Influence of Protein Source on Growth Performance in Nursery Pigs

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Summary
A total of 330 pigs (241 × 600, DNA; initially 10.7 lb) were used to determine the influence of dietary protein source on growth performance in nursery pigs. At weaning, pigs were randomly allotted to 1 of 6 dietary treatments with 4 or 5 pigs per pen and 12 replications per treatment. Dietary treatments were arranged in a one-way treatment structure with diets containing different protein sources; enzymatically treated soybean meal (HP 300; Hamlet Protein, Findlay, OH), spray-dried bovine plasma (APC Corp, Ankeny, IA), fermented soybean meal (ME-PRO; Prairie Aquatech, Brookings, SD) with or without fish solubles (TASA, Lima, Peru), fish meal (TASA Prime meal; TASA, Lima, Peru), and custom-made fish meal (TASA Swine; TASA, Lima, Peru). Because of a delay in arrival of the fish meal source, all pigs were placed on a common phase 1 diet for 3 d after weaning. On d 3, all feeders were weighed, dumped, and refilled with experimental diets. Pigs were fed experimental phase 1 diets for 9 d (d 3 to 12) followed by phase 2 diets for 15 d. Following phase 2, all pigs were fed a common diet for an additional 15 d. In all weigh periods and overall, there were no significant differences between treatments for BW, ADG, ADFI, and F/G. For economic analysis (d 0 to 40), pigs fed spray-dried bovine plasma had the greatest (P ≤ 0.001) feed cost and feed cost per lb of gain compared to all other treatments. There were no differences in revenue or IOFC between treatments. In summary, utilizing alternative protein sources in phase 1 and 2 nursery pigs’ diets had no effect on growth performance. However, there was a 5 to 7% improvement in ADG for pigs fed spray-dried bovine plasma and custom-made fish meal.

Introduction
Although soybean meal is the predominant protein source used in nursery pig diets, it contains antinutritional factors that limit its inclusion rate in diets immediately after weaning. Thus, other protein sources are used to meet the pig’s amino acid requirements. These protein sources must be highly digestible and palatable to encourage feed intake. Ideally, the protein source will also provide other benefits, such as improving the omega 6:3 fatty acid ratio or providing other immunological benefits.

Fish meal traditionally has been known as a highly palatable and digestible ingredient for nursery pig diets. It is considered a good protein source due to its content of AA,

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vitamins, minerals, and omega 3 fatty acids. Fish meal has been shown to increase nursery pig feed intake and body weight gain. In recent years, fish meal has often been replaced with fermented or enzymatically hydrolyzed soybean products to reduce cost or because of variation in quality of fish meal sources. Fermented soybean meal has also been shown to improve feed efficiency and AA digestibility. However, a high-quality fish meal or additives produced from whole fish rather than fish byproducts may impact feed intake and pig performance more than other protein sources. Therefore, the objective of this study was to evaluate the influence of various protein sources on nursery pig performance.

**Procedures**
The Kansas State University Animal Care and Use Committee approved the protocol used in this experiment. The experiment was conducted at the Kansas State University Swine Teaching and Research Center. Each pen was equipped with a 4-hole, dry self-feeder and a nipple waterer to provide ad libitum access to feed and water.

**Animals and diets**
A total of 330 pigs (241 × 600, DNA; initially 10.7 lb) were used in a 40-d nursery trial. Pigs were weaned at approximately 19 d of age and placed in pens of 4 or 5 pigs each based on initial weight and gender. At weaning, pigs were randomly allotted to 1 of 6 dietary treatments with 12 replications per treatment. Due to a limited number of pigs, 42 pens were allotted with 5 pigs per pen (7 replications per treatment) and the remaining 30 pens were allotted with 4 pigs per pen (5 replications per treatment). Dietary treatments were arranged in a one-way treatment structure with diets containing different protein sources. Protein sources included enzymatically treated soybean meal (HP 300; Hamlet Protein, Findlay, OH); spray-dried bovine plasma (APC Corp, Ankeny, IA); fermented soybean meal (ME-PRO; Prairie Aquatech, Brookings, SD) with or without fish solubles (TASA, Lima, Peru); fish meal (TASA Prime meal; TASA, Lima, Peru); and custom-made fish meal (TASA Swine; TASA, Lima, Peru). Protein sources were added to the diet on a digestible lysine basis to keep soybean meal level consistent across all treatments. Diets were formulated to contain 1.40% (phase 1) and 1.35% (phase 2) SID Lys and met or exceeded nutrient requirements established by the NRC (2012). Because of a delay in arrival of the fish meal source, all pigs were placed on a common phase 1 diet for 3 d after weaning. On d 3, all feeders were weighed, dumped, and refilled with experimental diets. On average, each pig consumed 0.5 lb of common phase 1 diet. Treatment diets were fed for 9 d in phase 1 (d 3 to 12) and 13 d in phase 2 (d 12 to 25). Following phase 2, all pigs were fed a common diet for an additional 15 d (d 25 to 40).

