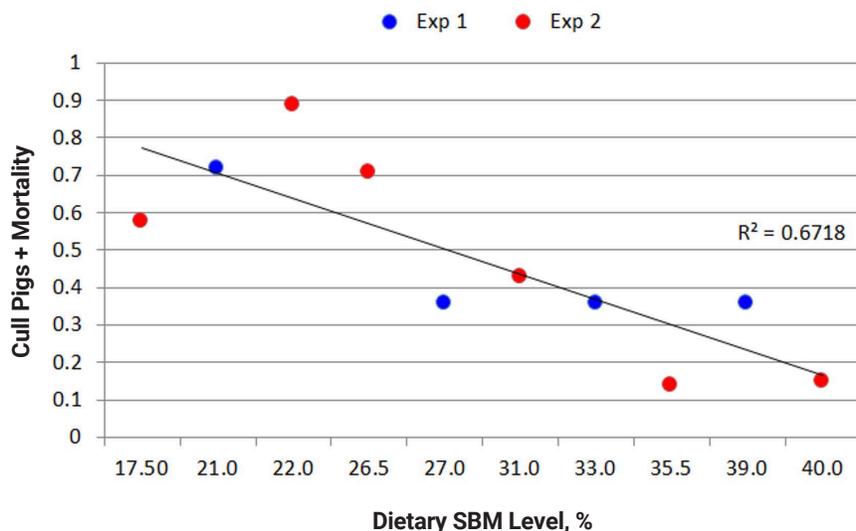
Mechanisms for disease mitigating effects of SBM

A discussion of mode of action for the disease-mitigating effects of SBM is beyond the scope of this paper, but is the topic for our next article in this series. A few examples are provided here to support our hypothesis that systemic health was improved by dietary SBM during an infection with SRD complex.

We are indebted to human medical research for our understanding of disease mitigating mechanisms of soybeans. A variety of disease-uncoupling actions are exerted simultaneously by an equally diverse set of FM. Some mechanisms improve or balance the animal’s survival response

Figure 4. The ability of late nursery pigs to thrive improved as dietary SBM increased (figure drawn from data provided in Cemin et al., 2020).

Exp. 1 was conducted at a New Horizon Farms nursery (Pipestone, Minnesota) and involved 2233 pigs over the 24 to 49 lbs phase of growth; Exp. 2 was conducted at a JBS Live Pork site (Tipton, Missouri) and involved 3795 pigs over the 39 to 78 lbs phase. Data reflect a relatively short test period (21 d) and pigs were in moderate to good health. Cull pig disqualification was based on extreme low weight and (or) poor physical condition at the end of test. Dietary SBM content for Exp. 1 was 21.0, 27.0, 33.0, 39.0% and Exp 2 was 17.5, 22.0, 26.5, 31.0, 35.5 and 40.0%. The average SEM for Exp. 1-2 was 0.401. Linear equation: $Y = -0.02597X + 1.2288$



to infection (no. 2, 3, 4 below), while other mechanisms operate to reduce pathogen concentration (no. 1). Disease mitigation mechanisms include (Chatterjee et al., 2018):

1. Anti-viral

Reduce virus replication and (or) increase viral clearance

2. Oxidation stress reduction

System responds to infection with free-radical production to combat many pathogens. Over-production of free radicals must be neutralized to prevent harm to animal cells and cell components.

3. Anti-inflammatory

Certain FM operate to control the level and balance of pro-inflammatory cytokines produced by the animal in response to infection. Over-production can be harmful to the animal.

4. Improve function of existing immune cells

5. Preserve intestinal barrier integrity

Lunasin, a polypeptide derived from SBM protein, exerts gut protective effects to protect barrier function.

Control of systemic disease requires multiple countering mechanisms that act in concert (e.g. anti-inflammatory, antioxidant) to reduce the damaging effects of pathogens. An effective counter to disease damage results in a durable or resilient state for normal function. The respiratory disease complex that we encountered in the Hanor study involved at least 3 known pathogens (virus, bacteria). Multiple pathogen infection tends to be the norm in commercial systems.

