# MOIST EXTRUSION OF SOY PRODUCTS INFLUENCES GROWTH PERFORMANCE AND NUTRIENT UTILIZATION IN THE EARLY-WEANED PIG

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## Summary

One hundred and seventy pigs (initially 12.8 lb and 21 d of age) were used to determine the effect of moist extrusion on soybean products when fed to the early-weaned pig. Dietary treatments, including a positive control, fed d 0 to 14 postweaning were arranged in a 2 × 3 factorial. Pigs were fed one of the seven diets: 1) control diet (milk): corn+dried skim milk+dried whey+casein; 2 and 3) corn+defatted soy flakes with or without moist extrusion; 4 and 5) corn+toasted soy flour with or without moist extrusion; and 6 and 7) corn+soy protein concentrate with or without moist extrusion. The diets were formulated to 1.4% dietary lysine and 24.4% lactose, with soy products and purified lactose replacing the milk products on an isolysine and isolactose basis. From d 14 to 35 postweaning, all pigs were fed a common (1.25% lysine) corn-soybean meal diet containing 10% dried whey and 4% select menhaden fish meal. Pigs fed extruded soy products had improved ADG, ADFI, and F/G compared to pigs fed nonextruded soy products, with the largest improvement in pigs fed extruded soy flakes and flour. Dry matter and N digestibilities also were greater in pigs fed extruded soy products compared to pigs fed nonextruded soy products. When pigs were fed a common diet (d 14 to 35), ADFI and F/G were improved in pigs fed a nonextruded soy product from d 0 to 14 than in pigs fed an extruded soy product. Cumulative (d 0 to 35) ADG, ADFI, and F/G were improved in pigs fed extruded soy products compared to pigs fed nonextruded products. These data suggest that growth performance of early-weaned pigs fed less refined soy products (soy flakes and soy flour) processed by moist extrusion can be comparable to that of pigs fed highly refined soy products (soy protein concentrate).


(Key Words: Pigs, Soy Protein, Moist Extrusion, Nutrient Digestibility.)

## Introduction

A common practice in the swine industry is to decrease the age of weaning in order to increase sow productivity. However, by decreasing the weaning age to 21 d, the young pig is often subject to a postweaning growth depression. Prior to weaning, the young pig receives sow's milk, a highly palatable, readily digestible diet. At weaning, the young pig is often fed a dry, complex carbohydrate, plant protein-based diet that is not readily utilized. Research has indicated that the early-weaned pig suffers from an immune (allergic) response to soy protein in the small intestine. This response results in intestinal damage, decreasing nutrient absorption, and, ultimately, poor growth performance. Previous research at Kansas State University suggests that moist extrusion processing can be used to increase digestibility and reduce the antigenicity of less refined soy products. Thus, the objective of this experiment was to further assess the effect of moist extrusion on soy products for inclusion in starter pig (phase I) diets.

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## Procedures

One hundred and seventy pigs averaging 21 ± 1 d of age (initially 12.8 lb) were used to determine the effect moist extrusion has on soybean products when fed to the early-weaned pig. The experiment was designed as a randomized complete block with treatments arranged as a 2 × 3 factorial plus a positive control. Treatments were arranged to assess the main effects of soy product and extrusion processing. At weaning, pigs were allotted to one of seven dietary treatments based upon weight, gender, and ancestry. Treatments included were: 1) control diet: corn+dried skim milk+dried whey+casein, 2 and 3) corn+defatted soy flakes with or without moist extrusion, 4 and 5) corn+toasted soy flour with or without moist extrusion, and 6 and 7) corn+soy protein concentrate with or without moist extrusion. Experimental diets were formulated to contain 1.4% lysine, 24.4% lactose, .9% Ca, and .8% P (Table 1). The positive control diet was formulated with predominately milk protein sources. The soy products replaced milk products (dried skim milk, dried whey, and casein) on a lysine basis. Chromic oxide was included in the experimental diets as an undigestible marker to determine apparent nutrient digestibility. Experimental diets were fed from d 0 to 14 postweaning. All pigs were fed a common corn-soybean meal diet (1.25% lysine) containing 10% dried whey and 4% select menhaden fish meal from d 14 to 35 postweaning. Pigs were housed in an environmentally controlled nursery with wire mesh flooring. Each pen contained a self feeder and a nipple waterer to provide ad libitum access to feed and water. There were five pigs per pen (4 ft × 5 ft) and five replicate pens per treatment. Weekly pig weights and feed consumption were collected to calculate ADG, average daily feed intake (ADFI), and F/G.

