ABSTRACT: An experiment was conducted in growing pigs to investigate the additivity of apparent ileal digestibility (AID) or standardized ileal digestibility (SID) of CP and AA in mixed diets containing multiple protein sources. Using the determined AID or SID for CP and AA in corn, soybean meal (SBM), corn distillers’ dried grains with solubles (DDGS), or canola meal (CM), the AID or SID for 4 mixed diets based on corn–SBM, corn–SBM–DDGS, corn–SBM–CM, or corn–SBM–DDGS–CM were predicted and compared with determined AID or SID, respectively. Eighteen growing pigs (initial BW = 61.3 ± 5.5 kg) were surgically fitted with T-cannulas and assigned to a duplicated 9 × 4 incomplete Latin square design with 9 diets and 4 periods. The 9 experimental diets consisted of a nitrogen-free diet (NFD) to estimate basal ileal endogenous loss (BEL) of AA, 4 semipurified diets to determine the AID and SID of CP and AA in the 4 ingredients, and 4 mixed diets to test the additivity of AID and SID. Chromic oxide was added as an indigestible marker. Pigs were fed 1 of the 9 diets during each 7-d period, and ileal digesta were collected on d 6 and 7, from 0800 to 1800 h. The analyzed AA levels for the mixed diets were close to the calculated values based on the AA composition of each ingredient. The results revealed that the predicted SID were consistent with determined values, except for Leu, Thr, Asp, Cys, Pro, and Ser in the corn–SBM diet and Met and Cys in the corn–SBM–DDGS diet. The determined AID for total AA and Arg, His, Trp, Gly, and Pro in the corn–SBM diet were greater (P < 0.05) than predicted. For the corn–SBM–DDGS diet, the determined AID were greater (P < 0.05) than predicted AID for CP, total AA, and all AA except for Arg, Leu, and Pro. In the corn–SBM–CM diet, the determined AID were greater (P < 0.05) than predicted AID for Arg, Cys, and Gly. When compared with determined values, predicted AID in the corn–SBM–DDGS–CM diet were lower (P < 0.05) for total AA and Arg, Met, Cys, and Pro. In conclusion, the results substantiate the notion that SID of AA are more accurate than AID for predicting ileal digestibility of AA in mixed diets containing multiple protein sources. In addition, the lack of additivity of AID in mixed diets could be attributed to the intrinsic characteristics of the feed ingredient, especially its AA content.

Key words: additivity, amino acid, basal endogenous loss, ileal digestibility, pigs

INTRODUCTION

It is widely accepted that the nutrient requirements of livestock should be considered on a digestible nutrient basis (NRC, 2012). When diets are formulated to meet the requirements, the additivity of digestible nutrients is the fundamental assumption (Stein et al., 2007). It is assumed that the amount of digestible nutrients in feed is equal to the sum of that digestible nutrient from different ingredients. Therefore, it is critical, when feeding, to validate the additivity assumption.

For AA, apparent ileal digestibility (AID) and standardized ileal digestibility (SID) values have been determined for commonly used feed ingredients (Stein et al., 2007; NRC, 2012). However, it was demonstrated that AID for complete diets predicted from AID of ingredients underestimates AID for AA and CP in diets for growing pigs (Furuya and Kaji, 1991; Stein et al., 2005). This underestimation could be a result of the relatively higher contribution of basal ileal endogenous loss (BEL) to the total ileal AA flow for low-CP ingredients.
such as cereal grains (Rademacher et al., 2001). For this reason, some studies suggested that SID of CP and AA in feed ingredients are more likely to be additive than AID in mixed diets because these values are independent of BEL (Furuya and Kaji, 1991; Nyachoti et al., 1997; Mosenthin et al., 2000; Stein et al., 2001, 2007). Stein et al. (2005) reported that SID for corn, soybean meal (SBM), and canola meal (CM) were additive in mixed diets based on corn–SBM, corn–CM, or SBM–CM. Therefore, it is suggested that SID should be used for feed formulation (Stein et al., 2007). However, this assumption of additivity is not well established in diets containing more than 2 protein sources, which is often observed in practical swine diets. Therefore, the aim of this experiment was to investigate the additivity of AID and SID of CP and AA in mixed diets containing multiple protein sources, which are similar to practical diets for growing pigs.

