Evaluation of Live Performance, Carcass Composition and Meat Quality of Market Hogs Fed Diets with Various Combinations of Peas, Canola Meal and Soybean Meal with Wheat or Corn as the Cereal Base

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Abstract

An experiment was carried out to evaluate the live performance, carcass characteristics and meat quality of pigs (Genex) fed diets based on wheat or corn supplemented with soybean meal (SBM), peas and canola meal either alone or in combination. Six dietary treatments (3 wheat, 3 corn) were evaluated utilizing 144 pigs starting at 50 kg live weight. Dietary specifications were changed at 80 kg live weight and fed to 110 kg. Wheat was fed with SBM, peas and peas/canola mixture while corn was fed with soybean meal, soybean/peas and soybean/canola mixtures. Diets were formulated to meet or exceed NRC (1998) requirements.

Feed intake on both wheat and corn diets were excellent and exceeded 2 kg per day with canola meal diets having slightly lower intake. However, feed conversions on the canola

diets were not different from the other diets. Daily gains followed the same pattern as feed intake.

Carcasses of pigs fed the wheat based diets had similar grades, lean yield, relative proportion of cuts, loin eye area and overall proportion of lean, fat and bone in the four lean cuts. The peacan supplemented diet resulted in carcasses with softer fat ($P<0.05$) compared to the SBM supplemented diet (fat hardness readings of 719 and 787, respectively), while the pea supplemented diet produced fat similar in hardness to the SBM diet (769). This may have been a reflection of different levels of canola oil added to make the diets isocaloric. Regardless of source of supplementary protein, there were no differences in color or water holding properties, in shear values or sensory attributes of pork produced by the wheat based diets. The intramuscular fat content of loins derived from pigs fed the wheat-pea diet and the wheat-peacan diet was lower ($P<0.05$) than from pigs fed the SBM supplemented diet (1.47% and 1.58% compared to 1.84%, respectively). Loin muscle from pea fed pigs had a slightly higher ($P<0.05$) protein content compared to pigs fed SBM or peacan meal (22.4% compared to 22.1% and 22.0%, respectively).

Supplementation of corn based diets with peas or canola meal in addition to SBM had no effect on carcass grade, lean yield, proportion of cuts, loin eye area or relative proportion of tissues in the four lean cuts compared to supplementation with SBM only. The soy/canola treatment produced carcasses with softer fat ($P<0.05$) compared to the soy/pea and SBM treatments (fat hardness readings of 680, 733 and 749, respectively). This may also have been due to a higher level of added canola oil in the corn-soy/canola diet. Pork quality characteristics (color and water holding properties) were unaffected by dietary treatment. While shear values were higher ($P<0.05$) for pigs fed peas compared to canola meal (5.715 and 5.074 kg, respectively), the difference would not likely be detected by consumers. Dietary treatment had no effect on any of the sensory attributes evaluated. Protein content of the loin muscle from pigs fed the corn-SBM diet was slightly higher ($P<0.05$) than from pigs fed the other two corn based diets (22.4% compared to 22.1%).

This study clearly demonstrates that swine diets incorporating peas and/or canola meal produce carcasses of similar composition and pork of equal quality compared to diets supplemented with SBM. When it is necessary to add supplemental fat to diets containing corn and canola meal, it is recommended to use tallow to reduce the risk of producing carcasses with unacceptable, soft fat.

Introduction

For many years soybean meal (SBM) was used as the chief source of vegetable protein in swine diets in Western Canada. Over the past decade other locally grown feedstuffs have successfully substituted for SBM. Peas and canola meal (CM) are being used more extensively in swine diets in western Canada because of economic reasons. These protein supplements are produced locally and are usually available at competitive prices. Although the local market has shown good acceptance of the meat produced from the use of these ingredients, the export market for Canadian pork has questioned the quality and eating characteristics of pork produced on these feed supplements. In addition, prospective foreign buyers for peas and canola for animal feed uses have also posed the same question. Recent data is not presently available in this area.

The inclusion of 30% peas in weaner diets and up to 50% in feeder pig diets have resulted in excellent pig performance (Kehoe et al., 1995; Jaikaran et al., 1995) in terms of average daily gain, average daily feed intake and feed efficiency. Castell and Cliplef (1993) used 42.5% pea screenings in grower finisher pig diets with acceptable performance. Most Alberta grown peas range from 16 to 24% protein (Jaikaran et al., 1995). Canola meal (CM) is also commonly used as a protein source in grower and finisher swine diets in western Canada. Numerous research experiments have demonstrated its appropriate use in weaner, grower and finisher swine diets. Canola meal can be included in hog grower and finisher diets at levels of up to 15% and 20% without any reductions in pig performance (Hickling, 1994: Siljnader-Rasi et al., 1996).

The use of peas and canola meal together (peacan) in the diet is increasing since the amino acid profiles of these two protein supplements complement each other with respect to the amino acid requirements of the pig. This was clearly demonstrated by Castell and Clipleff (1993) in which pigs performed better on diets containing both CM and peas than on either one by itself. From the amino acid standpoint, peas are low in the sulfur amino acids (methionine and cystine), while canola meal is quite rich in these. The higher digestible energy content of peas helps makeup for the shortfall in canola meal. Presently, a 2:1 mixture by weight of ground peas and canola meal is available commercially and goes by the name of peacan meal.

Effects of supplementing swine diets with peas and/or canola meal on carcass and meat quality were studied by Castell and Clipleff (1993). They fed barley based diets supplemented with either soybean meal, peas, canola meal or two peas/canola meal mixtures. Carcasses from all treatments were similar for all carcass and meat quality parameters with the exception of dressing percent, carcass grade, liver weight, and intramuscular fat (marbling). Compared with soybean meal fed pigs, canola meal fed pigs had reduced dressing percent, poorer carcass grade and larger livers. Compared with pigs fed canola meal, the pigs fed peas had higher carcass grades, more marbling of their lean tissue and a higher degree of saturated fat. Differences among the five diets, however, did not affect the sensory evaluation of the cooked lean. In another study by Jaikaran and Aherne (1998) in which peacan meal replaced 33, 66 and 100 percent of soybean meal in hulless barley based diets, there were no differences in carcass quality or carcass grades based on the slaughter house data.

Now that the optimum performance levels of soybean meal, canola meal, peas and peacan meal in the diets of growing swine are established, it is valuable to use one experiment to compare the effects of these diets on live performance and carcass and meat quality parameters. This should provide knowledge for raising the animals as well as information for promotion and sales of commodities and their value added meat products. The few earlier studies which did examine dietary effects on carcass and meat quality, slaughtered the experimental animals at relatively light weights (90 – 100 kg live weight) in comparison to typical slaughter weights of today (110+ kg), thus increasing the importance and relevance of this study.

Objectives

1. To compare live animal performance of pigs fed wheat based or corn based diets supplemented with peas, canola meal and soybean meal.

2. To compare carcass composition and meat quality of pigs fed wheat based or corn based diets supplemented with peas, canola meal and soybean meal.

Methods

All animals used in this trial were raised and slaughtered at the Lacombe Research Centre in accordance with the principles and guidelines set out by the Canadian Council of Animal Care (1993).

Live animal feeding

One hundred and forty-four pigs (72 barrows and 72 gilts) were allocated by sex and weight to one of six dietary treatments, starting at 50.7 (± 0.3) kg. The dietary treatments are shown in the following table.

