EFFECT OF RATIO OF PROTEIN FROM CORN AND SOYBEAN MEAL IN DIETS OF VARYING TOTAL PROTEIN ON PERFORMANCE, CARCASS DESIRABILITY AND DIET DIGESTIBILITY IN SWINE

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Feedstuffs commonly used for growing pigs are widely variable in the amino acids which are limiting for growth. When the most limiting amino acids are present in adequate quantities, there is usually an excess of other amino acids which results in relatively inefficient protein utilization, although maximum growth may be obtained. Ultimate muscle size is controlled mainly by the genetic makeup of the animal. However, the rate at which muscle growth occurs, depends to a large degree upon the nutritional adequacy (amino acid levels) in the diet. The level of amino acids required for maximum growth or feed efficiency may not be the same as required for maximum muscle development. Calories from protein consumed in excess of that required for maintenance and muscle growth may be deposited as fat after being subjected to the metabolic processes. Therefore, there is no point in attempting to exceed the genetic limitations. The amino acid requirements of pigs which are genetically superior in developing muscle cannot be determined using pigs that lack this potential.

The objectives of this study were to evaluate the total amino acids requirement of growing pigs and to determine the optimum ratio of amino acid from corn and soybean meal necessary for maximum growth, feed efficiency and muscle development.

Experimental

Four trials involving a total of 144 weanling pigs averaging 20.9 kg. initially were conducted over four consecutive summer and winter seasons to study performance, carcass quality and diet digestibility in growing pigs fed corn-soybean meal diets of varying protein quality and level. Nine treatments were replicated four times in each trial.

Diets 1 and 2 (table 1) contained 11.3 and 12.8% crude protein, respectively, with 40% of the protein from soybean meal and 60% from corn. Diets 3, 4 and 5 contained 11.3, 12.8 and 14.3% crude protein, respectively, with 50% of the protein from soybean meal and 50% from corn. Diets 6, 7, 8 and 9 contained 11.3, 12.8, 14.3 and 17.2% crude protein, respectively, with 60% of the protein supplied by soybean meal and 40% from corn. Corn sugar was used to adjust the protein level down to the desired level and to maintain a constant proportion of protein from corn and soybean meal within each ratio.

In the first trial 2 Duroc and 2 crossbred (Hampshire-Poland-Duroc-Yorkshire) pigs were assigned to each diet. All pigs in trials 2, 3 and 4 were farrowed by the same group of 3 breed (Poland-Duroc-Landrace) crossbred sows mated to Hampshire boars. In trials 1, 2 and 3, barrows and gilts were evenly divided between treatments. Pigs in trial four were selected from four litters. This resulted in three barrows and one gilt receiving several diets. An adjustment for sex was made before the data were subjected to statistical analysis.

Average initial weights of the pigs between treatments in each trial were nearly equal. All pigs were fed individually from a self-feeder, and water was provided automatically. The pigs were housed in an enclosed building in individual 1.2×2.7 m. pens with concrete floors. No bedding or heat was provided during winter, and no artificial cooling was provided in summer. The pigs were weighed and feed consumption was recorded biweekly. Wasted feed was weighed and not included as feed consumed.

Pigs were removed from test individually at approximately 95 kg. live weight. Carcass data were collected only in the last three trials. The pigs were tattooed for identification and slaughtered at a commercial packing plant. The following carcass data were taken following a 24 hr. chill: carcass weight, backfat thickness and weight of the trimmed hams, loins and shoulders. Backfat thickness was

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<table>
<thead>
<tr>
<th>Item</th>
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<tr>
<td>Yellow corn</td>
<td>77.50</td>
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<td>83.18</td>
<td>51.65</td>
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<td>10.98</td>
<td>......</td>
<td>21.68</td>
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<td>32.38</td>
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<td>8.90</td>
<td>10.00</td>
<td>11.10</td>
<td>12.50</td>
<td>14.25</td>
<td>13.35</td>
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<td>1.50</td>
<td>1.32</td>
<td>1.12</td>
<td>1.60</td>
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<td>1.25</td>
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<td>Limestone (38% Ca)</td>
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<td>0.50</td>
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<td>Vitamin suppl. b</td>
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<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
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### Analysis:

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<th>Protein level</th>
<th>11.4 ± 0.38</th>
<th>12.8 ± 0.64</th>
<th>11.1 ± 0.67</th>
<th>12.8 ± 0.43</th>
<th>14.4 ± 0.57</th>
<th>11.3 ± 0.39</th>
<th>12.8 ± 0.51</th>
<th>14.3 ± 0.31</th>
<th>17.2 ± 0.65</th>
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<tr>
<td>Amino acid level</td>
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<td></td>
<td></td>
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<tr>
<td>Lysine</td>
<td>0.45</td>
<td>0.50</td>
<td>0.49</td>
<td>0.55</td>
<td>0.63</td>
<td>0.53</td>
<td>0.60</td>
<td>0.68</td>
<td>0.80</td>
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<tr>
<td>Methionine+cystine</td>
<td>0.40</td>
<td>0.45</td>
<td>0.39</td>
<td>0.44</td>
<td>0.50</td>
<td>0.39</td>
<td>0.43</td>
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<td>Tryptophan</td>
<td>0.11</td>
<td>0.12</td>
<td>0.11</td>
<td>0.12</td>
<td>0.14</td>
<td>0.11</td>
<td>0.13</td>
<td>0.14</td>
<td>0.17</td>
</tr>
</tbody>
</table>

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*a Trace mineral salt contained: 97% evaporated salt; 0.80% zinc; 0.40% manganese; 0.33% iron; 0.05% copper; 0.02% cobalt and 0.01% iodine.
*b Provided: 1200 USP units vitamin A; 1100 USP units vitamin D; 1.1 I.U. vitamin E; 4.4 mg. riboflavin; 10.1 mg. pantothenic acid; 20.2 mg. niacin; 55.0 mg. choline chloride; 10 mcg. vitamin B12; 10 mg. oxytetracycline and 250 mg. butylated hydroxy tolene.
*c Kehltdahl method—variation indicated by the standard deviation includes mixing; sampling and laboratory errors between batches.
*d Percent of the diet as calculated from values presented by C. H. Hubbell (1965).
recorded as the average of measurements taken at the first, last thoracic and last lumbar vertebrae.

A digestion study was conducted during the fourth trial, using the chromium oxide indicator method (Clawson et al., 1955). The pigs averaged approximately 68 kg at this time. Both feed and fecal samples were analyzed for moisture, ash, ether extract and nitrogen by the procedure of the A.O.A.C. (1960). Chromium oxide was determined by a method described by Bolin et al. (1952) as modified by Smart and Clawson (unpublished data).

The statistical design was a general factorial with nine treatments, four trials and two sexes, with two observations per sex in each trial. The analysis was calculated by methods described by Steel and Torrie (1960). Single degree of freedom comparisons of treatment effects were made for performance and carcass characteristics using the Duncan multiple range method.

Results and Discussion

The average number of days on test ranged from 93 to 100 among pigs fed the nine diets (table 2). The differences in rate of gain resulted from dietary differences in amino acid source, rather than level of protein as indicated in tables 2 and 3. During the first 56 days, pigs that received diets containing 11.3 or 12.8% protein gained significantly (P<0.05) and (P<0.01) faster, respectively, when 50 or 60% of the amino acids was provided by soybean meal than when 40% was provided by this source. This advantage in gain for the higher ratio of amino acids from soybean meal persisted for the entire trial in those pigs fed diets containing 12.8% protein, but not in those fed the 11.3% level.

There was no significant difference in daily gain in comparisons between adjacent levels of protein of equal amino acid source ratio for the first 56 days or for the entire experiment. These results indicate that satisfactory growth can be obtained in pigs fed a 11.3% protein diet from weaning to market when a proper amino acid balance is provided. These results are in agreement with a previous report by Clawson et al. (1962) in which excellent daily gains were reported from pigs fed 10, 11 and 12% protein diets when approximately 70% of the amino acids was provided by soybean meal. Kropf et al. (1959) reported equal rate of gain between pigs fed 12 and 16% protein of “high quality” but reduced gains in pigs fed a 16% diet with “low quality” protein. In work reported by Catron et al. (1952), Ashton et al. (1955), Aunan et al. (1961) and Nielsen et al. (1963), a minimum protein level of 14% was required for maximum growth in pigs from weaning to 45 kilograms. This apparent disagreement is probably the result of differences in amino acid source ratio rather than protein level. The findings of this experiment are not in agreement with a report by Abernathy et al. (1958) in which significantly (P<0.05) faster gains were obtained from pigs fed 18%, as compared to 14% protein diets from 18 to 50 kilograms. Neither do they agree with the findings of Crum et al. (1964) or Seymour et al. (1964). This was not unexpected, inasmuch as the protein levels compared by Crum et al. (1964) and Seymour et al. (1964) were markedly different in amino acid source ratio.