---


The basal diets for phases 1 and 2 were manufactured at Hubbard Feeds in Beloit, KS. The basal diets were divided into 6 batches and protein sources were added and mixed at the Kansas State University O.H. Kruse Feed Technology Innovation Center in Manhattan, KS, to form the six experimental diets. Individual pig weights and feed disappearance were measured on d 12, 19, 25, 33, and 40 to determine ADG, ADFI, and F/G.

A sample of each protein source was submitted for amino acid profile (Table 1). Representative diet samples were obtained from every fifth bag of manufactured feed. The diet samples were stored at -20°C (-4°F) until they were homogenized, subsampled, and submitted for analysis of crude protein (CP), dry matter (DM), ether extract (EE), Ca, and P (Tables 2 and 3). All samples were submitted to the University of Missouri Experiment Station Chemical Laboratories (Columbia, MO).

**Economic analysis**

For the economic analysis, total feed cost per pig, feed cost per lb of gain, revenue, and income over feed cost (IOFC) were calculated for high and low ingredient prices and market pig price. Feed cost per pig placed was determined by multiplying total feed intake by diet cost. Feed cost per lb of gain was calculated by dividing the total feed cost per pig by the total weight gained. Revenue per pig placed was determined by total gain times the dressing percentage (0.75) and then multiplied by carcass price to convert to a live price. Income over feed cost (IOFC) was calculated using revenue per pig placed minus feed cost per pig placed. For high ingredient price scenarios, the following prices were used: corn = $6.00/bushel ($214.29/ton); soybean meal = $400/ton; L-Lys HCl = $0.80/lb; DL-Met = $2.50/lb; L-Thr = $1.20/lb; L-Trp = $5.00/lb; L-Val = $4.00/lb; enzymatically treated soybean meal = $0.52/lb; spray-dried bovine plasma = $2.50/lb; fermented soybean meal = $0.61/lb; enriched fermented soybean meal = $0.62/lb; fish meal = $0.70/lb; custom-made fish meal = $0.77/lb. For low ingredient price scenarios, the following prices were used: corn = $3.00/bushel ($107.14/ton); soybean meal = $300/ton; L-Lys HCl = $0.65/lb; DL-Met = $1.70/lb; L-Thr = $0.85/lb; L-Trp = $3.00/lb; L-Val = $2.50/lb; enzymatically treated soybean meal = $0.52/lb; spray-dried bovine plasma = $2.50/lb; fermented soybean meal = $0.61/lb; enriched fermented soybean meal = $0.62/lb; fish meal = $0.70/lb; custom-made fish meal = $0.77/lb.

**Statistical analysis**

Data were analyzed as a completely randomized design using the RStudio environment (Version 1.3.1093, RStudio, Inc., Boston, MA) using R programming language [Version 4.0.2 (2020-06-22), R Core Team, R Foundation for Statistical Computing, Vienna, Austria] with pen as the experimental unit. Main effects of protein source were tested. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

**Results and Discussion**

The analyzed AA profile and proximate analysis (Table 1, 2, and 3) were reasonably consistent compared to formulated values for protein sources and diets.

In all weigh periods and overall (Table 4), there were no differences between treatments for BW, ADG, ADFI, and F/G. Although there was a 5 to 7% improvement in ADG
during the treatment period for the spray-dried bovine plasma and custom-made fish meal treatment, the differences were not significant.

For economic analysis in both ingredient price scenarios, pigs fed spray-dried bovine plasma had the greatest ($P \leq 0.001$) feed cost and feed cost per lb of gain compared to all other treatments. There were no differences between treatments for revenue or IOFC in either price scenario.

In summary, the results of this experiment indicate that the protein sources used in this study did not significantly affect growth performance of nursery pigs differently. However, feeding spray-dried bovine plasma and custom-made fish meal can numerically improve weight gain.

