4. INGREDIENTS

The science of nutrition, as it applies to diet formulation, involves essentially five steps, as outlined in chapter 5: define feeding objectives, establishment requirements needed to achieve the objectives, select ingredients, formulate diets and evaluate diets once made. This chapter focuses on ingredients and how they might be used in diets.

In recent years, swine nutritionists have made huge advances in defining the pig's nutrient requirements and further developments in this area are almost a certainty. Progress in defining the nutrient specifications of ingredients has been somewhat slower and now provides a serious challenge to commercial nutritionists. The precision with which we can define nutrients supplied to the animal appears to be considerably less than that with which we can define nutrients required by the pig. The two major challenges relate to nutrient variability and nutrient availability. Consequently, to consistently achieve the level of animal performance expected on an ongoing basis, and to do so at the lowest possible cost, nutritionists must address these two issues. Failure to do so will result in either excessive feed costs or variable animal performance or both!

Ingredient Versus Nutrient

Pig diets should be formulated primarily from the perspective of nutrients and less so on the basis of ingredients. Over many centuries of domestication, the pig has demonstrated a marvellous ability to perform successfully using a diverse array of ingredients; the pig is an omnivore, meaning it has the ability to utilize feedstuffs of animal or vegetable origin. The history of the pig is filled with examples of this culinary diversity.

Indeed, the future success of pork production probably rests, in part, on our ability to utilize many ingredients effectively in pig diets. In localized areas, or on a regional basis, successful pork producers seek out and utilize ingredients that are discounted for reasons that are often founded less on nutritive value than on tradition and personal preference. For those readers whose experience with feeding pigs is limited to using one or two grains (wheat, barley, corn) and one protein source (soybean meal), it would be a worthwhile exercise to study diets utilized in other parts of the world, where these ingredients represent less than half of the total diet, the remainder consisting of other crop (eg. lupins, peas, canola, tapioca) or animal (blood meal, meat and bone meal, feather meal) products.

Nutrient based diet formulation, or formulation on the basis of nutrients irrespective of source, is not new, but a surprisingly significant emphasis on ingredients remains in our culture. While corn and soybean meal may represent a standard against which other ingredients may be compared, and therefore give a level of comfort to pork producers due to experience and tradition, it is essential to recognize that equivalent performance can be achieved with many other ingredients.

Therefore, ingredients should be selected on the basis of composition, cost, availability and palatability. There is nothing magical about one ingredient versus another, provided resulting diets are properly formulated.

Composition is the first consideration. Is the nutrient composition of an ingredient known with some reasonable degree of accuracy? If so, the ingredient can be used to its maximum level with confidence. If not, then nutritionists tend to be more conservative and use less than they otherwise might, just to avoid unpleasant surprises!

Table 4-1. Consistency of Various Protein Sources Used in Swine Diets.

Ingredient	Number of Samples	Protein Content Average	Protein Content Range	Standard Deviation
Plant Sources				
Barley	25	11.1	9.5 - 12.4	0.80
Wheat	26	13.4	11.6 - 15.6	0.92
Corn	20	9.2	8.2 - 11.1	0.85
Oats	9	10.4	8.4 - 12.1	1.25
Soybean meal	32	47.4	46.1 - 48.8	0.52
Canola meal	42	34.2	32.7 - 36.3	0.79
Animal Sources				
Fish Meal	5	62.7	60.3 - 66.6	2.72
Meat Meal*	29	54.2	49.8 - 58.5	2.04

*This analysis contains data from samples described as both meat meal and animal or feeding tankage.
Example of variation in protein content observed in commercial samples of the ingredients listed. Above example refers to samples collected and analysed during April and May, 1995.
Supplied by Federated Co-operatives Ltd.., Saskatoon, Saskatchewan.

Based on nutrient composition, can the ingredient be included in the diet and still meet the needs of the pig? For example, corn can be used in place of wheat, or vice versa, in a starter diet, because they are both high energy grains. Oats would not be used to replace either wheat or corn, because they are too low in energy.

Is the composition consistent? As a rule, proteins derived from vegetable sources, such as soybean meal or canola meal, are relatively consistent from batch to batch and from supplier to supplier. Conversely, protein supplements manufactured as part of the meat processing industry tend to be less consistent. One can obviously use a consistent product with a greater degree of confidence. Table 4-1 illustrates this point. Quality control data supplied by the Feed Department of Federated Co-operatives Ltd. shows that products of plant origin tend to be relatively consistent, as indicated by a smaller standard deviation (a measure of variability). Products of animal origin tend to be less consistent and have a larger standard deviation. This does not mean that they should not be used, but rather that more caution needs to attend their inclusion in the diet. Advances in the technology associated with processing of offal is resulting in a more consistent product than was possible in the past.

Does the ingredient contain any anti-nutritive or toxic compounds? For example, the old rapeseed meal contained glucosinolates that reduced feed intake and impaired animal health. The new canola meal has essentially eliminated such problems.

Based on composition, is the product economical compared to other available ingredients? Cost should be considered in terms of profit, not price per tonne. If an ingredient can reduce the overall cost of production, it should be used. If not, a more economical ingredient should be selected.

Finally, is the ingredient appealing to the pig? This is a difficult question to answer, because pigs have a limited vocabulary! Unfortunately, we tend to think we know what is attractive to the pig. It is very important that one does not use human values to select ingredients for pig feed. Pigs eat many things that humans will not, and indeed, there are things that humans will eat that pigs find unappealing.

The basis for diet formulation is knowledge. Lack of knowledge means uncertainty and this translates into errors. The flow diagram in Figure 4-1 helps determine ingredient usage.

INGREDIENT

Is its nutrient composition, including availability, known?

Yes — Can the pig's nutrient requirements be met if this ingredient is used?

No — Determine nutrient composition

Yes — Is it economical?

No — Reject

Yes — Is it readily available?

No — Reject

Yes — Is it palatable to the pig and safe to use?

No — Reject

Yes — Use the ingredient.

No — Reject

Figure 4-1. Flow Diagram Showing Choices in Selection of Ingredients Used in Practical Diets.

This chapter discusses the use of many ingredients in swine diets. Where possible, recommendations for inclusion in the diet are provided. In providing these guidelines, certain assumptions have been made. For example, replacement of current ingredients with an alternative should not change the overall nutrient composition of the diet. If so, a depression in performance will probably occur.

The following section contains a discussion on the utilization of common and some not so common ingredients in swine diets. Detailed feedstuff composition tables appear in the Appendix. For further information on a particular ingredient, useful articles are listed at the end of the chapter.

Animal Sources

The quality of feed ingredients derived from the meat processing industry has improved considerably in recent years. Improvements in quality control have resulted in products that are superior to that sold even ten years ago. As with any product, quality varies among suppliers and attention to good purchasing practices, including regular feed testing, is advised.

A recent concern with many by-product meals relates to their use in minimum disease herds. Since offal can be contaminated with salmonella, or other pathogens, meat and bone meal, feather meal and blood meal are often excluded from diets destined for herds with a high health status. Certainly, the possibility of contamination exists, although modern rendering plants are designed such that once the rendered product leaves the cooking vats and is thus sterilized, it cannot come in contact with incoming uncooked material. While the risk of re-contamination is always present, products not associated with the rendering process may be at equivalent risk. The onus is on the management of the rendering plant and truckers, to ensure that contamination does not occur.

If there is concern, the matter should be discussed with a herd health veterinarian. In seeking zero risk, by-product meals are often avoided by some producers. However, they should be aware that other protein meals can, and have, become contaminated, probably during transport.

Blood Meal

Blood meal, as its name implies, is a high protein ingredient manufactured from animal blood collected from abattoirs. The nutrient composition of blood meal will vary a great deal among suppliers, due primarily to two factors: the method of processing and the nature of the source material used in the manufacturing of the product. Book values will not suffice, unless extremely conservative values are employed. For example, one study of five different batches of blood meal revealed that total lysine varied from 7.7 to 10.6% of the dry matter! Differences in digestibility of lysine would further increase the variability of the product.

A variety of processes can be used to convert raw blood (approximately 20% dry matter) to the dry powder useable in animal feeds. Vat drying is essentially a batch process and results in the product of lowest nutritional quality; in North America, vat drying represents a very small portion of the total blood meal available to the livestock industry. Vat-dried blood meal is not recommended for use in swine diets, as the availability of nutrients is low; for example, the digestibility of lysine is probably less than 20%.

