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doi: 10.2527/jas.2009-2640 originally published online Jul 2, 2010;

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http://jas.fass.org/cgi/content/full/88/11/3725
Feed preferences and performance of nursery pigs fed diets containing various inclusion amounts and qualities of distillers coproducts and flavor

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ABSTRACT: We evaluated the preferences of nursery pigs for diets containing increasing distillers dried grains with solubles (DDGS), varying in color, or high-protein distillers dried grains (HP-DDG) and the effects of flavor supplementation on pig preference and growth performance. In Exp. 1 through 5, diet preference was determined in weanling pigs adjusted to a commercial diet for at least 10 d, and then housed individually for a 2-d double-choice preference test. In Exp. 1, a total of 60 pigs (11.6 ± 0.3 kg of BW) were given a choice between a reference diet (0% DDGS) and test diets containing 0, 10, 20, or 30% DDGS. In Exp. 2, a total of 80 pigs (10.8 ± 0.1 kg of BW) were given a choice between a reference diet (0% HP-DDG) and diets containing 0, 10, 20, or 30% HP-DDG. In Exp. 3, a total of 80 pigs (10.3 ± 0.2 kg of BW) were given a choice between a reference diet (0% DDGS) and diets containing 0%, 30% light, or 30% dark DDGS. In Exp. 4, a total of 80 pigs (11.2 ± 0.2 kg of BW) were given a choice between a reference diet without DDGS and a diet containing either 0% DDGS, 10 or 20% light DDGS, or 10 or 20% dark DDGS. In Exp. 5, a total of 108 pigs (9.0 ± 0.2 kg of BW) were given a choice between a reference diet (0% DDGS and no flavor) and a diet without or with flavor and containing 0, 10, or 20% DDGS. In Exp. 1 and 2, DDGS and HP-DDG, respectively, linearly decreased (P < 0.01) pig preference. In Exp. 3, dark DDGS were preferred (P < 0.05) compared with light DDGS. In Exp. 4, preferences were linearly reduced (P < 0.01) with DDGS inclusion, and dark DDGS tended (P = 0.06) to be preferred compared with light DDGS. In Exp. 5, DDGS reduced preference (P < 0.01) and flavor reduced preference (P < 0.01) regardless of DDGS level. In Exp. 6, a total of 192 pigs (6.7 ± 0.1 kg of BW) were fed starter 1 diets without or with flavor for 1 wk. Subsequently, pigs were fed starter 2 and 3 diets (2 wk each) containing 0, 10, or 20% DDGS while continuing to receive their respective flavor treatment. Flavor addition during the starter 1 phase increased ADFI (P = 0.02), and DDGS inclusion tended to decrease ADG (P = 0.06) and decreased ADFI (P = 0.03) during the starter 2 phase. Volatile components in DDGS and HP-DDG varied greatly depending on the source. Nursery pigs preferred a diet without DDGS or HP-DDG, and this appeared to be unrelated to color differences between sources. Knowledge of volatile compounds that enhance or suppress the palatability of feed may lead to further development of feed additives for masking relatively unpalatable, albeit cost-effective, ingredients.

Key words: distillers grains, flavor, palatability, performance, pig, preference

 INTRODUCTION

Feed intake, an important factor affecting growth performance, can be affected by feed composition, temperature, disease, sex, genetics, and palatability of feed ingredients (Ellis and Augspurger, 2001; Frederick and van Heugten, 2002). One strategy to increase feed intake is to choose ingredients that are highly palatable. Pigs are able to clearly distinguish the palatability of different diets (Ermer et al., 1994; Yang et al., 1997; Solà-Oriol et al., 2007).
Coproduct ingredients, such as distillers dried grains with solubles (DDGS) and high-protein distillers dried grains (HP-DDG), may improve the profitability of pork production by replacing high-cost ingredients; however, little is known about their palatability. The quality of DDGS varies among sources and batches (Palm et al., 2008). Typically, DDGS that is dark in color exhibits a burned, smoky odor, likely caused by overheating in the drying process of DDGS production (Cromwell et al., 1993). Although poorer quality DDGS is nutritionally inferior to better quality DDGS, palatability studies of varying DDGS qualities have not been conducted.

Feed flavors have been used in nursery pig diets since early 1960 as palatability enhancers and feed attractants (Torrallardona et al., 2000). Tedó et al. (2008) reported that flavor masked the negative effect of less palatable ingredients (rapeseed meal) on voluntary intake. This can be especially important for pigs after weaning, when feed intake is relatively low, because pigs are adapting to solid feed and a new environment. Although weanling pigs often show a preference for a diet when given a choice, results vary for growth performance when no choice is given (Whitney and Shurson, 2004; Cook et al., 2005; DeDecker et al., 2005; Linneen et al., 2008). The objectives were to evaluate the preferences of nursery pigs for diets containing increasing amounts and qualities of DDGS or HP-DDG and to examine the effects of flavor supplementation on pig preferences and growth performance.

**MATERIALS AND METHODS**

All procedures were approved by the North Carolina State University Animal Care and Use Committee.

**Exp. 1 to 5**

Pigs were weaned at 21 d of age and housed approximately 8 pigs per pen in a nursery room with 12 pens. After a 2-wk adjustment period (to ensure adequate feed consumption of a complex starter diet lacking DDGS or HP-DDG), 20 pigs (18 pigs in Exp. 5) were selected and moved to a nursery room with 20 pens (1.73 × 0.83 m) to conduct double-choice preference comparisons. Each pen contained 2 identical feeders (side-by-side) and housed 1 pig. Pigs were blocked by BW and location within the nursery when assigned to preference comparisons. For Exp. 1, one feeder contained a diet with 0% DDGS (Renaissance Nutrition, Roaring Spring, PA) as a reference diet, and the other feeder contained a test diet with either 0, 10, 20, or 30% DDGS, resulting in 4 preference comparisons. There were 5 blocks of the 4 different comparisons per period and 4 total periods, resulting in 20 total blocks per comparison and 80 total observations. For Exp. 2, one of the double-choice feeders contained a diet with 0% HP-DDG as a reference, and the other feeder contained a test diet with 0, 10, 20, or 30% HP-DDG. There were 5 blocks of the 4 preference comparisons per period and 4 total periods, resulting in 20 blocks per comparison and 80 total observations. For Exp. 3, comparisons included 0% DDGS (reference) vs. 0% DDGS, 0% DDGS vs. 30% light DDGS (Poet Nutrition, Sioux Falls, SD), 0% DDGS vs. 30% dark DDGS (Poet Nutrition, Ashton, IA), and 30% light vs. 30% dark DDGS. There were 5 blocks of the 4 comparisons per period and 4 total periods, resulting in 20 blocks per comparison and 80 observations in total. For Exp. 4, comparisons included 0% DDGS as a reference diet (same sources as those used in Exp. 3) vs. 0% DDGS, 10% light DDGS, 10% dark DDGS, 20% light DDGS, and 20% dark DDGS. For Exp. 5, comparisons included 0% DDGS (Southern States, Richmond, VA) without flavor as the reference diet vs. 0% DDGS without flavor, 0% DDGS with flavor, 10% DDGS without flavor, 10% DDGS with flavor, 20% DDGS without flavor, and 20% DDGS with flavor. The experimental flavor used was characterized by a creamy and milky cheese profile with sweet and vanilla bottom notes (Luctarom Laboratory reference number 5103, Lucta S.A., Barcelona, Spain). There were 3 blocks of the 6 comparisons per period and 6 total periods, resulting in 18 blocks per comparison and 108 pigs total. For each experiment, the position of the feeders was alternated from each block of treatment comparisons to the next to minimize side preferences. Thus, one-half of the feeders containing the reference diet were positioned on the left side of the pen and one-half were positioned on the right side of the pens. Control comparisons (both feeders in the pen contained the same diet with 0% of the test ingredient) were included in each experiment to validate proper control and to ensure that factors such as feeder placement, temperature, and ventilation differences were not confounding. Pigs were allowed to consume feed freely from either feeder for 48 h, and feed intake was measured after 24 h and again at the end of the 48-h trial. Pigs were weighed at the onset of the trial and again at the end of 48 h.

Pigs were returned to the original nursery room at the end of the experiment, and subsequent groups of pigs were used to achieve the desired number of pigs per treatment comparison. A total of 60 (11.6 ± 0.3 kg of BW), 80 (10.8 ± 0.1 kg of BW), 80 (10.3 ± 0.2 kg of BW), 80 (11.2 ± 0.2 kg of BW), and 108 (9.0 ± 0.2 kg of BW) pigs were used in Exp. 1, 2, 3, 4, and 5, respectively, resulting in 15, 20, 20, 16, and 18 pigs per treatment comparison, respectively.