*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. Chemical and calculated analysis of protein sources

<table>
<thead>
<tr>
<th>Item, %</th>
<th>Enzymatically treated SBM</th>
<th>Bovine plasma</th>
<th>Fermented SBM</th>
<th>Enriched fermented SBM</th>
<th>Fish meal</th>
<th>Custom-made fish meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>92.45</td>
<td>88.68</td>
<td>94.53</td>
<td>92.08</td>
<td>92.43</td>
<td>90.11</td>
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<tr>
<td>CP</td>
<td>55.63</td>
<td>76.21</td>
<td>72.39</td>
<td>70.24</td>
<td>66.73</td>
<td>64.94</td>
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<tr>
<td>EE</td>
<td>2.12</td>
<td>0.00</td>
<td>1.61</td>
<td>1.80</td>
<td>8.76</td>
<td>8.48</td>
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<tr>
<td>Crude fiber</td>
<td>4.08</td>
<td>0.00</td>
<td>6.69</td>
<td>6.26</td>
<td>0.28</td>
<td>0.26</td>
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<tr>
<td>Ash</td>
<td>6.86</td>
<td>8.04</td>
<td>1.33</td>
<td>2.16</td>
<td>16.75</td>
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Amino acids

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<tr>
<td>Asp</td>
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<tr>
<td>Cys</td>
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<tr>
<td>Glu</td>
<td>9.90</td>
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<tr>
<td>Gly</td>
<td>2.30</td>
</tr>
<tr>
<td>His</td>
<td>1.40</td>
</tr>
<tr>
<td>Ile</td>
<td>2.69</td>
</tr>
<tr>
<td>Leu</td>
<td>4.20</td>
</tr>
<tr>
<td>Lys</td>
<td>3.14</td>
</tr>
<tr>
<td>Met</td>
<td>0.76</td>
</tr>
<tr>
<td>Phe</td>
<td>2.87</td>
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<tr>
<td>Pro</td>
<td>2.72</td>
</tr>
<tr>
<td>Ser</td>
<td>2.36</td>
</tr>
<tr>
<td>Thr</td>
<td>2.12</td>
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<tr>
<td>Trp</td>
<td>0.71</td>
</tr>
<tr>
<td>Tyr</td>
<td>2.04</td>
</tr>
<tr>
<td>Val</td>
<td>2.74</td>
</tr>
</tbody>
</table>

1 A sample of each protein source was collected, homogenized, subsampled, and submitted to the University of Missouri Experiment Station Chemical Laboratories (Columbia, MO) for proximate analysis and amino acid profile.

2 Analysis of enriched soybean meal was calculated using the chemical analysis of fermented soybean meal (ME-PRO; Prairie Aquatech; Brookings, SD) and fish solubles (TASA; Lima, Peru). SBM = soybean meal.

3 Analysis of custom-made fish meal (TASA Swine; TASA, Lima, Peru) was calculated using the chemical analysis of fish meal (TASA Prime meal; TASA, Lima, Peru) and fish solubles (TASA, Lima, Peru).

EE = ether extract.
Table 2. Phase 1 diet composition (as-fed basis)\textsuperscript{1}

<table>
<thead>
<tr>
<th>Item</th>
<th>Enzymatically treated SBM\textsuperscript{2}</th>
<th>Bovine plasma\textsuperscript{2}</th>
<th>Fermented SBM\textsuperscript{2}</th>
<th>Enriched fermented SBM\textsuperscript{2}</th>
<th>Fish meal\textsuperscript{2}</th>
<th>Custom-made fish meal\textsuperscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>37.89</td>
<td>41.67</td>
<td>39.78</td>
<td>39.57</td>
<td>40.77</td>
<td>40.54</td>
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<tr>
<td>Soybean meal (46.5% CP)</td>
<td>23.72</td>
<td>23.72</td>
<td>23.72</td>
<td>23.72</td>
<td>23.72</td>
<td>23.72</td>
</tr>
<tr>
<td>Whey powder</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Enzymatically treated soybean meal</td>
<td>7.00</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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<tr>
<td>Fermented soybean meal</td>
<td>---</td>
<td>---</td>
<td>5.00</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Enriched fermented soybean meal</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>5.21</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Fish meal</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>4.85</td>
<td>---</td>
</tr>
<tr>
<td>Custom-made fish meal</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>5.05</td>
</tr>
<tr>
<td>Spray-dried bovine plasma</td>
<td>---</td>
<td>3.50</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Corn oil</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.81</td>
<td>0.83</td>
<td>0.76</td>
<td>0.76</td>
<td>0.51</td>
<td>0.53</td>
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<tr>
<td>Monocalcium phosphate (21% P)</td>
<td>0.65</td>
<td>0.55</td>
<td>0.78</td>
<td>0.78</td>
<td>0.18</td>
<td>0.20</td>
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<tr>
<td>Salt</td>
<td>0.33</td>
<td>0.13</td>
<td>0.35</td>
<td>0.35</td>
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<tr>
<td>L-Lys-HCl</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
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<tr>
<td>DL-Met</td>
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<td>L-Thr</td>
<td>0.15</td>
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<td>L-Trp</td>
<td>0.02</td>
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<td>L-Val</td>
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<tr>
<td>Vitamin premix\textsuperscript{3}</td>
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<td>Trace mineral premix</td>
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<tr>
<td>Total</td>
<td>100</td>
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<td>100</td>
<td>100</td>
<td>100</td>
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</table>

