Effects of pelleting and storage of a complex nursery pig diet on lysine bioavailability

I. Mavromichalis and D. H. Baker

Department of Animal Sciences and Division of Nutritional Sciences, University of Illinois, Urbana 61801

ABSTRACT: The effects of pelleting and storage of a complex nursery pig diet (28% lactose and 1.4% lysine) on lysine bioavailability were assessed in a chick bioassay. The nursery diet was steam-conditioned at 60°C for 45 s and then pelleted through a 5-mm die with a depth of 38 mm. Samples of meal and pelleted diet were placed in metallic feeders in an occupied nursery facility for 1 wk (warm) or were stored at 4°C (cool). For the standard-curve bioassay, a total of 144 8-d-old chicks were offered the following dietary treatments: 1 to 3) a basal diet (lysine deficient) and two levels (.08 and .16%) of added lysine (from L-lysine·HCl); 4 and 5) two positive controls (.7% added lysine with or without 10% of the nursery diet); and 6 to 9) basal diet plus 10% of one of the four nursery diet samples (meal or pellet stored cool or warm for 1 wk). Pelleting had no effect (P > .10) on lysine bioavailability, probably because pelleting conditions (temperature, humidity, and pellet size) were not aggressive enough to result in detectable effects on lysine utilization. However, storage in the nursery facility for 1 wk reduced (P < .03) lysine bioavailability by an average of 10%. No significant (P > .10) interactions were observed. Furthermore, true digestibility of lysine in the four pig diet samples was estimated in a cecectomized cockerel digestibility assay using 15 adult Single-Comb White Leghorn cockerels. Lysine digestibility in all samples was high (average of 94%) and was not affected (P > .10) by treatment. We conclude that the pelleting conditions used in our experiments did not decrease lysine utilization. More research is needed to define thermal processing conditions that might cause protein quality deterioration. However, typical warm and humid environmental conditions encountered in modern nursery facilities have a negative effect on protein quality of diets rich in reducing sugars and lysine.

Key Words: Lysine Bioavailability, Diets, Pelleting, Storage


Introduction

Most postweaning pig diets that contain relatively high amounts of lysine and reducing sugars (e.g., lactose) are pelleted. Because these diets are fed in small amounts (total of 1 to 2 kg per pig), it is often suggested that they should be offered as a single initial allotment (i.e., enough for an entire feeding period of 7 to 10 d). This practice reduces labor and storage space requirements. However, pelleting and in-feeder storage result in diets being exposed to rather high temperatures and humidity for various periods of time. These conditions are favorable for initiation of the Maillard reaction process (Adrian, 1974), and lysine is clearly the most reactive and vulnerable amino acid in the Maillard reaction (Carpenter, 1973; Ashoor and Zent, 1984).

The purpose of our study was to determine the effects of pelleting and in-feeder storage on lysine bioavailability of a complex nursery pig diet. Standard-curve methodology was used, with chick growth as a function of lysine intake being used as the criterion of lysine bioavailability assessment. True lysine digestibility was also determined with adult cecectomized cockerels.

Experimental Procedures

Preparation of Nursery Diet

A 907-kg batch of a typical complex diet (Table 1), suitable for feeding nursery pigs during the 1st wk postweaning, was prepared at 0830 at the University of Illinois Central Feed Mill in July 1998. After meticulous mixing in a vertical-type mixer with a capacity of 907 kg, a 20-kg sample (meal) was collected immediately in plastic containers. The remaining batch was steam-conditioned at 60°C for 45 s and then pelleted (CPM

