Industry Chair for Swine Research

Optimal Whole Soybean Inclusion Rate for Commercial Swine Diets and The Use of Rye as a Feed Ingredient for Swine Rations on Prince Edward Island

Final Report

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Prepared For:
PEI Pork
NRC-IRAP
Pig Production Innovation Group
PEI Grain and Protein Council
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Executive Summary - Conclusions

- The increasing levels of soybeans in the diet had no effect on growth or carcass characteristics. Thus there are no changes in revenue or premiums expected with an increased inclusion rate of soybeans.

- Increases in the inclusion rate of soybeans decreased the feed conversion. The optimal rate depends on the cost of whole soybeans., If the feed conversion gain offsets the higher diet cost associated with more soybeans, it pays to increase the inclusion rate of whole soybeans

- The addition of synthetic lysine did not improve growth rate, feed conversion or carcass parameters

- The use of rye was not found to be detrimental for both growth and efficiency. This makes rye a suitable choice for feeding pigs. There are environmental and production advantages to the use rye as a feed ingredient, and these results indicate its use should be researched further

Rye is a crop that can be seeded in the fall to provide a winter cover crop that can prevent erosion. As an alternative to Barley it has numerous advantages.

Background

Soybeans

Soybean meal, the most common source of protein for pigs, is the by-product of soybean oil production. The bean is crushed and the oil is extracted by the use of solvents leaving a high protein (44 to 49% crude protein) meal. Although soybean meal is a high quality product, its availability and price are controlled by a few large multi-national companies. This 'external' influence on the cost of pork production removes the ability for the local producer to have some control over feed prices.

In recent years soybean varieties which grow well in Prince Edward Island have become available. This has helped to reduce the influence of large soybean meal manufacturers, and local producers are beginning to use whole (full-fat) soybeans in hog rations. As no oil extraction plants exist in the region, other methods of processing (roasting and extrusion) must be employed.

Full-fat soybeans allow the opportunity for swine producers to utilize a home-grown protein product. They fit in well in Atlantic Canada because their high fat (20%) and moderate protein content (36.7%) (NRC, 1988) provide the extra energy and protein, in an easily handled form, required in diets which contain barley as the primary starch source.

As soybeans contain anti-nutritional factors, such as trypsin inhibitors, they must be treated with heat before they can be fed to pigs (Rackis, 1974). Heat treatment is possible by roasting or extruding (DeSchutter and Morris, 1990). Roasting and extrusion of soybeans has been successful in Prince Edward Island and the rest of Atlantic Canada with roasting being the more common practice. Recent work at the Pork Production Innovation Group (PPIG) research facility has shown that growing pigs perform well on diets based either on extruded or roasted soybeans. It was also shown that the oil in soybeans is incorporated into the fat of the pork resulting in a meat product containing a high proportion of unsaturated long chain fatty acids.

Despite the success of previous trials at the PPIG facility, questions remain regarding the optimum inclusion rate for soybeans and the role of supplemental amino acids to maximize performance and profitability.

This project is part of a larger study which we hope will be funded from several sources and cover at least two years in duration. In the interest of time, Part 1 of this long term project is being submitted now with a larger submission to follow. The longer term study encompasses animal nutrition, meat quality, crop fertility, and environmental impact and manure management.

Rye

Barley is the traditional energy source for feeding pigs on Prince Edward Island. It can be grown easily in rotation with potatoes, and provides a marketable crop in between potato years. An alternate crop that fits even better in the potato rotation is rye. Rye has several advantages over barley as follows:

- Rye can be planted in the fall and provides a ground cover to prevent winter erosion
- Rye can be seeded and harvested at a time that does not compete with other cropping events
- Straw production with rye is higher than barley which provides an excellent source of livestock bedding or organic matter for the soil
- Rye has such significant benefits that some producers plant in the fall and plow that under in the spring before a subsequent crop. By letting the rye mature and then harvesting for feed can provide a valuable efficiency saving for the potato rotation.

- Significant environmental and soil benefits will develop if it can be shown that Rye can be fed to pigs.

Rye is not a traditional feed source for pigs. Early varieties were susceptible to ergot development, which limited its use in livestock. Newer Rye varieties have overcome this problem. We propose that a ration utilizing rye in the place of barley be fed to measure the performance of PEI pigs with PEI rye and PEI barley.