**Exp. 6**

A total of 192 pigs (6.7 ± 0.1 kg of BW) were weaned at approximately 21 d of age. Pigs were weighed, blocked by BW, and assigned within a BW block to 1 of 6 dietary treatments. Four pigs were housed in each of 48 pens (1.63 × 0.91 m), resulting in 8 blocks per treatment. Pigs were fed a 3-phase dietary program. The first phase diet (starter 1) was fed immediately...
after weaning for 7 d. One-half of the pigs received a flavored starter 1 diet, whereas the other one-half received the nonflavored basal starter 1 diet. The experimental flavor used was identical to the flavor used in Exp. 5 and had a creamy and milky cheese profile with sweet and vanilla bottom notes (Luctarom laboratory reference number 5103). The second- and third-phase diets (starter 2 and starter 3) were fed for 2 wk each. Pigs that were fed the flavored starter 1 were fed flavored starter 2 and starter 3 with 0, 10, or 20% DDGS, whereas those fed the nonflavored starter 1 were fed nonflavored starter 2 and starter 3 with 0, 10, or 20% DDGS. Dietary treatments were arranged in a 2 × 3 factorial randomized complete block design. Factors consisted of 1) DDGS inclusion in starter 2 and 3 diets (0, 10, or 20%), and 2) the presence or absence of flavor in all 3 diet phases. Diets were formulated based on least cost, as is common in commercial practice.

Pigs were weighed weekly on an individual basis throughout the 5-wk experiment. Feed added to the feeders was recorded and feeders with remaining feed were weighed weekly to determine feed intake.

**Diets**

Diets for Exp. 1 to 4 were mixed at the North Carolina State University Grinnells laboratory using a common basal diet, formulated to contain 1.25% lysine, and were presented in meal form (Tables 1 and 2). Distillers dried grains with solubles replaced corn and soybean meal on a lysine basis without changing any other ingredients, to control for potential differences in palatability attributable to other ingredient changes. Diets for Exp. 5 and 6 were formulated based on least cost to closely mimic general commercial practices and were mixed at the North Carolina State University Feed Mill Education Unit (Tables 3, 4, and 5). To minimize variation among feed batches, a basal diet of only dry ingredients was manufactured within each quantity of DDGS for each diet phase. Each basal diet was split into 2 equal portions. One portion received no added flavor, and fat was added to mix the final nonflavored diets. The other portion received flavor at 0.2%. Fat was then added to mix the final nonflavored diets. The other portion received flavor at 0.2%. Fat was then added to manufacture the flavored diets. All diets for Exp. 5 and 6 were presented in pelleted form to mimic commercial practices.

**Chemical Analyses**

Representative samples of the diets and the DDGS and HP-DDG used in this study were analyzed at Dairy-One Forage Laboratory Services (Ithaca, NY) for CP, ADIN (DDGS and HP-DDG only), ADF, NDF, Ca, P, Mg, K, S, Na, Fe, Zn, Cu, and Mn (Tables 2 to 6). Additionally, DDGS and HP-DDG were analyzed for aflatoxin, vomitoxin (deoxynivalenol, DON), zearalenone, and acrylamide.
Table 2. Analyzed nutrient composition of experimental diets fed to nursery pigs (as fed, Exp. 1 to 4)\(^1\)

<table>
<thead>
<tr>
<th>DDGS or HP-DDG, %</th>
<th>CP, %</th>
<th>ADF, %</th>
<th>NDF, %</th>
<th>Ca, %</th>
<th>P, %</th>
<th>Mg, %</th>
<th>K, %</th>
<th>Na, %</th>
<th>Fe, mg/kg</th>
<th>Zn, mg/kg</th>
<th>Cu, mg/kg</th>
<th>Mg, mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>20.1</td>
<td>5.1</td>
<td>8.1</td>
<td>0.81</td>
<td>0.68</td>
<td>0.18</td>
<td>0.86</td>
<td>0.21</td>
<td>302</td>
<td>149</td>
<td>192</td>
<td>43</td>
</tr>
<tr>
<td>10</td>
<td>21.3</td>
<td>4.5</td>
<td>9.6</td>
<td>0.93</td>
<td>0.73</td>
<td>0.22</td>
<td>0.88</td>
<td>0.22</td>
<td>306</td>
<td>216</td>
<td>218</td>
<td>113</td>
</tr>
<tr>
<td>20</td>
<td>21.2</td>
<td>5.6</td>
<td>12.2</td>
<td>1.00</td>
<td>0.79</td>
<td>0.25</td>
<td>1.01</td>
<td>0.32</td>
<td>338</td>
<td>322</td>
<td>295</td>
<td>199</td>
</tr>
<tr>
<td>30</td>
<td>21.6</td>
<td>6.0</td>
<td>13.5</td>
<td>0.97</td>
<td>0.78</td>
<td>0.27</td>
<td>0.98</td>
<td>0.33</td>
<td>354</td>
<td>365</td>
<td>227</td>
<td>266</td>
</tr>
<tr>
<td>Exp. 2</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0</td>
<td>18.4</td>
<td>5.1</td>
<td>6.7</td>
<td>0.85</td>
<td>0.65</td>
<td>0.15</td>
<td>0.70</td>
<td>0.24</td>
<td>272</td>
<td>173</td>
<td>252</td>
<td>44</td>
</tr>
<tr>
<td>10</td>
<td>19.7</td>
<td>4.2</td>
<td>8.8</td>
<td>0.69</td>
<td>0.65</td>
<td>0.17</td>
<td>0.81</td>
<td>0.22</td>
<td>236</td>
<td>171</td>
<td>155</td>
<td>43</td>
</tr>
<tr>
<td>20</td>
<td>21.5</td>
<td>4.2</td>
<td>12.6</td>
<td>0.80</td>
<td>0.67</td>
<td>0.17</td>
<td>0.78</td>
<td>0.21</td>
<td>269</td>
<td>211</td>
<td>168</td>
<td>48</td>
</tr>
<tr>
<td>30</td>
<td>22.1</td>
<td>4.5</td>
<td>16.2</td>
<td>0.60</td>
<td>0.60</td>
<td>0.16</td>
<td>0.76</td>
<td>0.23</td>
<td>207</td>
<td>151</td>
<td>134</td>
<td>39</td>
</tr>
<tr>
<td>Exp. 3(^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>18.8</td>
<td>4.6</td>
<td>8.4</td>
<td>0.87</td>
<td>0.71</td>
<td>0.17</td>
<td>0.81</td>
<td>0.21</td>
<td>321</td>
<td>230</td>
<td>209</td>
<td>50</td>
</tr>
<tr>
<td>30 light</td>
<td>21.9</td>
<td>7.1</td>
<td>14.0</td>
<td>0.78</td>
<td>0.79</td>
<td>0.22</td>
<td>0.82</td>
<td>0.21</td>
<td>271</td>
<td>185</td>
<td>218</td>
<td>45</td>
</tr>
<tr>
<td>30 dark</td>
<td>21.5</td>
<td>7.0</td>
<td>14.0</td>
<td>0.73</td>
<td>0.74</td>
<td>0.20</td>
<td>0.79</td>
<td>0.22</td>
<td>246</td>
<td>182</td>
<td>192</td>
<td>44</td>
</tr>
<tr>
<td>Exp. 4(^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>20.3</td>
<td>4.0</td>
<td>9.4</td>
<td>0.77</td>
<td>0.68</td>
<td>0.17</td>
<td>0.84</td>
<td>0.19</td>
<td>273</td>
<td>187</td>
<td>152</td>
<td>54</td>
</tr>
<tr>
<td>10 light</td>
<td>21.7</td>
<td>4.7</td>
<td>9.9</td>
<td>0.58</td>
<td>0.53</td>
<td>0.15</td>
<td>0.76</td>
<td>0.21</td>
<td>188</td>
<td>170</td>
<td>150</td>
<td>37</td>
</tr>
<tr>
<td>10 dark</td>
<td>20.5</td>
<td>4.1</td>
<td>9.1</td>
<td>0.72</td>
<td>0.68</td>
<td>0.19</td>
<td>0.81</td>
<td>0.20</td>
<td>255</td>
<td>256</td>
<td>185</td>
<td>63</td>
</tr>
<tr>
<td>20 light</td>
<td>22.7</td>
<td>5.6</td>
<td>11.6</td>
<td>0.82</td>
<td>0.75</td>
<td>0.21</td>
<td>0.97</td>
<td>0.26</td>
<td>271</td>
<td>253</td>
<td>201</td>
<td>53</td>
</tr>
<tr>
<td>20 dark</td>
<td>20.9</td>
<td>6.4</td>
<td>11.9</td>
<td>0.81</td>
<td>0.71</td>
<td>0.20</td>
<td>0.81</td>
<td>0.21</td>
<td>279</td>
<td>270</td>
<td>205</td>
<td>56</td>
</tr>
</tbody>
</table>

\(^1\)Distillers dried grains with solubles (DDGS) were used in Exp. 1, 3, and 4, and high-protein distillers dried grains (HP-DDG) were used in Exp. 2.