\textsuperscript{1} Table continued
### Table 2. Phase 1 diet composition (as-fed basis)

<table>
<thead>
<tr>
<th>Item</th>
<th>Enzymatically treated SBM</th>
<th>Bovine plasma</th>
<th>Fermented SBM</th>
<th>Enriched fermented SBM</th>
<th>Fish meal</th>
<th>Custom-made fish meal</th>
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<tbody>
<tr>
<td>Lys</td>
<td>1.40</td>
<td>1.40</td>
<td>1.40</td>
<td>1.40</td>
<td>1.40</td>
<td>1.40</td>
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<tr>
<td>Ile:Lys</td>
<td>62</td>
<td>56</td>
<td>62</td>
<td>61</td>
<td>58</td>
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<tr>
<td>Leu:Lys</td>
<td>116</td>
<td>114</td>
<td>119</td>
<td>118</td>
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<td>111</td>
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<tr>
<td>Met:Lys</td>
<td>36</td>
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<td>36</td>
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<td>Thr:Lys</td>
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<tr>
<td>Trp:Lys</td>
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<tr>
<td>Val:Lys</td>
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<tr>
<td>His:Lys</td>
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<tr>
<td>Total Lys, %</td>
<td>1.53</td>
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<td>1.54</td>
<td>1.54</td>
<td>1.55</td>
<td>1.54</td>
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<tr>
<td>NE NRC, kcal/lb</td>
<td>1,186</td>
<td>1,192</td>
<td>1,188</td>
<td>1,188</td>
<td>1,194</td>
<td>1,194</td>
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<tr>
<td>SID Lys:NE, g/Mcal</td>
<td>5.36</td>
<td>5.33</td>
<td>5.35</td>
<td>5.35</td>
<td>5.32</td>
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<tr>
<td>CP, %</td>
<td>21.9</td>
<td>21.0</td>
<td>21.8</td>
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<tr>
<td>Ca, %</td>
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<td>P, %</td>
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<tr>
<td>STTD P, %</td>
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Analyzed values, %

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<tr>
<th>Item</th>
<th>DM</th>
<th>CP</th>
<th>Ether extract</th>
<th>Crude fiber</th>
<th>Ash</th>
<th>Ca</th>
<th>P</th>
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<tr>
<td></td>
<td>91.32</td>
<td>18.73</td>
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<tr>
<td></td>
<td>90.87</td>
<td>19.18</td>
<td>3.72</td>
<td>1.81</td>
<td>6.32</td>
<td>0.69</td>
<td>0.64</td>
</tr>
</tbody>
</table>

1 Phase 1 diets were fed from approximately 11 to 13 lb.

2 1) HP 300; Hamlet Protein, Findlay, OH. 2) Spray-dried bovine plasma; APC Corp, Ankeny, IA. 3) ME-PRO; Prairie Aquatech, Brookings, SD. 4) ME-PRO with fish solubles; Prairie Aquatech, Brookings, SD; TASA, Lima, Peru. 5) TASA Prime meal; TASA, Lima, Peru. 6) TASA Swine; TASA, Lima, Peru. SBM = soybean meal.