**MATERIALS AND METHODS**

The experiment protocol was approved by the Purdue University Animal Care and Use Committee (West Lafayette, IN).

**Animals and Sample Collection**

Eighteen growing pigs (initial BW = 61.3 ± 5.5 kg) were surgically fitted with T-cannulas at the ileocecal junction as described by Dilger et al. (2004). The pigs were assigned to 2 blocks on the basis of BW and assigned to a duplicated 9 × 4 incomplete Latin square design with 9 diets and 4 periods. All pigs were housed in 2 environmentally controlled rooms (ambient temperature at 21 ± 2°C) in individual floor pens with feeders and low pressure, automatic waterers under a 12-h lighting program. Pigs were fed 1 of the 9 diets during each of the 7-d periods, and the ileal digesta were collected on d 6 and 7, from 0800 to 1800 h. Pigs received a daily feed allowance equivalent to 3% of the BW of heaviest pig in each block, divided into 2 equal amounts, and fed at 0700 and 1700 h. Ileal digesta were collected into Whirl-Pak bags (NASCO, Fort Atkinson, WI) containing an added 10 mL of 10% formic acid to reduce microbial activity. The bag was inspected at 30 min intervals and changed immediately as needed. Collected ileal samples were stored in a freezer at –20°C. At the end of each period, all the ileal samples from the same pig were pooled and subsampled for freeze-drying.

**Dietary Treatments**

The 9 experimental diets consisted of a nitrogen-free diet (NFD) to estimate BEL of AA, 4 semipurified diets to determine the AID and SID of CP and AA in the 4 ingredients, and 4 mixed diets to test the additivity of AID and SID (Table 1). The 4 ingredients were corn, SBM, corn distillers’ dried grains with solubles (DDGS), and CM. The 4 mixed diets were based on corn–SBM, corn–SBM–DDGS, corn–SBM–CM, and corn–SBM–DDGS–CM. Those combinations of ingredients are common in practical diets for swine. All the mixed diets were formulated to contain approximately 16% CP, and corn starch was included as the main protein-free ingredient in the diet. Chromic oxide was added as an indigestible marker.

**Chemical Analyses**

All diets and freeze-dried ileal digesta samples were ground using a mill grinder (Retsch ZM 100; Retsch GmbH and Co., K.G., Haan, Germany) to pass through a 0.5-mm screen before analysis. The DM of diets, ingredients, and freeze-dried digesta samples were determined by drying in a force-aired oven (Precision Scientific Co., Chicago, IL) for 24 h at 105°C (method 934.01; AOAC, 2006). Wet digestion in nitric acid and 70% perchloric acid were conducted before chromium determination (Fenton and Fenton, 1979) for the diets, ingredients, and freeze-dried digesta samples followed by measuring absorption using a spectrophotometer at 450 nm (Spectronic 21D; Milton Roy Co., Rochester, NY). The N concentration in diets, ingredients, and freeze-dried ileal digesta samples was measured by the combustion method (model FP2000; LECO Corp., St. Joseph, MI; method 990.03; AOAC, 2000). Crude fiber (method 978.10; AOAC, 2006), ADF (method 973.18 (A-D); AOAC, 2006), NDF (van Soest et al., 1991), ash (method 942.05; AOAC, 2006), and crude fat (without acid hydrolysis; method 920.39 (A); AOAC, 2006) contents of the ingredients were analyzed. Amino acid analyses (method 982.30 E (a, b, c); AOAC, 2006) for the diets, ingredients, and freeze-dried ileal digesta samples were performed by the University of Missouri Experiment Station Chemical Laboratories (Columbia, MO).