The majority of blood meals would be flash dried, using the ring, roller, drum or belt methods. Ring-dried blood meal is quantitatively the most common product available in North America. In this process, coagulated blood particles would be inserted into rotating rings where high temperatures, in the range of 550°C, force off the water, leaving a product with as little as 5% total moisture. Flash-dried blood meal is particularly popular in cattle feeds, as the rumen degradability characteristics are highly desirable in support of maximum animal performance. Ring-dried blood meal can be effectively used in swine diets; typical recommendations include up to 2% in later phase starter diets (pigs over 15 kg) and up to 5% in growout and sow diets.

Increasing in popularity is spray-dried blood meal. In this process, blood is treated with an anticoagulant to keep it in liquid form. It is pre-heated and then spray-dried in vertical or horizontal cylinders; retention times of 2 minutes or less and temperatures of less than 250°C are typical. In the spray drying process, the lower temperatures and shorter retention times, as compared to flash drying results in a final product that is superior in terms of amino acid availability. Spray-dried blood meal is considerably more expensive than flash dried product, and is used most commonly in starter diets, especially those employed for the young pig. Phase I diets may contain as much as 2% to 3% while Phase III diets may contain up to 5% to 7% spray-dried blood meal.

The use of blood meal requires consideration be paid to sulphur amino acid and branched chain amino acid levels. There is research demonstrating that starter diets containing blood meal may be deficient in methionine, while higher levels of blood meal (approaching 10%) in growout diets may result in problems with leucine levels being excessive or isoleucine levels being inadequate.

Unlike meat and bone meal, blood meal is not a particularly good source of calcium or phosphorus. The energy level in blood meal appears to be highly variable, so individual suppliers should be asked to provide DE or ME values for their product.

Blood Meal	
DE	3050
Crude Protein	84.0
Lysine	7.60
Digestible Lysine	6.38
Digestible Threonine	3.11
Digestible Tryptophan	0.92
Calcium	0.50
Phosphorus	0.21

Blood meal is obviously a good source of iron. However, iron supplementation is relatively inexpensive and indeed, the need for iron supplements in market hog diets has been questioned. Thus, attributing a value to blood meal for its iron content would be questionable.

Blood meal tends to be hydroscopic, meaning that it attracts water. Consequently, feeds containing blood meal are more likely to bridge in the feeder, so that feeder management is critical to ensuring maximum feed intake is achieved.

Additional Reading and References

Miller, E.R. 1990. Blood meal: Flash dried. in Non-traditional feed sources in swine production, P.A. Thacker and R.A. Kirkwood, eds. London: Butterworth. pp. 53 - 60.

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Batterham, E.S., R.F Lowe, R.E. Darnell and E.J. Major. 1986. Availability of lysine in meat meal, meat and bone meal and blood meal as determined by the slope-ratio assay with growing pigs, rats and chicks and by chemical techniques. Brit. J. Nutr. 55:427 - 440.

Bone Meal

At one time, bone meal was a common ingredient in animal diets, but more recently it has become too expensive for routine use. It is an excellent source of calcium and phosphorus, containing about 24% and 12% respectively. However, products of equal mineral value are now available at much less cost.

Bone Meal	
Crude Protein	28.0
Lysine	1.00
Digestible Lysine	0.77
Digestible Threonine	0.51
Calcium	30.00
Phosphorus	12.50

Feather Meal

Feather meal is a by-product of the poultry processing industry. Although rich in crude protein, raw chicken feathers are of little nutritional value to the pig; the digestibility of the protein is essentially zero. Commercially available feather meals are often referred to as hydrolysed feather meal, because they are steam treated under pressure to improve their nutritive value. For maximum nutritive value, feathers need to be autoclaved for 30 to 60 minutes at 142°C to 153°C (40-60 p.s.i.). Higher pressures for shorter periods are also employed commercially. Lower final temperatures greatly increase the processing time needed; however, excessive treatment periods, even at lower temperatures appear to result in an inferior final product.

Feather Meal	
DE	2250
Crude Protein	85.0
Lysine	1.67
Digestible Lysine	1.09
Digestible Threonine	2.54
Digestible Tryptophan	0.29
Calcium	0.34
Phosphorus	0.93

Like most by-product ingredients of animal origin, variability of nutritional quality is a major concern. Even if total amino acid content does not change, availability may differ vastly according to processing method.

Very little research on feather meal has been conducted with pigs. However, commercially available feather meals have supported growth in chicks equal to that of soybean meal, if essential amino acids are properly supplemented. For the chick, methionine, lysine, histidine and tryptophan were required. Since amino acid requirements of the pig differ from those of the chick, different amino acids may be needed. However, the clear message is that feather meal can be used, provided it is appropriately supplemented with deficient nutrients.

Feather meal can be used successfully in the diet of pigs if the nutrient composition is accurately known. As a minimum, it can be used at the rate of 3-4% in grower or sow diets. Its use in starter diets is not recommended unless it is known that the product being used is of superior quality. These levels are conservative and greater quantities can no doubt be used, but care in balancing for essential amino acids would become more critical.

Additional Reading and References

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Fish Meal

Fish meals are high in protein (50 to 75%) and amino acids. The protein is of good quality (especially high in methionine) and is generally highly digestible. Due to fat content (approximately 10%) the DE content is comparable to or higher than that in soybean meal. The levels of most minerals, particularly calcium and phosphorus are similar to or higher than those in other protein sources. Phosphorus availability in fish meals is high.

Saltwater species of fish commonly used for fish meal include menhaden, anchovy, herring, red fish, tuna, salmon and white fish.

The quality of fish meal will have important effects on its feeding value. Factors that should be considered include: the source material (type of fish, whole fish vs fish offal), storage of the raw material (partial decomposition before processing) and processing (overheating, moulding, excessive oil). For example, meal made from viscera will be lower in mineral content than meal made from whole fish or heads and frames.

Oxidizing oils present in fish meal may cause the destruction of vitamins A and E in the diet which could result in a vitamin deficiency. It is therefore imperative that antioxidants be added during processing. Fresh fish products also contain high levels of the enzyme thiaminase which acts to destroy the B-vitamin thiamine. If fish meal is properly heat-treated this enzyme will be destroyed. However, in order to ensure that a vitamin deficiency does not occur, it may be worthwhile to consider supplementation of thiamine when diets containing high levels of fish silage are fed.

Another concern with the use of fish products is the possible presence of high levels of mercury. Fish accumulate mercury in their body tissues and the possibility exists that pigs fed silage could produce a carcass unacceptable to humans due to mercury consumption. Fish products containing more than .5 mg/kg of mercury should not be used in swine rations.

Fish Meal: Herring	
DE	3725
Crude Protein	71.0
Lysine	5.82
Digestible Lysine	4.95
Digestible Threonine	2.41
Digestible Tryptophan	0.58
Calcium	2.75
Phosphorus	1.75

Fish Meal: Menhaden	
DE	3700
Crude Protein	61.2
Lysine	4.82
Digestible Lysine	4.10
Digestible Threonine	1.94
Digestible Tryptophan	0.52
Calcium	5.11
Phosphorus	2.92

Fish Meal: White	
DE	3550
Crude Protein	63.8
Lysine	4.34
Digestible Lysine	3.69
Digestible Threonine	2.11
Digestible Tryptophan	0.50
Calcium	7.00
Phosphorus	3.50

Over the last years many studies have been conducted that demonstrate the beneficial effects of including good quality fish meal (select menhaden or herring) in weaner and starter pig diets. Possible explanations include diet palatability, good amino acid balance and availability, content of specific long chain poly-unsaturated fatty acids, an underestimation of the available energy content, and the absence of an allergic response by the pig's gut to fish meal (as observed with soybean meal). Good quality fish meal is routinely included in diets for young pigs (at levels up to 10%) to replace the more expensive milk protein (primarily from dried skim milk). It is generally too expensive to include fish meal in the diet for grower-finisher pigs and sows.

When large quantities of fish meal are used in starter pig diets, close attention should be given to the level of lactose (normally supplied by milk products) and minerals (calcium and phosphorus) in the diet. A concern with using fish meal in finishing pig diets is its effect on meat quality. Problems may arise with a fishy taint in carcasses from pigs fed fish meals. This can largely be attributed to the oil content of fish meal. In the finisher diet, the amount of oil derived from fish products should not exceed 1%.