3 Vitamin premix with phytase provided an estimated release of 0.13% STTD P.

Table 3. Phase 2 diet composition (as-fed basis)\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Enzymatically treated SBM(^2)</th>
<th>Bovine plasma(^2)</th>
<th>Fermented SBM(^2)</th>
<th>Enriched fermented SBM(^3)</th>
<th>Fish meal(^2)</th>
<th>Custom-made fish meal(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>53.37</td>
<td>57.15</td>
<td>55.27</td>
<td>55.07</td>
<td>56.28</td>
<td>56.02</td>
</tr>
<tr>
<td>Soybean meal, 46.5% CP</td>
<td>24.82</td>
<td>24.82</td>
<td>24.82</td>
<td>24.82</td>
<td>24.82</td>
<td>24.82</td>
</tr>
<tr>
<td>Whey powder</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Enzymatically treated soybean meal</td>
<td>7.00</td>
<td>---</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Fermented soybean meal</td>
<td>---</td>
<td>---</td>
<td>5.00</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Enriched fermented soybean meal</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>5.21</td>
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<td>---</td>
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<tr>
<td>Fish meal</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>4.85</td>
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<tr>
<td>Custom-made fish meal</td>
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<td>---</td>
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<td>---</td>
<td>---</td>
<td>5.05</td>
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<tr>
<td>Spray-dried bovine plasma</td>
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<td>3.50</td>
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<td>Corn oil</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Limestone</td>
<td>0.91</td>
<td>0.93</td>
<td>0.88</td>
<td>0.86</td>
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<td>Monocalcium phosphate, 21% P</td>
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<td>1.03</td>
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<tr>
<td>Salt</td>
<td>0.55</td>
<td>0.35</td>
<td>0.55</td>
<td>0.55</td>
<td>0.53</td>
<td>0.53</td>
</tr>
<tr>
<td>L-Lys-HCl</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
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<td>0.38</td>
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<tr>
<td>DL-Met</td>
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<td>0.18</td>
<td>0.20</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
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<tr>
<td>L-Thr</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
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<td>0.18</td>
<td>0.18</td>
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<tr>
<td>L-Trp</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
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<tr>
<td>L-Val</td>
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<td>0.09</td>
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<td>0.07</td>
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<td>0.11</td>
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<tr>
<td>Zinc oxide</td>
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<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>Vitamin premix(^3)</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>Trace mineral premix</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

---

\(^1\) Data followed by an --- indicates that the item is not included in the diet.

\(^2\) All diets receive a complete and balanced diet.

\(^3\) Vitamin premix includes all vitamins except vitamin A and D3.

continued
Table 3. Phase 2 diet composition (as-fed basis)\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Enzymatically treated SBM(^2)</th>
<th>Bovine plasma(^2)</th>
<th>Fermented SBM(^2)</th>
<th>Enriched fermented SBM(^2)</th>
<th>Fish meal(^2)</th>
<th>Custom-made fish meal(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lys</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
</tr>
<tr>
<td>Ile:Lys</td>
<td>62</td>
<td>55</td>
<td>61</td>
<td>61</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>Leu:Lys</td>
<td>120</td>
<td>119</td>
<td>123</td>
<td>123</td>
<td>116</td>
<td>115</td>
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<tr>
<td>Met:Lys</td>
<td>36</td>
<td>33</td>
<td>36</td>
<td>36</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Met and Cys:Lys</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>Thr:Lys</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Trp:Lys</td>
<td>19.4</td>
<td>19.3</td>
<td>19.2</td>
<td>19.2</td>
<td>19.3</td>
<td>19.2</td>
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<tr>
<td>Val:Lys</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>His:Lys</td>
<td>37</td>
<td>37</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Total Lys, %</td>
<td>1.49</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
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<tr>
<td>NE NRC, (^4) kcal/lb</td>
<td>1,131</td>
<td>1,137</td>
<td>1,133</td>
<td>1,133</td>
<td>1,140</td>
<td>1,139</td>
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<tr>
<td>SID Lys:NE, g/Mcal</td>
<td>5.41</td>
<td>5.39</td>
<td>5.40</td>
<td>5.40</td>
<td>5.37</td>
<td>5.38</td>
</tr>
<tr>
<td>CP, %</td>
<td>22.0</td>
<td>21.1</td>
<td>21.9</td>
<td>21.9</td>
<td>21.7</td>
<td>21.7</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.76</td>
<td>0.73</td>
<td>0.76</td>
<td>0.75</td>
<td>0.74</td>
<td>0.75</td>
</tr>
<tr>
<td>P, %</td>
<td>0.63</td>
<td>0.61</td>
<td>0.63</td>
<td>0.63</td>
<td>0.62</td>
<td>0.63</td>
</tr>
<tr>
<td>STTD P, %</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Analyzed values, %

<table>
<thead>
<tr>
<th>Item</th>
<th>DM</th>
<th>CP</th>
<th>Ether extract</th>
<th>Crude fiber</th>
<th>Ash</th>
<th>Ca</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>90.06</td>
<td>22.84</td>
<td>2.43</td>
<td>2.13</td>
<td>6.12</td>
<td>0.64</td>
<td>0.54</td>
</tr>
<tr>
<td>CP</td>
<td>89.98</td>
<td>17.08</td>
<td>2.27</td>
<td>2.06</td>
<td>5.73</td>
<td>0.66</td>
<td>0.52</td>
</tr>
<tr>
<td>Ether extract</td>
<td>90.23</td>
<td>18.75</td>
<td>2.39</td>
<td>2.29</td>
<td>5.50</td>
<td>0.64</td>
<td>0.52</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>90.21</td>
<td>18.41</td>
<td>2.36</td>
<td>2.32</td>
<td>5.92</td>
<td>0.75</td>
<td>0.55</td>
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<tr>
<td>Ash</td>
<td>90.25</td>
<td>17.58</td>
<td>2.94</td>
<td>1.74</td>
<td>5.93</td>
<td>0.75</td>
<td>0.57</td>
</tr>
<tr>
<td>Ca</td>
<td>90.09</td>
<td>18.47</td>
<td>2.85</td>
<td>1.83</td>
<td>6.69</td>
<td>0.68</td>
<td>0.59</td>
</tr>
</tbody>
</table>