Project Objectives:

1. To determine the optimal level of feeding whole soybeans to commercial market pigs on PEI
2. To determine the feeding value of rye compared to barley when using a grain and soybean ratio fed to commercial market pigs on PEI.

Scientific Plan:

Experimental design:

The study will use 700 pigs, born the same week, on one farm, with a uniform SPF health status. They will be housed in pens of twenty five pigs and segregated by gender.
The diets to be tested will contain graded levels of roasted soybeans (RSB) as well as barley, wheat and a vitamin/mineral premix. Animals will be housed on slatted floors and deep bedded pens and will be offered feed *ad libitum*. Feed intake per experimental group will
be measured weekly. The study will test seven experimental groups testing three soybean levels and two lysine supplementation levels in two replicates as well as replacement of barley with rye in a soybean diet for a total of two pens of 25 pigs per gender per treatment.

All pigs will be fed a starter (20 - 40 kg live weight), grower (40 -70 kg live weight) and finisher (70-110 kg live weight) diet. Diet formulations are as attached.

Parameters to be determined.-

Weight gain	Measured at the start and end of the growth phase (finisher). Measurements are for individual animals.
Feed consumption	Measured on a per feeder basis for the duration of the experiment
Feed conversion	Calculated from weight gain and feed consumption (feed/gain)
Carcass quality	Back fat depth, loin eye depth, carcass weight, lean yield, grade index
Health status	Any health problems during grow out will be documented. At slaughter lung, and liver
Meat Quality	Fat and lean texture, colour and marbling scores

Collaborating Scientists:

Dr Dan Hurnik – PI Research Chair, PEI Hog Commodity Marketing Board
Dr Ted Van Lunen - AVC / AAFC
Dr John MacLeod - AAFC
Dr Alan Campbell - AAFC
Dr Shona Whyte – AVC Inc / PPIG

Starter

	Diet 6	*Diet 5*	*Diet 4*	*Diet 3*	*Diet 2*	*Diet 1*	*Diet 7*
Barley	420	410	400	421.5	411.5	401.5	0
Rye	0	0	0	0	0	0	411.5
Wheat	200	200	200	200	200	200	200
Soybeans	350	360	370	350	360	370	360
Lysine	1.5	1.5	1.5	0	0	0	0
Vitamin/Mineral**	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Total	1000	1000	1000	1000	1000	1000	1000

Grower

	Diet 6	*Diet 5*	*Diet 4*	*Diet 3*	*Diet 2*	*Diet 1*	*Diet 7*
Barley	546	531	511	546.5	531.5	511.5	0
Rye	0	0	0	0	0	0	531.5
Wheat	150	150	150	150	150	150	150
Soybeans	275	290	310	275	290	310	290
Lysine	0.5	0.5	0.5	0	0	0	0
Vitamin/Mineral**	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Total	1000	1000	1000	1000	1000	1000	1000

Finisher

	Diet 6	*Diet 5*	*Diet 4*	*Diet 3*	*Diet 2*	*Diet 1*	*Diet 7*
Barley	746	734	721	746.5	734.5	721.5	0
Rye	0	0	0	0	0	0	734.5
Soybeans	225	237	250	225	237	250	237
Lysine	0.5	0.5	0.5	0	0	0	0
Vitamin/Mineral**	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Total	1000	1000	1000	1000	1000	1000	1000

** Inclusion rate may change based on level recommended by manufacturer.

Materials and Methods

Formulae

GROWTH RATE	
Average Daily Gain	(Market weight – start weight)/(days between weighing and shipping) for all pigs with clear identification
Days to gain 86 kg	86 kg of gain/average daily gain
MEAT QUALITY	
Lean Yield	Probe output for all pigs dressing more than 80 kg less than 95kg
Backfat Depth	Probe output for all pigs dressing more than 80 kg less than 95kg
Loin eye Depth	Probe output for all pigs dressing more than 80 kg less than 95kg
Marbling	Manual score 1 to 5 with 5 as the greatest marbling
Fat firmness	Manual score 1 to 5 with 5 as the greatest fat firmness
Muscle Firmness	Manual score 1 to 5 with 5 as the greatest muscle firmness
Light Reflectance	Value from Minolta colour meter = % light reflected (higher number means more light reflected , meaning paler pork)

Statistical Analysis

The statistical analysis used a random effects regression model. This method accounted for the variation due to pens, gender, bedding and pig weights so that the effect of the feeds could be evaluated without the influence of the other factors. The p-value is reported when relevant. This number refers to the likelihood that the difference noted arose by chance. Generally, a p value of under 0.05 is considered to be statistically significant. The closer the p-value is to 0 the stronger is our confidence that the difference really exists. Values that are statistically different from the others are underlined in this report.