SBM – tactical option for SRD mitigation: DVM perspective

SBM is a tactical ingredient option in mitigating the severe growth and FCE impairing effects of SRD. We applied the term prescriptive to this ingredient as a cuing device for veterinary and nutrition decision-makers to be mindful of the mitigating benefits of SBM during SRD, in addition to its amino acid and energy value. Replacing SBM with alternative protein sources can be made an equal trade for nutrition, but this is not true for FM even among other legumes. SRD imposes significant hidden costs in FCE loss, increased medical treatment and potentially fewer pigs that thrive in late nursery through early growth. These costs are hidden because they are 'folded' into barn 'closeout' data, but they can add \$3-6/pig to cost (range \$2-9).

SRD complex is prevalent in many North American systems during January – April, when barns are closed for cold weather (see *endnote for respiratory disease pathogens*). Influenza is also a problem in the fall for some systems, but the economic cost of winter-spring SRD tends to be more persistent.

The financial value of tactical SBM use can be determined by comparing performance for (1) system diets and (2) prescriptive diets (system diets plus 30% more SBM in each diet to finish). Diets need to be equally applied by site and sex, using large numbers and in the time frame specified by the veterinarian(s). Key measures are tracked to compute the financial outcome (e.g., 1000 pig basis), including full-value (FVP) and cull-value pig market revenue, total diet cost and medication cost.

Carcass weight is a priority measure. Although growth rate is reflected in FVP carcass pounds, the diet effect on population carcass weight is important because a decline can begin to emerge even prior to summer heat stress. The motive is to see if the system is experiencing a leading edge to summer carcass weight dip (*later article in this series*). Carcass weight decline can begin to appear in April when heat is not yet a problem and becomes worse during summer. The reason for a premature decline in carcass weight can be confusing, but it could be due to unchecked SRD impaired-growth. Summer carcass weight dip is a very costly problem; one that is preventable provided that pre-summer carcass weight decline is controlled.

An example of ingredient constraints (SBM, DDGS) for a field test of standard and prescriptive or tactical SBM diets is shown in the Auxiliary section below (provided courtesy of The Hanor Company).

Key Conclusions

1. Respiratory disease (SRD) impairs feed conversion and daily gain by at least 8 and 10%
2. Increasing dietary SBM above typical levels mitigates FCE and ADG loss during SRD
3. SBM is both a nutritional and prescriptive ingredient
4. Cost-effective periods for elevated SBM may be during winter-spring seasons, when barns are closed tight and when SRD is often a problem

Endnote

The most problematic swine respiratory diseases include *Mycoplasma hyopneumonia*, Porcine reproductive and respiratory syndrome (PRRSv), Influenza A virus in swine, *Streptococcus suis*, *Hemophilus parasuis*, and *Actinobacillus suis pleuropneumonia*.

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Auxiliary backgrounder

Framework for Tactical SBM diets during persistent respiratory disease (SRD) challenge

The framework of SBM and key ingredient specifications below is an example of minimum SBM constraints when persistent respiratory disease exists to performance test against the normal diet program being used for a system. Veterinarians should determine whether SRD infection is a significant problem; if there is concern, identify the season for test (e.g., winter-spring spring). The SBM constraint is the suggested minimum required to exhibit mitigating effects on SRD impaired-growth and feed efficiency. Minimum DDGS use is suggested for its perceived health benefit as some veterinarians believe that fewer gut health problems have been encountered with its use in diets.

Suggested SBM Test Diet Format, lbs/ton

| Diet | Start WT | End WT | Max | Min | Min | Max | SID | NE |
|------------|----------|---------|----------|-----|------|-----|---|---------|
| Name | lbs/pig | lbs/pig | Lys. HCl | SBM | DDGS | | Lysone % | Kcal/lb |
| Diet 25-50 | 25 | 54 | 12.5 | 560 | 100 | 150 | SID Lysine, Ideal Pattern and NE per AMVC | |
| Diet 1 | 54 | 79 | 12.0 | 500 | 100 | 200 | | |
| Diet 2 | 79 | 101 | 11.0 | 400 | 125 | 200 | | |
| Diet 3 | 101 | 122 | 10.0 | 360 | 125 | 300 | | |
| Diet 4 | 122 | 159 | 8.0 | 300 | 125 | 400 | | |
| Diet 5 | 159 | 191 | 7.0 | 260 | 125 | 400 | | |
| Diet 6 | 191 | 220 | 6.0 | 230 | 125 | 400 | | |
| Diet 7 | 220 | MKT | 5.0 | 200 | 125 | 300 | | |

Diet phases can be adapted to meet company policy for no. and length of phases.

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