Evaluation of Feed Grains with Dried Skim Milk and Added Carbohydrate Sources on Weanling Pig Performance1,2,3

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ABSTRACT: Two experiments were conducted to evaluate the effects of 1) two grain mixtures and 2) various carbohydrate sources and levels fed to weanling pigs during the initial 2 wk postweaning. A total of 720 crossbred pigs were weaned at 23 ± 2 d of age at an average BW of 5.8 kg. In Exp. 1, a 2 x 3 factorial experiment in a randomized complete block design was conducted in 12 replicates. Treatment diets formulated to 1.40% lysine were fed for a 14-d period. These diets contained dried skim milk (DSM) at a 45% level and an oat groat-soybean meal (OG-SBM-DSM) or a corn-soybean meal (C-SBM-DSM) mixture. In addition, the diets contained one of three carbohydrate sources (cornstarch, dextrose, lactose) at a 12% level. From 15 to 35 d postweaning, all groups were fed a 1.15% lysine corn-soybean meal (C-SBM) diet. The results demonstrated that during the period from 0 to 14 d weight gains were similar when either grain source was provided, but gain:feed ratio was superior and serum urea N was lower when the OG-SBM-DSM diet was fed. The addition of lactose or dextrose to either grain mixture resulted in greater weight gains (P < .05) than when cornstarch was the carbohydrate source. The second experiment was a randomized complete block design conducted in six replicates. The C-SBM-DSM diet of Exp. 1 served as the positive control diet. The other diets used corn gluten meal (CGM), SBM, and DSM with the three carbohydrate sources added at 22.5 or 35.5%. This resulted in total simple dietary carbohydrate levels of 22.5, 45, or 58%. The results demonstrated that when cornstarch was the added carbohydrate, weight gains and feed intake responses were lower during the initial 14 d postweaning, whereas supplemental lactose or dextrose resulted in improved weight gains (P < .01) to a total dietary level of 45%. These results suggest that dietary simple carbohydrate (lactose or dextrose) levels between 34.5 and 45% may be necessary during the initial 14-d postweaning period. During the subsequent period from d 15 to 35 when the C-SBM diet was fed, gain and feed performance responses were similar for all groups in both experiments and were not affected by their previous treatment diet.

Key Words: Lactose, Dextrins, Starch, Oats, Pigs, Weaning

Introduction

The diet initially provided to weanling pigs frequently contains high percentages of milk products. The use of these products in combination with cereal

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Processed soybean meal, the second major component of a corn-soybean meal (C-SBM) mixture, can contain growth inhibitors that decrease the secretion of pancreatic proteolytic enzymes (Gorill and Thomas, 1967; Gorill et al., 1967; Khorasani et al., 1989). Soybean protein also contains antigenic factors (Miller et al., 1984a,b; Li et al., 1990), which can have detrimental effects on small intestinal villi (Dunsford et al., 1989) and which have resulted in lowered postweaning pig performance (Li et al., 1990).

Because of poorer nutrient availability and/or absorption of nutrients from these two major dietary components, high dietary levels of corn and/or soybean meal could be detrimental to the pig postweaning. The present experiment evaluated the efficacy of different feed grain sources in a diet with a high percentage of milk product. In addition, the efficacy of added carbohydrate sources and levels was evaluated during the initial 2 wk postweaning.

**Experimental Procedures**

**General.** Two experiments were conducted using pigs weaned at 23 ± 2 d of age. The experiments were conducted at two locations, and pigs within replicate were allotted by weight, litter, and sex. Pigs at Location 1 (Columbus) were housed in groups of six in 1.2-m × 1.2-m raised-deck nursery pens with rubber-coated, expanded metal floors, one nipple waterer, and one five-hole self-feeder. Pigs at Location 2 (Wooster) were housed either in pens identical to those at Location 1 or in 1.5-m × 3.2-m floor pens with 2.5-cm concrete (.5-cm slat spacing) slats with nine pigs per pen. Each floor pen contained a heat lamp over a covered hover area (25% of pen space), a rubber floor mat under the hover, one nipple waterer, and one six-hole self-feeder. Each replicate was conducted in the same type of nursery pen. The temperature in the nurseries was initially 29°C but was lowered to approximately 22°C by the end of the experiment. Pigs were allowed ad libitum access to their diets throughout the 35-d test period. Pig weights and feed consumptions were collected weekly but composited for the periods from d 0 to 14 and d 15 to 35.