Analysis of Carcass Grading

All of the carcass data from the study pigs was downloaded from the APHIN database, giving the following information was gathered:

- Pen Specific tattoo
- Carcass index
- Carcass weight (dressed warm)
- Loin eye depth
- Backfat depth
- Lean Yield (%)
- Pneumonia prevalence
- Liver spot prevalence
- Adhesion prevalence

To compare the carcass quality, calculations excluded any pigs in the following categories:

- Pigs from pens not on the study
- Pigs from which there were no probe data to calculate a lean yield

Meat Quality Assessment

The quality of the pork was also evaluated using the loins of the pigs examined 24 hours after slaughter. The loin was split where the grading probe was inserted (Figure 3). On the loin muscle and the backfat the following data were recorded:

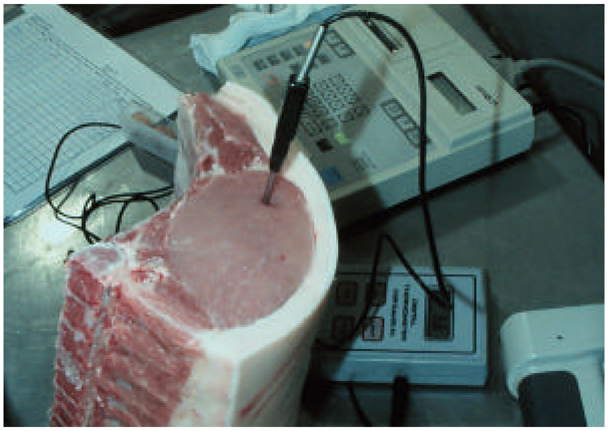

Figure 1 A cross section of the loin where the meat and fat was examined in detail.

- **Marbling –** a visual score rated 1 to 5 with a score of 5 having the highest amount of marbling
- **Muscle firmness** – a tactile score rated 1-5 with a score of 5 having being most firm.
- **Fat firmness -** a tactile score rated 1-5 with a score of 5 having being most firm.
- **Colour –** a reading with a Minolta colour meter that measured light reflectance as a percentage. The higher the number, the more light was reflected and the paler the meat was.

Results

Growth Rate

The growth rate (g/day) was calculated by dividing the weight gained by each pig by the length of its stay in the barn. Pigs that were excluded from the calculations were the ones that died or were removed from the study. Also not included were pigs that could not be definitively matched to their start weight. Those would be pigs that lost and changed eartags, or a definite match could not be made. Of the 700 pigs that began the study, good data were obtained from 661 pigs. This was an adequate number to accurately estimate the growth rate of the pigs. The average for each feed was as follows:

Feed	Average g/day
1	869
2	887
3	870
4	888
5	927
6	888
7	879
Barn Average	887

When the same data was put into a model using a Random effect regression that accounted for the variation due to the pen, the gender of the pig, the flooring type and the starting weight, the results indicate the following:

```
Random-effects ML regression                    Number of obs      =       661
Group variable (i) : pen                        Number of groups   =        28

Random effects u_i ~ Gaussian                   Obs per group: min =        21
                                                               avg =      23.6
                                                               max =        25

                                                LR chi2(7)         =     97.34
Log likelihood  =  608.80545                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
         adg |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         soy |   .0070209   .0060696     1.16   0.247    -.0048753    .0189171
      gender |  -.0462931   .0094239    -4.91   0.000    -.0647636   -.0278226
      lysine |   .0156531   .0093301     1.68   0.093    -.0026337    .0339398
    flooring |  -.0451507   .0091268    -4.95   0.000    -.0630388   -.0272625
       north |  -.0079678   .0092819    -0.86   0.391    -.0261599    .0102243
        west |   .0052543   .0092919     0.57   0.572    -.0129574     .023466
     startwt |   .0034455    .000419     8.22   0.000     .0026243    .0042668
       _cons |   .7293367   .0284105    25.67   0.000     .6736531    .7850203
-------------+----------------------------------------------------------------
    /sigma_u |   .0139864   .0056801     2.46   0.014     .0028536    .0251193
    /sigma_e |    .095498   .0026853    35.56   0.000      .090235     .100761
-------------+----------------------------------------------------------------
         rho |   .0209995   .0169005                      .0035729    .0842422
------------------------------------------------------------------------------
Likelihood ratio test of sigma_u=0: chibar2(01)=    2.48 Prob>=chibar2 = 0.058
```