Additional Reading and References

Gore, A.M., R.W. Seerly and M.J. Azain. 1989. Menhaden fish meal and dried whey levels in starter diets. Univ. Georgia Swine Res. Rep. P. 11.

Stoner, G.R., J.L. Nelssen and R.H. Hines. 1988. Replacing dried skim milk with select menhaden fish meal in a high nutrient dense diet. Kansas State Univ. Swine Res. Rep. P. 57.

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Wiseman, J., S. Jaggert, D.J.A. Cole and W. Haresign. 1991. The digestion and utilization of amino acids of heat treated fish meal by growing-finishing pigs. Anim. Prod. 53:215-225.

Fish Silage

Fish silage is produced by adding organic acids to whole or parts of fish. The addition of acid activates enzymes present in the raw fish and thus stimulates the break down of the tissue protein. The resulting product has a nutrient content similar to fish meal except that fish meal has a dry matter content of about 90% while fish silage has a dry matter content in the range of 15-30%.

The process of making fish silage offers the potential of utilizing wastes from the fishing industry in areas where the quantity of waste material is insufficient to justify the production of fish meal. Producers with operations located in the vicinity of these processing plants can obtain a high quality of protein supplement at a relatively low cost and thereby increase the efficiency and profitability of their swine operations.

The potential feeding value of fish silage is determined mainly by the quality of the material being ensiled. Fish silage produced using a high percentage of whole fish will have a higher nutritional value than will silage produced using offal. In addition, the type of fish used will affect the quality of the silage produced. For example, silage based on white fish is different from that based on herring and it is important to differentiate between these when discussing their nutritional value.

White fish silage has a dry matter content of about 20%. On a dry matter basis, it contains approximately 70% crude protein, 3% ether extract and 16% ash. In contrast, herring fish silage has a dry matter content of about 35% and on a dry matter basis, it contains only 43% crude protein and 8% ash. However, it has an ether extract content of over 42%.

The energy and mineral content and amino acid profile of fish silage closely resembles that of fish meal made from the same type of raw material (see section on fish meal). As a consequence, fish silage would appear an excellent source of protein and minerals for use as a supplement to cereal grains. However, some of the concerns that apply to fish meal (oxidizing oils, thiamin supplementation, contamination with mercury, effect on carcass quality) apply to fish silage as well (see fish meal).

Fish silage can be used quite successfully in swine rations. The results of a research trial conducted at the University of Georgia using weanling pigs fed either 0, 3, 6 or 9% fish silage for six weeks are presented in Table 4-2. It can be seen that the performance of weanling pigs fed diets containing 3 or 6% fish silage was not significantly different from the control group while those fed diets containing 9% fish silage gained weight at a slower rate. The major factor responsible for this reduction in growth rate appeared to be a reduction in intake.

Table 4-2. Performance of Weanling Pigs Fed Diets Containing Graded Levels of Fish Silage.

	Fish Silage (%)			
	0	3	6	9
Daily gain (kg)	0.42	0.40	0.43	0.39
Daily feed (kg)	0.87	0.89	0.91	0.80
Feed conversion	2.07	2.22	2.12	2.07

Adapted: Tibbetts et al., 1981, J. Anim. Sci 52:93-100.

Growing pigs also perform well on fish silage. The results of an experiment conducted in Britain in which growing pigs between 25 and 55 kg body weight were fed diets containing 0, 5, 10 or 15% fish silage are presented in Table 4-3. The inclusion of fish silage in the diet slightly reduced feed intake. Pigs fed fish silage grew faster than those fed the control diet without fish silage. Yet, there was no difference in growth rate between pigs fed diets containing 5, 10 or 15% fish silage. Feed efficiency was best when the inclusion level of fish silage was 10%. The experiment showed no significant effects of the inclusion level of fish silage on the various carcass characteristics of pigs slaughtered at 55 kg body weight (dressing percentage, carcass weight, backfat measurements, fatty acid profile of the subcutaneous carcass fat). However it was noted that the backfat was slightly more yellow in the carcasses of pigs fed the 15% fish meal diet.

Table 4-3. Performance of Growing Pigs (25 to 55 kg body weight) Fed Diets Containing Graded Levels of Oily Fish Silage (44% fat in the pure product).

	Fish Silage (%)			
	0	5	10	15
Daily gain (kg)	.65	.71	.73	.71
Daily feed intake (kg)	1.43	1.42	1.41	1.40
Feed Conversion	2.23	2.01	1.96	1.99
P2 Backfat (mm)	10.0	11.0	10.4	10.0

Adapted: Green et al., 1988, Anim. Feed Sci. Techn. 21:43-56.

There would appear to be some problems when it comes to feeding fish silage to breeding stock. The results of one experiment in which fish silage was fed to sows during gestation are shown in Table 4-4. Preweaning mortality has been shown to be significantly higher when diets containing 6% fish silage are fed to sows during gestation. The reason for this increase in mortality has not been determined.

Table 4-4. Effect of Feeding Fish Silage on the Reproductive Performance of Sows.

	Control	6% Fish Silage
Pigs born alive	11.4	11.1
Birth weight (kg)	1.4	1.3
Pigs weaned	9.7	8.2
Weaning weight (kg)	4.4	4.4
Mortality (%)	14.9	26.1

Adapted: Tibbetts et al., 1981, J. Anim. Sci. 52:93-100.

The major problem using fish silage is finding an acceptable method of feeding the product. Because of the high moisture content of the silage, diets containing fish silage must be mixed on a daily basis or else the cereal portion of the ration may start to spoil. In addition, rations containing high levels of fish silage tend to bridge if fed in traditional types of feeders. Therefore, unless an acceptable method of feeding fish silage is developed, its use will be limited to small scale producers who mix and feed by hand.

Additional Reading and References

Green, S., J. Wiseman and D.J.A. Cole. 1988. Examination of stability, and its effect on the nutritive value, of fish silage in diets from growing pigs. Anim. Feed Sci. Techn. 21:43-56.

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Meat and Bone Meal

Meat and bone meal, or often referred to as meat meal, is a by-product from the animal packing industry. The crude protein content of meat and bone meal (50%) is slightly higher than that of soybean meal while its amino acid profile is surprisingly similar to that of soybean meal although containing less tryptophan. However, the amino acids in meat and bone meal are generally less available to the pig (see below). The energy content of meat meal varies due to differing mineral content, but overall is less than that of barley or canola meal. The calcium and phosphorus content is a bonus since phosphorus is an especially expensive nutrient. Care must be taken to consider the sodium and chloride (salt) content of meat meals. The salt content has been reduced in recent years, but is still sufficiently high to require adjustment of added salt, especially in the diets of young pigs.

Meat and Bone Meal	
DE	2825
Crude Protein	50.0
Lysine	2.70
Dig. Lysine	1.89
Dig. Threonine	1.09
Dig. Tryptophan	0.17
Calcium	9.50
Phosphorus	4.70

For example, in some samples of meat meal the bone content is low. This will result in increases in protein levels (sometimes as high as 60% protein and 3.1% lysine) and reductions in mineral levels (can be as low as 6.5% calcium and 3.5% phosphorus). The fat content of meat and bone meal is usually about 8%, since any additional fat in the raw material is removed in the processing of tallow.

Raw materials incorporated into meat and bone meal include such things as trim, hides, heads, feet and entrails. Although meat and bone meal are two different products, the terms are often used interchangeably. Whether it contains bones or not has a considerable influence on the nutritive value of the final product. For example, as bone content rises, the crude protein content tends to fall. The fat content of meat meal is usually about 8%, since any additional fat in the raw material is removed in the processing tallow.

The major problem with meat and bone meal is variability of nutrient composition. For example, one survey of only 17 samples revealed lysine content ranged from 2.38% to 3.86%. Tryptophan varied even more, from 0.20% to 0.69% and threonine ranged from 1.81% to 2.72%. Amino acids were not the only nutrient to vary. Calcium content was 0.9% to 15.8%. This lack of uniformity makes it a difficult product to use to maximum advantage in swine diets.

The degree of variability will depend on a number of factors. If the meal is produced from a single source of relatively constant composition, then the meal will reflect this in being consistent. However, it is made from a variety of ingredients, such as whole carcasses, offal and blood, and contains beef, poultry and swine, the final product will likewise be less consistent. If this can be considered in the diet formulation, no harm will be done. For example, hard offal, which includes bones, heads and hooves is a less desirable component, because it results in a meat meal with a poorer amino acid profile due to a high collagen content. Soft offal, consisting of gut material, tends to produce a superior product with a more desirable amino acid profile.