**Experiment 1.** The first trial was a 2 × 3 factorial arrangement of treatments in a randomized complete block experiment conducted in 12 replicates over time. A total of 504 crossbred ([Yorkshire × Landrace × Hampshire] × Duroc) pigs initially averaging 5.2 kg BW were allotted to treatment diets with eight replicates conducted in deck pens and four replicates in floor pens.

Treatment diets during the initial 14-d postweaning period were formulated using 45% dried skim milk (DSM) but different basal grain sources (oat groats [OG] or corn [C]). The diets incorporated one of three carbohydrate sources (cornstarch, dextrose, or lactose) at a 12% level. Soybean meal (SBM) was incorporated to attain a 1.40% dietary lysine level. Treatment diets were thus identified as OG-SBM-DSM or C-SBM-DSM (Table 1). After the initial 14-d period, all pigs were provided a C-SBM diet.
formulated to contain 1.15% lysine during the period from d 15 to 35 (Table 1). Within each of six replicates, five pigs per pen were selected at random on 3, 7, 14, and 21 d postweaning and bled via cardiac puncture. Blood was initially placed on ice and centrifuged and serum was collected, pooled by pen in equal amounts per pig, frozen, and later analyzed for urea N (Sigma, 1983).

Pooled by pen in equal amounts per pig, frozen, and placed on ice and centrifuged, serum was collected, and bled via cardiac puncture. Blood was initially conducted in a randomized complete block designed experiment.

Because there was a growth response to supplemental dextrose and(or) lactose in Exp. 1, this experiment evaluated the effects of different levels of the three carbohydrate sources when added to diets that contained 45% DSM. The C-SBM-DSM diet of Exp. 1 was considered the positive control diet. Corn gluten meal (CGM) and cornstarch replaced the corn protein (lysine equivalent basis) and cornstarch of the C-SBM-DSM diet. The use of CGM allowed the incorporation of higher levels of supplemental carbohydrate than the 12% permitted in Exp. 1 while maintaining a dietary amino acid profile relatively similar to that of the C-SBM-DSM diet. The addition of supplemental cornstarch to the CGM-SBM-DSM diet was considered nutritionally equivalent to the C-SBM-DSM diet but was identified as the negative control diet. Lactose or dextrose was subsequently added at 22.5 or 35.5% at the expense of cornstarch. Soybean meal was incorporated at a constant level in all diets. Because of the indigenous lactose content (approximately 50%) of DSM (Tomkins, 1989), the positive and negative control basal diets both contained a calculated 22.5% lactose level. The combination of the added lactose and(or) dextrose and the indigenous lactose from DSM resulted in total simple carbohydrate dietary levels of 22.5, 45, or 58% (Table 2). As in Exp. 1, all pigs were fed the C-SBM (1.15% lysine) diet from 15 to 35 d postweaning (Table 1).

Statistical Analysis. Pen means for each measurement variable were considered the experimental unit. Location, type of pen, time, and replicate were incorporated into the statistical model. Statistical analysis was performed using the GLM procedure of SAS (1985). No interaction between pen type, time, or location × treatment diets occurred for the various measurements. In Exp. 1 no interaction occurred between grain or carbohydrate sources. The LSD test compared treatment means between carbohydrate sources in Exp. 1. In Exp. 2 linear regression analysis compared carbohydrate levels using total lactose or lactose plus dextrose level combinations as the contrast variable. The positive and negative control diets were compared in Exp. 2.

Results

Experiment 1. During the initial 14-d period, pig weights and daily gains were similar between the two grain sources, but daily feed intake was greater (P <

<table>
<thead>
<tr>
<th>Table 2. Percentage composition of experimental diets (Exp. 2)</th>
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<tbody>
<tr>
<td><strong>Item</strong></td>
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<tr>
<td><strong>Protein source:</strong></td>
</tr>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>Corn gluten meal (60% CP)</td>
</tr>
<tr>
<td>Soybean meal (44% CP)</td>
</tr>
<tr>
<td>Dried skim milk</td>
</tr>
<tr>
<td>Lactose</td>
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<tr>
<td>Dextroseb</td>
</tr>
<tr>
<td>Cornstarch</td>
</tr>
<tr>
<td>Coconut oil</td>
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<tr>
<td>Dicalcium phosphate</td>
</tr>
<tr>
<td>Limestone</td>
</tr>
<tr>
<td>Se premixc</td>
</tr>
<tr>
<td>Trace-mineral saltd</td>
</tr>
<tr>
<td>Vitamin mixe</td>
</tr>
<tr>
<td>Antibacterial agent</td>
</tr>
<tr>
<td>Dietary carbohydrate, %</td>
</tr>
<tr>
<td>Lactose + dextrosef</td>
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</tbody>
</table>