**Calculation and Statistical Analysis**

The AID, SID, and BEL were calculated using the equations described by Dilger et al. (2004):

\[
\text{AID, } \% = \left[1 - \left(\frac{\text{Cr}_i}{\text{Cr}_o}\right) \times \left(\frac{\text{AA}_o/\text{AA}_i}{100}\right)\right] \times 100
\]

\[
\text{BEL} = \frac{\text{AA}_o}{\left(\frac{\text{Cr}_i}{\text{Cr}_o}\right)}
\]

\[
\text{SID, } \% = \text{AID} + \left(\frac{\text{BEL}/\text{AA}_i}{100}\right)
\]

in which \(\text{Cr}_i\) and \(\text{Cr}_o\) are the concentration of chromium in diet and ileal output, respectively (mg/kg of DM); \(\text{AA}_i\) and \(\text{AA}_o\) are the concentration of AA in diet and ileal output, respectively (mg/kg of DM); and BEL (mg/kg of DMI) of an AA is calculated from the NFD. The average

...
BEL of an AA from all pigs that received the NFD was used to derive SID. The equations were also used for calculating CP digestibility with AA replaced by N.

The predicted AID and SID of AA in mixed diets were calculated using the values determined in the semi-purified diets and the AA contributed by each ingredient to the mixed diets, using the following equation (Kong and Adeola, 2013):

\[
\text{AID}_P = \left[ \left( \text{AA}_C \times \text{AID}_C \right) + \left( \text{AA}_{\text{SBM}} \times \text{AID}_{\text{SBM}} \right) + \left( \text{AA}_D \times \text{AID}_D \right) + \left( \text{AA}_{\text{CM}} \times \text{AID}_{\text{CM}} \right) \right] \left( \text{AA}_C + \text{AA}_{\text{SBM}} + \text{AA}_D + \text{AA}_{\text{CM}} \right),
\]

in which AID\(_P\) (%) is the predicted AID for an AA in the mixed diet; AA\(_C\), AA\(_{\text{SBM}}\), AA\(_D\), and AA\(_{\text{CM}}\) are the concentrations (%) of that AA contributed by corn, SBM, DDGS, and CM, respectively, which were calculated by multiplying the concentration of that AA (%) in that ingredient by the proportion (%) of the ingredient in the mixed diet; and AID\(_C\), AID\(_{\text{SBM}}\), AID\(_D\), and AID\(_{\text{CM}}\) are the AID (%) of the AA determined ingredient. The predicted SID of AA in mixed diets were calculated using the same equation as with AID, but SID replaced AID.

The data for AID and SID for CP and AA for each ingredient and mixed diets were analyzed using the MIXED procedure of SAS (9.2). The diet was considered as a fixed effect and block and period were random effects in the model. The \(t\) test was applied to test the null hypothesis that the difference between the determined and predicted AID or SID of CP and AA for mixed diet is equal to 0. Statistical differences were established at \(P \leq 0.05\), whereas \(0.05 < P \leq 0.10\) was considered a trend.

**RESULTS AND DISCUSSION**

The analyzed concentrations of CP, Ca, total P, crude fiber, ADF, NDF, crude fat, ash, and AA of corn, SBM, DDGS, CM are shown in Table 2. The analyzed CP and AA composition for experimental diets are presented in Table 3. The CP levels of each mixed diets were approximately 16%, which was close to a practical complete diet for growing pigs. The calculated N and AA concentrations in mixed diets were similar to determined values.

**Table 1. Composition of experimental diets (% as fed)\(^1\)**

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<tr>
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</thead>
<tbody>
<tr>
<td>Corn</td>
<td>–</td>
<td>91.85</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>65.20</td>
<td>57.20</td>
<td>57.80</td>
</tr>
<tr>
<td>SBM</td>
<td>–</td>
<td>–</td>
<td>33.00</td>
<td>–</td>
<td>–</td>
<td>21.60</td>
<td>17.00</td>
<td>13.20</td>
</tr>
<tr>
<td>Corn DDGS</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>57.80</td>
<td>–</td>
<td>–</td>
<td>10.50</td>
<td>–</td>
</tr>
<tr>
<td>Canola Meal</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>45.00</td>
<td>–</td>
<td>–</td>
<td>13.20</td>
</tr>
<tr>
<td>Corn starch</td>
<td>75.80</td>
<td>–</td>
<td>58.85</td>
<td>34.05</td>
<td>46.85</td>
<td>5.05</td>
<td>7.15</td>
<td>7.65</td>
</tr>
<tr>
<td>Dextrose</td>
<td>10.00</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Soy 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>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Chronic oxide premix(^2)</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Monocalcium phosphate</td>
<td>2.00</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.50</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Solka-floc</td>
<td>5.00</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Salt</td>
<td>0.40</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Vitamin premix(^3)</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>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Mineral premix(^4)</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Selenium premix(^5)</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Potassium carbonate</td>
<td>0.40</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>0.10</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

\(^1\) NFD = nitrogen-free diet; SBM = soybean meal; DDGS = distillers' dried grains with solubles; CM = canola meal.