### Table 2. Effect of Ratio of Amino Acids from Corn and Soybean Meal and Dietary Protein Level on Performance of Pigs

<table>
<thead>
<tr>
<th>Item</th>
<th>40–60</th>
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<th>50–50</th>
<th>50–50</th>
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<tr>
<td>Protein level, %</td>
<td>11.3</td>
<td>12.8</td>
<td>11.3</td>
<td>12.8</td>
<td>14.3</td>
<td>11.3</td>
<td>12.8</td>
<td>14.3</td>
<td>17.2</td>
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<td>Final wt., kg.*</td>
<td>96.4</td>
<td>95.9</td>
<td>95.9</td>
<td>97.3</td>
<td>94.5</td>
<td>94.5</td>
<td>95.9</td>
<td>95.0</td>
<td>95.5</td>
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<td>Performance first 56 days:</td>
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<tr>
<td>Av. daily gain, kg.</td>
<td>0.71</td>
<td>0.70</td>
<td>0.74</td>
<td>0.77</td>
<td>0.74</td>
<td>0.76</td>
<td>0.80</td>
<td>0.78</td>
<td>0.78</td>
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<tr>
<td>Av. daily feed, kg.</td>
<td>2.36</td>
<td>2.22</td>
<td>2.38</td>
<td>2.36</td>
<td>2.22</td>
<td>2.38</td>
<td>2.40</td>
<td>2.35</td>
<td>2.24</td>
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<tr>
<td>Feed:gain ratio</td>
<td>3.34</td>
<td>3.16</td>
<td>3.23</td>
<td>3.08</td>
<td>2.99</td>
<td>3.13</td>
<td>3.00</td>
<td>3.01</td>
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<td>Performance entire experiment</td>
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<tr>
<td>Av. daily gain, kg.</td>
<td>0.77</td>
<td>0.73</td>
<td>0.78</td>
<td>0.81</td>
<td>0.76</td>
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<tr>
<td>Av. daily feed, kg.</td>
<td>2.70</td>
<td>2.54</td>
<td>2.70</td>
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<td>2.70</td>
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<tr>
<td>Feed:gain ratio</td>
<td>3.51</td>
<td>3.48</td>
<td>3.48</td>
<td>3.36</td>
<td>3.34</td>
<td>3.43</td>
<td>3.31</td>
<td>3.37</td>
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* Sixteen individually fed pigs per treatment, average initial weight 21 kilograms.
Barrows gained an average of 0.78 and 0.80 kg per day which was significantly (P < 0.01) faster than for gilts that gained 0.72 and 0.75 kg per day for the first 56 days and the entire experiment, respectively. This is in agreement with the finding of Bruner et al. (1958), Mulholland et al. (1960) and Wagner et al. (1963). There was also a significant (P < 0.05) sex by treatment interaction associated with daily gain. Barrows gained faster on diets of lower protein quality and level than did gilts. No other treatment interaction had a significant effect on average daily gain. The first 56 days, pigs gained significantly (P < 0.05) faster in the winter than in the summer. The winter and summer trials were started approximately November 1 and May 1. The mean low, mean high and mean temperature for the two respective seasons were 0.0°C to 13.1°C, 6.7°C and 16.3°C, 28.6°C, 22.4°C C.

There was no significant difference in daily feed intake of pigs fed the 11.3% protein diets of varying amino acid source. Pigs that received the diet which contained 12.8% protein with 50 or 60% provided from soybean meal had a higher (P < 0.05) daily feed intake than pigs fed the diet which also contained 12.8% protein, but with 40% of the protein provided from soybean meal. This difference was evident for the first 56 days and for the entire experiment. Diets 4 and 7 (12.8% protein) contained corn sugar which may have increased palatability and could account for the increased feed intake when compared to diet 2. However, the graded level of sugar added to the 11.3% protein diets did not result in significant differences in feed intake, so it is doubtful if this was the cause. The only other significant comparison of feed intake was a protein level comparison with the average of the 11.3 and 12.8% compared to the average of the 14.3% protein diets where soybean meal provided 50 and 60% of the protein. The higher level of protein significantly (P < 0.05) decreased daily feed intake for the first 56 days and for the entire experiment. A slight imbalance of amino acids may be compensated for by increased feed intake. This may have been the reason for the higher feed intake of pigs fed the lower protein diets.