aC = corn; SBM = soybean meal; DSM = dried skim milk; CGM = corn gluten meal.
bHydrolyzed cornstarch.
cSee footnote c in Table 1 for composition.
dSupplied per kilogram of diet: 8 mg of Cu, 100 mg of Fe, 20 mg of I, 15 mg of Mn, 120 mg of Zn, and 4.22 g of NaCl.
eSee footnote d in Table 1 for composition.
fSee footnote e in Table 1 for composition.
gAssumes an indigenous lactose content of 50% from dried skim milk.
.05) when the C-SBM-DSM diet was provided (Table 3). The gain:feed ratio was improved (P < .05), however, when the OG-SBM-DSM diet was fed.

From 15 to 35 d postweaning when all treatment groups were fed the 1.15% lysine C-SBM diet, pig weight gains and feed intakes were greater than during the previous period but were similar among all treatment groups. Comparing pig weight gains during the week immediately before (8 to 14 d) and after (15 to 21 d) the transition from the treatment to the C-SBM diet, daily gain responses were similar, whereupon they subsequently increased (data not presented).

The addition of the carbohydrate sources at 12% to either the OG-SBM-DSM or C-SBM-DSM diets resulted in increased daily gains (P < .05) and feed intakes (P < .05) from 0 to 14 d postweaning only when dextrose or lactose, but not when cornstarch, was the added carbohydrate source. The total simple dietary carbohydrate level of these diets when the lactose from DSM was considered was 22.5% in the treatment groups. Comparing pig weight gains during the previous carbohydrate source did not influence serum urea N concentrations at any measurement period and was similar among all treatment groups. The similarity of these performance responses confirms the nutritional equivalence of these two diet compositions.

Supplementing the CGM-SBM-DSM diet (22.5% indigenous lactose) with additional lactose or dextrose resulted in total dietary levels of 22.5, 45, or 58% of the less-complex carbohydrates. A quadratic improvement (P < .01) in pig weight gain occurred from the 22.5 to the 45% total carbohydrate level, but there was a decline when the level was further increased to 58%. The poorer response to the high carbohydrate level was similar whether lactose or dextrose was the added carbohydrate source.

During the initial 14-d postweaning period, there was a greater feed intake when the 45% carbohydrate level was provided but a lower intake when the diets contained 58%, a response which was, however, not significant. The results demonstrated a quadratic plateau (P < .01) in gain:feed ratio to the 45% carbohydrate level when lactose, but a decline when dextrose, was added to the diet, resulting in a trend (P < .12) toward an interaction response between carbohydrate sources.

From 15 to 35 d postweaning, gains, feed intakes, and gain:feed ratios were similar for all treatment groups.

**Table 3. Effect of dietary carbohydrate and grain source on weanling pig performance (Exp. 1)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Grain source&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Carbohydrate source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OG</td>
<td>C</td>
</tr>
<tr>
<td>No. of pigs</td>
<td>252</td>
<td>252</td>
</tr>
<tr>
<td>Weight, kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 d</td>
<td>8.7</td>
<td>8.8</td>
</tr>
<tr>
<td>35 d</td>
<td>16.8</td>
<td>17.1</td>
</tr>
<tr>
<td>Daily gain, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 14 d</td>
<td>240</td>
<td>245</td>
</tr>
<tr>
<td>15 to 35 d</td>
<td>387</td>
<td>394</td>
</tr>
<tr>
<td>Daily feed, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 14 d</td>
<td>298</td>
<td>316</td>
</tr>
<tr>
<td>15 to 35 d</td>
<td>687</td>
<td>702</td>
</tr>
<tr>
<td>Gain:feed ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 14 d</td>
<td>.805</td>
<td>.775</td>
</tr>
<tr>
<td>15 to 35 d</td>
<td>.563</td>
<td>.562</td>
</tr>
</tbody>
</table>

<sup>a</sup>OG = oat groats; C = corn.

<sup>b</sup>,<sup>c</sup>Means within a row between carbohydrate source with different superscripts differ (P < .05).