1Funded in part by the Illinois Agric Exp. Sta. (Project #35-0321).
2To whom correspondence should be addressed: 288 ASL, 1207 W. Gregory Dr. (phone: (217) 333-4366; fax: (217) 333-7861; E-mail: mavromic@uiuc.edu).
Received April 14, 1999.
Accepted August 19, 1999.
Table 1. Percentage composition of the nursery pig diet and the lysine-deficient chick diet (as-fed basis)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Nursery diet</th>
<th>Chick assay diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>32.85</td>
<td>48.55</td>
</tr>
<tr>
<td>Lactose</td>
<td>10.00</td>
<td>—</td>
</tr>
<tr>
<td>Dehulled soybean meal</td>
<td>20.00</td>
<td>—</td>
</tr>
<tr>
<td>Edible-grade dried whey</td>
<td>25.00</td>
<td>—</td>
</tr>
<tr>
<td>Feather meal</td>
<td>—</td>
<td>6.00</td>
</tr>
<tr>
<td>Peanut meal, solvent</td>
<td>—</td>
<td>24.95</td>
</tr>
<tr>
<td>Spray-dried animal plasma</td>
<td>7.50</td>
<td>—</td>
</tr>
<tr>
<td>Degummed soybean oil</td>
<td>—</td>
<td>5.02</td>
</tr>
<tr>
<td>Animal-vegetable fat mix</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Animal meal</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Salt</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Trace mineral premix</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Vitamin premix</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Choline chloride, 60%</td>
<td>—</td>
<td>0.10</td>
</tr>
<tr>
<td>Antibiotic</td>
<td>—</td>
<td>0.025f</td>
</tr>
<tr>
<td>Zinc oxide (72% Zn)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Fe-Methionine</td>
<td>0.09</td>
<td>—</td>
</tr>
<tr>
<td>L-Threonine</td>
<td>—</td>
<td>0.21</td>
</tr>
<tr>
<td>L-Tryptophan</td>
<td>—</td>
<td>0.03</td>
</tr>
<tr>
<td>L-Histidine</td>
<td>—</td>
<td>0.03</td>
</tr>
<tr>
<td>L-Isoleucine</td>
<td>—</td>
<td>0.03</td>
</tr>
<tr>
<td>Chemical composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein, %b</td>
<td>21.30</td>
<td>21.50</td>
</tr>
<tr>
<td>Lysine, %b</td>
<td>1.40</td>
<td>0.68</td>
</tr>
<tr>
<td>Available phosphorus, %b</td>
<td>0.50</td>
<td>0.45</td>
</tr>
<tr>
<td>Calcium, %b</td>
<td>0.85</td>
<td>1.00</td>
</tr>
<tr>
<td>Metabolizable energy, kcal/kgb</td>
<td>3,065</td>
<td>3,200</td>
</tr>
</tbody>
</table>

aSupplied the following per kilogram of complete diet: Fe, 90 mg (FeSO4·H2O); Zn, 100 mg (ZnO); Mn, 20 mg (MnO); Cu, 8 mg (CuSO4·H2O); I, 35 mg (CaI2); Se, 3 mg (Na2SeO3); NaCl, 3 g.
bSupplied the following per kilogram of complete diet: Fe, 75 mg (FeSO4·H2O); Zn, 75 mg (ZnO); Mn, 75 mg (MnO); Cu, 5 mg (CuSO4·H2O); 1, 75 mg (ethylene diamine dihydroiodide); Se, 1 mg (Na2SeO3).
cSupplied the following per kilogram of complete diet: Retinyl acetate, 2,273 μg; cholecalciferol, 16.5 μg; ni, n-tocopherol acetate, 88 mg; menadione, 4.4 mg; riboflavin, 8.8 mg; vitamin B12, 26 μg; choline chloride, 319 mg.
dSupplied the following per kilogram of complete diet: Retinyl acetate, 1,514 μg; cholecalciferol, 25 μg; n-tocopherol acetate, 11 mg; menadione sodium bisulfite complex, 2.3 mg; niacin, 22 mg; vitamin B12, 11 μg.
eProvided 110 mg of chlortetracycline, 110 mg of sulfamethazine, and 55 mg of penicillin per kilogram of complete diet.
fProvided 50 mg of bacitracin per kilogram of complete diet.
gSupplied the following per kilogram of complete diet: Menadione sodium bisulfite complex, 4.4 mg; vitamin B12, 1.1 mg.
hProvided the following per kilogram of complete diet: Retinyl acetate, 2,273 μg; cholecalciferol, 16.5 μg; ni, n-tocopherol acetate, 88 mg; menadione, 4.4 mg; riboflavin, 8.8 mg; vitamin B12, 26 μg; choline chloride, 319 mg.
iProvided the following per kilogram of complete diet: Retinyl acetate, 1,514 μg; cholecalciferol, 25 μg; n-tocopherol acetate, 11 mg; menadione sodium bisulfite complex, 2.3 mg; niacin, 22 mg; vitamin B12, 11 μg.
jProvided 110 mg of chlortetracycline, 110 mg of sulfamethazine, and 55 mg of penicillin per kilogram of complete diet.