Dietary Treatments						
Energy source	Wheat			Corn		
Protein supplement	Soybean meal	Peas	Peacan meal	Soybean meal + peas	Soybean meal	Soybean meal + canola meal

Pigs were housed at the Lacombe Research Centre swine unit. The treatment unit consisted of a pen of either three barrows or three gilts, with four pens of barrows and four pens of gilts per treatment. The feeding trial was conducted in four blocks (four separate research rooms) with one pen of barrows and one pen of gilts per treatment in each block. Individual blocks started and finished on different dates over a four month period.

Feed and water was supplied *ad libitum*. The pigs were fed in two phases with a diet change when the pigs were 79.4 (± 0.6) kg. Diet formulations are presented in Appendix C (grower) and Appendix D (finisher). Diets were formulated to meet or exceed NRC (1998) requirements. Canola oil was used at levels between 0 and 25 kg per tonne to equalize digestible energy levels. Synthetic lysine and methionine were used to bring these amino acids levels in the diets to levels necessary for ideal protein formulation (Baker and Chung, 1992). Feed disappearance and live weights were recorded weekly throughout the feeding trial to determine the effect of dietary treatment on feed intake, average daily gain and feed conversion efficiency.

Carcass and meat quality

When the test animals in a pen averaged approximately 107 kg, the final weight off test (108.3 ± 0.6 kg) and final feed weigh backs were recorded at 1:00 P.M of the day prior to slaughter. The pigs were held in their respective pens with access to water only, and shipped in the morning to the Lacombe Research Centre abattoir where they were directly slaughtered using typical commercial procedures. Final live weight (shrunk) was obtained immediately prior to electrical stunning with a head to shoulder electrode (400 V, 60 Hz). Carcasses were trimmed to standard commercial specifications and carcass weights recorded. A Hennessy Grading Probe (HGP; see Figure 1) was used to obtain fat and muscle thickness measurements at the grade site (7 cm off the midline between the 3rd and 4th last ribs). After washing, carcass sides were chilled at 1°C and air velocity of 1 m/sec^{-1} for approximately 24 h and re-weighed to ascertain shrinkage losses during cooling. Firmness of the subcutaneous fat above the 2^{nd} thoracic vertebra of the right side was measured at this time using a Bristol Fat Hardness Meter (AFRC Institute of Food Research, Bristol, U.K, 1988.; Sather *et al.*, 1995; see Figure 2). The meter has a spring loaded probe which is placed against the fat surface, and a simple measurement is made of the retraction of the probe against the resistance of the calibrated spring.

The left side of each carcass was fabricated into primal and sub-primal cuts: shoulder – picnic and butt, loin, ham, and belly (see Figure 3). The picnic, butt, loin and ham were dissected into bone, lean and fat depots – body cavity, subcutaneous and intermuscular fat; while the belly was reduced to a squared, skinless and trimmed bacon piece and side ribs. The cut-out breakpoints used are described by the Canadian Meat Council (1986). Dissected yield was calculated as the sum of the lean in the picnic, butt, loin and ham plus the weight of the bacon piece and side ribs expressed as a proportion of cold side weight. Loin eye area at the 12^{th} rib was determined using image analysis of acetate tracings (see Figure 4). Fat color was measured using a Minolta CR-300 color meter on the subcutaneous fat of the front half of the loin (3^{rd} to 12^{th} rib), after the skin had been removed. Three color measurements along the dorsal surface of the loin were averaged.

Muscle pH and temperature was measured in the loin eye muscle (*longissimus thoracis,* LT) at 40 minutes post-stunning and ultimate pH was measured in the same muscle 2 days post-mortem. The anterior portion of the LT from the 3^{rd} to the 12^{th} rib was collected during cut out and meat quality determinations were conducted as described below.

1) **Drip loss.** A 20 mm thick chop, cut from the 12th rib end, was weighed onto an absorbent pad in a styrofoam retail display tray and over-wrapped with oxygen-permeable film. After storage for 48 h at 4°C, the chop was blotted dry on paper towel and re-weighed. Drip loss was expressed as the difference in initial and final weights as a proportion of initial weight.

2) **Subjective color and structure scores.** The muscle sample was held overnight at 1°C and then trimmed of all external fat and silverskin (connective tissue, fascia). After a 20 minute bloom period, subjective color and structure scores were assigned by experienced raters, according to the Agriculture Canada Pork Quality Standards (Agriculture Canada, 1984):

Color	Structure
1 = Extremely pale	1 = Extremely soft, exudative
2 = Slightly pale	2 = Slightly soft, exudative
3 = Normal	3 = Normal
4 = Slightly dark	4 = Slightly firm, dry
5 = Extremely dark	5 = Extremely firm, dry

3) **Objective color.** A second chop of 35 mm thickness was fabricated from the 11th rib end of the LT, and the fresh surface was allowed to bloom for 15 minutes prior to measuring color using a Minolta CR-300 color meter (see Figure 5).

4) **Marbling score.** Marbling is the intramuscular fat deposits or specks of fat within the muscle (see Figure 7). A marbling score was assessed by an experienced rater, on the same chop on which color was measured using the following scale:

100 = devoid

200 = practically devoid

300 = traces

400 = slight

500 = small

600 = modest

700 = moderate

800 = slightly abundant

900 = moderately abundant

1000 = abundant

1100 = very abundant

Marbling was recorded in 10% increments, e.g. 530 represents 30% of the distance between small^0 and modest^0. Pictorial standards representing the minimum level of marbling for each category were used as benchmarks during the assessment.

5) **Shear value.** The second chop was then cooked on a grill (Garland grill model ED30B, Condon Barr Food Equipment Ltd., Edmonton, AB) to an internal temperature of 40 °C, turned, and cooked to a final temperature of 72 °C. Further cooking was arrested by cooling the chop in an ice bath. The chop was held overnight at 4 °C and then two cores of 19 mm diameter were removed parallel to the muscle fibers. The cores were sheared at right angles to the fibers in a Warner-Bratzler shear cell (see Figure 6) and the maximum force required to shear the cores was recorded using an Instron Model 4301 Materials Testing System (Burlington, ON).

6) **Proximate analyses.** The remainder of the LT was ground and analyzed for moisture, fat and protein. Moisture was determined gravimetrically by drying at 102 °C for 24 h. Petroleum ether fat extractions were conducted on the resultant dried product using a Tecator Soxtec Extraction System (Tecator, AB, Hoganas, Sweden). The dried

product was also used to determine protein content using a Leco FP-2000 nitrogen analyzer (Leco Instruments Ltd., Mississauga, ON).

7) **Soluble protein.** A sub-sample of the fresh ground product was frozen and stored at –25 °C for subsequent determination of soluble protein according to the method of Barton-Gade (1984), except that the result was expressed as a proportion of soluble protein to lean muscle instead of optical density (Murray *et al.* 1989).

Sensory panel evaluations

After the cut out a six inch portion of the loin posterior to the 12th rib (*longissimus thoracis et lumborum)* was collected, multivaced, frozen and held at – 25 °C for subsequent sensory panel evaluation.

Roasts were removed from the freezer and stored at 4°C for 48 h to thaw. Roasts were placed on a small broiling pan, thermocouples inserted into the geometric centre and then roasted in a Baxter Rack Oven (Model Advantage 1B). Roasts were removed from the oven at an internal temperature of 72°C. Four one half inch samples were sliced (Rival Meat Slicer, Model 602) from the middle of each roast and four ½ inch cubes were cut from the middle of each slice. Each panelist received two adjacent cubes from a slice for their evaluation.

