GROWTH PERFORMANCE OF WEANLING PIGS FED CORN-SOYBEAN MEAL DIETS WITH OR WITHOUT DRIED WHEY AT VARIOUS L-LYSINE·HCI LEVELS1,2

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ABSTRACT

A total of 490 crossbred weanling pigs were used to evaluate the responses to and the subsequent interaction between dietary dried whey and crystalline L-lysine·HCl on postweanling growth and feed efficiency at two periods postweaning. The experiment was conducted as a 2 × 5 factorial arrangement of treatments in a randomized complete block design to evaluate two levels of edible-grade dried whey (0 or 25%) and five dietary lysine levels ranging from 1.10 to 1.50% in .10% increments using a corn-soybean meal mixture as the basal feedstuff. Pigs were allotted by weight, litter, and sex to seven replicates at weaning (23 ± 2 d) and fed their treatment diets for a 35-d period. Daily gain and feed intake were greater (P < .01) for both the 0- to 21- and the 22- to 35-d periods when dried whey was fed; the relative magnitude of the response to dried whey was greatest during the initial 21-d period. Growth responses during the 0- to 21-d period were, however, independent of dietary lysine level, suggesting that dietary lysine at a level of 1.10% is not the limiting nutrient in a corn-soybean meal diet or a corn-soybean meal diet with dried whey. From 22 to 35 d postweaning a linear growth response to lysine level occurred when the dried whey diet was fed, but no response was detected when lysine was added to the corn-soybean diet, resulting in a diet × lysine level interaction (P < .10). These results suggest that a component of dried whey other than lysine (e.g., lactose) was the most limiting nutrient in a corn-soybean meal-based diet, but when dried whey was supplemented, growth responses to crystalline lysine occurred during the latter phase of the starter period.

Key Words: Pigs, Weaning, Dried Whey, Lysine


Introduction

Weanling pigs between 3 and 4 wk of age is becoming commonplace in many swine production systems. Environmental, nutritional, and disease stresses often are manifested early postweaning through reduced growth rates and feed intakes. The transition toward a mature enzyme profile in swine that can effectively hydrolyze the complex molecules of cereal grains does not seem to occur as rapidly with early-weaned pigs as it does with later-weaned pigs. Researchers have attempted to overcome this digestive insufficiency by supplementing weaning pig diets with more easily digested milk products such as dried whey; whey of high quality consistently has improved postweaning growth rate (Graham et al., 1981; Mahan et al., 1981; Cera et al., 1988). The beneficial weight gain and feed intake responses to dietary dried whey may result not only from its higher digestibility, but also because it contains more and different...
allowed waterers, and five-hole heat pads
rubber-coated expanded metal floors, electric
Elevated 1.2-m pens were formulated to contain 1.10% without or with dried whey. Analy-
without human edible-grade dried whey. The experiment was conducted in seven replicates as a 2 × 5 factorial arrangement of treatments in a randomized complete block design. Pigs were blocked to treatment pens by initial weight, litter, and sex.
Dietary treatments provided two levels of dried whey (0 vs 25%), each at five dietary lysine levels ranging in total concentration from 1.10 to 1.50% in .10% increments. Two basal diets were formulated to contain 1.10% lysine using corn and soybean meal with or without human edible-grade dried whey (Table 1). Because diet formulation was based on total lysine content, diets that contained dried whey were approximately 2% lower in CP content than those without dried whey. Analysis of the two basal diets revealed a 1.11 and 1.07% lysine level for the two low-lysine diets without or with dried whey, respectively. Crystalline L-lysine-HCl (78.8% L-lysine) was added at the expense of corn to attain the desired dietary lysine level for the various treatment groups. All diets were fortified to meet or exceed other nutrient requirements (NRC, 1988).
Pigs were housed in groups of seven in elevated 1.2-m × 1.2-m nursery pens with rubber-coated expanded metal floors, electric heat pads (50% of floor surface area), nipple waterers, and five-hole self feeders. Pigs were allowed ad libitum access to their treatment diet and water for a 35-d period. Environmental temperature was initially established at ~28°C; temperature declined gradually to 21°C by the end of the experimental period. Pig weights and feed consumption were determined weekly; the data were consolidated for the 0- to 21- and 22- to 35-d periods.
Pen was considered the experimental unit; data were analyzed using the GLM procedure of SAS (1985). The experiment was conducted over four time periods, but when time was included in the model, it was found to have no effect on statistical inferences. Least squares means for main effects of dried whey and dietary lysine level subsequently were tested by single-degree-of-freedom comparisons or by linear regression analysis. Because it is commonplace to sequence the starter diet of weaning pigs into two or three dietary changes postweaning, the subsequent effects of the single-treatment diet fed throughout the 35-d trial also were partitioned into two postweaning periods (0 to 21 d and 22 to 35 d) and the period interaction evaluated.