Meat meal has the potential to be an important protein source in swine diets, provided certain features of the products are recognized. Some meat meal will contain a great deal of connective tissue. Although this is protein, it is not well digested and its amino acid profile is quite poor. Also, a high mineral content in meat meal could cause a disturbance of the calcium:phosphorus ratio and possibly cause a zinc deficiency, **if** the diet is not properly formulated. If the formulation takes into account the calcium and phosphorus content of meat meal, and indeed takes advantage of them to satisfy the pig's requirements, then no harm will be done and performance will be quite satisfactory.

Processing method can also be an important factor. Excessive temperature will reduce nutrient quality and performance will be depressed. For example, increasing the cooking temperature from 125°C to 150°C has been found to reduce lysine availability from 84% to 38%.

As mentioned above, the amino acid availability of meat meal tends to be lower than comparable values for cereal grains and vegetable protein sources. For example, various studies have concluded that lysine is 54-67% available for meat and bone meal, as compared to 81-87% for soybean meal and 71% for fish meal. However, some individual meat and bone meal samples have lysine availabilities equal to that of soybean meal.

A potential concern if including meat and bone meal in pig feeds is its contamination with harmful, disease causing organisms such as salmonella. However, various recent surveys demonstrate that the incidence of salmonella contamination in properly processed meat and bone meals (proper temperature, no contamination of processed with unprocessed material) is very low. In fact, some surveys demonstrate that feedstuffs of vegetable origin, such as cereal grains and soybean meal can be contaminated with salmonella as well. A further point worth noting is that there are a whole range of types of salmonellas. Only a very limited number of salmonella strains are considered harmful to pigs or humans.

Success in using meat and bone meal will depend on one's ability to define nutrient composition. High quality meal, purchased from a good supplier with a sound quality control program, can be used at high levels in market hog diets (10-15%) as well as those for sows (5-10%). Otherwise, meat and bone meal should be limited to 5-7% of grower and gestation diets, 3-5% of lactation diets and 2% or less in starter diets.

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Whole Milk

Whole cow's milk is usually not included in swine rations because its value in human diets makes it too expensive. However, it is perhaps nature's most perfect feed and can be used very successfully in swine rations. Milk provides more essential nutrients than any other feed ingredient. Whole milk is very easily digested and is extremely palatable. The amino acid balance of milk protein is excellent and because of its high protein quality, lower levels of crude protein can be fed when using whole milk than the levels commonly advised in feeding standards.

Milk provides energy in its milk fat and milk sugar (lactose). It is an outstanding source of calcium and a good source of phosphorus. It is high in vitamin A, rich in riboflavin and is a good source of niacin, thiamine, vitamin B-12 and other B-complex vitamins. However, it is not perfect. The iron content is extremely low and it is a poor source of vitamin D. Therefore, it is important that a vitamin-mineral premix be utilized when whole milk is being fed.

A nutritional breakdown of whole cow's milk is shown below. Basically five pounds of whole milk will supply the same amount of nutrients as one pound of complete feed.

Whole Milk	
Digestible Energy	660
Crude Protein	3.50
Lysine	0.28
Digestible Threonine	0.13
Calcium	0.12
Phosphorus	0.09

An example of a feeding regime using whole milk is shown in Table 4-5. Best use of the protein in whole milk can be made if no other protein supplement is used in the ration. However, since less dry feed is to be fed, it is recommended that higher levels of vitamin-mineral premix be included in the diet.

Table 4-5. Replacement Scheme for Using Whole Milk in Swine Diets.

Weight of Pig (kg)	Meal (kg)	Milk (Litres)
18	0.84	1.80
23	0.86	3.20
34	1.28	4.10
45	1.50	5.00
68	2.12	5.90
91	2.36	7.00

[1]Meal should contain 95% cereal grain and 5% vitamin-mineral premix. Additional protein supplements are not required.

Dried Skim Milk

Dried Skim Milk is of course skim milk which has had the water evaporated from it. The only major difference between dried whole milk and dried skim milk is that in skim milk, most of the fat and fat soluble vitamins have been removed so that all other components of the diet are increased proportionally.

Dried Skim Milk	
Digestible Energy	3850
Crude Protein	33.4
Lysine	2.43
Digestible Threonine	1.31
Calcium	1.20
Phosphorus	1.00

Because of price, skim milk is not a commonly used ingredient in swine diets. However, skim milk may be diverted to animal feed if excess supplies develop or if a given shipment fails to meet certain quality standards. Since these standards may relate to factors of little nutritional importance, a real opportunity exists. However, if the milk powder has been over-heated during drying, then its nutritional value will be compromised.

Generally, even skim milk powder sold at distress prices is economical only in creep and starter diets, where it can make up to 20 - 30% of the total formula. Pigs of all ages can be fed skim milk. Their feces may become loose as they adjust to the lactose in the milk but this is usually a temporary problem and will disappear in a few days. The problem of milk intolerance in pigs tends to be overestimated.

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Whey

When whole milk is treated with the enzyme rennet, the protein casein is precipitated and takes with it most of the fat and about half of the calcium and phosphorus. The remaining liquid is called whey. Sweet whey arises from the production of Swiss- or cheddar-type cheeses and acid whey from cottage cheese production. About 9 kg of sweet whey or 6 kg of acid whey will be produced per kilogram of cheese. Sweet whey contains slightly more crude protein (12 - 14 vs 10 - 12%), more lactose (68 - 72 vs 60 - 65%) and less ash (7.5 - 9.0 vs 9.5 - 11.5%) than acid whey. As its name implies, it also contains less lactic acid (1.5 - 3.0 vs 5.5 - 7.5%). Whey contains almost all of the lactose from milk and significant portions of the mineral fraction as well. Since casein has been removed, the major protein in whey is lactoglobulin, which fortuitously is of good quality. Lactose is desired in diets of newly weaned pigs, due to its digestibility. However, some commercial whey powders have had some of the lactose removed so the content may vary from 35 to 58% of the dry matter. As the amount of lactose increases, the protein content decreases from 26 to 16%.

In its crude form, whey is a liquid; more than 90% of fresh whey is in fact water. Although liquid whey can, and is, fed to swine, most has been dried before inclusion in the diet. On a dry matter basis, fresh whey is 70-77% lactose (milk sugar), 17% crude protein, 9% ash (minerals), 1.0% calcium and 0.8% phosphorus. Although the true protein in whey is of good quality, it must be recognized that up to 25% of the nitrogen in whey is present as non-protein nitrogen. Therefore, nitrogen assays tend to overestimate the true protein content.

Dried whey is generally used in the diet of early weaned pigs, as a source of highly digestible lactose and protein. However, excessive utilization of whey can lead to diarrhea; the exact amount will depend on other factors in the diet. Generally, starter diets will contain no more than 15 - 20 % whey, if for no other reason than cost. Concerns about scouring often lead nutritionists to use skim milk powder rather than exceed 20 % whey in the diet. Again, cost becomes a limiting factor in such diets, since skim milk powder is also very expensive.

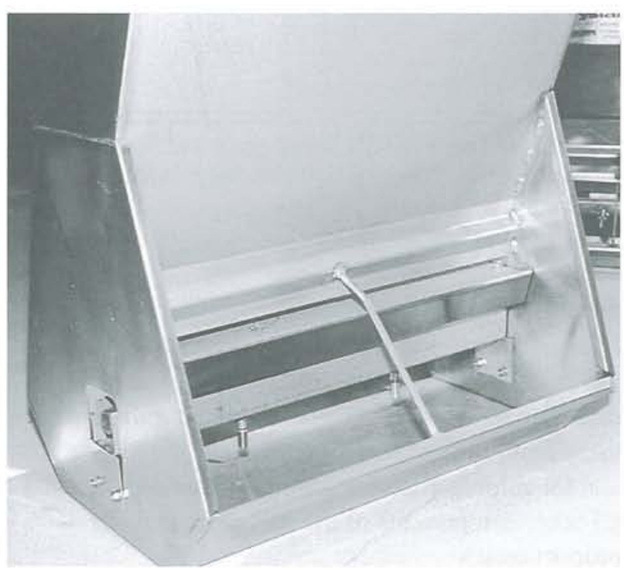
Typical diets for the early weaned pig contain 10 - 20 % whey, while diets for pigs 5 weeks of age and older will contain perhaps 5 - 10 % whey. Although the presence of whey in such diets is desirable, nutrient composition must be considered to ensure maximal performance. The addition of whey alone to a diet cannot be considered sufficient to maximize growth rate and feed efficiency.