Gender	Average (g/day)
Barrow	908
Gilt	865

The gilts appeared to grow slower than the barrows by about 6%. This is consistent with what is expected; barrows normally grow faster than gilts, but lay down more fat.

There was a difference between the pigs growing on the bedded or the slatted floor portion of the barn. In this study the pigs grew faster on the slatted floor portion of the barn.

Gender	Average (g/day)
Slatted floors	910
Bedding	863

Starting weight appeared to have a significant effect, which is logical in that larger pigs beginning the trial grew faster throughout the study. The pigs in the study were generally the same age. The pigs that were larger at the start, likely had a superior growth rate from birth on. This advantage seemed to be maintained through to market weight.

Neither the increasing levels of soybean in the ration, nor the addition of lysine had any effect on the growth rate in this study.

A similar analysis using the rye ration, indicated no difference in growth other than what would be attributable to gender differences.

Feed Conversion:

Feed	Feed Conversion
1	2.95
2	3.17
3	3.15
4	2.98
5	3.10
6	3.17
7	3.03
Barn Average	3.08

The regression model which looked at the variables independently gave the following results:

```
      Source |       SS       df       MS              Number of obs =      28
-------------+------------------------------           F(  4,    23) =    6.65
       Model |   .18642201     4  .046605502           Prob > F      =  0.0010
    Residual |  .161309654    23  .007013463           R-squared     =  0.5361
-------------+------------------------------           Adj R-squared =  0.4554
       Total |  .347731664    27  .012878951           Root MSE      =  .08375

------------------------------------------------------------------------------
  conversion |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 soybean rate|   -.069008   .0210343    -3.28   0.003    -.1125208   -.0254951
      lysine |   .0166464   .0325066     0.51   0.613    -.0505986    .0838915
      gender |  -.1034601   .0324067    -3.19   0.004    -.1704986   -.0364217
     bedding |  -.0679717   .0325066    -2.09   0.048    -.1352167   -.0007267
       _cons |   3.308306   .0508526    65.06   0.000     3.203109    3.413502
```

The inclusion rate of the soybeans appeared to affect the feed efficiency significantly. This is presented more precisely below:

```
                        | Summary of
                        | conversion
           Soybean rate |    Mean
            ------------+------------
                    low |   3.1695391
                 medium |   3.0998944
                   high |   3.0185906
            ------------+------------
                  Total |   3.0965633

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups       .09137479      2   .045687395      4.46     0.0221
 Within groups      .256356874     25   .010254275
------------------------------------------------------------------------
    Total           .347731664     27   .012878951

Bartlett's test for equal variances:  chi2(2) =   0.1627  Prob>chi2 = 0.922
```

It appears that again the performance of diets in terms of feed conversion is proportional to the inclusion rate of the soybeans. The higher the inclusion rate the more efficient the the conversion of feed to pork. Whole soybeans are both high in nutrients and highly digestible. These finding verify some of the earlier trial data. Other factors influencing feed conversion are gender and perhaps the use of bedding. The rye ration had no difference from the comparable barley ration, when variation due to bedding and gender was removed.

Index

For the carcass analysis portion of the study, data from the APHIN data set were used. Excluded animals were those who had no probe reading and those outside the optimal weight window (80-95kg). The reason to exclude the light and heavy pigs is that these pigs are downgraded not due to lean or fat content but for other reasons such as demerits and poor pig weighing. These factors are not associated with the feed. It is logical to work with the pigs that express the carcass attributes clearly.