### Table 1. Composition of Basal Diets

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Dried whey, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground yellow corn</td>
<td>0 25</td>
</tr>
<tr>
<td>Soybean meal (44% CP)</td>
<td>33.00 25.00</td>
</tr>
<tr>
<td>Dried whey b</td>
<td>1.75 1.20</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>1.05 .85</td>
</tr>
<tr>
<td>Limestone</td>
<td>.15 .15</td>
</tr>
<tr>
<td>Se premix c</td>
<td>.35 .35</td>
</tr>
<tr>
<td>Trace-mineral salt d</td>
<td>.15 .15</td>
</tr>
<tr>
<td>Vitamin mix e</td>
<td>.25 .25</td>
</tr>
<tr>
<td>Antibacterial agent f</td>
<td>.25 .25</td>
</tr>
</tbody>
</table>

*Diets containing 1.20, 1.30, 1.40, and 1.50% lysine were formulated from each of the two basal diets by the addition of .12, .25, .37, or .50% L-lysine-HCl, respectively, at the expense of corn.

bSpray-dried edible grade whey contained .90% lysine.

Adding, .15% of the premix contributed .3 ppm Se in a limestone carrier.

The premix contributed the following per kilogram of diet: 10 mg Ca, 100 mg Fe, .2 mg I, 40 mg Mn, 120 mg Zn, and 2.77 g NaCl.

The premix contributed the following per kilogram of diet: 6,600 IU vitamin A, 330 IU vitamin D3, 16.5 IU vitamin E, 3.0 mg vitamin K, 4.9 mg riboflavin, 21.4 mg panthothenic acid, 33 mg niacin, 33 μg vitamin B12, 450 mg choline, and .3 mg biotin.

The antibacterial agent contributed 55 mg carbadox/kg of diet.
TABLE 2. MAIN EFFECT OF DIETARY LYSINE LEVELS WITH OR WITHOUT DIETARY DRIED WHEY ON WEANLING PIG PERFORMANCE

<table>
<thead>
<tr>
<th>Item</th>
<th>Lysine, %</th>
<th>Dried whey, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.10</td>
<td>1.20</td>
</tr>
<tr>
<td>Weight, kg Initial</td>
<td>6.19</td>
<td>6.03</td>
</tr>
<tr>
<td>21 d</td>
<td>11.02</td>
<td>10.84</td>
</tr>
<tr>
<td>Final</td>
<td>18.06</td>
<td>18.30</td>
</tr>
<tr>
<td>Daily gain, g 0 to 21 d</td>
<td>234</td>
<td>233</td>
</tr>
<tr>
<td>22 to 35 d</td>
<td>495</td>
<td>522</td>
</tr>
<tr>
<td>Daily feed intake, g 0 to 21 d</td>
<td>390</td>
<td>370</td>
</tr>
<tr>
<td>22 to 35 d</td>
<td>919</td>
<td>890</td>
</tr>
<tr>
<td>Gain-to-feed ratio 0 to 21 d</td>
<td>.603</td>
<td>.626</td>
</tr>
<tr>
<td>22 to 35 d</td>
<td>.551</td>
<td>.560</td>
</tr>
</tbody>
</table>

*a Dried whey response (P < .01).
* Linear response (P < .01).
* Quadratic response (P < .05).