\(^1\) Phase 2 diets were fed from approximately 13 to 26 lb.
\(^2\) 1) HP 300; Hamlet Protein, Findlay, OH. 2) Spray-dried bovine plasma; APC Corp, Ankeny, IA. 3) ME-PRO; Prairie Aquatech, Brookings, SD. 4) ME-PRO with fish solubles; Prairie Aquatech, Brookings, SD; TASA, Lima, Peru. 5) TASA Prime meal; TASA, Lima, Peru. 6) TASA Swine; TASA, Lima, Peru. SBM = soybean meal.

\(^3\) Vitamin premix with phytase provided an estimated release of 0.13% STTD P.

Table 4. Effects of protein source on nursery pig performance\(^{1,2}\)

<table>
<thead>
<tr>
<th>Protein source:</th>
<th>Enzymatically treated SBM(^3)</th>
<th>Bovine plasma(^3)</th>
<th>Fermented SBM(^3)</th>
<th>Enriched fermented SBM(^3)</th>
<th>Fish meal(^3)</th>
<th>Custom-made fish meal(^3)</th>
<th>SEM</th>
<th>P =</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW, lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d 0</td>
<td>10.8</td>
<td>10.7</td>
<td>10.7</td>
<td>10.7</td>
<td>10.7</td>
<td>0.12</td>
<td>0.996</td>
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</tr>
<tr>
<td>d 12</td>
<td>13.0</td>
<td>13.4</td>
<td>12.9</td>
<td>13.3</td>
<td>13.5</td>
<td>13.4</td>
<td>0.25</td>
<td>0.507</td>
</tr>
<tr>
<td>d 25</td>
<td>25.1</td>
<td>26.2</td>
<td>25.3</td>
<td>25.4</td>
<td>25.8</td>
<td>26.2</td>
<td>0.57</td>
<td>0.652</td>
</tr>
<tr>
<td>d 40</td>
<td>43.6</td>
<td>45.2</td>
<td>43.6</td>
<td>43.6</td>
<td>44.2</td>
<td>44.8</td>
<td>0.93</td>
<td>0.731</td>
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<td>Day 0 to 12(^4)</td>
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</tr>
<tr>
<td>ADG, lb</td>
<td>0.19</td>
<td>0.22</td>
<td>0.19</td>
<td>0.19</td>
<td>0.21</td>
<td>0.23</td>
<td>0.018</td>
<td>0.449</td>
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<tr>
<td>ADFI, lb</td>
<td>0.36</td>
<td>0.34</td>
<td>0.31</td>
<td>0.32</td>
<td>0.34</td>
<td>0.36</td>
<td>0.019</td>
<td>0.293</td>
</tr>
<tr>
<td>F/G</td>
<td>1.96</td>
<td>1.58</td>
<td>1.68</td>
<td>1.75</td>
<td>1.66</td>
<td>1.70</td>
<td>0.107</td>
<td>0.211</td>
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<tr>
<td>Day 12 to 25</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lb</td>
<td>0.93</td>
<td>0.99</td>
<td>0.95</td>
<td>0.94</td>
<td>0.94</td>
<td>0.98</td>
<td>0.030</td>
<td>0.601</td>
</tr>
<tr>
<td>ADFI, lb</td>
<td>1.27</td>
<td>1.36</td>
<td>1.31</td>
<td>1.25</td>
<td>1.27</td>
<td>1.34</td>
<td>0.040</td>
<td>0.283</td>
</tr>
<tr>
<td>F/G</td>
<td>1.36</td>
<td>1.37</td>
<td>1.38</td>
<td>1.34</td>
<td>1.34</td>
<td>1.37</td>
<td>0.017</td>
<td>0.502</td>
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<tr>
<td>Day 0 to 25 (experimental period)</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lb</td>
<td>0.58</td>
<td>0.62</td>
<td>0.59</td>
<td>0.58</td>
<td>0.59</td>
<td>0.62</td>
<td>0.021</td>
<td>0.426</td>
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<tr>
<td>ADFI, lb</td>
<td>0.83</td>
<td>0.87</td>
<td>0.83</td>
<td>0.80</td>
<td>0.82</td>
<td>0.87</td>
<td>0.026</td>
<td>0.318</td>
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<tr>
<td>F/G</td>
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<td>1.40</td>
<td>1.42</td>
<td>1.39</td>
<td>1.38</td>
<td>1.41</td>
<td>0.021</td>
<td>0.346</td>
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<tr>
<td>Day 25 to 40 (common period)</td>
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<td></td>
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</tr>
<tr>
<td>ADG, lb</td>
<td>1.23</td>
<td>1.26</td>
<td>1.22</td>
<td>1.21</td>
<td>1.23</td>
<td>1.24</td>
<td>0.035</td>
<td>0.926</td>
</tr>
<tr>
<td>ADFI, lb</td>
<td>1.99</td>
<td>1.96</td>
<td>1.96</td>
<td>1.96</td>
<td>1.94</td>
<td>1.94</td>
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<td>F/G</td>
<td>1.62</td>
<td>1.56</td>
<td>1.61</td>
<td>1.62</td>
<td>1.57</td>
<td>1.56</td>
<td>0.026</td>
<td>0.258</td>
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<td>Day 0 to 40</td>
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<td></td>
</tr>
<tr>
<td>ADG, lb</td>
<td>0.82</td>
<td>0.86</td>
<td>0.82</td>
<td>0.81</td>
<td>0.83</td>
<td>0.85</td>
<td>0.022</td>
<td>0.601</td>
</tr>
<tr>
<td>ADFI, lb</td>
<td>1.26</td>
<td>1.27</td>
<td>1.25</td>
<td>1.24</td>
<td>1.23</td>
<td>1.27</td>
<td>0.030</td>
<td>0.908</td>
</tr>
<tr>
<td>F/G</td>
<td>1.54</td>
<td>1.48</td>
<td>1.52</td>
<td>1.52</td>
<td>1.48</td>
<td>1.49</td>
<td>0.020</td>
<td>0.162</td>
</tr>
</tbody>
</table>