In older pigs, concern is often expressed about their ability to utilize the lactose in whey. It is known that as the pig ages, and no longer consumes lactose, the special digestive enzyme called lactase, that breaks down lactose in the gut, will decrease. This is no surprise, since lactase is used solely to degrade lactose, and if it is not present in the diet, there is little reason for the gut to continue to produce it. Consequently, farmers have become reluctant to utilize whey in the diet of growing or finishing animals, even if a local milk processing plant can supply fresh whey at an economical price.

The truth of the matter is that pigs can tolerate lactose quite well. Research in Wisconsin demonstrated that the pig can tolerate up to 30 % lactose in its diet. Since whey is about 70-77 % lactose, this translates into about 40 % whey in the diet on a dry matter basis. Indeed, the scientists also learned that removal of lactose from the diet of the older pig will not diminish its ability to digest lactose in the future. The pig's adaptability, in terms of diet, was reaffirmed!

The major problem with feeding liquid whey to swine is the high moisture content, and the pig's inability to consume sufficient dry matter to grow rapidly. Thus, care must be taken to ensure that sufficient dry matter from other sources is provided

Photo 4-1.



Wet-Dry Feeder.

to pigs to support normal growth. If liquid whey is being fed to pigs, the dry feed can be adjusted to contain less protein and more mineral:vitamin premix. Since whey is rich in protein, less supplemental protein would be required in the dry feed. The premix must be increased since the pigs would eat fewer kilograms of dry feed per day, but their daily requirement would remain the same. The exact adjustment would depend on the amount of whey being eaten. Since the final ration, including proportions of whey, grain and premix will vary depending on pig size and amount of whey consumed, a qualified nutritionist should be involved in setting up feeding programs on individual farms. Liquid feeding systems, in which the dry feed and water are mixed prior to feeding, offer considerable potential for liquid whey feeding. Also, wet-dry feeders have been used for the same purpose.

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Plant Sources

Feeds derived from plants tend to be relatively uniform in composition within species. This helps avoid the variability problems associated with feeds derived from animal sources. However, ingredients derived from plant sources have other problems which may limit their inclusion in swine diets. For example, unprocessed oats are too low in energy to be utilized as a major constituent in most swine diets. Barley, although higher in energy than oats, is of limited value to nursing sows and baby piglets if maximum performance is to be recognized. Some plant products contain anti-nutritional factors that impair digestion, reduce appetite, or may compromise the health of the pig.

Alfalfa

There are problems associated with alfalfa (Medicago sativa) which limit its usefulness as a feedstuff for pigs. The protein and energy are poorly digested and it contains toxic factors such as saponins and tannins which reduce growth rates of animals fed diets containing alfalfa. However, despite the negative factors present, there is still interest in the use of alfalfa as a component of swine diets and research continues to attempt to overcome these problems. If this work is successful, the use of alfalfa in swine diets may increase.

Alfalfa Meal	
Digestible Energy	1850
Crude Protein	17.0
Lysine	0.76
Digestible Lysine	0.36
Digestible Threonine	0.34
Digestible Tryptophan	0.10
Calcium	1.33
Phosphorus	0.23

The nutritional quality of alfalfa varies with stage of maturity, soil fertility, variety, physical handling and other factors. The most significant factor affecting the nutritional value of alfalfa is the stage of growth at which it is cut. As the forage becomes more mature, it contains less protein and more fibre. Because of this variation in nutrient content, producers are advised to submit samples for laboratory analysis before including alfalfa in any diet.

The primary factor limiting the use of alfalfa in swine diets is its low digestible energy content. The crude fibre content of alfalfa is extremely high compared with grains and oilseeds. Since the pig has a simple stomach of relatively small capacity, it is less able to utilize crude fibre than are other types of farm livestock. Therefore, the digestible energy content of alfalfa is approximately half of that found in common cereal grains.

Alfalfa ranges from 12 - 22% crude protein (N x 6.25). Unfortunately, the protein in alfalfa is not very digestible. The high crude fibre content of alfalfa prevents the digestive enzymes from gaining access to the soluble cellular proteins. As a result, the protein in alfalfa is only about 50% digestible. Alfalfa contains a good balance of amino acids and a reasonable level of lysine. However, because of the high fibre level, the availability of the lysine in alfalfa is likely to be low.

Alfalfa is characteristically high in calcium. However, it has only a moderate phosphorus content. When grown on phosphorus-deficient soils, it may be very low in phosphorus. Therefore, rations containing high levels of alfalfa require supplemental phosphorus to meet the pig's requirement and to narrow the wide calcium:phosphorus ratio present in this forage. Alfalfa is a good source of most vitamins and is an excellent source of vitamins A, E and K. However, the advent of relatively cheap sources of these nutrients added via the premix has resulted in a reduction in the need for alfalfa in the diet as a source of vitamins.

Alfalfa should not be used in diets fed to weanling pigs. Its high crude fibre content and low digestible energy level are likely to limit growth and reduce the efficiency of feed utilization when fed to pigs of this weight range. Higher energy feedstuffs should be used as the foundation for a high quality starter diet.

It is recommended that no more than 5% alfalfa be included in the diet of grower pigs. The data in Table 4-6 illustrate the adverse effects of alfalfa meal when included in the diet of market hogs. The reduction in gain would appear to be the result of insufficient dietary energy to meet requirements for maximum growth.

Table 4-6. Growth, Feed Intake and Carcass Characteristics of Pigs (54 to 100 kg) Fed Alfalfa.

	% Dietary Alfalfa			
Criteria	0.0	20.0	40.0	60.0
Daily Gain (kg/day)	0.86	0.73	0.63	0.41
Daily Intake (kg/day)	3.0	3.0	3.2	2.7
Feed/Gain	3.6	4.1	5.0	6.7
Dressing (%)	77.9	76.2	75.4	75.2
Backfat Thickness (cm)	3.9	3.5	3.2	2.9

Powley et al., 1981, J. Anim. Sci. 53: 308-316.

Poor palatability is one factor accounting for the reduction in performance when high levels of alfalfa are included in the diet of the growing pig. Saponins are a bitter tasting compound present in alfalfa. Recently, cultivars of alfalfa varying in saponin content have been developed. It would appear that cultivars containing lower levels of saponins are more palatable and support higher levels of performance than do the traditional alfalfa varieties. Future research may allow for higher levels of alfalfa to be incorporated into swine diets. However, at the present time, it is not possible to justify the use of high levels of alfalfa meal.

The subject of whether or not it is beneficial to include alfalfa in diets fed to sows is controversial. While some studies have supported its use, the benefits can often be attributed to the vitamin E and selenium supplied by the alfalfa meal. Since synthetic sources of both vitamin E and selenium are available, there does not appear to be any necessity for the inclusion of alfalfa in gestation diets. If it must be used, it would seem wise to limit the levels of alfalfa fed during gestation to a maximum of 25 - 30% of the diet.

Alfalfa meal should not be fed to sows during lactation. Feeding alfalfa meal during lactation will reduce the energy intake of sows resulting in reduced milk production. However, some producers include bulky ingredients such as alfalfa meal in the diets of sows during prefarrowing and early lactation to prevent constipation. If this is the case, higher levels of wheat or fat are needed to maintain a high energy content.

In summary, alfalfa meal should not be included in diets fed to starter and grower pigs and lactating sows because of its high crude fibre content and low digestible energy level. In rations fed to the gestating sow, a maximum of 25 - 30% of the diet is suggested.

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Barley

Swine producers and feed manufacturers who are oriented towards corn are sometimes unaware of the wide use of barley (*Hordeum vulgare*) as a swine feed and are often sceptical about its use. However, barley is an excellent feed for swine and millions of pigs are raised annually on barley-based diets.

Unfortunately, barley is not just barley, There is a tremendous amount of variability in the types of barley available for use in swine production. Barley can be either two-rowed or six-rowed, hulled or hulless, awned or awnless. In addition, variation exists among the lysine and starch content of barleys. Even barley of the same genetic background can vary greatly since growing and harvesting conditions can have profound effects on the nutrient composition of barley.