A single screw extruder (Wenger X-20, Wenger Mfg. Sebetha, KS) equipped with a high shear screw, barrel, and die arrangement was used to moist extrude all soy products. Operating conditions were held constant between soy products. Slight alterations were made during the process, if machine stability was not maintained. Steam and water were added to the extruder to facilitate processing and to prevent burning of the soy product. The extruded product (approximately 30% moisture) was dried in a double pass, gas-fired dryer to approximately 12% moisture. After extrusion, the dried product was ground through a 1/16 in. hammermill screen and mixed into the experimental diets.

## Results and Discussion

Moist extrusion of soy flakes and soy flour decreased trypsin inhibitor concentrations by 26.5 and 31.2 mg/g protein, respectively. Trypsin inhibitor concentrations were similar among all three soy products following extrusion processing. Glycinin and $\beta$-conglycinin concentrations of soy products were reduced to nondetectable levels after moist extrusion. Protein dispersibility index was decreased in extruded soy flakes and flour but increased in extruded soy protein concentrate.

Average daily gain, ADFI, and F/G were improved ($P<.01$) in pigs fed a milk-based diet compared to pigs fed a soy-based diet (Table 2). Diets with moist extruded soy flakes, soy flour, and soy protein concentrate improved ADG, ADFI, and F/G ($P<.01$) from d 0 to 14 postweaning. An interaction ($P<.05$) between moist extrusion and soy product source was observed, with pigs fed extruded soy flakes and flour having larger improvements in ADG, ADFI, and F/G than pigs fed extruded soy protein concentrate. Pigs fed nonextruded soy protein concentrate had improved ($P<.05$) ADG, ADFI, and F/G compared to pigs fed either nonextruded soy flakes or soy flour from d 0 to 14 postweaning. Apparent DM and N digestibilities (Table 2) were increased ($P<.01$) on d 13 postweaning in pigs fed extruded soy products and were highest in pigs fed a milk diet ($P<.01$). On d 14 postweaning, a soy protein source by extrusion processing inter-

action ($P < .05$) was observed for serum urea N, with pigs fed extruded soy flakes and soy flour having the largest decrease in urea N concentration. Urea N concentration was lowest ($P < .01$) in pigs fed a milk diet from d 0 to 14 postweaning.

From d 14 to 35 postweaning, when pigs were fed a common corn-soybean meal diet, ADG was not different ($P > .10$), regardless of d 0 to 14 protein source. Feed consumption and F/G from d 14 to 35 were maximized ($P < .01$) in pigs fed a milk diet from d 0 to 14 and increased in pigs fed extruded soy flakes and flour compared to nonextruded soy flakes and flour from d 0 to 14 postweaning.

Cumulative (d 0 to 35) ADG, ADFI, and F/G were lowest ($P < .05$) in pigs fed a milk diet from d 0 to 14 postweaning. Again, an interaction ($P < .05$) between moist extrusion and soy product existed, with greater improvements in ADG, ADFI, and F/G detected in pigs fed extruded soy flakes and flour. Moist-extruded soy flakes and flour in the starter diet (d 0 to 14) improved ADG and ADFI ($P < .01$) from d 0 to 35 postweaning.

These data suggest that moist extrusion can be used to improve less refined soy products for use in starter pig diets. Average daily feed intake and feed efficiency were improved in pigs fed moist extruded soy products, resulting in increased ADG. In conjunction, moist extrusion of soy flakes and flour increased apparent nutrient digestibility and amino acid utilization, resulting in improved ADG and feed efficiency from d 0 to 14 and for the entire 35 d trial. Therefore, moist extrusion offers an alternative processing method to improve the nutritional value of soy products for the early-weaned pig.