Feed	Index
1	109.87
2	109.73
3	110.57
4	110.48
5	109.94
6	110.18
7	110.59
Barn Average	110.18

```
Random-effects ML regression                     Number of obs      =       479
Group variable (i) : tattoo                      Number of groups   =        22

Random effects u_i ~ Gaussian                    Obs per group: min =        17
                                                                avg =      21.8
                                                                max =        24

                                                 LR chi2(5)         =     15.13
Log likelihood  = -1465.7645                     Prob > chi2        =    0.0098

------------------------------------------------------------------------------
       index |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     soybean |   .0150869   .3481601     0.04   0.965    -.6672944    .6974682
      gender |   1.700211   .4846823     3.51   0.000     .7502511    2.650171
     bedding |    .501721   .4779655     1.05   0.294    -.4350742    1.438516
      lysine |   .3366432   .5129914     0.66   0.512    -.6688015    1.342088
      weight |  -.1387194   .0797618    -1.74   0.082    -.2950496    .0176108
       _cons |   120.9078   7.042581    17.17   0.000     107.1046     134.711
-------------+----------------------------------------------------------------
    /sigma_u |          0   .4131581     0.00   1.000     -.809775     .809775
    /sigma_e |   5.160909   .1667414    30.95   0.000     4.834101    5.487716
-------------+----------------------------------------------------------------
         rho |          0          .                             .           .
------------------------------------------------------------------------------
Likelihood ratio test of sigma_u=0: chibar2(01)=    0.00 Prob>=chibar2 = 1.000
```

The regression model indicates that in the soybean study, the only factor the impacted on carcass index was the gender. Neither soybean inclusion rate of the use of lysine made any difference. Similarly in the Rye diets there was no difference in carcass index when the effect of gender was controlled for.

Lean Yield

Feed	Lean yield
1	59.60
2	59.68
3	60.75
4	60.59
5	60.72
6	60.15
7	60.75
Barn Average	60.31

```
Random-effects ML regression                    Number of obs      =       528
Group variable (i) : tattoo                     Number of groups   =        22

Random effects u_i ~ Gaussian                   Obs per group: min =        22
                                                               avg =      24.0
                                                               max =        25

                                                LR chi2(5)         =     13.36
Log likelihood  = -1582.7752                    Prob > chi2        =    0.0202

------------------------------------------------------------------------------
       yield |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     soybean |  -.0946103   .3632516    -0.26   0.795    -.8065703    .6173497
      gender |   1.412718   .5065382     2.79   0.005     .4199213    2.405514
     bedding |   .5276546   .5007888     1.05   0.292    -.4538734    1.509183
      lysine |   .6497612   .5443504     1.19   0.233    -.4171459    1.716668
      weight |  -.1007837   .0412929    -2.44   0.015    -.1817164   -.0198511
       _cons |   67.81461   3.678025    18.44   0.000     60.60582    75.02341
-------------+----------------------------------------------------------------
    /sigma_u |   .6189383   .3380994     1.83   0.067    -.0437243    1.281601
    /sigma_e |   4.815235   .1514759    31.79   0.000     4.518347    5.112122
-------------+----------------------------------------------------------------
         rho |   .0162534   .0176494                      .0013913    .0993141
------------------------------------------------------------------------------
Likelihood ratio test of sigma_u=0: chibar2(01)=    1.25 Prob>=chibar2 = 0.132
```

There was no effect on Lean yield due to feed. The only significant effects were due to carcass weight and gender. Both these factors have a known effect on lean yield and were expected and controlled for.

Backfat

Feed	Backfat
1	17.90
2	19.28
3	18.72
4	18.75
5	19.22
6	18.20
7	18.38
Barn Average	18.63

```
Random-effects ML regression                    Number of obs      =       528
Group variable (i) : tattoo                     Number of groups   =        22

Random effects u_i ~ Gaussian                   Obs per group: min =        22
                                                               avg =      24.0
                                                               max =        25

                                                LR chi2(5)         =    126.14
Log likelihood  = -1457.5646                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
         fat |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     soybean |   .2844342   .2443441     1.16   0.244    -.1944714    .7633398
      gender |  -3.157907   .3404601    -9.28   0.000    -3.825197   -2.490618
     bedding |   -.015488   .3366761    -0.05   0.963     -.675361    .6443851
      lysine |   .2534321   .3652382     0.69   0.488    -.4624215    .9692858
      weight |   .2487939   .0324807     7.66   0.000     .1851329     .312455
       _cons |  -2.259598   2.862067    -0.79   0.430    -7.869147    3.349951
-------------+----------------------------------------------------------------
    /sigma_u |          0   .3430638     0.00   1.000    -.6723927    .6723927
    /sigma_e |   3.825161   .1176868    32.50   0.000     3.594499    4.055823
-------------+----------------------------------------------------------------
         rho |          0          .                             .           .
------------------------------------------------------------------------------
Likelihood ratio test of sigma_u=0: chibar2(01)=    0.00 Prob>=chibar2 = 1.000
```