For example, the results represented in Table 4-7 indicate that differences in growth rates and feed efficiency between growing-finishing pigs fed samples of different barley varieties can be as much as 609%. The observed differences in animal performance can largely be attributed to differences

Table 4-7. Composition of Barley Varieties and Performance of Growing-finishing pigs (approximately 20 to 95 kg body weight) Fed Various Barley Varieties*

	Barley Variety					
	Boyer[a]	Camelot[b]	Clark[b]	Harrington[b]	Hesk[a]	Steptoe[c]
Chemical composition**						
Dry matter, %	91.6	91.4	91.3	91.2	91.8	91.9
Crude Protein, %	9.4	13.2	10.2	11.0	9.1	9.9
Lysine, %	.36	.44	.38	.42	.35	.36
Animal performance						
Feed intake, kg/d	2.32	2.25	2.35	2.16	2.30	2.29
Growth rate, kg/d	.78	.78	.80	.78	.79	.75
Feed : Gain	2.99	2.98	2.90	2.79	2.92	3.05

* The barley samples were supplemented with soybean meal and lysine to maintain similar lysine levels in all grower (.75% lysine) and finisher (.60% lysine) diets and with vitamins and minerals. The inclusion levels of the barley samples were 83.2 and 88.9% in the grower and finisher diet, respectively.
**As fed basis, analyses of the barley samples.
[a] Six-row winter barley varieties.
[b] Two-row spring varieties.
[c] Six-row spring variety.

Adapted from Michal et al., 1993. Washington State University Information Day Proc. Vol.8:69-74.

in unavailable energy content between the barley samples that were evaluated. Small differences in palatability (voluntary feed intake) were also observed. In this study, Harrington barley (a two-row spring barley variety) supported the best feed efficiency while Steptoe (a six-row spring barley variety) results in the poorest growth rate and feed efficiency. As only one sample of each barley variety was evaluated, the differences in observed levels of animal performance may have been due to factors other than variety. For an estimation of the feeding value of barley, producers are thus encouraged to have their barley tested before feeding it to their pigs.

Barley is intermediate to wheat and oats as an energy source for pigs. Its relatively high crude fibre content (5.1%) is one of the major reasons for the comparably low energy value. The digestible energy (DE) content in individual barley samples may be predicts from the dry matter and crude fibre content:

DE (Kcal/kg of dry matter) = 4228 - 140 x Crude fibre content (% in dry matter)."

The protein content of barley is intermediate to that of wheat and corn and similar to the level contained in oats. Relative to requirements, barley protein is generally low in lysine, isoleucine, threonine, tryptophan and the sulfur containing amino acids. The lysine content of barley is approximately equal to that of wheat. The amino acid content of barley can be predicted using regression equations based on crude protein. These equations can be found in chapter 3.

Barley	
Digestible Energy	3100
Crude Protein	10.6
Lysine	0.39
Digestible Lysine	0.27
Digestible Threonine	0.23
Digestible Tryptophan	0.10
Calcium	0.07
Phosphorus	0.35

Because of its lower energy content, barley finds only limited use in diets fed to starter pigs. However, when the cost of other cereals is very high it may be possible to include some barley in the diet of the weanling pig. Only good quality barley should be used. Barley can be fed very successfully to growing pigs and in fact most pigs in Western Canada are raised on barley. To maximize growth rate, high energy cereals such as corn or wheat are often used in combination with barley. Growth rates in finishing pigs fed barley-based diets are generally similar to these fed corn or wheat-based diets. This is because finishing pigs are generally able to compensate for reductions in diet DE content with increases in daily feed intake in such a manner that the daily energy intake is dependent on diet DE content.

Barley can constitute the sole cereal grain in diets fed to sows during gestation. However, because of its lower energy content, it may be beneficial to include between 25-75% wheat in the diet of sows during lactation.

The performance of pigs fed barley-based diets has been shown to be markedly improved as a result of pelleting. The reason for the improvement in performance is a subject of much debate. Some researchers feel that the improvement is due to a reduction in wastage, while others suggest that the improvement is due to an increase in feed consumption or to an increase in nutrient digestibility.

Barley that is frozen or sprouted sometimes becomes available to the pork industry, and questions arise regarding its feeding value. Recent studies carried out at the University of Alberta indicate that sprouting or frost damage will not necessarily impair pig performance (Table 4-8). In this report, bushel weight fell as low as 42 lb, but all pigs performed equally, as compared to a control diet based on normal barley.

Table 4-8. Utilization of Frozen or Sprouted Barley (Bonanza) by Growing Pigs[1]

	Control Frozen	Sprout Frozen	Sprout Frozen
Grain Analysis			
Damage (%)	0.1	18.7	6.9
	75	>75	>>75
C. Protein (%)	12.1	13.3	11.0
	11.4	11.7	12.2
C. Fibre (%)	6.5	7.3	7.3
	7.4	7.9	9.0
Bushel Wt (lb)	51	48	45
	47	42	43
Pig Performance			
Ave. Daily Gain (kg)	0.71	0.72	0.70
	0.71	0.70	0.69
Ave. Daily Feed (kg)	2.27	2.24	2.23
	2.18	2.22	2.29
Feed Conversion	1.59	1.61	1.56
	1.56	1.56	1.58

Adapted from Plett, and Aherne, 1987, Proc. Western Nutrition Conf. pp. 128-131.

[1] Barley represented 80% of the diet in all cases. Initial pig weight averaged 20.8 kg; final weight was not specified.

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Barley: High Moisture

Barley is traditionally harvested after it has been field dried to a moisture content of 14-15%. This drying is necessary in order to prevent deterioration of the grain during storage. Spoiled grain is useless as an animal feed since molds growing on the grain may produce mycotoxins which cause poor growth and reproductive problems.

Grain drying systems have been developed which allow crops to be harvested at higher than normal moisture levels and then dried for storage. This artificial drying requires a lot of energy. As energy costs increase, it may become less attractive to harvest grain in this manner. Therefore, producers are looking for alternative harvesting methods. One method that has generated considerable interest is that of harvesting high moisture grain.

High moisture grains are preserved in a manner similar to silage. In the absence of oxygen, acid producing bacteria proliferate and produce acids by fermenting barley sugars and carbohydrates. The acids produced stop further bacterial action. The ideal moisture content to ensile wet grain for swine appears to be in the 22-28% range. A moisture content greater than 28% leads to greater fermentation, resulting in more acid production which tends to be less palatable to the pig. On the other hand, the fermentation of grain containing less than 22% moisture is relatively slow and the amount of acid produced may not be sufficient to kill those organisms that cause spoilage.

A four-year research project conducted at Montana State University showed that high-moisture barley could be harvested an average of 12 days sooner than dry barley. By harvesting early, the risk of losses due to high winds, rain, snow or frost is minimized. Harvesting grain at a higher moisture content also results in higher yields compared to traditional harvesting methods. Field losses are reduced because high-moisture barley does not shatter like dry barley does. In the Montana State University tests, high moisture barley yielded 16.7% more grain compared with similar fields which were harvested as dry grain. In addition, high moisture grain helped to control weeds, especially wild oats since reduced shattering resulted in fewer weed seeds left in the field to germinate.

Although high moisture barley can be stored as silage, several problems arise when it comes time to feed the product. Since the grain contains moisture, spoilage is always possible. Therefore, high moisture grain must be fed soon after being taken from storage. Untreated high moisture barley will heat within hours of removal from the silo because of microbial activity. Because of this, high moisture barley diets must be mixed on a daily basis and in amounts readily consumed over a short period of time. Once a silo is opened, it is necessary to remove approximately 7.5 cm per day from the exposed surface of the silo to control spoilage. If this does not match the daily feed requirements of the pigs, some feed may be wasted.

A second alternative, treating grain with organic acids, has kindled further interest in the use of high moisture grains. The application of acid preserves the grain by inhibiting mold growth. The acid reduces the pH of the grain below the mold requirement and also kills the grain germ. Propionic, acetic and formic acids are most common.

The main advantage of preserving grain with organic acid is the fact that the grain does not have to be stored in the absence of air. Therefore, existing storage structures can be utilized. In addition, the complete ground ration will not spoil in self feeders and therefore, daily mixing is not required.