**Table 1. Composition of Diets d 0 to 14 Postweaning (Exp. 2)**

| Ingredient, % | Milk[a] | Soy flakes | Soy flour | Soy protein concentrate | d 14 to 35 Common diet[b] |
|---|---|---|---|---|---|
| Corn | 43.56 | 24.07 | 27.13 | 34.41 | 55.83 |
| Soy protein | -- | 40.85 | 37.74 | 31.33 | |
| Soybean meal (48% CP) | -- | -- | -- | -- | 22.71 |
| Fish meal, select menhaden | -- | -- | -- | -- | 4.00 |
| Dried whey, edible grade | 20.00 | -- | -- | -- | 10.00 |
| Dried skim milk | 20.00 | -- | -- | -- | -- |
| Casein | 7.41 | -- | -- | -- | -- |
| Lactose | -- | 24.40 | 24.40 | 24.40 | -- |
| L-Lysine-HCL | .15 | -- | -- | -- | -- |
| Soybean oil | 6.00 | 6.00 | 6.00 | 6.00 | 4.00 |
| Monocalcium phosphate (21% P) | 1.24 | 2.17 | 2.23 | 2.15 | 1.46 |
| Limestone | .49 | 1.07 | 1.05 | 1.01 | .55 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 |
| Copper sulfate | .10 | .10 | .10 | .10 | .10 |
| Selenium premix | .05 | .05 | .05 | .05 | .05 |
| Salt | -- | .30 | .30 | .30 | .30 |
| Antibiotic[c] | .50 | .50 | .50 | .50 | .50 |
| Chromic oxide | .10 | .10 | .10 | .10 | -- |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets contained 1.4% lysine, 24.4% lactose, .9% Ca, and .8% P.
[b]Diet contained 1.25% lysine, 7.2% lactose, .9% Ca, and .8% P.
[c]CSP-250 provided the following per lb of complete diet (g): oxytetracycline, .11; sulfathiazole, .11; penicillin .055.

**Table 2. Growth Performance, Apparent Nutrient Digestibility, and Serum Urea Nitrogen of Weanling Pigs Fed Soy Proteins with or without Moist Extrusion[a]**

| Item | Milk | Soy flakes | Extruded soy flakes | Soy flour | Extruded soy flour | Soy protein concentrate | Extruded soy protein concentrate | CV |
|---|---|---|---|---|---|---|---|---|
| d 0 to 14 | | | | | | | | |
| ADG, lb[bcdef] | .64 | .14 | .50 | .15 | .44 | .44 | .46 | 18.3 |
| ADFI, lb[bcde] | .66 | .42 | .59 | .43 | .58 | .54 | .55 | 9.4 |
| F/G[bcdef] | 1.03 | 3.00 | 1.18 | 2.87 | 1.32 | 1.23 | 1.20 | 30.8 |
| d 14 to 35 | | | | | | | | |
| ADG, lb | 1.09 | .99 | 1.04 | .99 | 1.12 | 1.06 | 1.00 | 7.5 |
| ADFI, lb[bcd] | 1.78 | 1.46 | 1.72 | 1.47 | 1.74 | 1.62 | 1.59 | 6.3 |
| F/G[bcd] | 1.63 | 1.47 | 1.65 | 1.48 | 1.55 | 1.53 | 1.59 | 3.8 |
| d 0 to 35 | | | | | | | | |
| ADG, lb[bcdef] | .91 | .65 | .83 | .65 | .85 | .81 | .79 | 7.1 |
| ADFI, lb[bcd] | 1.34 | 1.04 | 1.27 | 1.06 | 1.28 | 1.19 | 1.18 | 5.8 |
| F/G[bcdef] | 1.47 | 1.60 | 1.53 | 1.63 | 1.51 | 1.47 | 1.49 | 3.4 |
| d 13 digestibility | | | | | | | | |
| DM dig., %[bd] | 92.1 | 84.7 | 89.9 | 85.3 | 89.3 | 89.3 | 90.6 | 2.1 |
| N dig., %[bd] | 93.3 | 71.7 | 86.2 | 71.6 | 86.8 | 86.5 | 88.8 | 4.7 |
| Serum urea N, mg/dL[bcd] | 2.9 | 23.0 | 17.9 | 21.0 | 16.5 | 17.7 | 17.4 | 12.5 |

[a]A total of 170 pigs, average initial weight = 5.8 kg, 5 pigs/pen, 5 pens/treatment.
[b]Milk vs soy protein ($P < .01$).
[c]Moist extrusion processing × protein source interaction ($P < .05$).
[d]Extruded soy protein vs nonextruded soy protein ($P < .01$).
[e]Soy flakes vs soy protein concentrate ($P < .05$).
[f]Soy flour vs soy protein concentrate ($P < .05$).