Barrows consumed 2.42 and 2.76 kg of feed daily, and gilts consumed 2.23 and 2.54 kg for the first 56 days and for the entire experiment, respectively. The significant (P < 0.01) difference in daily feed intake between trials was mainly associated with season. Pigs consumed an average of 2.25 and 2.53 kg of feed daily during the summer, as compared to 2.41 and 2.76 kg during the winter trials for the first 56 days and the entire experiment, respectively.

Feed required per kg of gain was significantly (P < 0.01 and P < 0.05) influenced by treatment for the first 56 days and the entire trial, respectively. As the proportion of amino acids from soybean meal increased, feed per kg of gain was decreased (P < 0.01 and P < 0.05) and, as the level of protein increased from 11.3 to 12.8%, feed per kg of gain also decreased (P < 0.01 and P < 0.05) during the first 56 days and during the entire trial, respectively. No further decrease in feed per kg of gain was obtained by increasing protein level comparison with the average of the 11.3 and 12.8% compared to the average of the 14.3% protein diets where soybean meal provided 50 and 60% of the protein. The higher level of protein significantly (P < 0.05) decreased daily feed intake for the first 56 days and for the entire experiment. A slight imbalance of amino acids may be compensated for by increased feed intake. This may have been the reason for the higher feed intake of pigs fed the lower protein diets.
level beyond 12.8%. These results agree with work reported by Clawson et al. (1963) in studies concerned with amino acid source ratio, and with reports by Stevenson et al. (1960) and Wagner et al. (1963) in studies of protein level.

Pigs fed diets which contained 11.3% protein with 40% of the amino acids provided from soybean meal required significantly (P<0.05) more feed per kg. of gain (3.34, 3.23 and 3.13) than did pigs fed diets which also contained 11.3% protein, but with either 50 or 60% of the amino acids provided from this source. This was true at 56 days but not for the entire trial. The difference in feed per kg. of gain between the 40 and 60% levels from soybean meal was significant (P<0.01 and P<0.05) for both the first 56 days and for the entire trial. Pigs fed diets which contained 12.8% protein with 40% of the amino acids provided from soybean meal required significantly (P<0.01) more feed per kg. of gain (3.16 vs. 3.00 kg. for 56 days and 3.48 vs. 3.31 kg. for the entire trial) than did pigs fed the diet which also contained 12.8% protein, but with 60% of the amino acids provided from soybean meal. There was no significant difference over the entire trial in feed required per kg. of gain between diets that contained at least 12.8% protein where 50 or 60% of the amino acids was provided from soybean meal. Feed per kg. of gain during the summer trials was 3.05 and 3.28 kg., as compared to 3.15 and 3.52 kg. during the winter trials for the first 56 days and the entire test period, respectively. This seasonal difference was significant (P<0.01). The mean monthly temperatures for May, June and July were 18.9°, 23.4° and 24.6° C., and for November, December and January 11.0°, 4.2° and 4.9° C. respectively.

In this experiment, feed per kg. of gain was not directly influenced by sex. In contrast, Crum et al. (1964) reported that gilts were more efficient than barrows. A significant sex by treatment interaction (P<0.01 and P<0.05) associated with feed efficiency was found for the first 56 days and for the entire experiment, respectively. There was a greater variation in feed required per kg. of gain for gilts than for barrows as the protein level and amino acid source ratio varied. This is in agreement with an observation of Wallace (1965) that gilts are less tolerant than barrows to low-protein diets.

The results of the treatments on carcass characteristics are presented in table 4. Carcass weight was taken after a 24-hr. chill and does not include the head and leaf fat. The influence of amino acid source ratio and level on average backfat thickness was not significant for the over-all analysis or for any single degree of freedom comparison when adjacent levels and amino acid source ratios were compared. These results agree with the findings of Wilson et al. (1953), Aunan et al. (1961), Clawson et al. (1962) and Meade et al. (1966). These workers reported no significant difference in backfat thickness from carcasses of pigs fed protein levels ranging from 10 to 20%. In contrast, Stevenson et al. (1960) Wagner et al. (1963), Crum et al. (1964) and Seymour et al. (1964) reported a significant decrease in carcass backfat in pigs as the protein level in the diet was increased. Carcasses from gilts had significantly (P<0.05)

<table>
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<th>Ratio of amino acids from corn and soybean meal and dietary protein level on carcass measurements of pigs</th>
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<td>Item</td>
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</tr>
<tr>
<td>Carcass wt., kg.</td>
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<td>Dressing, %</td>
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<td>Backfat, cm.</td>
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<td>% ham</td>
</tr>
<tr>
<td>% loin</td>
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<tr>
<td>% lean cuts</td>
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</table>