Results

Main and individual treatment effects are presented in Tables 2 and 3, respectively. The inclusion of dried whey in the diet of weanling pigs resulted in heavier BW at 21 (P < .01) and 35 d (final; P < .01) postweaning (Table 2). Increased growth rates occurred during both the 0- to 21-d (P < .01) and the 22- to 35-d (P < .01) periods when dried whey was fed. Although ADG in both groups increased from the first to the second period, the response to dried whey was higher when expressed on a relative basis (> 20% vs < 5%) for the earlier rather than the later period, respectively (Table 2). This resulted in a diet × period interaction (P < .01). Growth response to either diet during the initial 21-d postweaning period was independent of dietary lysine level, implying that the dietary lysine requirement of the weanling pig for this time period did not exceed 1.10%, even with the higher

TABLE 3. TREATMENT EFFECT OF DIETARY LYSINE LEVELS WITH OR WITHOUT DIETARY DRIED WHEY (DW) ON WEANLING PIG PERFORMANCE

<table>
<thead>
<tr>
<th>Item</th>
<th>C-SBM (% lysine)</th>
<th>C-SBM-DW (% lysine)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.10 1.20 1.30 1.40 1.50</td>
<td>1.10 1.20 1.30 1.40 1.50</td>
</tr>
<tr>
<td>21 d</td>
<td>10.64</td>
<td>10.45</td>
</tr>
<tr>
<td>Final</td>
<td>17.62</td>
<td>17.93</td>
</tr>
<tr>
<td>Daily gain, g 0 to 21 d</td>
<td>213</td>
<td>220</td>
</tr>
<tr>
<td>22 to 35 d</td>
<td>493</td>
<td>523</td>
</tr>
<tr>
<td>Daily feed intake, g 0 to 21 d</td>
<td>355</td>
<td>344</td>
</tr>
<tr>
<td>22 to 35 d</td>
<td>852</td>
<td>825</td>
</tr>
<tr>
<td>Gain to feed ratio 0 to 21 d</td>
<td>.599</td>
<td>.639</td>
</tr>
<tr>
<td>22 to 35</td>
<td>.579</td>
<td>.634</td>
</tr>
</tbody>
</table>

*C-SBM = corn-soybean meal mixture.
*b Interaction response (P < .10).
growth rate attained when the dried whey diet was fed (Figure 1). During the 22- to 35-d period, an interaction response ($P < .10$) occurred between diet and lysine level (Figure 2). Growth rate responded linearly as dietary lysine level increased from 1.10 to 1.50% in those diets that contained dried whey, with little improvement in gain above the 1.10% lysine level when corn-soybean meal-based diets were fed (Table 3). Covariate adjustment to the same 21-d BW and subsequent analysis of ADG still indicated an interaction effect ($P < .10$) between diet and lysine level. These results indicate that the weanling pigs' dietary lysine requirement had increased during the latter 14 d of the trial compared with the earlier 21-d period, and this was exacerbated when dried whey and lysine was incorporated in the diet but not when lysine was added singly to the corn-soybean meal diet.

Daily feed intake for both the 0- to 21- and 22- to 35-d period was higher ($P < .01$) when the dried whey diet was fed (Table 2). Supplemental crystalline lysine, however, resulted in a quadratically lower ($P < .05$) daily feed intake for the 22- to 35-d period (Table 2); this decline occurred with both the corn-soybean meal and dried whey diet (Table 3).

Gain-to-feed ratio was similar for both types of diet mixtures during the 0- to 21-d period but was poorer ($P < .01$) during the 22- to 35-d period ($P < .01$) when the dried whey diets were fed (Table 3). This resulted in a significant period $\times$ diet interaction ($P < .01$). Although there was no significant gain-to-feed response to dietary lysine level during the 0- to 21-d period, the data imply ($P < .14$) a response to $\leq 1.20\%$ lysine. During the subsequent 22- to 35-d period, there was a quadratic ($P < .05$) improvement in feed efficiency to dietary lysine level that reached a plateau at $\leq 1.30\%$ (Table 2). During the 22- to 35-d period, the data imply that gain-to-feed improved as dietary lysine level increased when dried whey was included in the diet, but not when the corn-soybean meal diet was fed; the interaction response, however, was not significant ($P > .15$).