The panel consisted of 5 to 7 trained members, screened and trained according to American Meat Science Association (1995) guidelines. Sensory attributes were scored on 15 cm unstructured line scales with each end point tagged with a descriptor as follows:

Sensory attribute	0 Endpoint	15 Endpoint
Softness	Soft	Hard
Initial tenderness	No force (tender)	Extreme force (tough)
Juiciness	Not juicy	Extremely juicy
Flavor intensity	None	Extreme
Off flavors	No off flavors	Strong off flavors
Chewiness	No force (tender)	Extreme force (tough)
Rate of breakdown	Fast	Slow
Mouth coating	None	Very much
Amount of perceptible connective tissue	None	Abundant

Softness evaluates the force required to compress the sample between the molar teeth. Initial tenderness evaluates the force required to chew the sample after three chews. Juiciness was evaluated after five chews as the amount of moisture released from the sample. Flavor intensity refers to the intensity of flavor present after eight chews. Off flavor intensity refers to the intensity of any flavor or aftertaste perceived as inappropriate to cooked pork. Chewiness is an assessment of the energy required to prepare the sample for swallowing, and is evaluated after nine chews. Rate of breakdown or number of chews is the assessment of the rate at which the sample disintegrates during the mastication process in preparation for swallowing. Mouth coating is the amount of oil/fat left on the mouth surfaces, while connective tissue refers to the amount of fibrous collagen matter remaining following mastication.

During panel sessions panelists were familiarized with selected internal references for softness and juiciness (Meilgaard *et al.* 1999). For mouth coating, panelists were presented with samples of lean back bacon, fatty side bacon and rendered pork fat which were anchored on the mouth coat scale by the panel as 1.6, 5.9 and 13.2 cm respectively. These references were presented and available to panelists at each session.

Statistical analyses

The live performance data was analyzed using the General Linear Models (GLM) procedure of the SAS Institute Inc. (1999), with $P<0.05$ used to indicate significance. Diet, sex and block (replication) were the main effects used in the model. There were no interactions between these effects and so they were dropped from the model. Pens were the experimental unit for average daily feed intake and feed efficiency, while the individual pig was the experimental unit for average daily gain.

Carcass and meat quality parameters were similarly analyzed using the GLM procedure with $P<0.05$ used as the significance level, but interactions between the main effects were retained in the model. Off-test weight was added to the model as a co-variate to analyze warm carcass yield percentage; and carcass weight was used as a co-variate to analyze carcass traits including HGP measurements, loin eye area and cut out data. Fat hardness measurements were analyzed using HGP fat thickness as a co-variate because backfat thickness is known to affect fat quality (Wood *et al.* 1989).

Distribution of carcasses by treatment and sex.

Energy source	Protein source	Barrows	Gilts	Total
Wheat	Soy	12	12	24
	Peas	11	12	23
	Peacan	11	11	22
	Total	*34*	*35*	*69*
Corn	Soy-peas	11	12	23
	Soy	11	11	22
	Soy-can	12	12	24
	Total	*34*	*35*	*69*

Results and Discussion

Diets

As separate groups the wheat diets and corn diets (Appendixes C and D) were formulated to be isocaloric and isolysine within each group. Laboratory analyses (Appendixes A and B) confirmed that protein and amino acids met or exceeded the calculated levels required for the experiment.

Wheat based diets

Feed intake on the wheat-peas diet (Table 1) was significantly higher ($P<0.05$) than on the wheat-soy and wheat-peacan diets throughout the experiment resulting in significantly higher weight gains even though the feed conversions for the three treatments were not different from one another. Pigs from the wheat-peacan diet performed as well as those on the soybean diet in all aspects. This is in agreement with results of previous experiments (Jaikaran and Aherne, 1998) in which hulless barley was used instead of wheat as the cereal base with soybean meal or peacan meal supplementation of market hog diets. Feed efficiency on wheat based diets was not different among treatments. Overall feed conversion on the wheat based diets was similar ($P=0.11$) for all three treatments.

All carcass traits related to yield and composition were similar among pigs fed the wheat based diets, regardless of source of protein supplementation. Pre-slaughter live weight shrinkage and warm carcass yields (dressing percentage) were unaffected by dietary treatment (Table 2). Castell and Clipleff (1993) observed lower carcass yields for pigs fed barley based diets supplemented with canola meal compared to those supplemented with soybean meal. Combinations of canola meal and pea screenings gave results similar to pigs fed soybean meal which is in agreement with our findings.

The Hennessy Grading Probe (HGP) measures fat and muscle thickness at the designated grade site and the measurements are used to predict carcass lean yield. In most provinces, the probe estimated yield and carcass weight are applied to a yield class by weight class grid to give a carcass index which is used for payment purposes between producer and packer. At least one province is now using only the muscle thickness measurement to determine a settlement price, because some elements of the pork industry feel there is insufficient emphasize placed on muscling and loin eye size. There were no statistically significant differences in either fat thickness or muscle thickness measurements (Table 3). Carcasses from pigs fed wheat based diets supplemented with peas or peacan meal indexed the same as those supplemented with soybean meal. Actual carcass lean yields established by cut out were also similar across the three diets.

Proportion of loin in the carcass and loin eye area are important traits, because of the high market value of the loin cut. Larger loin eyes are particularly valued for export markets. Source of protein supplementation had no affect on loin eye area measured at the 12th rib

(Table 3), nor were there any differences in proportional sizes of individual cuts (Table 4). Similarly, Castell and Clipleff (1993) found no significant differences in loin eye area when pigs were fed diets supplemented with combinations of canola meal and peas compared to supplementation with soybean meal.

Each of the four lean cuts (picnic, butt, loin and ham) were dissected to lean, bone and the three fat depots: body cavity fat, subcutaneous fat and skin, and intermuscular or seam fat. The sum of the three fat depots equals total dissectable fat. The relative proportions of lean, bone and total dissectable fat in the four lean cuts were not different among the three wheat based diets (Table 5). There were very small and inconsequential differences in the distribution of fat among the fat depots of carcasses from pigs fed peas compared to carcasses from pigs fed soybean meal. Pea fed pigs had slightly less body cavity fat (0.53% vs. 0.62%, P=0.002) and seam fat (4.58% vs. 4.95%, P=0.04) compared to pigs fed soybean meal, but the content of subcutaneous fat (P=0.71) and total dissectable fat (P=0.97) was not significantly different.

Quality of the subcutaneous fat of hog carcasses is largely a function of the degree of saturation of the fatty acids – the higher the level of polyunsaturated fatty acids, the softer the fat (Madsen *et al.* 1992). The amount of fat and the ratio of unsaturated to saturated fat in the diet has a major impact on quality of the carcass fat (Wood *et al.* 1989). If the pork carcass fat is too soft it creates difficulties in the processing of cuts, makes the bellies undesirable for production of bacon, and can be problematic in the manufacture of sausage (National Pork Producers Council, 2000; Sather *et al.* 1995). In this experiment, fat hardness was determined using the Bristol fat hardness meter. The wheat based diet supplemented with peacan meal produced carcasses with softer fat compared to the diet supplemented with soybean meal ($P<0.05$) and tended to produce softer fat compared to the diet supplemented with peas ($P=0.08$) (Table 6). The pea supplemented diet produced fat similar in hardness to that produced by the SBM supplemented diet. Three of 22, or 14% of the carcasses from pigs fed peacan meal had very soft, undesirable fat, while there were no incidences of very soft fat in the carcasses from pigs fed soybean meal or peas. A portion of the difference in fat quality may be explained by the higher levels of canola oil added to the wheat-peacan diet in order to make the wheat based diets isocaloric. No differences were found among dietary treatments in instrumentally measured color of the subcutaneous fat of the loin (Table 6).