\(^2\) Provided 3.4 g Cr/kg diet.

\(^3\) Vitamin premix supplied gram per kilogram of diet: vitamin A, 2,640 IU; vitamin D\(_3\), 264 IU; vitamin E, 17.6 IU; vitamin K activity, 2.4 mg; menadione, 880 μg; vitamin B\(_{12}\), 15.4 μg; riboflavin, 3.52 mg; D-pantothenic acid, 8.8 mg; and niacin, 13.2 mg.

\(^4\) Mineral premix supplied gram per kilogram of diet: Cu (as copper chloride), 9 mg; I (as calcium iodate), 0.36 mg; Fe (as ferrous carbonate), 194 mg; Mn (as manganese oxide), 17 mg; and Zn (as zinc oxide), 149 mg.

\(^5\) Supplied 300 μg of Se per kilogram of diet.
The AID for most of AA of the current study (Table 4) and 2 individual AA in the corn–SBM–DDGS diet, the determined AID were greater ($P < 0.05$) than predicted AID for CP, total AA, and all AA except for Arg, Leu, and Pro. In the corn–SBM–CM diet, the determined AID were greater ($P < 0.05$) than predicted AID for Arg, Cys, and Gly. When compared with determined values, the predicted AID in the corn–SBM–DDGS–CM diet were lower ($P < 0.05$) for total AA and 4 individual AA (Arg, Met, Cys, and Pro). These results indicate that the predicted values derived from AID of CP and AA for ingredients were different from the determined AID in mixed diets for several AA. These results are consistent with previous data reporting that AID for AA were not additive in mixed diets containing corn for nonruminant animals (Furuya and Kaji, 1991; Mosenthin et al., 2000; Stein et al., 2005; Kong and Adeola, 2013). However, the number of AA for which the predicted AID was different from the determined AID varied among the mixed diets used in the current study.

The addition of DDGS to the corn–SBM mixed diet to produce a corn–SBM–DDGS mixed diet resulted in the determined AID of CP and all AA but Pro being greater ($P < 0.05$) than the predicted AID (Table 7). An exception was Arg, which showed a tendency ($P < 0.10$) for the determined AID to be greater than the predicted AID. Thus, the addition of DDGS to a corn–SBM–DDGS mixed diet resulted in more individual AA having greater determined AID than predicted AID when compared with a corn–SBM mixed diet, in which 5 individual AA were observed to have greater determined than predicted AID. However, when CM was added to the corn–SBM–based diet to produce the corn–SBM–CM mixed diet, underestimation of AID was observed in only Arg, Cys, and Gly. It could be inferred from these results that AID of AA for CM might be more likely to be additive in mixed diets than those for DDGS.

The AID of AA for high-CP ingredients may be more likely to be additive in mixed diets than those for low-CP ingredients. Fan and Sauer (1995) reported that the AID for CM is not underestimated if measured using the direct procedure. The study of Stein et al. (2005) supported earlier reports that AID of AA in mixed diets based on SBM and CM are additive. In contrast, the AID for low-CP ingredients might underestimate the digestibility of AA, due to the relatively higher concentration of endogenous N and AA in total ileal N and AA flow (Fan et al., 1994). Therefore, if a mixed diet contains a high proportion of a low-CP ingredients such as corn, the predicted AID of