\(^2\)Source of DDGS used was either light or dark in color.
Table 3. Composition of flavored and nonflavored starter 1 diets fed to nursery pigs (as fed; Exp. 5 and 6)1

<table>
<thead>
<tr>
<th>Item</th>
<th>Nonflavored</th>
<th>Flavored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient, % as fed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>46.2</td>
<td>46.1</td>
</tr>
<tr>
<td>Whey, dried</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Soybean meal (47.5% CP)</td>
<td>16.1</td>
<td>16.1</td>
</tr>
<tr>
<td>Fish meal</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Blood plasma</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Poultry fat</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Blood cells</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>Monocalcium phosphate (21% P)</td>
<td>0.42</td>
<td>0.42</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>0.34</td>
<td>0.34</td>
</tr>
<tr>
<td>Salt</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Flavor3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lysine hydrochloride</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>DL-Methionine</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>L-Threonine</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Analyzed nutrient composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM, %</td>
<td>88.3</td>
<td>88.3</td>
</tr>
<tr>
<td>CP, %</td>
<td>21.4</td>
<td>21.7</td>
</tr>
<tr>
<td>ADF, %</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>NDF, %</td>
<td>5.9</td>
<td>4.5</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.78</td>
<td>0.81</td>
</tr>
<tr>
<td>P, %</td>
<td>0.66</td>
<td>0.67</td>
</tr>
<tr>
<td>Mg, %</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>K, %</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Na, %</td>
<td>0.35</td>
<td>0.37</td>
</tr>
<tr>
<td>Fe, mg/kg</td>
<td>434</td>
<td>385</td>
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<tr>
<td>Zn, mg/kg</td>
<td>2,240</td>
<td>2,180</td>
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<tr>
<td>Cu, mg/kg</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Mn, mg/kg</td>
<td>70</td>
<td>67</td>
</tr>
</tbody>
</table>

1Starter 1 diets were fed for 1 wk immediately after weaning.  
2Supplied per kilogram of complete diet: 12,225 IU of vitamin A; 1,322 IU of vitamin D₃ as D-activated animal sterol; 66 IU of vitamin E; 3.3 mg of vitamin K as menadione dimethylpyrimidinol bisulfate; 650 mg of choline as choline chloride; 55 mg of niacin; 33 mg of D-pantothenic acid as calcium pantothenate; 10 mg of riboflavin; 2 mg of pyridoxine as pyridoxine hydrochloride; 2 mg of thiamine; 0.03 mg of vitamin B₁₂; 2.2 mg of folic acid; 0.31 mg of b-biotin; 165 mg of Zn as ZnO; 41 mg of Fe as FeSO₄; 18 mg of Cu as CuSO₄; 41 mg of Mn as MnSO₄; 0.50 mg of I as ethylenediamine dihydriodide; and 0.30 mg of Se as Na₂SeO₃.  
3Experimental flavor (laboratory reference number 5103, Lucta S.A., Barcelona, Spain).

none, and T-2 toxin at the North Carolina Department of Agriculture and Consumer Services (Raleigh, NC; Table 6). Color scores were measured in triplicate for the DDGS sources using a Minolta Chroma Meter CR-200 (Minolta, Ramsey, NJ). Means for lightness (L*), redness (a*), and yellowness (b*) were calculated (Table 6).

Volatile compound evaluation via gas chromatography and headspace analysis was performed on the DDGS and HP-DDG test ingredients at the Analytical Research Laboratory of Lucta S.A. (Montornés del Vallés, Barcelona, Spain). A 2-g sample of each ingredient was placed into a 20-mL vial and extracted by solid-phase microextraction fibers. After 30 min of extraction of the volatile compounds from the headspace of the sample onto the solid-phase microextraction fiber, the fiber was automatically transferred into a gas chromatograph-mass spectrometer system (GC 6890-MSD 5973N, Agilent, Santa Clara, CA) for 10 min of desorption of the compounds followed by separation into a capillary chromatographic column, resulting in identification and quantification. For each volatile compound, values were expressed relative to the least concentration for the particular compound, which was set at 1.0.

Statistical Analyses

Data were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC). For Exp. 1 through 5, preference (%) was calculated as

\[ \text{preference} = 100 \times \left( \frac{\text{intake of test diets}}{\text{total intake}} \right) \]

Therefore, preference values ranged from 0 to 100% and a value of 50% indicated no preference. The model included block (BW and location in the nursery) and treatment comparison as main effects. Preference values were compared with the 50% no-effect level by Student’s t-tests, and differences from 50% were interpreted as a preference over the reference diet. Preference in control comparisons, which constituted a double-choice comparison between the same reference diets, should not differ from 50%. Orthogonal contrasts were used to determine linear and quadratic responses within DDGS amounts in Exp. 1 and 4, and HP-DDG amounts in Exp. 2. Additionally, for Exp 4, data were analyzed as a 2 × 2 factorial arrangement of treatments with DDGS amount (10 or 20%), DDGS color (light or dark), and their interaction represented in the model. The model for Exp. 5 and 6 included BW block, DDGS amount, flavor content, and the interaction between flavor and DDGS amount. Significance was declared at \( P \leq 0.05 \) and tendencies were considered at \( 0.05 < P < 0.10 \).

RESULTS

Exp. 1

On \( d \) 1, preferences for diets containing 20 and 30% DDGS were 26.9 and 16.5%, respectively, and were less \( (P < 0.05) \) than 50% (Table 7). Preference for the reference diet in the control comparison and the 10% DDGS diet were not different from 50%. On \( d \) 2, preference for all DDGS-containing test diets was less \( (P < 0.05) \) than 50%. Preference in the control comparison was not different from 50%. There was a decreasing linear response \( (P < 0.01) \) in preference to increasing inclusion of DDGS on \( d \) 1 and 2. Overall, preferences for all DDGS-containing diets were less \( (P < 0.01) \) than 50% (34.8% for the 10% diet, 26.4% for the 20% diet, and 16.3% for the 30% diet), and the response was linear \( (P < 0.01) \). The control comparison was not different from 50%.

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Exp. 2

On d 1 and 2, preferences of all HP-DDG-containing diets were less than 50% \((P < 0.01, \text{Table 7})\). The control comparison was different from 50% on d 2 \((P < 0.01)\). Overall, preference for all HP-DDG-containing diets was less \((P < 0.01)\) than 50%. The response in preference to HP-DDG inclusion was linear, indicating decreased preference with increasing HP-DDG in the diet, on d 1, d 2, and overall \((P < 0.01)\). A quadratic effect was also observed at all time points \((P < 0.05)\). Overall, the control comparison was not different from 50%.

Exp. 3

On d 1, d 2 and overall, preference for 30% dark DDGS, compared with 30% light DDGS, was greater than 50% \((P < 0.05)\), indicating that dark DDGS was preferred over light DDGS (Table 8). Comparisons between the reference diet and 0 or 30% DDGS-containing diets were not different from 50%.