Muscle color and structural properties are highly variable and important attributes of pork meat. Pork meat can range from pale, soft and exudative (PSE) through normal to dark, firm and dry (DFD) (Agriculture Canada, 1984). Export markets particularly discriminate against pale and/or soft, exudative pork. Capacity of the meat to hold or to bind water has implications for shrink losses during chilling and cooking, and important implications for further processing of pork products, i.e. cure uptake and retention. During the conversion of muscle to meat, the rate and extent of biochemical activity in the pork musculature following slaughter has a direct impact on the color and structural characteristics of the pork. A rapid rate of glycolysis and therefore, a rapid pH decline in the first hour post-mortem, such that the pH falls below 6.0 within that time frame and while the temperature of the muscle is still high, generally results in the production of PSE pork

(Murray, 1995). On the other hand, if muscle glycogen reserves are low at time of slaughter, then the pH of the muscle may never fall below 6.0 and DFD pork is the result. In this experiment, muscle pH was monitored at 40 minutes post-stunning to determine the rate of glycolysis, and measured again 48 h post-mortem to determine the extent of glycolysis. No differences were found in either initial or ultimate pH mean values among treatments (Table 7), and the mean values were all within the range associated with pork of normal color and structure. No differences were detected in instrumentally measured color of the lean of pork chops among the wheat based diets (Table 7), nor were there any statistically significant differences in subjective assessment of color or structure of the pork loins from which the chops were derived. Measures of water holding properties, including drip loss from a chop and soluble protein determinations of LT muscle, similarly did not differ among the three wheat based diets (Table 7).

Shear values are a widely used objective measure of tenderness. No differences were found in shear values of grilled pork chops from pigs fed these diets (Table 7). Castell and Clipleff (1993) also found no significant differences in shear values of broiled chops from barrows fed barley based diets supplemented with soybean meal, canola meal, ground pea screenings or two combinations of canola meal and peas.

Increased concerns regarding animal fat in the diet have consumers demanding minimal visual fat, yet marbling fat has long been associated with eating quality. Although marbling fat likely accounts for only a small portion of the variation found in any one palatability trait, it is still positively associated with juiciness, flavor, and overall palatability (Jeremiah, 1998; DeVol *et al.*, 1988; Hodgson *et al.*, 1991) . Pork with higher levels of marbling would be expected to produce meat which is more desirable and less variable in quality compared to pork with low levels of marbling. Marbling scores assigned to loins from pigs fed the wheat-pea diet were lower (P=0.004) than for loins from pigs fed the wheat-soy diet (Table 7). However, the magnitude of the difference in marbling score of one-half a marbling grade would not be expected to impact palatability characteristics to any extent. Chemical fat extractions of the loin muscle showed that the intramuscular fat content of loins derived from pigs fed both the wheat-pea diet (P=0.005) and the wheat-peacan diet (P=0.047) was lower than that from pigs fed the soy supplemented diet (Table 8). In contrast to our findings, Castell and Clipleff (1993) observed an increase in marbling of the loin muscle when ground pea screenings were included in barley based diets of growing-finishing barrows. However, Madsen *et al.* (1990) found no difference in intramuscular fat content of either the loin or the inside round (*semimembranosus)* of pigs fed diets in which all of the soybean meal had been replaced with peas or rapeseed cake. Dransfield *et al.* (1985) found no difference in intramuscular fat levels of meat from pigs fed barley based diets supplemented with soybean meal or different levels of rapeseed meal.

As would be expected, the higher fat content of the loins from the soy fed pigs was associated with slightly lower moisture content. LT muscle samples from pigs fed peas had a slightly higher (P<0.05) content of protein compared to pigs fed soybean meal or peacan meal (22.4% compared to 22.1% and 22.0%, respectively).

There were no differences in any of the sensory attributes assessed by the trained panel, including tenderness, juiciness or flavor intensity (Table 9). Similarly, Castell and Clipleff (1993) found only minor and non-significant differences in sensory attributes of cooked lean from barrows fed soybean meal, canola meal, or pea screenings.

Corn based diets

Feed intake on the corn-soy diet (Table 10) was significantly ($P<0.05$) higher than on the corn-soy/peas and corn-soy/canola diets throughout the trial resulting in higher daily gains. The soy/peas diet performed similar to the soy/canola diet in all respects. Overall feed conversion on the corn based diets was similar ($P=0.11$) for all treatments.

Supplementation of corn based diets with a combination of soybean meal and peas or soybean meal and canola meal had no effect on live weight shrinkage or warm carcass yields expressed as a percentage of final live (shrunk) weight compared to supplementation with soybean meal alone (Table 11). Although the pigs fed the corn-soy-peas diet or the corn-soy-canola diet had less fat at the grade site compared to pigs fed the corn-soy diet, their muscle thickness measurements were also lower so that average carcass index was the same across the three diets (Table 12). There were no statistically significant differences attributable to diet in cut out lean yield, or in relative proportions of lean, bone and fat in the four lean cuts (Table 14). Similarly no differences were apparent in relative size of individual cuts expressed as a percentage of cold side weight (Table 13), or in loin eye area (Table 12). These results are in agreement with Siljander-Rasi *et al.* (1996) who observed no difference in lean content of the carcass or eye muscle area when 33, 66 or 100% of soybean meal in barley based diets was replaced with low-glucosinolate rapeseed meal.

Carcasses from pigs fed the soy/canola supplemented diet had softer fat ($P<0.05$) compared to carcasses from pigs fed the other two corn based diets (Table 15). Six of 24 carcasses (25%) from pigs fed soybean and canola meals had very soft, undesirable fat. Two carcasses from pigs fed each of the other corn based diets had very soft fat. The pigs fed the soy/canola supplemented diet also had fat which was more yellow ($P<0.05$) than pigs fed the soy supplemented diet (hue angle = 50.1 and 46.1, respectively) and which tended to be more yellow ($P=0.08$) than fat of pigs fed the soy/peas supplemented diet (hue angle = 49.4). The increased yellowness did not stand out visually and therefore would be of limited practical concern. Madsen *et al.* (1992), in reviewing Danish results in the previous 40 years, concluded that rapeseed should be included in swine growing rations in limited amounts to avoid "high occurrences of unacceptable soft backfat", and in a 1990 study (Madsen *et al.* 1990) found diets containing greater than 4% rapeseed resulted in an unacceptable increase in iodine value of the backfat (higher iodine values indicating higher levels of unsaturated fatty acids). Siljander-Rasi *et al.* (1996) found no difference in backfat firmness assessed manually at five locations on the carcass even with substitution of soybean meal with rapeseed meal up to the 100% level, which represented 22.6% of the grower diet and 14.9% of the finisher diet. The variation in results reported by these authors and the limitation suggested by Madsen are explained by the fat content of the dietary supplements fed. Madsen *et al.* incorporated rapeseed having a fat content of 41.4% into the rations while the rapeseed meal used by Siljander-Rasi *et al.* had an ether extract of 5.3% (6.0% dry matter basis). In a survey to determine the variation in composition of commercial canola meal from different Western Canadian crushing plants, Bell and Keith (1991) found the average ether extract to be 3.92% (dry matter basis) with a range of 3.85% to 4.04%. The levels of canola meal in our corn-soy/canola diets were 11.5% and 9.0 % in the grower and finisher ration, respectively, well below the levels used by Siljander-Rasi *et al.* The difference in carcass fat quality in our trial may be explained by the addition of canola oil to the soy/canola supplemented diet at 1.8% in the grower ration and 1.4% in the finisher ration compared to lower levels in the soy/pea supplemented diet (0.7% and 0.6%, respectively) and no added fat in the SBM supplemented diet, in order to make the diets isocaloric.