\(^{1}\) Based on pooled analysis from 2019 and 2020.  
\(^{2}\) Data are presented as least squares means.  
\(^{3}\) Source of variation included in protein source.  
\(^{4}\) Effects were not pooled across years (2019 and 2020).  

continued
Table 4. Effects of protein source on nursery pig performance\(^1,2\)

<table>
<thead>
<tr>
<th>Protein source:</th>
<th>Enzymatically treated SBM(^3)</th>
<th>Bovine plasma(^3)</th>
<th>Fermented SBM(^3)</th>
<th>Enriched fermented SBM(^3)</th>
<th>Fish meal(^3)</th>
<th>Custom-made fish meal(^3)</th>
<th>SEM</th>
<th>(P = )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics,(^5,6) $/pig placed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low ingredient prices</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed cost</td>
<td>7.14(^b)</td>
<td>8.49(^b)</td>
<td>7.08(^b)</td>
<td>6.80(^b)</td>
<td>6.86(^b)</td>
<td>7.29(^b)</td>
<td>0.202</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Feed cost/lb gain(^8)</td>
<td>0.22(^b)</td>
<td>0.25(^b)</td>
<td>0.22(^b)</td>
<td>0.22(^b)</td>
<td>0.21(^b)</td>
<td>0.22(^b)</td>
<td>0.003</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Revenue(^9)</td>
<td>14.51</td>
<td>15.39</td>
<td>14.82</td>
<td>14.22</td>
<td>14.44</td>
<td>15.09</td>
<td>0.444</td>
<td>0.435</td>
</tr>
<tr>
<td>IOFC(^10)</td>
<td>7.38</td>
<td>6.91</td>
<td>7.74</td>
<td>7.42</td>
<td>7.58</td>
<td>7.80</td>
<td>0.274</td>
<td>0.240</td>
</tr>
<tr>
<td><strong>High ingredient prices</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed cost</td>
<td>9.72(^b)</td>
<td>11.16(^b)</td>
<td>9.71(^b)</td>
<td>9.32(^b)</td>
<td>9.38(^b)</td>
<td>9.98(^b)</td>
<td>0.274</td>
<td>0.001</td>
</tr>
<tr>
<td>Feed cost/lb gain(^8)</td>
<td>0.30(^b)</td>
<td>0.33(^b)</td>
<td>0.30(^b)</td>
<td>0.30(^b)</td>
<td>0.29(^b)</td>
<td>0.30(^b)</td>
<td>0.004</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Revenue(^12)</td>
<td>21.28</td>
<td>22.58</td>
<td>21.73</td>
<td>20.86</td>
<td>21.18</td>
<td>22.13</td>
<td>0.652</td>
<td>0.435</td>
</tr>
<tr>
<td>IOFC(^11)</td>
<td>11.57</td>
<td>11.42</td>
<td>12.02</td>
<td>11.54</td>
<td>11.75</td>
<td>12.15</td>
<td>0.417</td>
<td>0.781</td>
</tr>
</tbody>
</table>