Exp. 4

On d 1, preferences for diets containing 10 and 20% light DDGS were less \((P < 0.05 \text{ and } P < 0.01, \text{respectively})\) than 50%. Preference for 20% dark DDGS was also less \((P < 0.05)\) than 50% (Table 9). On d 2 and overall, only preferences for the 20% light and dark DDGS diets were less \((P < 0.01 \text{ and } P < 0.05, \text{respectively})\) than 50%. On d 1, d 2 and overall, there was a linear decrease \((P < 0.01)\) in preference with increasing inclusion of light DDGS, and there was a tendency for a linear decrease in preference \((P < 0.10)\) on d 2 and overall for increasing dark DDGS diets. Preference was affected by color, as indicated by a greater preference for dark DDGS on d 1 \((P = 0.02)\) and overall \((P =

---

### Table 4. Composition of flavored (FL) and nonflavored (NF) starter 2 diets fed to nursery pigs with different inclusion amounts of distillers dried grains with solubles (DDGS; as fed; Exp. 5 and 6)\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>0 NF</th>
<th>0 FL</th>
<th>10 NF</th>
<th>10 FL</th>
<th>20 NF</th>
<th>20 FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient, % as fed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>54.8</td>
<td>54.7</td>
<td>46.9</td>
<td>46.8</td>
<td>39.1</td>
<td>39.0</td>
</tr>
<tr>
<td>Soybean meal (47.5% CP)</td>
<td>25.0</td>
<td>25.0</td>
<td>23.1</td>
<td>23.1</td>
<td>21.2</td>
<td>21.2</td>
</tr>
<tr>
<td>DDGS</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Whey, dried</td>
<td>3.3</td>
<td>3.3</td>
<td>3.2</td>
<td>3.2</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Poultry fat</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Blood cells</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Monocalcium phosphate (21% P)</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.67</td>
<td>0.67</td>
<td>0.72</td>
<td>0.72</td>
<td>0.77</td>
<td>0.77</td>
</tr>
<tr>
<td>Vitamin and mineral premix(^2)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Salt</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Lysine hydrochloride</td>
<td>0.24</td>
<td>0.24</td>
<td>0.26</td>
<td>0.26</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Flavor(^3)</td>
<td></td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>L-Threonine</td>
<td>0.12</td>
<td>0.12</td>
<td>0.09</td>
<td>0.09</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>DL-Methionine</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
<td>0.02</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>Analyzed nutrient composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM, %</td>
<td>87.6</td>
<td>87.9</td>
<td>88.7</td>
<td>88.8</td>
<td>89.3</td>
<td>88.2</td>
</tr>
<tr>
<td>CP, %</td>
<td>20.0</td>
<td>20.0</td>
<td>21.5</td>
<td>22.1</td>
<td>23.0</td>
<td>22.0</td>
</tr>
<tr>
<td>ADF, %</td>
<td>3.9</td>
<td>4.4</td>
<td>4.5</td>
<td>5.3</td>
<td>5.4</td>
<td>6.3</td>
</tr>
<tr>
<td>NDF, %</td>
<td>7.4</td>
<td>6.9</td>
<td>8.6</td>
<td>8.3</td>
<td>10.7</td>
<td>9.4</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.93</td>
<td>0.83</td>
<td>0.52</td>
<td>0.73</td>
<td>0.86</td>
<td>0.82</td>
</tr>
<tr>
<td>P, %</td>
<td>0.70</td>
<td>0.69</td>
<td>0.46</td>
<td>0.68</td>
<td>0.74</td>
<td>0.71</td>
</tr>
<tr>
<td>Mg, %</td>
<td>0.17</td>
<td>0.16</td>
<td>0.14</td>
<td>0.19</td>
<td>0.27</td>
<td>0.25</td>
</tr>
<tr>
<td>K, %</td>
<td>0.87</td>
<td>0.85</td>
<td>0.70</td>
<td>0.99</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>Na, %</td>
<td>0.24</td>
<td>0.23</td>
<td>0.24</td>
<td>0.33</td>
<td>0.36</td>
<td>0.34</td>
</tr>
<tr>
<td>Fe, mg/kg</td>
<td>384</td>
<td>375</td>
<td>245</td>
<td>335</td>
<td>383</td>
<td>362</td>
</tr>
<tr>
<td>Zn, mg/kg</td>
<td>1,210</td>
<td>1,320</td>
<td>1,030</td>
<td>1,370</td>
<td>1,510</td>
<td>1,420</td>
</tr>
<tr>
<td>Cu, mg/kg</td>
<td>20</td>
<td>24</td>
<td>17</td>
<td>29</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>Mn, mg/kg</td>
<td>88</td>
<td>84</td>
<td>56</td>
<td>73</td>
<td>88</td>
<td>88</td>
</tr>
</tbody>
</table>

\(^1\) Starter 2 diets were fed for wk 2 and 3 after weaning.

\(^2\) Supplied per kilogram of complete diet: 12,225 IU of vitamin A; 1,322 IU of vitamin D\(_3\) as D-activated animal sterol; 66 IU of vitamin E; 3.3 mg of vitamin K as menadione dimethylpyrimidinol bisulfate; 650 mg of choline as choline chloride; 55 mg of niacin; 33 mg of pantothenic acid as calcium pantothenate; 10 mg of riboflavin; 2 mg of pyridoxine as pyridoxine hydrochloride; 2 mg thiamine; 0.03 mg of vitamin B\(_12\); 2.2 mg of folic acid; 0.31 mg of d-biotin; 165 mg of Zn as ZnO; 41 mg of Fe as FeSO\(_4\); 18 mg of Cu as CuSO\(_4\); 41 mg of Mn as MnSO\(_4\); 0.50 mg of I as ethylenediamine dihydriodide; and 0.30 mg of Se as Na\(_2\)SeO\(_3\).

\(^3\) Experimental flavor (laboratory reference number 5103, Lucta S.A., Barcelona, Spain).
0.06) compared with light DDGS. The control comparison for d 1 and overall was different \((P < 0.05)\) from 50%.

**Exp. 5**

Preferences for the nonflavored diet containing 20% DDGS were less than 50% on d 1, d 2, and overall (Table 10). Preferences for flavored diets at all inclusion amounts of DDGS were less than 50% on d 1, d 2, and overall. Inclusion of DDGS reduced pig preference on d 2 and overall \((P < 0.01)\) and tended to reduce pig preference on d 1 \((P < 0.10)\). Supplementation of flavor reduced pig preference on d 1 and overall \((P < 0.01)\) and tended to reduce pig preference on d 2 \((P < 0.10)\), regardless of the presence of DDGS.

**Exp. 6**

Inclusion of DDGS had no effect \((P = 0.123)\) on BW (Table 11). Average daily gain tended to decrease with DDGS inclusion during the starter 2 phase \((P = 0.056)\). Average daily feed intake tended to decrease \((P = 0.097)\) with DDGS inclusion during wk 3 and was decreased \((P < 0.05)\) during the overall starter 2 phase. Gain:feed was increased \((P < 0.05)\) during wk 4, but tended to decrease \((P = 0.084)\) during wk 5. Flavor supplementation had no effect on BW \((P = 0.237)\), ADG \((P = 0.107)\), or G:F \((P = 0.110)\). Average daily feed intake was increased \((P < 0.05)\) with flavor supplementation only during the starter 1 phase. There were no interactions between DDGS inclusion and flavor.

**Headspace Analysis**

The source of DDGS used in Exp. 1 contained greater concentrations of valeriane, aldehyde C-6, 2-amyl furan, and amyl alcohol (Table 12) than other DDGS samples. The light DDGS used in Exp. 3 and 4 contained a greater concentration of benzyl alcohol than all other samples. The dark DDGS used in Exp. 3 and 4

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**Table 5.** Composition of flavored (FL) and nonflavored (NF) starter 3 diets fed to nursery pigs with different inclusion amounts of distillers dried grains with solubles (DDGS; as fed; Exp. 6)¹

<table>
<thead>
<tr>
<th>Item</th>
<th>0 NF</th>
<th>0 FL</th>
<th>10 NF</th>
<th>10 FL</th>
<th>20 NF</th>
<th>20 FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient, % as fed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>64.3</td>
<td>64.2</td>
<td>56.5</td>
<td>56.4</td>
<td>48.6</td>
<td>48.6</td>
</tr>
<tr>
<td>Soybean meal (47.5% CP)</td>
<td>28.4</td>
<td>28.4</td>
<td>26.6</td>
<td>26.5</td>
<td>24.7</td>
<td>24.6</td>
</tr>
<tr>
<td>DDGS</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Poultry fat</td>
<td>3.4</td>
<td>3.4</td>
<td>3.2</td>
<td>3.2</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Monocalcium phosphate (21% P)</td>
<td>1.4</td>
<td>1.4</td>
<td>1.3</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Vitamin and mineral premix²</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Salt</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Flavor³</td>
<td>—</td>
<td>0.20</td>
<td>—</td>
<td>0.20</td>
<td>—</td>
<td>0.20</td>
</tr>
<tr>
<td>Lysine hydrochloride</td>
<td>0.27</td>
<td>0.27</td>
<td>0.29</td>
<td>0.29</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>Copper sulfate</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>L-Threonine</td>
<td>0.10</td>
<td>0.10</td>
<td>0.07</td>
<td>0.07</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>dl-Methionine</td>
<td>0.03</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Analyzed nutrient composition**