There were no significant differences in any of the measured pork quality characteristics of rib eye muscle from pigs fed the corn based diets with the exception of initial pH and shear value (Table 16). Initial pH, measured at 40 minutes post-stunning, was higher in the *longissimus* muscle of pigs fed the soy/canola supplemented diet compared to that of pigs fed the soy/peas diet. Initial muscle pH of pigs fed the soybean meal supplemented diet was intermediate between the other two. However, average initial pH for all three dietary treatments were in the normal expected range (Murray, 1995), and by 48 h the ultimate pH was similar across treatments. No incidences of pale or soft, exudative pork were noted for any of the muscle samples from pigs fed the corn based diets.

Additionally, instrumentally measured color and measurements of water holding properties of the meat did not differ between dietary treatments. Pork chops from pigs fed soybean meal and peas had significantly higher shear values (tougher) than pigs fed soybean meal and canola (5.715 and 5.074 kg, respectively). However, the magnitude of the difference was less than the threshold consumers would be expected to detect (L. Jeremiah, personal communication), and trained panelists failed to detect any difference in initial tenderness or chewiness of loin samples (Table 18). Dietary treatment also had no effect on any of the other sensory attributes evaluated by the panel. Dransfield *et al.* (1985) also found no adverse effects on eating quality of roasted pork loins when rapeseed meal was included in pig diets up to 330 kg $tonne^{-1}$. Siljander-Rasi *et al.* (1996) similarly found no difference in taste, tenderness or juiciness of pork loins from pigs fed soybean meal or diets in which 33, 66 or 100% of the SBM was replaced with rapeseed meal.

While the moisture and intramuscular fat content of loin eye muscle was similar regardless of source of protein supplementation (Table 17), the protein content of the longissimus from pigs fed the corn-soybean meal diet was slightly higher ($P<0.05$) than from pigs fed the other two corn based diets (22.4% compared to 22.1%).

Conclusion and Implications

The results of this study clearly demonstrate that swine grower and finisher diets incorporating peas and/or canola meal produce carcasses of similar yield and composition, pork meat of equal quality and similar sensory attributes compared to diets supplemented with soybean meal alone. When it is necessary to add supplemental fat to diets containing corn and canola meal, it may be wise to use tallow so as to avoid incorporating too high a level of polyunsaturated fatty acids into the diet and risking the production of carcasses with poor quality fat. Alternatively, research conducted at the Lacombe Research Centre indicates adding low levels (0.25 – 0.5%) of conjugated linoleic acid can counteract fat softening effects of canola oil, and potentially permit higher levels of canola oil to be fed without detriment to fat quality.

Local and export markets for Canadian pork can be assured that pork from pigs fed peas and/or canola meal is of equivalent quality to pigs fed soybean meal. This new data, pertaining to pigs of modern genetics and today's heavier slaughter weights, will be valuable to feed companies for developing export markets for peas and canola meal for animal feed uses as well as for strengthening sales to domestic buyers of these feed ingredients. Increased use of peas and canola meal for supplementing swine diets would reduce the reliance on imported soybean meal while establishing stronger markets for pea and canola producers.

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Wheat based diets

Table 1. Effect of source of protein supplementation of wheat based diets on live performance of pigs during the late growing (50 to 75 kg) and finishing periods (75 to 105 kg).

Performance Parameter	Protein source		
	Soy	Peas	Peacan
ADFI, g			
Growing phase[1]	2100*ab*	2265*b*	1911*a*
Finishing phase[2]	2617	2674	2392
Overall	2477*ab*	2555*b*	2243*a*
F:G			
Growing phase	2.48	2.39	2.35
Finishing phase	2.85	2.98	2.73
Overall	2.71	2.66	2.60
ADG, g			
Growing phase	851*a*	947*b*	827*a*
Finishing phase	947	907	892
Overall	912	960	871

ab Least square means with different letters are significantly different ($P<0.05$)

[1] First four weeks on test

[2] Weeks five through seven on test

Table 2. Effect of source of protein supplementation of wheat based diets on live weight shrinkage and carcass yields.

Trait	Protein source		
	Soy	Peas	Peacan
Weight off test, kg	107.8	110.4	106.6
Final live weight at abattoir (shrunk), kg	103.0	105.4	101.9
Pre-slaughter live weight shrinkage, %	4.51	4.52	4.42
Warm carcass weight, kg	85.6	88.0	84.9
Warm carcass yield[1], %	83.1	83.4	83.4

[1] Warm carcass weight * 100/Final live weight at abattoir, adjusted to same weight off test (108.3 kg)

Table 3. Effect of source of protein supplementation of wheat based diets on carcass characteristics of growing-finishing pigs.

Trait	Protein source		
	Soy	Peas	Peacan
HGP[1] fat thickness[2], mm	17.8	18.2	16.9
HGP muscle thickness[2], mm	48.8	49.7	50.5
Alberta index	108	108	107
Cut out lean yield[2], %	58.9	58.9	59.6
Loin eye area[2], sq. cm.	40.3	41.3	40.8

[1] HGP = Hennessy Grading Probe
[2] Adjusted to same carcass weight (86.2 kg)

Table 4. Effect of source of protein supplementation of wheat based diets on distribution of carcass primal or sub-primal cuts.

Cut[1]	Protein source		
	Soy	Peas	Peacan
Picnic	9.87	9.99	9.96
Butt	10.97	10.69	10.95
Loin	26.90	27.06	27.18
Ham	26.44	26.29	26.55
Belly	17.78	17.79	17.36

[1] Rough cut as proportion (%) of side, adjusted to same carcass weight (86.2 kg)

Table 5. Effect of source of protein supplementation of wheat based diets on distribution of carcass tissues in the four lean cuts[1].

Tissue[2]	Protein source		
	Soy	Peas	Peacan
Lean, %	62.70	62.69	63.38
Bone, %	8.86	8.92	8.97
Total dissectable fat[3], %	28.44	28.39	27.65
Fat distribution:			
Body cavity fat, %	0.62*b*	0.53*a*	0.58*ab*
Skin & subcutaneous fat, %	22.87	23.29	22.36
Intermuscular fat, %	4.95*b*	4.58*a*	4.71*ab*

ab Least square means with different letters are significantly different ($P<0.05$)
[1] Four lean cuts: picnic + butt + loin + ham
[2] Adjusted to same carcass weight (86.2 kg)
[3] Total (readily) dissectable fat = body cavity fat + subcutaneous fat + intermuscular fat

Table 6. Effect of source of protein supplementation of wheat based diets on subcutaneous fat hardness and color.

Trait	Protein source		
	Soy	Peas	Peacan
Fat hardness[1] @ 1 °C	787*b*	769*ab*	719*a*
L* (Brightness)	77.84	77.65	77.50
C* (Chroma)	5.96	6.03	5.83
Hue angle	44.79	45.25	46.00

ab Least square means with different letters are significantly different ($P<0.05$)
[1] Fat hardness measured using a Bristol fat hardness meter, adjusted to same HGP fat thickness

Table 7. Effect of source of protein supplementation of wheat based diets on meat quality characteristics of the rib eye muscle (*longissimus thoracis*).