Rates of acid application vary with the moisture content of the grain and the intended length of storage. The higher the moisture content of the grain, the greater the amount of acid needed for proper preservation. Grain treated with an organic acid should have a moisture content of 22% or less when harvested. A higher moisture level would make the chemical treatment expensive to use.

The major disadvantage of acid-treated grain is the corrosive effect the acids have on most types of metal in handling and storage equipment. The corrosion is usually most severe on surfaces in contact with the grain or vapour for the first weeks following grain treatment. It may also react with concrete, especially if the concrete is newly cured and unweathered.

In terms of chemical analysis, there is little difference between high moisture barley and regular barley on a dry matter basis (Table 4-9). High moisture barley may be slightly higher in crude fibre than regular barley since it loses less hull during threshing. It may also be slightly higher in protein content owing to the lighter and smaller kernels saved by harvesting high moisture barley which are slightly higher in protein but lower in carbohydrate.

Table 4-9. Chemical Analysis of High Moisture and Dry Barley.

Composition	High Moisture (%, in dry matter)	Dry
Protein	12.6	12.3
Ether Extract	2.2	1.9
Ash	3.0	2.7
Crude Fibre	6.4	4.9
Nitrogen Free Extract	70.7	71.1

Adapted from Krall, 1972, Montana State Agric. Exper. Station Bull. 625, pp 1-45.

There is evidence that carotene and vitamin E activity are reduced in acid treated grains. However, phosphorus is more available in high moisture grain compared with dry grain regardless of the preservation method.

High moisture barley may be used effectively as a feed grain. In formulating diets with high moisture grain, adjustments must be made for excess water. To convert wet grain to dry grain equivalent, divide the dry matter content of the dry grain by the dry matter content of the wet grain to establish an adjustment factor. This factor will tell how much more high moisture barley must be fed to supply amounts of nutrients as dry barley on a dry matter basis (Table 4-10).

Table 4-10. Amount of High Moisture Grain Necessary to Supply the Same Amount of Dry Matter as Regular Barley (90% DM).

% Moisture	High Moisture Barley (kg)
15	1.06
20	1.12
25	1.20
30	1.28
35	1.38
40	1.50
45	1.64

On a dry matter basis, there is no difference in the performance of pigs fed high moisture or dry barley. Average daily gain and feed conversion efficiency do not differ between pigs fed dry versus high moisture barley (Table 4-11).

Table 4-11. Performance and Carcass Characteristics of Pigs Fed Acid-treated High Moisture Barley (74.5% CM) or Regular Barley (85.8% DM).

	Regular	Acid-treated
Average Daily Feed (kg)	2.18	2.09
Average Daily Gain (kg)	0.69	0.69
Feed Conversion	3.15	3.02
Dressing Percentage	79.00	78.80
Carcass Backfat (cm)	3.35	3.55
Carcass grade	103.00	100.00

Adapted from Bowland and Corbet, 1973, Univ. Alberta-52nd Ann. Feeders Day Report, pp 3-6.

Several reports have indicated that high moisture barley may be more palatable than dry barley. This improvement in palatability may be due to the fact that high moisture grain is easier to roll and the rolling results in a flaky product which contains very little in the way of fines or dust. This lack of dust and fines in the ground product may be a factor in improving palatability. However, in most instances, when differences in dry matter are considered, consumption is about equal for high moisture and dry barley. Since high-moisture grain has the same feeding value as field dried grain when compared on an equal dry matter basis, the decision to use high-moisture grain should be made on the basis of cost, storage and handling and not on differences in nutritional value.

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Gibson, D.M., J.J. Kenelly and F.X. Aherne. 1987. The performance and thiamin status of pigs fed sulphur dioxide treated high moisture barley. Can. J. Anim. Sci. 67:841-854.

Barley: Hulless

The performance of pigs fed barley-based diets is generally inferior to that of pigs fed diets based on wheat or corn. The major factors responsible for the lower nutritional value of barley are its relatively high crude fibre content and resulting low energy level. However, since a large proportion of the crude fibre content of barley is contained in the hull fraction, it is possible that the removal of the hull from barley could substantially improve its nutritive value.

The hull of barley consists of two glumes, the lemma and the palea, which completely enclose the seed. In traditional, hulled varieties of barley, the glumes are fused together and are attached to the seed by a cementing substance produced by the caryopsis. This causes the hull to remain attached to the seed during harvest. Recently, cultivars of barley have been developed in which the fusion of the glumes does not occur, allowing the hull to be removed during the threshing process in a manner similar to that which occurs with wheat and many other cereals. These so called hulless varieties of barley would appear to have considerable potential for use in swine rations.

In general, hulless barley contains a higher protein level and a lower crude fibre content than hulled barley. All other nutrients are generally present at a slightly higher level in hulless versus hulled barley. This is to be expected when the diluting effect of the hull is removed.

Barley: Hulless	
DE	3250
Crude Protein	13.7
Lysine	0.54
Calcium	0.24
Phosphorus	0.37

Care must be taken when formulating diets using hulless barley to balance for the amino acid lysine rather than crude protein, since diet formulation on the basis of the latter may result in an amino acid deficiency. However, formulation on an amino acid basis may require higher than normal crude protein levels in the final diet in order to ensure that the diets are balanced for lysine.

Unfortunately, the development of hulless cultivars of barley has not resulted in consistent improvements in pig performance. Although several researchers have indicated that the performance of pigs fed hulless barley is superior to that of pigs fed hulled barley, other have observed little or no improvement in performance. This may be attributed to the actual samples of grains that were evaluated, or the way in which experimental diets were formulated, i.e. control of the proper lysine to energy ratio. In most samples of hulless barley, some hulls are still present. This is due to an incomplete removal of the seed hulls during the threshing process. The extent of de-hulling should thus be monitored via a visual inspection or fibre analyses in the cereal grain sample. Another argument is that the content of beta glucan, a soluble fibre, may in fact be higher in hulless barley as compared to hulled barley. The beta glucan content of barley is one of the factors that contributes to the reduced feeding value of barley as compared to wheat and corn, especially in starter pigs.

For example, the results summarized in Table 4-12 suggest that performance of starter pigs fed hulless barley is similar to that in pigs fed regular barley: pigs fed the hulless barley eat slightly less and used feed slightly more efficiently that the pigs fed the regular barley.

Table 4-12. Performance of Starter Pigs Fed Condor Hulless or Samson Hulled Barley.

	Hulled Barley	Hulless Barley
Feed intake, kg/d	0.90	0.85
Growth rate, kg/d	0.59	0.58
Feed : Gain	1.57	1.47

Thacker et al., 1987, University of Saskatchewan, Dept. of Anim. and Py. Sci. Research Reports, pp. 168-172.

Table 4-13. Performance of Growing-finishing Pigs Fed Diets Based on Hulled or Hulless Barley.

	Hulled	Hulless
Feed intake, kg/d	2.46	2.32
Growth rate, kg/d	.75	.74
Feed : Gain	3.30	3.13
Carcass dressing percentage	80.6	79.8
Backfat, cm	3.5	3.5
Carcass index*	103.7	103.6

* Canadian carcass grading system
Adjusted from Thacker et al., 1988, Anim. Feed Sci. Techn. 19:191-196.

The result of one experiment in which the hulless barley cultivar Scout was compared to the hulled cultivar Harrington for growing pigs are presented in Table 4-13. It can be seen that the average daily gain and feed intake of pigs fed the hulless barley diet was not significantly different from that of pigs fed hulled barley. However, the feed conversion efficiency of pigs given hulless barley was significantly better than that of pigs given hulled barley. This improvement in feed efficiency, in combination with the lower levels of soybean meal required in order to meet the pigs requirements for essential amino acids, may provide sufficient incentive to encourage the incorporation of hulless barley in swine diets, particularly when feed costs are high. There is no data available on the feeding value of hulless barley for breeding swine. However, given the benefits of increasing nutrient density in nursing sow rations, serious consideration should be given to the use of hulless barley in the lactation diet.

Additional Reading and References

Aherne, F.X. 1990. Barley: Hulless. In: Non-traditional Feed Sources for Use in Swine Production. Butterworths Publishers, Stoneham, MA, USA. (Thacker, P.A. and R.N. Kirkwood, Ed.).

Thacker, P.A., J.M. Bell, H.L. Classen, G.L. Campbell, and B.G. Rossnagel. 1988. The nutritive value of hulless barley for swine. Anim. Feed Sci. Tech. 19:191-196.