\(^1\) A total of 330 pigs (initial BW of 10.7 ± 0.38 lb) were used in a 40-d nursery trial with 4 or 5 pigs per pen and 12 pens per treatment. Pigs were weaned at approximately 19 d of age and allotted to treatment in a completely randomized design. Dietary treatments were arranged in a one-way treatment structure with main effects of protein source.

\(^2\) Pens of pigs were fed diets in 2 phases. Pigs were fed phase 1 diets from 0 to 12 d after weaning. Following phase 1, pigs were fed phase 2 diets from d 12 to 25. Following the experimental period, all pigs were fed a common diet from d 25 to 40.

\(^3\) 1) HP 300; Hamlet Protein, Findlay, OH. 2) Spray-dried bovine plasma; APC Corp, Ankeny, IA. 3) ME-PRO; Prairie Aquatech, Brookings, SD. 4) ME-PRO with fish solubles; Prairie Aquatech, Brookings, SD; TASA, Lima, Peru. 5) TASA Prime meal; TASA, Lima, Peru. 6) TASA Swine; TASA, Lima, Peru. SBM = soybean meal

\(^4\) All pigs were placed on a common phase 1 diet for 3 d after weaning. Once experimental diets arrived, all feeders were weighed, dumped, and refilled with experimental diets. On average, each pig consumed 0.5 lb of the common phase 1 diet.

\(^5\) In the low ingredient price scenario the total feed cost per ton were calculated: Phase 1) enzymatically treated soybean meal = $511.87; spray-dried bovine plasma = $617.91; fermented soybean meal = $502.97; enriched fermented soybean meal = $506.75; fish meal = $510.50; custom-made fish meal = $513.90; Phase 2) enzymatically treated soybean meal = $352.85; spray-dried bovine plasma = $459.06; fermented soybean meal = $344.19; enriched fermented soybean meal = $347.97; fish meal = $351.40; custom-made fish meal = $354.88.

\(^6\) In the high ingredient price scenarios the total feed cost per ton were calculated: Phase 1) enzymatically treated soybean meal = $597.53; spray-dried bovine plasma = $707.89; fermented soybean meal = $590.99; enriched fermented soybean meal = $594.54; fish meal = $600.30; custom-made fish meal = $608.33; Phase 2) enzymatically treated soybean meal = $447.73; spray-dried bovine plasma = $558.38; fermented soybean meal = $444.58; enriched fermented soybean meal = $445.15; fish meal = $451.40; custom-made fish meal = $458.53.

\(^7\) Corn = $3.00/bushel ($107.14/ton); soybean meal = $300/ton; L-Lys HCl = $0.65/lb; DL-Met = $1.70/lb; L-Thr = $0.85/lb; L-Trp = $3.00/lb; L-Val = $2.50/lb; enzymatically treated soybean meal = $0.52/lb; spray-dried bovine plasma = $2.00/lb; fermented soybean meal = $0.61/lb; enriched fermented soybean meal = $0.62/lb; fish meal = $0.70/lb; custom-made fish meal = $0.77/lb.

\(^8\) Feed cost/lb gain = total feed cost per pen ÷ total gain per pen.

\(^9\) Revenue = (total gain/pig placed × 0.75) × $0.60.

\(^10\) Income over feed cost = revenue – feed cost.

\(^11\) Corn = $6.00/bushel ($214.29/ton); soybean meal = $400/ton; L-Lys HCl = $0.80/lb; DL-Met = $2.50/lb; L-Thr = $0.85/lb; L-Trp = $5.00/lb; L-Val = $4.00/lb; enzymatically treated soybean meal = $0.52/lb; spray-dried bovine plasma = $2.00/lb; fermented soybean meal = $0.61/lb; enriched fermented soybean meal = $0.62/lb; fish meal = $0.70/lb; custom-made fish meal = $0.77/lb.

\(^12\) Revenue = (total gain/pig placed × 0.75) × $0.88.

\(^a,b\) Means with different superscript differ (\(P < 0.05\)).