<table>
<thead>
<tr>
<th>Item</th>
<th>0 NF</th>
<th>0 FL</th>
<th>10 NF</th>
<th>10 FL</th>
<th>20 NF</th>
<th>20 FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>90.6</td>
<td>88.2</td>
<td>88.7</td>
<td>89.4</td>
<td>89.7</td>
<td>90.5</td>
</tr>
<tr>
<td>CP, %</td>
<td>20.5</td>
<td>19.6</td>
<td>20.1</td>
<td>20.7</td>
<td>21.0</td>
<td>22.1</td>
</tr>
<tr>
<td>ADF, %</td>
<td>5.5</td>
<td>6.3</td>
<td>3.1</td>
<td>4.4</td>
<td>5.1</td>
<td>4.6</td>
</tr>
<tr>
<td>NDF, %</td>
<td>6.9</td>
<td>7.1</td>
<td>8.7</td>
<td>9.2</td>
<td>8.8</td>
<td>9.7</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.75</td>
<td>0.76</td>
<td>0.69</td>
<td>0.74</td>
<td>0.85</td>
<td>0.77</td>
</tr>
<tr>
<td>P, %</td>
<td>0.65</td>
<td>0.65</td>
<td>0.64</td>
<td>0.68</td>
<td>0.70</td>
<td>0.72</td>
</tr>
<tr>
<td>Mg, %</td>
<td>0.16</td>
<td>0.18</td>
<td>0.19</td>
<td>0.21</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>K, %</td>
<td>0.87</td>
<td>0.79</td>
<td>0.81</td>
<td>0.87</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>Na, %</td>
<td>0.24</td>
<td>0.23</td>
<td>0.23</td>
<td>0.26</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td>Fe, mg/kg</td>
<td>312</td>
<td>270</td>
<td>277</td>
<td>280</td>
<td>296</td>
<td>303</td>
</tr>
<tr>
<td>Zn, mg/kg</td>
<td>160</td>
<td>168</td>
<td>163</td>
<td>171</td>
<td>183</td>
<td>319</td>
</tr>
<tr>
<td>Cu, mg/kg</td>
<td>185</td>
<td>195</td>
<td>179</td>
<td>209</td>
<td>230</td>
<td>182</td>
</tr>
<tr>
<td>Mn, mg/kg</td>
<td>54</td>
<td>59</td>
<td>58</td>
<td>65</td>
<td>78</td>
<td>64</td>
</tr>
</tbody>
</table>

¹Starter 3 diets were fed for wk 4 and 5 after weaning.

²Supplied per kilogram of complete diet: 12,225 IU of vitamin A; 1,322 IU of vitamin D₃ as D-activated animal sterol; 66 IU of vitamin E; 3.3 mg of vitamin K as menadione dimethylpyrimidinol bisulfate; 650 mg of choline as choline chloride; 55 mg of niacin; 33 mg of d-pantothenic acid as calcium pantothenate; 10 mg of riboflavin; 2 mg of pyridoxine as pyridoxine hydrochloride; 2 mg of thiamine; 0.03 mg of vitamin B₁₂; 2.2 mg of folic acid; 0.31 mg of D-biotin; 575 mg of Ca; 165 mg of Zn as ZnO; 41 mg of Fe as FeSO₄; 18 mg of Cu as CuSO₄; 41 mg of Mn as MnSO₄; 0.50 mg of I as ethylenediamine dihydriodide; and 0.30 mg of Se as Na₂SeO₃.

³Experimental flavor (laboratory reference number 5103, Lucta S.A., Barcelona, Spain).
Table 6. Chemical analysis of distillers dried grains with solubles (DDGS) and high-protein distillers dried grains (HP-DDG) used in Exp. 1 to 6

<table>
<thead>
<tr>
<th>Nutrient, %</th>
<th>Test ingredient</th>
<th>Exp. 1 DDGS</th>
<th>Exp. 2 HP-DDG</th>
<th>Exp. 3 and 4 light¹ DDGS</th>
<th>Exp. 3 and 4 dark¹ DDGS</th>
<th>Exp. 5 and 6 DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td></td>
<td>85.4</td>
<td>89.8</td>
<td>89.4</td>
<td>88.4</td>
<td>87.5</td>
</tr>
<tr>
<td>CP</td>
<td></td>
<td>24.9</td>
<td>26.1</td>
<td>29.6</td>
<td>29.7</td>
<td>29.4</td>
</tr>
<tr>
<td>ADIN</td>
<td></td>
<td>1.9</td>
<td>1.8</td>
<td>1.1</td>
<td>2.3</td>
<td>1.4</td>
</tr>
<tr>
<td>ADF</td>
<td></td>
<td>11.5</td>
<td>15.0</td>
<td>13.3</td>
<td>13.1</td>
<td>13.9</td>
</tr>
<tr>
<td>NDF</td>
<td></td>
<td>27.5</td>
<td>35.1</td>
<td>27.7</td>
<td>27.8</td>
<td>23.7</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td>0.39</td>
<td>0.05</td>
<td>0.03</td>
<td>0.07</td>
<td>0.18</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.73</td>
<td>0.39</td>
<td>0.76</td>
<td>0.72</td>
<td>0.81</td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td>0.48</td>
<td>0.14</td>
<td>0.34</td>
<td>0.31</td>
<td>0.53</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>1.04</td>
<td>0.41</td>
<td>0.90</td>
<td>0.78</td>
<td>0.93</td>
</tr>
<tr>
<td>Na</td>
<td></td>
<td>0.44</td>
<td>0.08</td>
<td>0.13</td>
<td>0.15</td>
<td>0.39</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>0.67</td>
<td>0.63</td>
<td>0.88</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>Fe, mg/kg</td>
<td></td>
<td>272</td>
<td>66</td>
<td>79</td>
<td>85</td>
<td>121</td>
</tr>
<tr>
<td>Zn, mg/kg</td>
<td></td>
<td>552</td>
<td>41</td>
<td>91</td>
<td>82</td>
<td>195</td>
</tr>
<tr>
<td>Cu, mg/kg</td>
<td></td>
<td>40</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Mn, mg/kg</td>
<td></td>
<td>534</td>
<td>10</td>
<td>16</td>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>Aflatoxin, µg/kg</td>
<td></td>
<td>0.0</td>
<td>0.6</td>
<td>6</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Vomitoxin, µg/kg</td>
<td></td>
<td>4,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,846</td>
</tr>
<tr>
<td>Zearelomeone, µg/kg</td>
<td></td>
<td>138</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>102</td>
</tr>
<tr>
<td>T-2 toxin, µg/kg</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minolta color score²</td>
<td></td>
<td>50.3</td>
<td>ND¹</td>
<td>51.6</td>
<td>32.0</td>
<td>43.3</td>
</tr>
<tr>
<td>L*</td>
<td></td>
<td>9.2</td>
<td>ND¹</td>
<td>11.2</td>
<td>13.1</td>
<td>10.9</td>
</tr>
<tr>
<td>a*</td>
<td></td>
<td>37.2</td>
<td>ND¹</td>
<td>48.7</td>
<td>35.7</td>
<td>35.5</td>
</tr>
</tbody>
</table>

¹Light and dark DDGS were defined by origin and color of the DDGS.
²Minolta color scores indicate lightness (L*: a larger L* value indicates a lighter color), redness (a*: a larger a* value indicates a redder color), and yellowness (b*: a larger b* value indicates a more yellow color).
³Not determined.

Table 7. Effect of distillers dried grains with solubles (DDGS) and high-protein distillers dried grains (HP-DDG) inclusion on diet preference in nursery pigs (Exp. 1 and 2)

<table>
<thead>
<tr>
<th>Preference, %</th>
<th>Inclusion comparison,¹ %</th>
<th>SEM</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 vs. 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 vs. 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 vs. 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 vs. 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>47.99</td>
<td>6.71</td>
<td>&lt;0.001</td>
<td>0.857</td>
</tr>
<tr>
<td>Day 2</td>
<td>52.04</td>
<td>7.22</td>
<td>&lt;0.001</td>
<td>0.047</td>
</tr>
<tr>
<td>Overall</td>
<td>50.02</td>
<td>6.36</td>
<td>&lt;0.001</td>
<td>0.242</td>
</tr>
<tr>
<td>HP-DDG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>49.88</td>
<td>5.36</td>
<td>&lt;0.001</td>
<td>0.027</td>
</tr>
<tr>
<td>Day 2</td>
<td>60.84</td>
<td>5.24</td>
<td>&lt;0.001</td>
<td>0.039</td>
</tr>
<tr>
<td>Overall</td>
<td>55.96</td>
<td>4.29</td>
<td>&lt;0.001</td>
<td>0.006</td>
</tr>
</tbody>
</table>

¹Preference is expressed as the intake of the test diet as a percent of total intake.
²Comparisons consisted of double-choice preference tests between diets containing the test ingredient vs. the 0% inclusion reference diet.
³Denotes a difference (P < 0.01) from the 50% preference.