### Table 2. Analyzed nutrient composition in ingredients (% DM basis)

<table>
<thead>
<tr>
<th>Items</th>
<th>Corn</th>
<th>Soybean meal</th>
<th>DDGS¹</th>
<th>Canola meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>10.95</td>
<td>54.63</td>
<td>36.01</td>
<td>42.85</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.01</td>
<td>0.31</td>
<td>0.02</td>
<td>0.72</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.30</td>
<td>0.75</td>
<td>0.98</td>
<td>1.07</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>1.81</td>
<td>2.99</td>
<td>7.32</td>
<td>11.83</td>
</tr>
<tr>
<td>Acid detergent fiber</td>
<td>2.5</td>
<td>4.5</td>
<td>14.5</td>
<td>20.4</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>11.7</td>
<td>8.5</td>
<td>40.3</td>
<td>32.6</td>
</tr>
<tr>
<td>Crude fat²</td>
<td>3.3</td>
<td>0.7</td>
<td>7.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Ash</td>
<td>1.5</td>
<td>6.9</td>
<td>5.0</td>
<td>8.0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Indispensable AA</th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>0.55</td>
<td>4.02</td>
<td>1.68</td>
<td>2.56</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.31</td>
<td>1.42</td>
<td>0.98</td>
<td>1.15</td>
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<tr>
<td>Isoleucine</td>
<td>0.40</td>
<td>2.54</td>
<td>1.40</td>
<td>1.74</td>
</tr>
<tr>
<td>Leucine</td>
<td>1.27</td>
<td>4.19</td>
<td>4.23</td>
<td>3.04</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.39</td>
<td>3.51</td>
<td>1.23</td>
<td>2.38</td>
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<tr>
<td>Methionine</td>
<td>0.23</td>
<td>0.75</td>
<td>0.70</td>
<td>0.85</td>
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<tr>
<td>Phenylalanine</td>
<td>0.56</td>
<td>2.88</td>
<td>2.01</td>
<td>1.84</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.37</td>
<td>2.01</td>
<td>1.27</td>
<td>1.73</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.08</td>
<td>0.78</td>
<td>0.28</td>
<td>0.53</td>
</tr>
<tr>
<td>Valine</td>
<td>0.53</td>
<td>2.80</td>
<td>1.88</td>
<td>2.30</td>
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</table>

<table>
<thead>
<tr>
<th>Dispensable AA</th>
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<tbody>
<tr>
<td>Alanine</td>
<td>0.76</td>
<td>2.31</td>
<td>2.47</td>
<td>1.84</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>0.78</td>
<td>6.20</td>
<td>2.24</td>
<td>3.04</td>
</tr>
<tr>
<td>Cysteine</td>
<td>0.23</td>
<td>0.73</td>
<td>0.66</td>
<td>0.99</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>1.88</td>
<td>9.22</td>
<td>4.94</td>
<td>6.94</td>
</tr>
<tr>
<td>Glycine</td>
<td>0.42</td>
<td>2.27</td>
<td>1.41</td>
<td>2.12</td>
</tr>
<tr>
<td>Proline</td>
<td>0.93</td>
<td>2.71</td>
<td>2.72</td>
<td>2.55</td>
</tr>
<tr>
<td>Serine</td>
<td>0.46</td>
<td>2.14</td>
<td>1.42</td>
<td>1.47</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.32</td>
<td>1.88</td>
<td>1.20</td>
<td>1.17</td>
</tr>
<tr>
<td>Total AA</td>
<td>10.60</td>
<td>52.69</td>
<td>33.15</td>
<td>38.87</td>
</tr>
</tbody>
</table>

¹DDGS = distillers’ dried grains with solubles.
²Analyzed without acid hydrolysis.
Equine oocyte developmental competence

Equine oocyte developmental competence

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CP and AA are more likely to be lower than determined values, while predicted SID are similar to determined value because of the adjustment for BEL of AA. Therefore, Stein et al. (2005) concluded that the additivity of AID in mixed diets depends on the N and AA content in the semipurified diets used to determine the AID of AA in each ingredient. In diets commonly fed to pigs, the CP and AA contents are considerably higher than the semipurified diet used to determine the AID of AA in low-protein ingredient such as corn. Therefore the AID of AA in corn tends to be underestimated and eventually results in the lack of additivity. However, this explanation is not applicable for the DDGS used in this experiment. Although the DDGS semipurified diet contained high levels of N and AA, there was still underestimation of the AID of AA in DDGS, which resulted in a lower predicted AID than determined values in corn–SBM–DDGS diet. One possible reason for this phenomenon could be the high inclusion rate of DDGS in the semipurified diet used to determine the digestibility of CP and AA in the current study. A shortcoming of DDGS in swine diets is its high concentration of fiber (Stein and Shurson, 2009). The negative relationship between dietary fiber or non-starch polysaccharides (NSP) content and ileal digestibility of AA was reported in previous studies (Yin et al., 2000; Dilger et al., 2004). The semipurified diet formulated with DDGS for the current study contained 57.8% DDGS. Therefore, the underestimation of AID in DDGS could be attributed

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### Indispensable AA

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### Dispensable AA

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1NFD = nitrogen-free diet; SBM = soybean meal; DDGS = distillers’ dried grains with solubles; CM = canola meal.