Chick Bioassays

All experimental procedures were approved by the University of Illinois Laboratory Animal Care Advisory Committee. Female chicks from the cross of New Hampshire males and Columbian females from the University of Illinois Poultry Farm were used. Chicks were housed in thermoregulated starter batteries (Petersime Incubator Co., Gettysburg, OH) with raised wire floors in an environmentally controlled facility (24°C constant fluorescent lighting and 21°C ambient temperature). A standard 24% CP corn-soybean meal-based diet that met or exceeded NRC (1994) nutrient requirements was offered for ad libitum consumption during the first 7 d posthatching.

On the morning of d 8 after an overnight period of feed removal, chicks were weighed, wing-banded, and randomly allotted to quadruplicate experimental groups of four chicks such that the mean weight and weight range were nearly equal among groups (Sasse and Baker, 1973). Water and experimental diets were made freely available for ad libitum consumption throughout the 14-d growth period (d 8 to 22 posthatching). At the end of the experiment, chicks (held overnight without feed) and feeders were weighed to allow calculation of weight gain, feed consumption, and feed efficiency. Chicks were subsequently killed by exposure to CO2 gas (AVMA, 1993).

The lysine-deficient basal diet (Table 1) was based on corn, peanut meal, and feather meal. It was formulated to meet or exceed NRC (1994) requirements for all nutrients with the exception of lysine. Dietary additions of experimental ingredients were made at the expense of cornstarch, and all diets were fed in meal form.

Assay 1. This experiment used standard-curve methodology (Sasse and Baker, 1973) to assess the bioavailability of lysine in the pig nursery diet samples. A total of 144 chicks with an average initial body weight of 106 g was used. Dietary treatments 1 through 3 (standard curve) included the basal diet and two levels (.08 and .16%) of added crystalline lysine (from L-lysine-HCl) that were expected to result in a linear weight gain response (Han and Baker, 1994). Treatment 4 (.70% added lysine from L-lysine-HCl + 10% of the meal/cool nursery diet) was included to determine whether nursery diet addition, independent of its lysine in the nursery was 28°C, and relative humidity exceeded 90% for the duration of the experiment. Feed was stirred daily to ensure complete turnover and maximum contact with feeder walls. After 7 d, the diets were transferred in air-tight plastic containers and stored at 4°C. Diets were then kept in cool storage for approximately 1 mo. Prior to being added to the lysine-deficient chick diet and prior to being crop-intubated into adult cockerels, all pigs diets were ground through a hammermill equipped with a 3.2-mm screen.
content, would produce a growth response under conditions of lysine adequacy (NRC, 1994). The meal/cool sample was selected for use in treatment 5 because it was expected to have sustained the least amount of bioavailable lysine loss. Dietary treatments 6 through 9 contained 10% of each of the four nursery diet samples, and they were included to determine whether there were any changes in lysine bioavailability due to diet pelleting and storage.

Assay 2. In the first assay, diets were replenished only twice during the 14-d experimental period that took place during late August 1998. Although chicks were housed in an environmentally controlled facility, concern existed about possible interference from further in-house diet exposure for a prolonged time. Thus, another chick growth assay was designed to include treatments 1 (basal), 6 (least expected lysine loss), and 10 (most expected lysine loss) from Assay 1, with the exception that fresh diet was offered every 3 d from supplies that were stored in an air-conditioned feed storage room.

Assay 3. True digestibility of lysine in the four pig diets was estimated using cecectomized cockerels (Sibbald, 1979; Parsons et al., 1982). Fifteen adult Single-Comb White Leghorn cockerels, 60 wk of age, were used in a completely randomized design. Details of cecectomy have been described previously by Parsons et al. (1982). Following 24 h of feed removal, five cockerels per diet were administered a single dose (30 g) of the experimental diet via crop intubation. Endogenous lysine losses were estimated in five feed-deprived cockerels that served as negative controls. Birds were individually housed in pens with raised wire floors in an environmentally controlled laboratory room that was under a 16-h light regimen. Water was freely available throughout the excreta collection period. Plastic trays placed underneath each pen were used to collect excreta for 48 h, after which complete intestinal clearance of undigested lysine was assumed (Parsons et al., 1982). Excreta were transferred in individual plastic containers and immediately frozen at −20°C.