DISCUSSION

We previously demonstrated in a double-choice preference test comparing corn- and rice-based diets that preferences could be clearly measured and were well established after 2 d (van Heugten et al., 2006). Similarly,

contained a greater concentration of furfural and acetic acid than the light DDGS or the DDGS used in Exp. 1. The DDGS used in Exp. 5 and 6 contained smaller concentrations of acetic acid and greater concentrations of dimethyl sulfide, diacetyl, and acetyl methyl carbinol than all other DDGS samples.
Solà-Oriol et al. (2009c) demonstrated that differences in palatability could be detected after 1 to 2 d and that these differences remained unaffected when measurements were conducted for a longer period. Thus, the preference model used in the current study provides a quick, efficient method to determine ingredient and diet preference in pigs, and the use of a single pig may eliminate errors associated with feeding competition. Further, the current research investigated preferences in pigs that had been weaned for 2 wk to ensure adequate feed intake and improve the sensitivity of the experiments. Solà-Oriol et al. (2009c) demonstrated similar responses between newly weaned pigs and postweanling pigs in their preference tests using various feed ingredients; however, preferences in postweanling pigs were much more pronounced. Studies of preference and palatability are vital to understand how to increase or maintain feed intake in pigs, ultimately maximizing production. In the current preference studies, only corn and soybean meal were altered and replaced with the test ingredients to avoid confounding preference measures with changes in diet composition.

We included control comparisons to validate that the studies were properly controlled and not confounded by placement of feeders, temperature, and ventilation differences within the room, or other factors. Control comparisons were included in all preference studies and consisted of double-choice comparisons using 2 feeders per pen, both containing the reference diet with 0% of the test ingredient. Consumption from each feeder should not be different; therefore, control comparisons should not be different from the 50% preference index. This was the case in all preference studies, with the exception of Exp. 4, in which the control comparison was different from 50% on d 1 and overall. This indicates that factors beyond those that were controlled in our experimental design may have affected the results. Potential preferences for feeder location were accounted for in the experimental design of all experiments by assigning equal numbers of test and reference diets to feeders on each side of the pen.

Pigs had not been exposed to experimental feed ingredients before the study. For each preference experiment, pigs were fed a common complex starter diet (Launcher Plus Starter Program, Renaissance Nutrition) for 2 wk, followed by a corn- and soybean meal-based diet for 4 d before beginning the trial. Although the pigs on trial had been previously exposed to corn- and soybean meal-based diets, it has been shown that previous exposure has a limited impact on preference differences within the room, or other factors. Control comparisons were included in all preference studies and consisted of double-choice comparisons using 2 feeders per pen, both containing the reference diet with 0% of the test ingredient. Consumption from each feeder should not be different; therefore, control comparisons should not be different from the 50% preference index. This was the case in all preference studies, with the exception of Exp. 4, in which the control comparison was different from 50% on d 1 and overall. This indicates that factors beyond those that were controlled in our experimental design may have affected the results. Potential preferences for feeder location were accounted for in the experimental design of all experiments by assigning equal numbers of test and reference diets to feeders on each side of the pen.

### Table 8. Effect of distillers dried grains with solubles (DDGS) color (light or dark) on diet preference in nursery pigs (Exp. 3)\(^1\)

<table>
<thead>
<tr>
<th>Preference, (%)</th>
<th>Control</th>
<th>Light vs. reference</th>
<th>Dark vs. reference</th>
<th>Dark vs. light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>43.78</td>
<td>51.85</td>
<td>52.10</td>
<td>65.28*</td>
</tr>
<tr>
<td>Day 2</td>
<td>43.04</td>
<td>48.75</td>
<td>48.46</td>
<td>67.96†</td>
</tr>
<tr>
<td>Overall</td>
<td>43.30</td>
<td>50.44</td>
<td>49.45</td>
<td>67.59†</td>
</tr>
</tbody>
</table>

\(^1\)Comparisons consisted of double-choice preference tests between diets containing the test ingredients and the 0% inclusion reference diet. Light and dark DDGS were defined by origin and color of the DDGS.

### Table 9. Effect of distillers dried grains with solubles (DDGS) color (light or dark) and inclusion amount (%) on diet preference in nursery pigs (Exp. 4)\(^1\)

<table>
<thead>
<tr>
<th>Preference, (%)</th>
<th>Light DDGS</th>
<th>Dark DDGS</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 vs. 0</td>
<td>10 vs. 0</td>
<td>20 vs. 0</td>
</tr>
<tr>
<td></td>
<td>10 vs. 0</td>
<td>20 vs. 0</td>
<td></td>
</tr>
<tr>
<td>Day 1(^1),(^4)</td>
<td>61.47*</td>
<td>38.18*</td>
<td>21.83†</td>
</tr>
<tr>
<td>Day 2(^1),(^5)</td>
<td>61.20</td>
<td>43.96</td>
<td>28.00†</td>
</tr>
<tr>
<td>Overall(^1),(^6),(^7)</td>
<td>62.47*</td>
<td>40.32</td>
<td>25.30†</td>
</tr>
</tbody>
</table>

\(^1\)Comparisons consisted of double-choice preference tests between diets containing the test ingredient vs. the 0% inclusion reference diet. Light and dark DDGS were defined by origin and color of the DDGS.

### Footnotes
- \(^2\)Preference is expressed as the intake of the test diet as a percentage of total intake.
- \(^3\)Linear effect of light DDGS inclusion \((P < 0.01)\).
- \(^4\)Main effect of DDGS color \((P = 0.02)\).
- \(^5\)Main effect of DDGS color \((P = 0.06)\).
- \(^6\)Main effect of DDGS color \((P < 0.05)\).
- \(^7\)Linear effect of dark DDGS inclusion \((P < 0.10)\).
- \(^8\)Main effect of DDGS color \((P < 0.01)\).
- \(^9\)Denotes a difference \((P < 0.05)\) from the 50% preference; †denotes a difference \((P < 0.01)\) from the 50% preference.
for only d 1 (van Heugten et al., 2006), indicating that preference for the diet that pigs were exposed to previously should not have affected the results of the current study.

Experiments 1 and 2 clearly showed that the sources of DDGS and HP-DDG used led to reductions in preference, even at smaller inclusion amounts. As inclusion of DDGS increased, preference was significantly reduced. These results agree with those obtained by Hastad et al. (2005), who observed that preference decreased linearly as DDGS inclusion increased from 0 to 30% in the diet. Analysis of the DDGS source for Exp.

<table>
<thead>
<tr>
<th>Table 10. Effect of distillers dried grains with solubles (DDGS) inclusion and flavor supplementation on diet preference in nursery pigs (Exp. 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet preference comparison&lt;sup&gt;7&lt;/sup&gt;</td>
</tr>
<tr>
<td>Preference,&lt;sup&gt;1&lt;/sup&gt;%</td>
</tr>
<tr>
<td>0-NF vs. 10-NF vs. 20-NF vs. 0-FL vs. 10-FL vs. 20-FL vs. 0-NF</td>
</tr>
<tr>
<td>Day 1&lt;sup&gt;4,6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Day 2&lt;sup&gt;3,6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall&lt;sup&gt;3,6&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Preference is expressed as the intake of the test diet as a percent of total intake.

<sup>2</sup>Diets contained 0, 10, or 20% DDGS without supplemental flavor [0-no flavor (NF), 10-NF, and 20-NF, respectively] or with 0.2% supplemental flavor [0-flavor (FL), 10-FL, and 20-FL, respectively]. Preference was determined by double-choice preference comparisons using the 0-NF diet as the reference diet.

<sup>3</sup>Main effect of DDGS (<i>P</i> < 0.01).

<sup>4</sup>Main effect of FL (<i>P</i> < 0.01).

<sup>5</sup>Main effect of DDGS (<i>P</i> < 0.10).

<sup>6</sup>Main effect of DDGS (<i>P</i> < 0.01).

<sup>7</sup>Denotes a difference (<i>P</i> < 0.05) from the 50% preference; †denotes a difference (<i>P</i> < 0.01) from the 50% preference.