Trait	Protein source		
	Soy	Peas	Peacan
Initial pH	6.18	6.21	6.17
Ultimate pH	5.55	5.57	5.57
L* (brightness)	53.75	52.91	53.28
C* (chroma, saturation)	10.28	9.54	9.84
Hue angle	30.89	30.79	31.30
Marbling score	412*b*	363*a*	381*ab*
Drip loss from chop, %	6.43	6.06	5.99
Soluble protein, %	19.1	20.0	20.2
Shear value, kg	5.043	5.126	5.151

ab Least square means with different letters are significantly different ($P<0.05$)

Table 8. Effect of source of protein supplementation of wheat based diets on composition of the rib eye muscle (*longissimus thoracis*).

Trait	Protein source		
	Soy	Peas	Peacan
Moisture, %	74.96*a*	75.13*ab*	75.31*b*
Ether extractable Fat, %	1.84*b*	1.47*a*	1.58*a*
Protein, %	22.13*a*	22.40*b*	22.05*a*

ab Least square means with different letters are significantly different (P<0.05)

Table 9. Effect of source of protein supplementation of wheat based diets on sensory attributes of pork loins.

Attribute[1]	Protein source		
	Soy	Peas	Peacan
Softness	8.3	8.1	8.2
Initial tenderness	8.1	8.0	8.0
Juiciness	5.1	5.1	5.2
Flavor intensity	4.2	4.1	4.3
Off flavors	0.6	0.5	0.5
Chewiness	7.3	7.3	7.5
Rate of breakdown	7.5	7.4	7.5
Mouth coating	1.0	1.1	1.1
Connective tissue	1.2	1.1	1.3

[1] Sensory attributes were scored on 15 cm unstructured line scales (0 = soft, tender, not juicy, no pork flavor, no off flavors, fast rate of breakdown, no mouth coating, no connective tissue; 15 = hard, tough, extremely juicy, full pork flavor, strong off flavors, slow rate of breakdown, abundant mouth coating, abundant connective tissue)

Corn based diets

Table 10. Effect of source of protein supplementation of corn based diets on live performance of pigs during the late growing (50 to 75 kg) and finishing periods (75 to 105 kg).

Performance Parameter	Protein source		
	Soy-peas	Soy	Soy-canola
ADFI, g			
Growing phase[1]	2144*a*	2378*b*	2148*a*
Finishing phase[2]	2465*ab*	2931*b*	2476*a*
Overall	2447*ab*	2706*b*	2372*a*
F:G			
Growing phase	2.45	2.55	2.58
Finishing phase	2.72	2.82	2.69
Overall	2.69	2.78	2.71
ADG, g			
Growing phase	880	932	877
Finishing phase	970	1049	964
Overall	911	975	920

ab Least square means with different letters are significantly different ($P<0.05$)
[1] First four weeks on test
[2] Weeks five through seven on test

Table 11. Effect of source of protein supplementation of corn based diets on live weight shrinkage and carcass yields.

Trait	Protein source		
	Soy-peas	Soy	Soy-canola
Weight off test, kg	107.8	108.5	108.6
Final live weight at abattoir (shrunk), kg	103.7	104.3	104.3
Pre-slaughter live weight shrinkage, %	3.81	3.86	3.92
Warm carcass weight, kg	86.2	86.9	87.2
Warm carcass yield[1], %	83.0	83.3	83.5

[1] Warm carcass weight * 100/Final live weight at abattoir, adjusted to same weight off test (108.2 kg)

Table 12. Effect of source of protein supplementation of corn based diets on carcass characteristics of growing-finishing pigs.

Trait	Protein source		
	Soy-peas	Soy	Soy-canola
HGP[1] fat thickness[2], mm	16.9*a*	19.1*b*	16.5*a*
HGP muscle thickness[2], mm	49.3*ab*	51.3*b*	48.4*a*
Alberta index	107	107	107
Cut out lean yield[2], %	59.1	57.7	58.9
Loin eye area[2], sq. cm.	41.3	41.4	39.6

ab Least square means with different letters are significantly different ($P<0.05$)
[1] HGP = Hennessy Grading Probe
[2] Adjusted to same carcass weight (86.6 kg)

Table 13. Effect of source of protein supplementation of corn based diets on distribution of carcass primal or sub-primal cuts.

Cut[1]	Protein source		
	Soy-peas	Soy	Soy-canola
Picnic	9.78	9.98	9.72
Butt	10.66	10.90	10.91
Loin	27.25	27.07	27.13
Ham	26.47	26.42	26.65
Belly	17.69	17.48	17.34

[1] Rough cut as proportion (%) of side, adjusted to same carcass weight (86.6 kg)

Table 14. Effect of source of protein supplementation of corn based diets on distribution of carcass tissues in the four lean cuts[1].

Tissue[2]	Protein source		
	Soy-peas	Soy	Soy-canola
Lean, %	63.26	61.33	63.23
Bone, %	9.07	9.06	9.22
Total dissectable fat[3], %	27.67	29.61	27.55
Fat distribution:			
Body cavity fat, %	0.59	0.57	0.58
Skin & subcutaneous fat, %	22.51	24.40	22.54
Intermuscular fat, %	4.57	4.64	4.43

[1] Four lean cutrs: picnic + butt + loin + ham
[2] Adjusted to same carcass weight (86.6 kg)
[3] Total (readily) dissectable fat = body cavity fat + subcutaneous fat + intermuscular fat

Table 15. Effect of source of protein supplementation of corn based diets on subcutaneous fat hardness and color.

Trait	Protein source		
	Soy-peas	Soy	Soy-canola
Fat hardness[1] @ 1 °C	733*b*	749*b*	680*a*
L* (Brightness)	77.69	77.50	77.49
C* (Chroma)	6.45	5.91	5.97
Hue angle	49.38*ab*	46.06*a*	50.12*b*

ab Least square means with different letters are significantly different (P<0.05)
[1] Fat hardness measured using a Bristol fat hardness meter

Table 16. Effect of source of protein supplementation of corn based diets on meat quality characteristics of the rib eye muscle (*longissimus thoracis*).

Trait	Protein source		
	Soy-peas	Soy	Soy-canola
Initial pH	6.19*a*	6.21*ab*	6.29*b*
Ultimate pH	5.57	5.58	5.59
L* (brightness)	52.25	52.85	51.99
C* (chroma, saturation)	9.60	9.50	9.31
Hue angle	29.94	29.90	29.32
Marbling score	398	373	390
Drip loss from chop, %	5.36	5.54	4.91
Soluble protein, %	19.41	20.00	20.18
Shear value, kg	5.715*b*	5.118*ab*	5.074*a*

ab Least square means with different letters are significantly different (P<0.05)

Table 17. Effect of source of protein supplementation of corn based diets on composition of the rib eye muscle (*longissimus thoracis*).

Trait	Protein source		
	Soy-peas	Soy	Soy-canola
Moisture, %	75.15	75.03	75.26
Ether extractable Fat, %	1.75	1.54	1.66
Protein, %	22.08*a*	22.37*b*	22.08*a*

ab Least square means with different letters are significantly different (P<0.05)

Table 18. Effect of source of protein supplementation of corn based diets on sensory attributes of pork loins.