There was no effect on backfat due to feed. The only significant effects were due to carcass weight and gender. Both these factors have a known effect on fat levels and were expected and controlled for.

Loin Eye Size

Feed	Loin Depth
1	57.34
2	58.46
3	57.87
4	59.54
5	56.95
6	58.71
7	58.33
Barn Average	58.23

```
Random-effects ML regression                    Number of obs      =       528
Group variable (i) : tattoo                     Number of groups   =        22

Random effects u_i ~ Gaussian                   Obs per group: min =        22
                                                               avg =      24.0
                                                               max =        25

                                                LR chi2(5)         =     35.18
Log likelihood  = -1858.9941                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       lmeat |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     soybean |  -.0745083   .5413647    -0.14   0.891    -1.135564    .9865471
      gender |   1.630902   .7544649     2.16   0.031      .152178    3.109626
     bedding |   2.151014   .7460964     2.88   0.004     .6886921    3.613336
      lysine |   .7083172   .8097304     0.87   0.382    -.8787252     2.29536
      weight |     .33899   .0695428     4.87   0.000     .2026886    .4752915
       _cons |   26.73335    6.14049     4.35   0.000     14.69821    38.76849
-------------+----------------------------------------------------------------
    /sigma_u |    .461295   1.013129     0.46   0.649    -1.524401    2.446991
    /sigma_e |   8.169007   .2569704    31.79   0.000     7.665354     8.67266
-------------+----------------------------------------------------------------
         rho |   .0031786   .0139577                      1.29e-08    .5436298
------------------------------------------------------------------------------
Likelihood ratio test of sigma_u=0: chibar2(01)=    0.06 Prob>=chibar2 = 0.406
```

.

There was no effect on muscle size due to feed. The only significant effects were due to carcass weight and gender. It appears as well that pigs raised on the bedding had a higher loin eye size than pigs that grew to market on the slatted portion of the barn.

Animal Health

Feed	Pneumonia	Lung Adhesions	Ascarid lesions
1	2.51	2.06	0
2	3.24	2.06	0
3	2.38	2.11	0
4	2.11	2.11	0
5	2.45	2.08	0
6	2.10	2	0
7	2.75	2.17	0
Barn Average	2.51	2.08	0

There were no differences in health status between feeds, no were the effect attributable to gender or bedding choices. Animal health problems appear to be random events that are spread through out the barn.

Pork Quality

Feed	Reflectance	Marbling	Fat Firmness	Muscle Firmness
1	48.72	2.11	1.77	2.5
2	50.05	2.25	2.06	2.37
3	50.47	2.13	2.06	2.53
4	51.50	1.88	2.03	2.14
5	49.84	2.05	2.10	2.36
6	49.50	2.30	1.84	2.38
7	52.20	2.21	2.28	2.42
Barn Average	50.39	2.10	2.02	2.36

There were no pork quality differences attributable to the feed choices.

Conclusions

- The increasing levels of soybeans in the diet had no effect on growth or carcass characteristics. Thus there are no changes in revenue expected with an increased inclusion rate of soybeans.

- Increases in the inclusion rate of soybeans decreased the feed conversion. The optimal rate depends on the cost of whole soybean, and if the feed conversion gain offsets the higher feed costs associated with more soybeans.

- The addition of synthetic lysine did not improve growth rate, feed conversion or carcass parameters

- The use of rye was not found to be detrimental for both growth and efficiency. This makes rye a suitable choice for feeding pigs. There are environmental and production advantages to the use rye as a feed ingredient, and these results indicate its use should be researched further.