**Table 11. Effect of distillers dried grains with solubles (DDGS) inclusion amount and flavor on nursery pig performance (Exp. 6)<sup>1,2</sup>**

<table>
<thead>
<tr>
<th>Item</th>
<th>Nonflavored diet</th>
<th>Flavored diet</th>
<th>P-value&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>BW, kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>6.74</td>
<td>6.73</td>
<td>6.72</td>
</tr>
<tr>
<td>wk 1</td>
<td>7.93</td>
<td>7.87</td>
<td>7.89</td>
</tr>
<tr>
<td>wk 2</td>
<td>9.02</td>
<td>8.94</td>
<td>8.86</td>
</tr>
<tr>
<td>wk 3</td>
<td>11.31</td>
<td>10.60</td>
<td>10.85</td>
</tr>
<tr>
<td>wk 4</td>
<td>14.72</td>
<td>14.22</td>
<td>14.45</td>
</tr>
<tr>
<td>wk 5</td>
<td>17.51</td>
<td>16.65</td>
<td>16.70</td>
</tr>
<tr>
<td>ADFG, g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starter 1</td>
<td>169</td>
<td>164</td>
<td>167</td>
</tr>
<tr>
<td>Starter 2&lt;sup&gt;4&lt;/sup&gt;</td>
<td>242</td>
<td>195</td>
<td>212</td>
</tr>
<tr>
<td>Starter 3</td>
<td>443</td>
<td>432</td>
<td>418</td>
</tr>
<tr>
<td>Overall</td>
<td>308</td>
<td>284</td>
<td>285</td>
</tr>
<tr>
<td>ADFI, g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starter 1</td>
<td>211</td>
<td>195</td>
<td>214</td>
</tr>
<tr>
<td>Starter 2&lt;sup&gt;2&lt;/sup&gt;</td>
<td>354</td>
<td>320</td>
<td>325</td>
</tr>
<tr>
<td>Starter 3</td>
<td>712</td>
<td>667</td>
<td>665</td>
</tr>
<tr>
<td>Overall</td>
<td>465</td>
<td>430</td>
<td>439</td>
</tr>
<tr>
<td>G:F, kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starter 1</td>
<td>803</td>
<td>834</td>
<td>775</td>
</tr>
<tr>
<td>Starter 2</td>
<td>679</td>
<td>604</td>
<td>641</td>
</tr>
<tr>
<td>Starter 3</td>
<td>619</td>
<td>651</td>
<td>629</td>
</tr>
<tr>
<td>Overall</td>
<td>662</td>
<td>658</td>
<td>650</td>
</tr>
</tbody>
</table>

<sup>1</sup>Each value represents the mean of 8 pens with 4 pigs per pen.

<sup>2</sup>Starter 1, 2, and 3 diets were fed for 1, 2, and 2 wk, respectively, after weaning. Starter 1 diets did not contain DDGS, but were without flavor or were supplemented with flavor.

<sup>3</sup>Probability values for the effects of DDGS, flavor, and their interaction (flavor × DDGS).

<sup>4</sup>ADG of pigs eating 10% DDGS was less (<i>P</i> < 0.05) than ADG of pigs eating 0% DDGS.

<sup>5</sup>ADFI of pigs eating 10 or 20% DDGS was less (<i>P</i> < 0.05) than ADFI of pigs eating 0% DDGS.
1 showed that it contained 4 mg/kg of DON. Feeding DDGS at 30% would constitute approximately 1.2 mg/kg of DON in the as-fed diet. Swine are particularly sensitive to DON, and reduced feed intake and BW gain can be observed when feeding amounts of 2 to 3 mg/kg (van Heugten, 2001). Smith et al. (1997) observed that increasing inclusion of DON from 0 to 1.9 mg/kg reduced feed intake over a 3-wk period. In addition, the DDGS source that was used in Exp. 1 contained 27.5% NDF and 11.5% ADF compared with the reference diet, which contained 8.1% NDF and 5.1% ADF. Solà-Oriol et al. (2009a) reported a negative correlation between preference and crude fiber, possibly caused by the low energy density of high-fiber diets. Fiber content can also affect the texture of feed, which has been shown to influence feed preference (Solà-Oriol et al., 2009b). This could be another factor affecting the palatability of DDGS-containing diets.

The observation that HP-DDG decreased pig preference agrees with the results of Widmer et al. (2008), who observed that inclusion of 20 and 40% HP-DDG reduced feed intake during the growing period. In the current study, preference was reduced even at inclusion of 10%. Neither mycotoxins nor rancidity seemed to play a role in the negative preference of HP-DDG-containing diets, based on mycotoxin screening and the evaluation of volatile compounds. However, similar to DDGS, HP-DDG has more fiber than corn. Compared with the reference diet, which contained 6.7% NDF and 5.1% ADF, the source of HP-DDG used in Exp. 2 contained 35.1% NDF and 15.0% ADF, which could contribute to reduced palatability (Solà-Oriol et al., 2009a).

In Exp. 4, there was a linear reduction in palatability as DDGS increased in the diet, with the effect of light DDGS being more pronounced than dark DDGS. In addition, a greater preference for the dark DDGS than for the light DDGS compared with the reference diet was observed. In Exp. 3, there were no differences in preference when comparing 30% DDGS with the corn-soybean meal reference diet, regardless of color. However, the direct comparison between light and dark DDG-containing diets showed that light DDGS was less preferred than dark DDGS. The dark color of DDGS is typically caused by overheating during the drying process. Overheating causes Maillard reactions, and it could be assumed that this source of DDGS would be poorer quality and have less digestible lysine. Ergul et al. (2003) observed that DDGS that was of poor quality and dark in color contained approximately 0.38% digestible lysine, whereas lighter colored high-quality DDGS contained 0.65% digestible lysine when fed to poultry. Cromwell et al. (1993) reported that subjective color score and Hunterlab L (lightness-darkness) scores were highly correlated with growth rate and G:F in chicks, and that chicks can serve as models for determining the nutritional value of DDGS in pig diets. Stein et al. (2005) observed correlation coefficients for the relationship between ileal digestibility of lysine in the pig and the color of DDGS, determined by the Hunter and Minolta L, a, and b score, to be approximately 0.50, indicating that color may not be the most effective way to characterize DDGS quality. The dark DDGS source used in Exp. 3 and 4 had Hunterlab scores of 32.0, 13.1, and 35.7 for L, a, and b, respectively, whereas scores for the light DDGS source were 51.6, 11.2, and 48.7 for L, a, and b, respectively. Thus, the dark source of DDGS was darker and redder in color and presumably had inferior lysine digestibility. Even though the same DDGS source was used in Exp. 3 and 4, Exp. 3 was initiated approximately 2 mo before Exp. 4. During this time, feed was stored in an enclosed space without temperature control during the warm summer months. Therefore, development of rancidity of fat over time may have contributed to the decreased preference of

Table 12. Concentrations of volatile compounds detected by headspace analysis of distillers dried grains with solubles (DDGS) sources relative to the least concentration within each compound set at 1.01

<table>
<thead>
<tr>
<th>Volatile compound</th>
<th>Exp. 1, DDGS</th>
<th>Exp. 3 and 4, light DDGS</th>
<th>Exp. 3 and 4, dark DDGS</th>
<th>Exp. 5 and 6, DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl acetate</td>
<td>1.0</td>
<td>1.4</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Diacetyl</td>
<td>1.0</td>
<td>6.3</td>
<td>4.6</td>
<td>12.9</td>
</tr>
<tr>
<td>Valerianate</td>
<td>59.1</td>
<td>1.3</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dimethyl disulfide</td>
<td>1.2</td>
<td>1.2</td>
<td>1.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Aldehyde C-6</td>
<td>9.7</td>
<td>1.4</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>2-Amyl furan</td>
<td>6.9</td>
<td>1.8</td>
<td>1.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Amyl alcohol</td>
<td>29.1</td>
<td>1.8</td>
<td>1.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Acetyl methyl carbinol</td>
<td>1.9</td>
<td>1.0</td>
<td>1.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Furfural</td>
<td>3.8</td>
<td>3.4</td>
<td>10.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Butane-2,3-diol</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>3.0</td>
<td>3.0</td>
<td>5.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Propylene glycol</td>
<td>1.1</td>
<td>1.9</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>γ-Butyrolactone</td>
<td>1.0</td>
<td>3.3</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Furfuryl alcohol</td>
<td>1.0</td>
<td>2.3</td>
<td>2.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Benzyl alcohol</td>
<td>1.2</td>
<td>7.4</td>
<td>2.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Phenyl ethyl alcohol</td>
<td>1.0</td>
<td>1.5</td>
<td>1.1</td>
<td>2.0</td>
</tr>
</tbody>
</table>

1Light and dark DDGS were defined by origin and color of the DDGS.
the DDGS diets in Exp. 4 that was not observed in Exp. 3.