<sup>*</sup>Means differ (P < .05).
Discussion

The dietary combination of oat groats and soybean meal compared with the corn and soybean meal mixture did not improve postweaning pig weight, weight gain, or feed intake responses. The lower serum urea N concentrations and improved gain:feed ratios when the OG-SBM-DSM diet was provided suggest, however, that the amino acids from this combination of protein sources were more effectively utilized by weanling pigs but that this improvement did not increase pig growth rate.

The amount of soybean meal in either the oat groats- or corn-based diets was low compared with the amount in diets fed in other reported experiments, largely because of the relatively high proportion of dried skim milk used in our experiment. Walker et al. (1986) reported that high levels of soybean meal precipitated a detrimental growth response in weanling pigs, but they used a 26.7% soybean meal level in their treatment diets, compared with the 8.8% level in our study.

Our two experiments clearly demonstrated that even with the high level of DSM, which contained an approximate indigenous lactose level of 22.5%, the resulting diet was still limiting in the less-complex carbohydrates. The addition of supplemental lactose or dextrose to the diets in both experiments resulted in enhanced postweaning gains compared with the basal diet or when cornstarch was the added carbohydrate. This indicates that the weaned pig responds by greater weight gains when ≥ 34.5% simple carbohydrates are provided during the initial weeks postweaning, and that a digestive insufficiency to hydrolyze cornstarch exists during this period postweaning. Our results demonstrate that a dietary level between 34.5 and 45% is needed by the 3-wk-old weaned pig.

Several workers (Corring et al., 1978; Sloat et al.,
1985; Hampson and Smith, 1986) have previously suggested that the young pig's ability to digest the protein and carbohydrate fraction from cereal grains is not fully developed until the pig is approximately 5 wk of age. Our results support their conclusion.

The starch from corn contains approximately 25% amylose and 75% amylopectin. The activity of pancreatic α-amylase may be more effective with amylose than with amylopectin because of less chemical complexity of the straight-chain carbohydrate (Longland, 1991). The activities of maltase II and III produced in the brush border cells of the small intestinal mucosa may be important avenues for amylopectin digestion (Graham, 1991). Pancreatic α-amylase and maltase II and III production increase with age (Longland, 1991) but may be inadequate at 4 to 5 wk of age to obtain maximum digestion of the starch from corn. The large change in intestinal morphology immediately postweaning (Cera et al., 1988a) suggests that the production of the brush border enzymes may be affected. Consequently, our results suggest that the initial diet postweaning should contain a minimum of 34.5% of the less-complex carbohydrates and perhaps up to 45% to obtain maximum performance responses. The carbohydrate can be either lactose or dextrose.

Dextrose from hydrolyzed cornstarch and lactose resulted in similar growth responses, implying that the digestive and absorptive processes were adequate for both dietary carbohydrates. Our results are somewhat contrary to those of Giesting et al. (1985), who reported that weaning pigs fed diets containing cornstarch or hydrolyzed cornstarch (dextrose) had lower gains than pigs fed diets with added lactose.

In both experiments, after the initial 14-d postweaning period when the diets were changed to the C-SBM mixture, there was a 2-wk period during which daily gains were similar. Although an improvement in daily gain would be expected, this response implies that the digestive and absorptive processes may still be inadequate by 5 wk of age to adapt to the more complex ingredients from a C-SBM mixture. That is, however, confounded, because not only was the diet composition changed, but dietary lysine was also lowered from 1.40 to 1.15%. The lower lysine level may have been nutritionally inadequate to obtain the optimum performance response. Lepine et al. (1991), however, demonstrated no response to supplemental lysine > 1.10% when a C-SBM diet was fed from 3 to 5 wk postweaning, but they reported a growth response to higher lysine levels when dried whey was a dietary component. Their results suggest that the dietary lactose contribution from dried whey may have restricted the postweaning growth response to dietary lysine. Consequently, the carbohydrate component in the corn and soybean meal diet of our experiment (not lysine) may also have been limiting after 14 d postweaning.

Implications

When oat groats and a soybean meal mixture replaced the corn and soybean meal mixture, weaning pig growth rates were similar during the initial 14 d postweaning. Cornstarch was not as effectively used as a carbohydrate source as was lactose or dextrose by the young weaning pig during the initial 14-d postweaning period. The performance of weaned pigs may be improved by the inclusion of less-complex carbohydrate sources at dietary levels from 34.5 to 45%.

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