**Discussion**

The present experiment evaluated a relatively wide range of dietary lysine levels to study the growth-promoting effects of crystalline lysine supplemented to a corn-soybean meal diet with or without 25% dried whey. Our results suggest that nutritional or physiological factors other than lysine restricted the growth responses of weanling pigs fed the corn-soybean meal diet during the initial 21-d postweaning period, but ADG clearly was increased by feeding diets that contained dried whey. The beneficial effects of feeding high-quality dried whey to weanling pigs have been documented; dried whey levels ranging from 15 to 35% have consistently improved gain and feed intake of simple corn-soybean meal diets (Pals and Ewan, 1978; Mahan et al., 1981; Cera et al., 1988). The 20% growth response to dried whey inclusion during the early period of our study is consistent with these responses.
The high level of lactose in dried whey (~70%) may be an important factor in stimulating this early postweaning growth response (Tokach et al., 1989). Presumably, the benefit of dried whey inclusion, at least initially postweaning, may be from its lactose, not its protein or lysine contribution. In our experiment, lysine added to either basal diet did not increase ADG during the initial 21-d postweaning period, but some component in the dried whey diet, presumably lactose, improved pig growth responses. During the subsequent 14-d period, as crystalline lysine level increased above 1.10% in the dried whey diet, lactose, another whey component, or another physiological factor influenced pig gains when supplemental lysine was provided. Although the relative growth response to dried whey was less during the 22- to 35-d period than during the initial 21-d period, the results suggest that whatever limitations occurred from the corn-soybean meal diet during the initial period were at least partially overcome with time postweaning and/or age. Because ADG also was higher during the 22- to 35-d postweaning period with both diet formulations compared with the earlier 21-d period, and because added lysine improved growth rate only with the dried whey diet, the data suggest that the combination of dried whey and lysine increased the pigs’ dietary lysine requirement. The lactose component of dried whey presumably was more easily digested than was the starch from the cereal grains not only during the initial 21-d period postweaning; this probably contributed to the enhanced growth responses to added lysine during the latter phase of the starter period. Highly digestible carbohydrate, therefore, may be the limiting component of the corn-soybean meal diet for weanling swine. Our data imply that after the pig’s energy need is met from carbohydrate (i.e., lactose), growth rate increases in response to the second nutrient limitation (i.e., lysine). After the young pig’s digestive tract attained an ability to digest starch or to overcome other digestive limitations, the added lysine resulted in increased growth rate. This suggests that during both the 0- to 21-d and the 22- to 35-d postweaning periods, a more available carbohydrate (i.e., lactose) may have limited the pigs’ growth rate when the cereal grain diet was fed, but its relative importance was less during the latter 14-d period. Consequently, the energy (i.e., carbohydrate) limitations of a corn-soybean meal diet and the resulting interaction between carbohydrate and lysine level need further exploration. To effectively use dietary lysine during the postweaning period, a carbohydrate source that is more digestible than corn starch may be needed.

It is improbable that the level of dried whey in our study enhanced weanling pig performance simply by improving dietary amino acid balance or digestibility. Calculation of digestible lysine, tryptophan, isoleucine, and methionine + cystine values from available data (Heartland Lysine, 1988) resulted in similar digestibility values for diets within each basal group. Indeed, digestible arginine, histidine, leucine, phenylalanine, and valine values were 6 to 21% lower in diets that contained dried whey. Digestible threonine, considered the third-limiting amino acid in corn-soybean meal diets, however, was approximately 14% higher in the dried whey diets; it should not be limiting in the cereal grain diet and, therefore, probably was not the cause of the higher growth rate. Our calculated digestibility estimates assume that amino acid digestibilities of dried whey were similar to those of dried skim milk, but this may be an overestimation. Nevertheless, with the possible exception of threonine, the addition of dried whey to a corn-soybean meal diet does not improve the calculated digestible amino acid profile.

The protein fraction of dried whey is capable of stimulating growth responses in the weanling pig. When Cinq-Mars et al. (1986) included 33.7% whey protein concentrate in the diets of weanling pigs, gain increased by approximately 18% and feed efficiency by 40% compared with that of pigs fed a com-soybean meal diet. Tokach et al. (1989) also demonstrated that gain and feed conversion were improved when weanling pigs, within 2 wk postweaning, received diets with 8.34% added dietary whey protein concentrate. Whey protein concentrate contains ~50% lactose (Tokkins, 1989), which may have contributed toward the improved responses observed in the studies of Cinq-Mars et al. (1986) and Tokach et al. (1989).

Increased nutrient digestibility also has been suggested as a mechanism by which dried whey stimulates growth of the weanling pig. Pals and Ewan (1978) reported that 33 or 66% dried whey in the diets of pigs weaned at 33 d of age increased the apparent digestibility
coefficients for DM and energy as the percent-
age of dietary dried whey increased. Although
apparent N digestibility decreased by 2.5%, N
retention increased 2.3-fold when dried whey
was increased to 66% of the diet. Cera et al.
(1988) also reported that N retention in
weanling pigs increased when the starter diet
contained 25% dried whey, with no effect on
DM or fat digestibility.