Results from Exp. 5 showed that preference decreased for diets with increasing inclusion of DDGS when no flavor was added. This agrees with results from Exp. 1, in which preference linearly decreased with an increase in DDGS from 0 to 30% of the diet, and with those of Hastad et al. (2005), who observed a linear decrease in ADFI as DDGS increased in the diet. Analysis of the DDGS source used in Exp. 5 showed that it contained 2.8 mg/kg of DON. Feeding DDGS at 30% would contribute approximately 0.56 mg/kg of DON to the diet, which could have an effect on diet preference. Acid detergent-insoluble N is a measurement for estimating unavailable protein and was greater in this particular DDGS source than in any other source used in this research. Greater ADIN in DDGS indicates burning during the drying process (Berger and Good, 2007), which could indicate less digestible lysine in the DDGS, and potentially less preference for DDGS-containing diets. The reference diet (without flavor) was preferred over all diets containing flavor, regardless of DDGS inclusion, indicating that the flavor reduced palatability or may have induced a neophobic effect. Prior exposure to dietary ingredients plays a key role in determining food choices in mammals (Roura et al., 2008). Duran et al. (2000) observed that depression of feed intake in diets containing various amounts of rapeseed meal and canola meal was prevented by addition of a familiar flavor. On the other hand, the decreased preferences for flavored diets used in Exp. 5 disagree with the performance results (Exp. 6), which indicated that feed intake was increased during the starter 1 phase with the addition of flavor. No other performance variables were significantly affected by flavor. However, there was a tendency for increased ADG during the starter 3 phase for pigs fed flavored diets compared with pigs fed nonflavored diets. These results are partly consistent with those of McLaughlin et al. (1983), who observed that both BW gain and feed intake were affected by the addition of flavor for only the week immediately after weaning. Thus, flavors may encourage increased feed intake in pigs experiencing the stress of weaning or diet changes.

Research on the performance of pigs fed diets containing DDGS is conflicting. Whitney and Shurson (2004) reported that pigs fed 25% DDGS performed the same as pigs fed diets without DDGS. Cook et al. (2005) observed no effect of DDGS on ADG, ADFI, or G:F and a decrease in pig mortality as DDGS increased in the diet from 0 to 30%. DeDecker et al. (2005) also reported no effect of increasing the DDGS inclusion amount (0 to 30%) on ADG or ADFI, but reported a small improvement in G:F. In contrast, Whitney et al. (2006) reported a decrease in ADG and G:F at greater inclusion of DDGS, but no difference in ADFI. Linneen et al. (2008) observed a linear decrease in both ADG and ADFI when pigs were fed 0 to 30% DDGS. In Exp. 6, ADG and ADFI in the starter 2 phase were negatively affected by DDGS inclusion, but G:F was not affected. Overall, no significant DDGS effects were evident for any performance measurement, even though fiber content in the DDGS-containing diets was greater. High-fiber diets negatively affect the ADG, feed intake, and G:F of young pigs (Pond et al., 1988). The results of the current study partly agree with that observation because ADG and ADFI decreased when DDGS were first added to the diet. However, as pigs grow, they are more capable of digesting higher fiber diets, which may explain the lack of a DDGS effect during the starter 3 phase. The source of DDGS used in Exp. 6 was also used in Exp. 5, in which pig preference decreased for diets increasing in DDGS inclusion. Therefore, as in Exp. 5, DON and high ADIN may have had a role in decreased feed intake and, ultimately, decreased overall performance.

Diets used in the palatability study (Exp. 5) and performance study (Exp. 6) were identical and the studies were performed simultaneously. Differences in the response to flavor between the palatability study and the performance study may be related to the difference in age of the pigs or differences in diet phases. During the starter 1 phase of Exp. 6, pigs were approximately 21 d of age and had just been weaned and switched to a dry diet without or with flavor. The pigs used for the preference study were older, ranging from 31 to 49 d of age, and had already been consuming a flavor-free dry diet for at least 10 d before the beginning of the preference study. Thus, the addition of flavor may have caused a neophobic response in Exp. 5, whereas in Exp. 6, it may have attracted the attention of the pig to the feeder after weaning, increasing intake. In addition, the ingredient composition of the starter 1 diet was much different in complexity from the starter 3 diet used to conduct the preference study. Interactions of flavor with diet components may have changed flavor-related taste and odor sensing by the animal, which adds complexity when trying to explain the differences observed between the 2 experiments.

Headspace analysis of the DDGS showed the flavor-characterizing volatile compounds for DDGS used in Exp. 1 to be valerianate, aldehyde C-6, 2-amyl furan, and amyl alcohol. Valerianate and aldehyde C-6 contribute rancid notes to the sample. Greenberg et al. (1953) fed rats diets containing rancid fat and observed that feed intake was less than feed intake by rats fed diets without rancid fat. Similarly, Kimura et al. (2004) observed that rats given a choice between fresh oil and oxidized (rancid) oil significantly preferred fresh oil, indicating the unpalatable characteristics of rancid fat. 2-Amyl furan contributes a toasted cereal grain volatile note to the DDGS. Solà-Oriol et al. (2009a) reported that extrusion cooking increased the preference of pigs for corn and naked oats. This could be attributed to increased starch availability, but could also be a result of a changed volatile profile of these ingredients. Amyl alcohol contributed a fermented, yeasty note to the sample that was not as evident, quantitatively, in the
other DDGS samples. Lawlor et al. (2002) compared weaning pig feed intake of a dry control diet with an acidified liquid diet and a fermented liquid diet. They observed that DMI was greater for the fermented liquid diet than the control diet. If this greater intake is related to palatability, it would indicate that fermented volatile compounds may increase preference, which would disagree with the results observed in the current study. However, preference could also have been a result of diet texture. The main volatile compound differences between the light and dark DDGS used in Exp. 3 and 4 were the concentrations of furfural, acetic acid, and benzyl alcohol. Furfural is an aromatic compound often identified by its burned, smoky, almond aroma. The greater concentration of furfural in dark DDGS suggests initiation of the Maillard reaction, which may account for the color difference. In the current study, pigs preferred the diet with greater furfural (dark DDGS) compared with the diet with much less of this volatile compound. Furfural content was also greater in the dark DDGS sample than in the DDGS source used in Exp. 1, in which preference of the reference diet was much greater than for all DDGS-containing diets. Acetic acid, which is characterized by a sour, pungent aroma common to vinegar, was greatest in the dark DDGS compared with all other samples. Falkowski and Ah-erne (1984) observed that addition of organic acids led to a slight decrease in feed intake, possibly because of decreased palatability. Ettle et al. (2004) reported that, when given a choice between acidified and nonacidified diets, weanling pigs prefer the nonacidified diets. It is not clear why the dark DDGS with greater acetic acid content was more highly preferred. Benzyl alcohol is an aromatic that has a weak, pleasant fragrance and is often used in the production of soaps, lotions, perfumes, and flavors (Curry and Warshaw, 2005). The presence of this compound at greater concentrations observed in light DDGS seemed to have little to no positive influence on palatability, possibly because of its mildness. Greater concentrations of diacetyl, dimethyl sulfide and acetyl methyl carbinol were present in the DDGS used in Exp. 5 and 6. Diacetyl and acetyl methyl carbinol are by-products of fermentation and contribute to a buttery volatile note. Deuel and Movitt (1944) reported that rats preferred diets flavored with diacetyl to unflavored diets. This would disagree with the present study because DDGS with a greater proportion of buttery volatile components were not preferred. Dimethyl sulfide is often associated with the cooking of certain vegetables, such as cabbage and broccoli, and is considered a disagreeable volatile component for humans (Maruyama, 1970). Increased concentrations of this compound in DDGS used in Exp. 5 and 6 may have contributed to the lack of preference for these DDGS-containing diets.

Based on the present studies, inclusion of DDGS or HP-DDG, even at relatively small inclusion amounts, leads to reductions in preference. Even though these ingredients have proved to be effective as nutrient sources in pig diets, their palatability may compromise feed consumption in situations in which no choice is offered. However, performance may or may not suffer with inclusion of DDGS or other coproducts. In addition to inclusion amount, DDGS quality may be a factor influencing preference. However, dark DDGS, presumably of inferior quality, may be preferred over light DDGS when included at 30% of the diet. When given no choice, DDGS-containing diets had a negative effect on performance only in the starter 2 phase, possibly because pigs are able to adapt to this ingredient as they grow and as they are more capable of digesting diets with a greater fiber content. The flavor used in this study negatively affected preference regardless of inclusion amount of DDGS, possibly because of a neophobic effect. Nevertheless, under no-choice conditions, flavor improved feed intake at weaning regardless of the DDGS amount. Knowledge of volatile compounds that enhance or suppress the palatability of feed may lead to further development of feed additives for masking relatively unpalatable, albeit cost-effective, ingredients.

**LITERATURE CITED**