Chemical Analysis

Excreta samples were freeze-dried, weighed, ground, and stored at 4°C. Representative samples of excreta, chick bioassay basal diet, and nursery pig diet samples were subjected to 6 N HCl hydrolysis for 24 h at 110°C. Hydrolysates were subsequently analyzed for lysine using ion-exchange chromatography (Model 119CL Amino Acid Analyzer; Beckman Instruments, Palo Alto, CA).

Statistical Analyses

Each experiment was analyzed as a completely randomized design. Analysis of variance of pen means was conducted using the appropriate GLM procedures of SAS (1993). Mean differences were established based on the least significant difference multiple comparison procedure (Carmer and Walker, 1985). Differences were considered significant at P < .05.

In Assay 1, single degree-of-freedom contrasts also were performed using appropriate orthogonal polynomial contrasts (Steel et al., 1997). Treatments 1 through 3 were tested for linearity, and treatments 4 and 5 were contrasted against each other and also against treatment 3. A linear regression equation was developed (SAS, 1993), with weight gain per chick (g) as the dependent variable and intake of supplemental crystalline lysine per chick (mg) as the independent variable from data in treatments 1 through 3. Data from treatments 6 through 9 were analyzed as a 2 × 2 factorial. Lysine bioavailability was calculated for treatments 6 through 9 as the ratio of estimated bioavailable supplemental lysine intake (calculated from the standard curve regression equation) to the measured total lysine intake (feed intake × % added lysine).

Results

In Assay 1, growth performance (Table 2) of chicks fed graded doses of crystalline lysine (treatments 1 through 3) was linear (P < .01). Regression of weight gain on supplemental crystalline lysine intake gave a fit (r²) of .94 (Figure 1). Crystalline lysine has been shown to have a bioavailability of 100% (Izquierdo et al., 1988). Thus, supplemental total crystalline lysine intake corresponded to supplemental bioavailable lysine intake. Single degree-of-freedom contrasts revealed that treatments 4 and 5 supported greater (P < .05) growth performance than treatment 3. The addition of 10% of the meal/cool experimental diet in treatment 5 supported even greater (P < .05) growth performance than treatment 4. Because total lysine concentration in diet 4 exceeded the requirement, which was estimated to be 1.2% (Han and Baker, 1991), the increase in growth performance due to the addition of the experimental diet in treatment 5 was considered independent from responses to dietary lysine.

Factorial analysis of treatments 6 through 9 revealed no growth performance interactions. However, there was a trend for increased weight gain due to pelleting (P < .06) and to storage at low temperature (P < .10). Pelleting increased (P < .03) feed intake, but storage did not affect it. Also, there was a trend for gain:feed to be less when diets were pelleted (P < .06) or stored in the nursery environment (P < .10).

Factorial analysis of lysine bioavailability data (Table 3) revealed no interactions among treatments. Total supplemental lysine intake was increased by pelleting (P < .03) but not by storage conditions. There was a trend for greater supplemental bioavailable lysine intake due to pelleting (P < .06) and cool storage (P < .10). Lysine bioavailability was not affected by pelleting. However, storage in the nursery facility for 1 wk reduced (P < .03) lysine bioavailability by an average of 10%. The true digestibility of lysine in the four pig diets,
Table 2. Assessment of lysine bioavailability of a nursery pig diet using standard-curve methodology in a chick bioassay (Assay 1)