* Carcass data from 12 pigs per treatment.  
* No significant difference between dietary treatments, however the difference between sexes was significant (P<0.01).  
* The 12.8% protein level was significantly (P<0.01) higher than the 11.3% level. Sexes were also significantly (P<0.05) different.  
* The 12.8% protein level was significantly (P<0.01) higher than the 11.3% level. The 14.3% protein level was significantly (P<0.05) higher than the two lower levels. The sex and sex X treatment interactions were also significant (P<0.01).
PROTEIN RATIOS FOR SWINE

less backfat than from barrows (5.7 cm. as compared to 6.2 cm.).

Individual degree of freedom comparisons between adjacent ratios of amino acids from corn and soybean meal and between protein levels failed to show any significant difference in percent of ham. Gilt carcasses contained an average of 21.4% ham which was a significantly (P<0.01) higher yield than 20.6% for barrows. Pigs fed 12.8% protein yielded loins that were significantly (P<0.01) heavier than those fed 11.3% protein. There was no significant increase in loin weight when the level of protein was increased beyond 12.8%. Gilt carcasses yielded 14.9% and barrows 14.5% loin. This difference was significant (P<0.05) and in agreement with data presented by Bruner et al. (1958) and Wallace (1965).

Carcasses from pigs fed the 11.3 and 12.8% protein diets yielded 50.6 and 51.6% lean cuts, respectively. Pigs fed diets which contained 14.3% protein had a significantly (P<0.05) higher percent of lean cuts than those fed diets which contained lower levels of protein. Pigs fed the diet which contained 17.2% protein with 60% of the protein supplied by soybean meal, also yielded a significantly (P<0.05) higher percent of lean cuts than pigs fed diets which contained 11.3, 12.8 and 14.3% protein when a similar ratio of amino acids from corn and soybean meal was maintained. A linear increase in percent lean cuts was evident as protein level increased at each ratio of amino acids from corn and soybean meal. These results agree with findings of Wilson et al. (1953), Kropf et al. (1959), Wagner et al. (1963) and Wallace (1964).

Carcasses from gilts and barrows yielded 52.1 and 50.6% lean cuts, respectively. This difference was significant (P<0.01). Gilts responded with a greater increase in percent lean cuts as the amino acid source ratio and level of protein increased than did barrows. Kropf et al. (1959) suggested that carcass composition of gilts may be more sensitive to changes in “quality” and “quantity” of dietary protein than barrows.

In the comparison of all diets, level of protein had a significant (P<0.01) effect on apparent digestibility of crude protein. In comparing specific levels, a significant (P<0.05) increase in digestibility of protein was observed between 11.3 and 12.8%. In the comparison between the 12.8 and 14.3% protein levels in which soybean meal supplied at least 50% of the amino acids, there was no significant difference in apparent digestibility. Apparent digestibility of crude protein was significantly (P<0.05) higher for the 17.2% protein level as compared to the average of the 11.3, 12.8 and 14.3% protein diets when all contained a 60:40 ratio of amino acids from soybean meal and corn. Armstrong and Mitchell (1955) reported a linear positive relation between fecal nitrogen and dietary protein level in swine diets in the range from zero to 16%.

There was no significant effect on apparent digestibility of the other components of the diet. A large variation in ether extract digestibility between diets was observed. However, a large variation within samples from the same diet resulted in a large experimental error.

Summary

Four trials, involving a total of 144 pigs, were conducted to determine the effects of varying the ratio of amino acids from corn and soybean meal, and the dietary protein level on performance, carcass quality and diet digestibility. The diets contained a 60:40, 50:50 or 40:60 ratio of amino acids from corn and soybean meal. The pigs were self fed from an initial weight of 20.9 kg. to approximately 95 kilograms.

The results of this study indicate that satisfactory growth can be obtained from weanling (21 kg.) pigs fed a 11.3% protein corn-soybean meal diet when at least 50% of the amino acids is supplied by soybean meal. At least 12.8% protein with 50% or more supplied by soybean meal was required for maximum feed efficiency, and carcass leanness was improved up to 14.3% dietary protein. A further increase in dietary protein level did not result in a further increase in lean cuts. The level of amino acids required appears to be different for maximum growth, feed efficiency and muscle development.

Literature Cited


A.O.A.C. 1960. Official Methods of Analysis (9th