Attribute[1]	Protein source		
	Soy-peas	Soy	Soy-canola
Softness	8.3	8.3	8.1
Initial tenderness (3 chews)	8.2	8.1	7.9
Juiciness (5 chews)	5.1	5.0	5.2
Flavor intensity (8 chews)	4.1	4.2	4.4
Off flavors	0.6	0.5	0.5
Chewiness (9 chews)	7.5	7.5	7.2
Rate of breakdown (# of chews)	7.7	7.6	7.3
Mouth coating	1.1	0.8	1.0
Connective tissue	1.2	1.2	1.1

[1] Sensory attributes were scored on 15 cm unstructured line scales (0 = soft, tender, not juicy, no pork flavor, no off flavors, fast rate of breakdown, no mouth coating, no connective tissue; 15 = hard, tough, extremely juicy, full pork flavor, strong off flavors, slow rate of breakdown, abundant mouth coating, abundant connective tissue)

Figure 1. Measuring thickness of backfat and muscle at the 3rd/4th last rib using the Hennessy Grading Probe.

Figure 2. Measuring fat firmness with the Bristol Fat Hardness Meter.

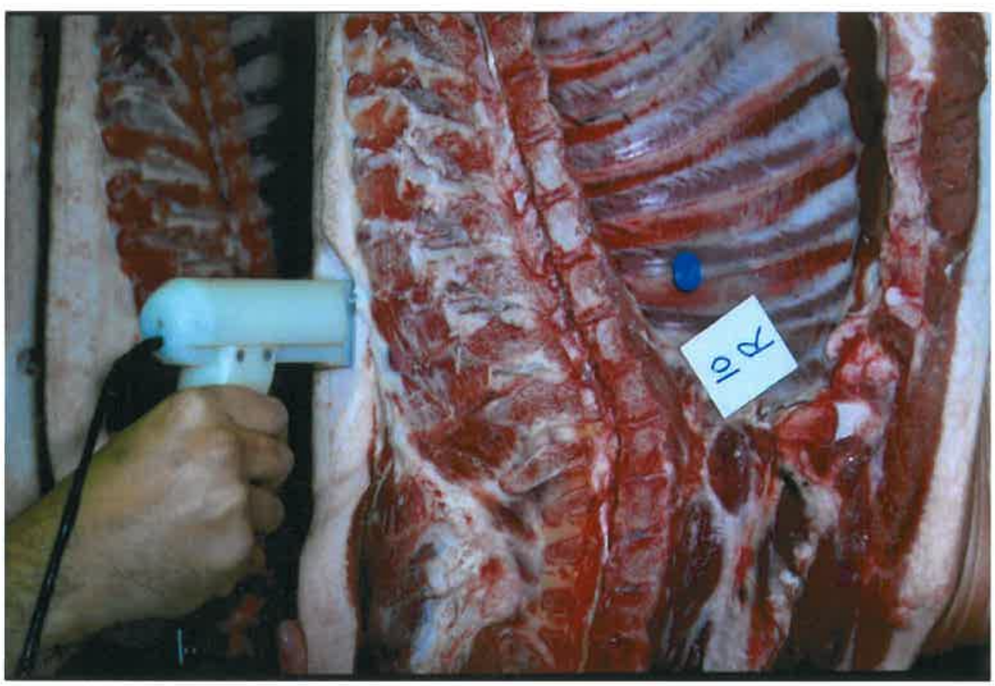


Figure 3. Principle cuts of a hog carcass.

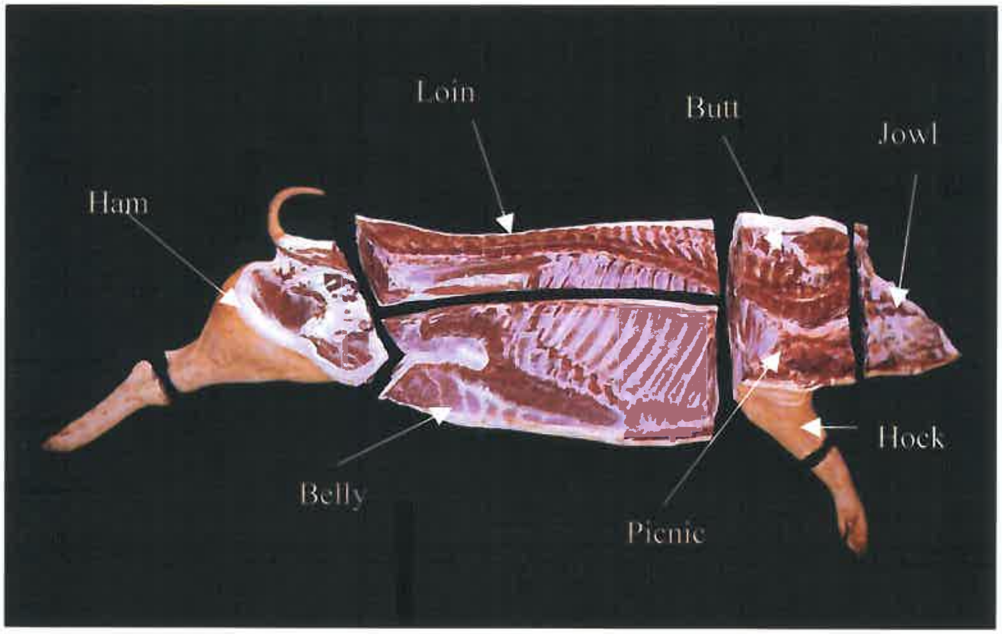


Photo courtesy National Livestock and Meat Board, Chicago, Ill. (Meat Identification Slides)

Figure 4. Cross-section of the loin at the 12th rib. Loin eye area was measured at this site.

Figure 5. Measuring meat color using the Minolta CR-300 reflectance meter

Figure 6. Warner-Bratzler shear cell attached to a Instron Materials Testing System. A core of cooked meat is placed in the triangular shaped blade, which is then pulled upwards shearing through the core sample.