Increased luminal digestive enzyme activ-
ities support a possible role for dietary whey
in improving nutrient digestibility. Adding 20
to 25% dried whey to the diets of weanling pigs
did not affect the specific activities of lipase,
amylase, chymotrypsin, or trypsin concentra-
tions in the pancreas (Graham et al., 1981;
Lindemann et al., 1986; Owsley et al., 1986),
but, because of the heavier pancreas weights,
total pancreatic activity was increased (Graham
et al., 1981). Graham et al. (1981) and Owsley
et al. (1986) observed higher total amylase,
chymotrypsin, and trypsin activities in the
total intestinal contents of weanling pigs fed
diets containing dried whey. This suggests that
higher protein and carbohydrate hydrolysis
activities occur within the intestinal lumen
when dried whey is fed. A more mature
intestinal enzyme profile in older pigs enables
them to more effectively digest the starch
component from a corn-soybean meal diet,
which, in effect, reduces the benefit from
added lactose.

The NRC (1988) lists the lysine require-
ment of the 5- to 10-kg pig as 1.15% and that
of the 10- to 20-kg pig as 95%. The lysine
requirement for the 5- to 10-kg pig is based
largely on studies in which 5 to 25% milk
products were fed, but corn-soybean meal
combinations have generally served as the
basis for establishing the requirement for pigs
heavier than 10 kg. Our results concur with the
NRC (1988) recommendation for the
5- to 10-kg pig but differ from NRC recom-
endations for pigs heavier than 10 kg. Within
the NRC publication, however, several reports
are listed in which a corn-soybean meal-dried
whey diet was used to evaluate the growth
response to lysine level (Miyada and Cline,
1983; Pollmann et al., 1983a,b, 1984; Lin and
Jensen, 1985a,b). From their publication
(NRC, 1988) the optimum ADG response to
dietary lysine occurred at a higher level,
generally by ~10%, when diets containing
dried whey were provided than when corn-
soybean meal diets were fed. Although these
reports were conducted independently, the
summary implies a finding similar to ours (i.e.,
that a more easily digestible carbohydrate
source enhances the response to lysine for pigs
heavier than 10 kg). Although the dietary dried
whey level used in our study (i.e., 25%) is
somewhat higher than that incorporated by
most other workers, it gave us the opportunity
to identify more clearly the interaction effects
of these two dietary formulations.

Consequently, including dried whey in
the diets of weanling pigs has several effects.
First, ADG is consistently greater from a diet
containing high-quality dried whey than from a
cereal grain starter diet. Second, this relative
ADG response to dried whey declines with
time postweaning. Third, early postweaning
growth responses to dietary dried whey inclu-
sion may be a result of other components in
whey (e.g., carbohydrate) or other factors (e.g.,
reduced diarrhea, lower soy protein level)
rather than a result of its lysine contribution.
Responses during the latter part of the starter
phase also may be attributed to the compo-
nents of dried whey that are enhanced when
supplemental lysine is provided. Finally, post-
weaning responses to lysine-fortified corn-
soybean meal diets can be addressed only
when other nutritional limitations of this cereal
grain mixture are met.

Implications

A corn-soybean meal diet formulated to
1.10% lysine for pigs weaned between 3 and 4
wk of age is limiting in nutrients other than
lysine, but these are effectively provided by
dried whey. Inclusion of dietary dried whey at
25% increased the growth response of wean-
ling pigs independent of lysine level during the
initial 21 d postweaning. Subsequent ADG for
pigs during the 22- to 35-d postweaning period
resulted in improved growth responses when
dried whey with supplemental lysine was
incorporated into the diets of weanling pigs.
Factors in dried whey other than protein (e.g.,
lactose) may stimulate the postweaning re-
sponse to dried whey addition to starter pig
diets. A highly available carbohydrate source
may be necessary to achieve maximum growth
responses by weanling pigs to corn-soybean
meal diets supplemented with L-Lysine-HCl.

Literature Cited

of dietary dried whey and corn oil on weanling pig
performance, fat digestibility and nitrogen utilization.
LEPINE ET AL.