### Table 4. Endogenous AA losses at the terminal ileum of pigs fed nitrogen-free diet

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<th>Mean</th>
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<td>137</td>
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<td>2</td>
<td>1.27 0.13</td>
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1Means of 7 observations. One of the pigs on the nitrogen-free diet did not produce enough ileal digesta for chemical analysis.

2Ratios are calculated by dividing endogenous loss of each AA by the endogenous loss of lysine and multiplying by 100.
### Table 5. Apparent ileal digestibility (AID) of N and AA in ingredients and mixed diets, \(^1\) %

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\(^1\) Means of 8 observations. SBM = soybean meal; DDGS = distillers’ dried grains with solubles; CM = canola meal.

### Table 6. Standardized ileal digestibility (SID) of N and AA in ingredients and mixed diets, \(^1\) %

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<td>85.3</td>
<td>87.1</td>
<td>83.4</td>
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\(^1\) Means of 8 observations. SBM = soybean meal; DDGS = distillers’ dried grains with solubles; CM = canola meal.
to the negative influence of high fiber or NSP content in the semipurified diet that was used to determine the ileal digestibility of CP and AA in DDGS. Further studies are needed to confirm this assumption. Furthermore, the AA composition and digestibility in corn DDGS (Stein and Shurson, 2009) could lead to an unbalanced AA profile in the DDGS semipurified diet and therefore affect the determination of AID of AA.

It appears that ingredients could contribute to additivity or nonadditivity of AID in mixed diets. In the mixed diets in the current study, SBM and CM contributed to the additivity of AID. Corn and DDGS contributed to the nonadditivity of AID in mixed diets. Therefore, an explanation for the variation of differences between determined and predicted AID for the 4 mixed diets could be the different concentration of ingredients in the complete diet. Corn accounted for 37% of CP in the corn–SBM diet, while the SBM was responsible for 63% of CP. With the addition of DDGS in the corn–SBM–DDGS diet, approximately 51% of CP was derived from corn–DDGS, which contributed to the nonadditivity of AID, and CP from SBM was reduced to 49%. Therefore, in the corn–SBM–DDGS diet, more AA were not additive in AID than in the corn–SBM. However, in the corn–SBM–CM diet the SBM–CM accounted for 68% of CP in the mixed diets. In this case, the portion of CP that originated from ingredients that contributed to the additivity of AID was greater than in the corn–SBM and the corn–SBM–DDGS diets. Consequently, there were fewer AA for which the predicted AID was different from the determined AID in the corn–SBM–CM diet.

For the corn–SBM–DDGS–CM diet, the portion of CP derived from SBM–CM was lower compared with the corn–SBM–CM diet, which resulted in more AA having greater determined than predicted AID.

In conclusion, the results indicate that SID of AA are more accurate than AID for predicting ileal digestibility of AA in mixed diets containing multiple protein sources. In addition, the lack of additivity of AID in mixed diets could be attributed to the intrinsic characteristics of each feed ingredient, especially its AA content.

LITERATURE CITED

Table 7. Differences\(^1\) between determined and predicted values of apparent ileal digestibility (AID) and standardized ileal digestibility (SID; %) for nitrogen and AA in mixed diets\(^2\)

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</table>

**P ≤ 0.05; ***P ≤ 0.01.

1\(^\text{Difference is calculated by subtracting predicted AID or SID for nitrogen or individual AA from determined value.}

2SBM = soybean meal; DDGS = distillers’ dried grains with solubles; CM = canola meal.

3+ 0.05 < P ≤ 0.10.

4P ≤ 0.05; **P ≤ 0.01.