<table>
<thead>
<tr>
<th>Dietary treatmentb</th>
<th>Weight gain, g</th>
<th>Feed intake, g</th>
<th>Gain:feed, g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basal diet (lysine deficient)</td>
<td>155t</td>
<td>350s</td>
<td>445s</td>
</tr>
<tr>
<td>2. As 1 + .08% Lys from L-Lys HCl</td>
<td>207s</td>
<td>429t</td>
<td>485s</td>
</tr>
<tr>
<td>3. As 1 + .16% Lys from L-Lys HCl</td>
<td>255s</td>
<td>468s</td>
<td>545s</td>
</tr>
<tr>
<td>4. As 1 + .70% Lys from L-Lys HCl</td>
<td>314s</td>
<td>493t</td>
<td>637s</td>
</tr>
<tr>
<td>5. As 4 + .14% Lys from meal/cool dietc</td>
<td>338s</td>
<td>503s</td>
<td>673s</td>
</tr>
<tr>
<td>6. As 1 + .14% Lys from meal/cool dietc</td>
<td>236s</td>
<td>430g</td>
<td>552s</td>
</tr>
<tr>
<td>7. As 1 + .14% Lys from meal/warm dietc</td>
<td>229g</td>
<td>430g</td>
<td>533g</td>
</tr>
<tr>
<td>8. As 1 + .14% Lys from pellet/cool dietc</td>
<td>253g</td>
<td>474g</td>
<td>534g</td>
</tr>
<tr>
<td>9. As 1 + .14% Lys from pellet/warm dietc</td>
<td>238g</td>
<td>466g</td>
<td>510g</td>
</tr>
</tbody>
</table>

Significance of F-test (diets 6 to 9):
- Feed form (meal or pellet): .06 .03 .06
- Storage (cool or warm): .10 .84 .10
- Interaction: .54 .80 .54
- Pooled SEM: 6 15 11

aData represent means of four pens of four female chicks, with an average initial body weight of 106 g, during a 14-d feeding period (8 to 22 d of age). Data from treatments 1 through 3 were tested for linearity (P < .01), and single degree-of-freedom contrasts were performed between the following treatments: 3 vs 4 (P < .01), 3 vs 5 (P < .01), and 4 vs 5 (P < .05). Treatments 6 through 9 were analyzed as a 2 × 2 factorial.

bRefer to Table 1 for composition of the basal diet. Test ingredients were added at the expense of cornstarch.

cSamples of the nursery pig diet were collected before (meal) and after pelleting (pellet). Subsamples were kept for 1 wk in airtight containers at 4°C (cool) or placed in metallic feeders and exposed to the warm and humid environment of a typical nursery facility (warm).
t,u,v,w,x,y,zMeans within columns followed by different superscript letters are different (P < .05).

estimated in the cecotomized cockerel digestibility assay (Table 3), was not affected (P > .10) by treatment. Lysine digestibility in all diets was high (i.e., average of 94%), reflecting the presence of highly digestible ingredients such as free lysine, plasma proteins, and whey.

Results from Assay 2 (Table 4) revealed no differences in performance between the meal/cool and pellet/warm experimental diets. This is in agreement with Assay 1, with the exception of gain:feed, which differed between these two treatments in Assay 1 but not in Assay 2.

The increment of gain (24 g) resulting from the addition of 10% of the pig diet to the lysine-adequate chick diet is difficult to interpret. We concluded that it is unlikely that the lysine-deficient basal diet would respond to anything other than lysine in the supplemented pig diet. Thus, we opted not to correct our gain data for treatments 6 through 9 for the 24-g increment in gain. Had we subtracted this gain increment from the weight gain data for the pig diets, relative bioavailability values for diets 6 through 9 would have been 68, 62, 80, and 66%, respectively. However, these corrected values are far less than the true ileal digestibility values from Assay 3, which are in good agreement with the uncorrected bioavailability values.

Discussion

The Maillard reaction involves binding of amino groups to the carbonyl group of reducing sugars such as glucose or lactose (Maillard 1912a,b; 1916). Although sugar losses are greater and more intense than lysine losses (Adrian et al., 1962), the deterioration of protein quality is of most concern to nutritionists (Adrian, 1974). Coloration (nonenzymatic browning) and amino acid losses are two independent phenomena of the Maillard reaction that differ radically (Lea and Hannan, 1950). During the initial stages of the Maillard reaction, products remain colorless but amino acids have already undergone change (Lewis and Lea, 1950). Therefore, color change is not a good indicator of protein quality damage, which occurs rather early. The Maillard reaction takes place even at room temperature, but its in-
Table 3. Estimated lysine relative bioavailability (Assay 1) and true lysine digestibility (Assay 3)\(^{a,b}\)