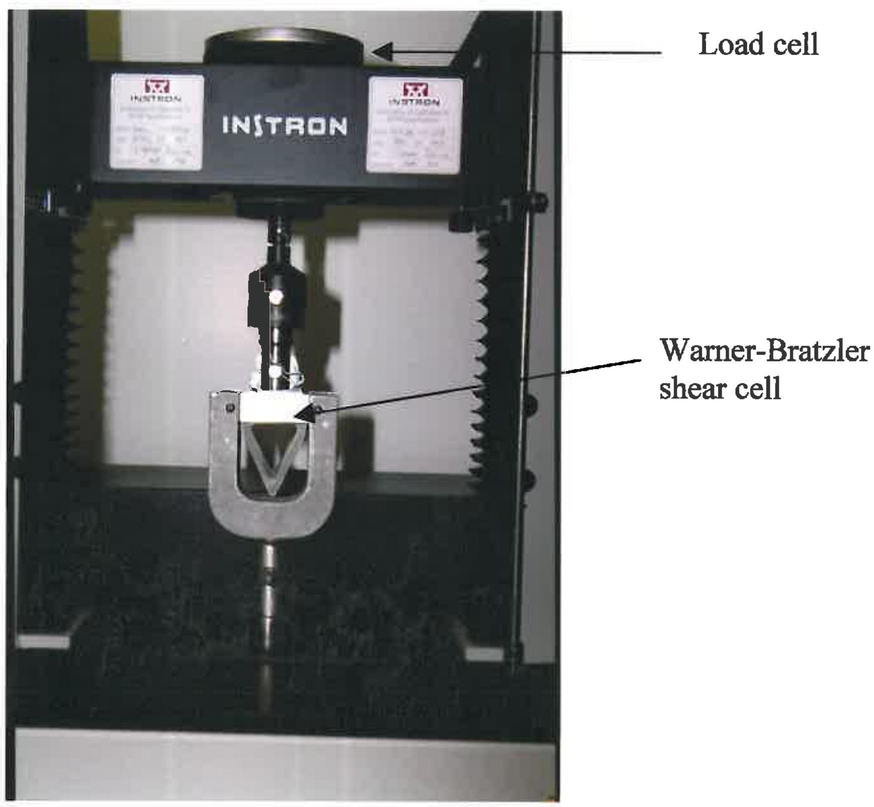
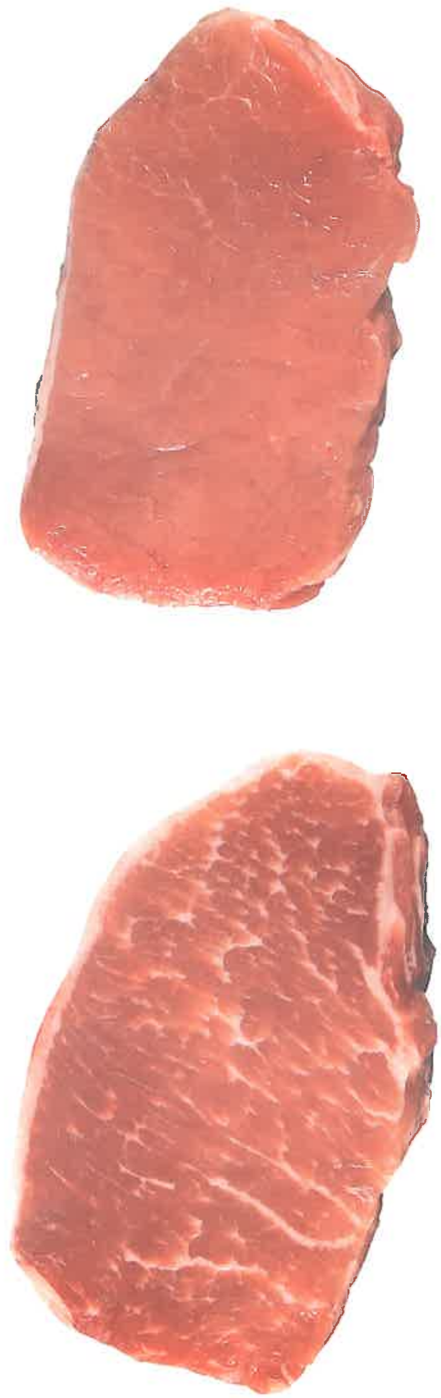


Figure 7. Examples of different levels of marbling.



Photos courtesy of National Pork Producers Council, Des Moines, IA
pork® Official Color and Marbling Standards

Appendix A

Laboratory Analyses of Experimental Grower Diets Fed to 50 – 80 kg Pigs (%, Dry matter basis)

Energy source	Wheat			Corn		
Protein supplement	**Soy**	**Peas**	**Peacan**	**Soy-peas**	**Soy**	**Soy-canola**
Protein	20.0	18.5	19.3	18.6	18.9	18.2
Calcium	0.85	0.76	0.82	0.67	0.90	0.89
Phosphorus	0.49	0.51	0.56	0.51	0.57	0.66
Lysine	1.01	0.97	0.98	1.06	1.08	1.01
Methionine	0.27	0.28	0.28	0.30	0.27	0.31
Cystine	0.34	0.30	0.35	0.31	0.29	0.31
Threonine	0.67	0.60	0.67	0.76	0.75	0.74
Tryptophan	0.34	0.31	0.28	0.27	0.29	0.31
Isoleucine	0.77	0.69	0.72	0.84	0.81	0.76
Leucine	1.37	1.22	1.27	1.75	1.77	1.67
Valine	0.91	0.81	0.89	0.96	0.93	0.92

Appendix B

Laboratory Analyses of Experimental Finisher Diets Fed to 80 - 110 kg Pigs (%, Dry matter basis)

Energy source	Wheat			Corn		
Protein supplement	Soy	Peas	Peacan	Soy-peas	Soy	Soy-canola
Protein	16.8	16.1	17.2	16.4	18.1	16.3
Calcium	0.80	0.65	0.78	0.73	0.70	0.72
Phosphorus	0.47	0.43	0.47	0.48	0.50	0.51
Lysine	0.77	0.86	0.82	0.81	0.98	0.80
Methionine	0.24	0.21	0.25	0.24	0.25	0.25
Cystine	0.32	0.29	0.33	0.27	0.28	0.26
Threonine	0.54	0.59	0.60	0.64	0.68	0.65
Tryptophan	0.29	0.25	0.28	0.22	0.22	0.20
Isoleucine	0.64	0.65	0.65	0.68	0.67	0.67
Leucine	1.13	1.16	1.17	1.57	1.78	1.65
Valine	0.77	0.79	0.82	0.81	0.89	0.82

Appendix C

Feed Formulas for Grower Diets (50-80 kg liveweight)

Energy source	**Wheat**			**Corn**		
Protein supplement	**Soy**	**Peas**	**Peacan**	**Soy-peas**	**Soy**	**Soy-canola**
Wheat	711	429	501			
Barley	100	100	100			
Corn				627	768	727.4
Soy	150			135	200	115
Canola			115			115
Peas		425	230	200		
Lysine	2.00	0.25	1.00		1.20	1.60
Meth		0.60	0.20			
Limestone	12	12	11	10	10	10
Dical Phos	3	4	3	7	7	7
Salt	4	4	4	4	4	4
Oil (Canola)	8	15	25	7		18
VitMin	10	10	10	10	10	10
Total	1000	1000	1000	1000	1000	1000

Calculated analysis (as fed basis)

DE kcal	3357	3341	3337	3444	3449	3445
Protein %	16.64	14.86	15.96	15.48	15.67	15.55
Ca %	0.6	0.60	0.6	0.59	0.60	0.64
Av P %	0.20	0.20	0.19	0.21	0.21	0.21
Tot Lys %	0.87	0.88	0.89	0.88	0.88	0.89
TID Lys %	0.78	0.77	0.76	0.76	0.77	0.76
TID Met%	0.21	0.21	0.22	0.21	0.24	0.25
TID Thr %	0.47	0.42	0.46	0.49	0.49	0.49
TID Tryp%	0.18	0.12	0.14	0.14	0.15	0.14

NB: TID means true ileal digestible, referring to amino acids.

Appendix D

Feed formulas for Finisher Diets (80 - 110 kg)

Energy source	**Wheat**			**Corn**		
Protein supplement	**Soy**	**Peas**	**Peacan**	**Soy-peas**	**Soy**	**Soy-canola**
Wheat	771	556	578			
Barley	100	100	100			
Corn				725	840	777
Soy	90			90	130	90
Canola			90			90
Peas		300	180	150		
Lysine	1.5		0.25		1.25	0.75
Meth		0.25				
Limestone	12	12	11	10	10	9
Dical Phos	2	2	2	5	5	5
Salt	4	4	4	4	4	4
Oil (canola)	10	16	25	6		14
VitMin	10	10	10	10	10	10
Total	1000	1000	1000	1000	1000	1000

Calculated analysis (as fed basis)

DE kcal	3353	3352	3352	3445	3446	3448
Protein %	14.55	13.80	14.89	13.21	13.07	13.90
Ca %	0.57	0.56	0.57	0.54	0.54	0.54
Av P %	0.18	0.17	0.17	0.16	0.16	0.16
Tot Lys %	0.68	0.71	0.73	0.69	0.70	0.71
TID Lys %	0.60	0.61	0.61	0.60	0.61	0.60
TID Met%	0.18	0.17	0.19	0.19	0.21	0.23
TID Thr %	0.39	0.38	0.42	0.41	0.40	0.43
TID Tryp%	0.15	0.12	0.13	0.11	0.12	0.12