<table>
<thead>
<tr>
<th>Dietary treatment(^{a})</th>
<th>Analyzed lysine, % Before treatment</th>
<th>Analyzed lysine, % After treatment</th>
<th>Supplemental lysine intake, mg/chick Total(^{a})</th>
<th>Bioavailable(^{c})</th>
<th>Relative bioavailability, %(^{d})</th>
<th>True digestibility, %(^{e})</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Basal + .14% Lys from meal/cool diet</td>
<td>1.40</td>
<td>1.40</td>
<td>601</td>
<td>585</td>
<td>97</td>
<td>96</td>
</tr>
<tr>
<td>7. Basal + .14% Lys from meal/warm diet</td>
<td>1.40</td>
<td>1.33</td>
<td>602</td>
<td>534</td>
<td>88</td>
<td>93</td>
</tr>
<tr>
<td>8. Basal + .14% Lys from pellet/cool diet</td>
<td>1.40</td>
<td>1.41</td>
<td>663</td>
<td>711</td>
<td>107</td>
<td>94</td>
</tr>
<tr>
<td>9. Basal + .14% Lys from pellet/warm diet</td>
<td>1.40</td>
<td>1.38</td>
<td>653</td>
<td>602</td>
<td>92</td>
<td>94</td>
</tr>
</tbody>
</table>

Significance of F-test (\(P < .05\))
- Feed form (meal or pellet): \(.03 .06 .18 .67\)
- Storage conditions (cool or warm): \(.86 .10 .03 .27\)
- Interaction: \(.80 .54 .54 .44\)

\(d^{a}\)Data from Assay 1 represent means of four pens of four female chicks, with an average initial body weight of 106 g, during a 14-d feeding period (8 to 22 d of age). Data were analyzed as a 2 × 2 factorial.
\(d^{b}\)Data from Assay 3 represent means of five cecectomized adult Single-Comb White Leghorn cockerels administered a single dose (30 g) of the experimental diet via crop intubation (after 24 h fasting) followed by 48-h collection period.
\(d^{c}\)Refer to Tables 1 and 2 for composition of basal diet and description of dietary treatments, respectively.
\(d^{d}\)Estimated based on the regression equation from Figure 1: Gain (\(Y\)) = 156.4 + .1355 × supplemental Lys intake (\(X\)).
\(d^{e}\)Calculated by dividing bioavailable Lys intake by total Lys intake. Had analyzed Lys values after treatment been used to calculate total Lys intake, relative bioavailability would have been 98, 94, 107, and 94% for diets 6, 7, 8, and 9, respectively.

Under conditions of elevated temperature and humidity, any compound or ingredient with a free amino group is vulnerable, and this would include free amino acids (Johnson et al., 1977; Robbins and Baker, 1980), epsilon amino groups of protein-bound lysine, and free amino groups of thiamin, folacin, and gossypol (Baker, 1959). The initial Maillard reaction products have autocatalytic properties that intensify the effects of heat treatment (Bensabat et al., 1958).

Table 4. Comparison of a pig nursery diet (meal) stored cool and a pelleted diet stored warm using a chick bioassay (Assay 2)\(^{a}\)

<table>
<thead>
<tr>
<th>Dietary treatment(^{b})</th>
<th>Weight gain, g</th>
<th>Feed intake, mg</th>
<th>Gain:fed, g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basal diet (lysine-deficient)</td>
<td>137(^{p})</td>
<td>336(^{p})</td>
<td>408(^{p})</td>
</tr>
<tr>
<td>2. As 1 + .14% Lys from meal/cool diet</td>
<td>217(^{p})</td>
<td>430(^{p})</td>
<td>503(^{p})</td>
</tr>
<tr>
<td>3. As 1 + .14% Lys from pellet/warm diet</td>
<td>221(^{p})</td>
<td>460(^{p})</td>
<td>480(^{p})</td>
</tr>
</tbody>
</table>

\(d^{a}\)Data represent means of four pens of four female chicks, with an average initial body weight of 92 g, during a 14-d feeding period (8 to 22 d of age). See Table 1, footnote c for description of dietary treatments.
\(d^{b}\)Refer to Table 1 for composition of basal diet. Test ingredients were added at the expense of cornstarch.

The adverse effects of the Maillard reaction on lysine bioavailability have been extensively demonstrated in many single feed ingredients such as field peas (van Barneveld et al., 1994), soybean meal (Hancock et al., 1990; Fernandez and Parsons, 1996), fish protein isolate (Plakas et al., 1988), casein (Moughan et al., 1996), egg albumin (Sgarbieri et al., 1973), canola meal (Anderson-Hafermann et al., 1993), peanut meal (Zhang and Parsons, 1996), and sunflower meal (Zhang and Parsons, 1994). Thermal overprocessing of high-protein materials generally reduces lysine bioavailability, depending on temperature levels and the duration of heat.
application. It seems that there is an inverse relationship between temperature and time such that as temperature declines more time is needed for the same loss of lysine bioavailability, and vice versa (Adrian, 1974).

Nursery pig diets are rich in milk products, which contain relatively high amounts of lactose (Mader et al., 1949; Cook et al., 1951). Moreover, most complex diets contain a plethora of other equally sensitive ingredients such as blood products, soybean proteins, fish meal, and wheat gluten that readily contribute to the Maillard reaction problem. During pelleting, feed is exposed to relatively high humidity and temperature levels. Usually 3 to 6% moisture is added to the mash during conditioning at temperatures that can range from 60 to 90°C for several seconds to 20 or more min (Fairfield, 1994). Extremely high temperatures can also develop during pellet formation due to friction with the die walls as the conditioned mash is forced through die openings (Fairfield, 1994).

Storage of heat-sensitive material in the form of finished diets or raw materials for prolonged periods of time can initiate a second cycle of Maillard reactions (Henry et al., 1946). This is of paramount importance in nursery feed management because the conditions of high temperature (28 to 32°C) and relative humidity (70 to 100%) usually observed in most hot nurseries during the 1st wk postweaning are extremely favorable for the Maillard reaction. Residual feed moisture greatly affects the extent of the Maillard reaction during storage. A 10% moisture level in milk powder stored for 10 wk at 30°C resulted in a 20% loss in lysine bioavailability (Erbersdobler, 1970). Exposure of feed to adverse environmental conditions can occur not only in animal rooms, but also during storage in silos and general storage areas during the summer months.

Surprisingly, lysine bioavailability was not affected by pelleting in the experiments reported herein. Several factors might have contributed to this unexpected outcome. The pelleting procedure might have increased lysine bioavailability, either by reducing various antinutritional factors or making the protein more digestible. Also, the pelleted diets may not have been exposed to sufficiently high temperatures for substantial lysine destruction to occur. Our pelleting process resulted in a pellet diameter of 5 mm, which is greater than the 2 to 3 mm diameter often used for 1st-wk postweaning diets (Johnson et al., 1999). This might have prevented the development of high friction temperatures during pelleting. Dale (1992) also observed no reduction in lysine utilization of a dried bakery product in pelleted poultry diets that were steam-conditioned at 87°C. More aggressive feed processing methods, such as expansion, extrusion, double pelleting, prolonged mash conditioning, and pelleting to a smaller pellet diameter should be investigated concerning their effects on protein quality.

Storage of the diets for 1 wk at approximately 28°C resulted in reduced lysine bioavailability. Average lysine relative bioavailability was 90 and 102% for the diets stored in the warm nursery facility and the refrigerator, respectively. Data from the true digestibility assay did not indicate any loss of lysine digestibility as a result of warm storage for 1 wk in the nursery environment. However, true lysine digestibility was calculated using lysine intake values that were based on lysine analyzed after storage. Had lysine intake data been calculated based on lysine analyzed before storage, true digestibility values would have been 96, 88, 95, and 93% for diets 6, 7, 8, and 9, respectively.

Implications

A complex nursery pig diet that was pelleted to 5 mm in diameter sustained no losses of lysine bioavailability due to thermal processing. However, storage for 1 wk in an occupied nursery facility at 28°C decreased lysine bioavailability by approximately 10%. More research is needed to determine the effects of a smaller pellet size and of other thermal feed manufacturing technologies on nutrient bioavailability.

Literature Cited