Beet Pulp

Beet pulp (*Beta Vulgaris*) is becoming a less common ingredient in swine diets in Canada due to changes in the sugar beet crop. Reduced availability and consequent increases in the price have forced nutritionists to seek alternative ingredients.

Beet pulp achieved its greatest popularity as a highly palatable soluble fibre source in the diet of sows. It contains about 20% crude fibre, 24% acid detergent fibre and 35% neutral detergent fibre. However, the crude fibre portion tends to be more digestible by swine than that of straw or oats. Consequently, the digestible energy content of beet pulp is about 86% of barley and 84% of wheat. Crude protein content is only about 10-12%.

Beet Pulp	
DE	3000
Crude Protein	9.9
Lysine	0.60
Calcium	0.70
Phosphorus	0.37

Beet pulp has proven to be a popular ingredient in sow diets. It is often added to prevent constipation problems. Five to seven percent beet pulp in sow diets tends to solve all but the most challenging cases of constipation.

It should be noted that the addition of beet pulp to swine diets tends to reduce the digestibility of energy and nitrogen. This is unlikely to be a practical problem, as only small quantities are generally used commercially.

Additional Reading and References

Graham, H., K. Hesselman and P. Aman. 1986. The influence of wheat bran and sugar-beet pulp on the digestibility of dietary components in a cereal-based diet. J. Nutr. 116:242 - 251.

Stebbens, H.R. 1991. The digestion and utilisation of food fibre by growing pigs. Ph.D. Thesis, University of Edinburgh, UK.

Buckwheat

At the present time, buckwheat (*Fagopyrum sagittatum*) is most commonly grown as a grain for human consumption with small amounts used in pancake mixes, breakfast cereals and in certain breads and ethnic dishes. Buckwheat has not been widely utilized as a livestock feed although it now appears that it has considerable potential for use as an ingredient in swine diets.

Buckwheat	
DE	3010
Crude Protein	11.2
Calcium	0.08
Phosphorus	0.32

The protein quality of buckwheat is reported to be among the highest in the plant kingdom. The concentration of several of the essential amino acids is higher in buckwheat than any of the commonly utilized cereal grains. Of particular importance are the levels of lysine and threonine which are the first and second limiting amino acids in most cereal grains. Buckwheat contains significantly higher levels of both of these amino acids. Relative to the requirements of the growing pig, buckwheat protein contains adequate levels of almost all of the essential amino acids. Only isoleucine and methionine are not present at a level greatly in excess of requirement. Unfortunately, buckwheat supplies a relatively low level of digestible energy (3000 kcal/kg). The prime factors accounting for its low energy content are a high crude fibre content (12.0%) and a low level of fat (2.1%). This low digestible energy content is the prime factor limiting the usefulness of buckwheat in swine diets.

Another factor limiting the nutritional value of buckwheat is the presence of a photosensitizing agent known as fagopyrin. Pigs fed high levels of buckwheat develop peculiar eruptions and intense itching of the skin when exposed to sunlight. This condition is known as fagopyrism or buckwheat poisoning. Only white or light-coloured areas of the skin are affected and only if they are exposed to direct sunlight. If animals are kept indoors, away from sunlight, they remain normal. Therefore, under modern systems of confinement, fagopyrism is unlikely to be a problem for pigs fed buckwheat.

Buckwheat also contains several other anti-nutritional factors that may limit pig performance. There is a trypsin inhibitor in buckwheat which may decrease the digestibility of buckwheat protein. In addition, condensed tannins are also present in buckwheat but at a level considerably lower than those found in sorghum or fababeans. Despite its high quality protein, buckwheat should not be used in diets fed to starter pigs. Its high crude fibre content and low digestible energy level are likely to limit growth and reduce the efficiency of feed utilization when fed to pigs of this weight range. Other alternatives are available and producers would be wise to choose a higher energy feedstuff as the foundation for their starter diets.

The results of a feeding trial in which buckwheat was used to replace 0, 25, 50, 75 or 100% of the cereal portion of barley-based grower diets is shown in Table 4-14. Substitution of buckwheat for barley had no significant effect on feed intake, daily gain or feed efficiency. In addition, pigs fed diets containing a higher level of buckwheat tended to have leaner carcasses in comparison with pigs fed barley. Therefore, when prices dictate, buckwheat can replace barley in rations fed to growing pigs.

Table 4-14. Performance of Growing Pigs (20-60 kg) Fed Diets Containing Various Levels of Buckwheat in Combination With Barley.

	Percent of Cereal as Buckwheat				
	0	25	50	75	100
Daily Gain (kg)	0.70	0.70	0.72	0.66	0.70
Daily Feed (kg)	1.95	2.12	2.27	1.94	2.01
Feed/Gain	2.79	3.02	3.16	2.93	2.91
Backfat (mm)	30.90	31.10	29.00	27.30	27.50

Anderson and Bowland, 1984, Can. J. Anim. Sci. 64: 985-995.

There is very little research conducted on the feeding value of buckwheat for the breeding herd. Based on its nutrient content, it is likely that buckwheat could be used in gestation diets. However, buckwheat should not be used if the gestating sows are housed outdoors. In addition, because of its low energy content, buckwheat should not be fed to sows during lactation.

Additional Reading and References

Anderson, D. M. and J.P. Bowland, 1984. Evaluation of buckwheat (*Fagopyrum esculentum*) in diets for growing pigs. Can. J. Anim. Sci. 64:985-995.

Farrell, D.J. 1978. A nutritional evaluation of buckwheat (*Fagopyrum Esculentum*). Anim. Feed Sci. Technol. 3:95-108.

Thacker, P.A., D.M. Anderson and J.P. Bowland, 1984. Buckwheat as a potential feed ingredient for use in pig diets. Pig News and Information. 5:77-81.

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Canola Meal

Canola is a crop derived from rapeseed, but developed by Canadian researchers to contain low levels of erucic acid (< 2% of the oil) and glucosinolates (<30 um/g in the meal). Previously, these two constituents of rapeseed meal had impaired its use in swine diets. The improved quality of canola has elevated the crop to huge levels in Canada, surpassing all other export crops except wheat; canola in its various forms - seed, oil and meal - is now the second largest agricultural export from Canada.

There are two types of canola currently grown: Legend and AC Excel are commonly grown varieties of Argentine canola (*Brassica napus*), while Reward and Parkland are varieties of Polish canola (*Brassica rapa*). Argentine cultivars of canola are generally later maturing but higher yielding than Polish varieties.

Canola meal is produced from the seed, following a series of processes designed to maximize the oil yield; unlike the soybean industry, canola is still driven by oil production as opposed to the meal. During processing, the seed is first warmed to prevent shattering, cleaned and then passed through roller mills to produce a flake. The flakes are then conditioned using heat and moisture to prepare them for oil extraction, which occurs through a series of pre-pressing, mechanical extrusion and finally hexane extraction. The solvent is then removed from the meal using high temperature and steam which also serve to ensure that myrosinase, an enzyme involved in glucosinolate metabolism, is denatured and thus rendered inactive. The meal emerges free of solvent, with a moisture content of 8 - 10% and an oil content of less than 1.5%. Gums, a phospholipid by-product of oil extraction, may be added back to the meal at this point.

The greatest limitation to greater canola usage is not palatability, although this unfortunately remains a topic of discussion. Countless experiments have demonstrated the ability of the pig to consume canola-based diets with little or no resistance - provided the diets are properly balanced and presented to the pig. A relatively low energy level, similar to that of barley, is a much greater problem, since soybean meal contains 15% to 20% more digestible energy.

Research on lowering the fibre content of the meal could help to overcome the relatively low energy concentration. Some breeding programs are selecting for reduced hull, as another way to increase DE.

Research at the Prairie Swine Centre has revealed that if diets are formulated on an equal nutrient basis, canola meal will support performance equivalent to that of soybean meal (Table 4-15).

Table 4-15. Performance of Female and Castrated Male Pigs Fed Diets Containing Equal Levels of Digestible Nutrients (based on either soybean meal, or a combination of canola and soybean meals).

	Canola Meal	Soybean Meal
% Canola Meal	12.0	0.0
% Soybean Meal	8.3	16.1
Initial wt., kg	24.0	23.8
Final wt., kg	103.8	104.4
Ave. daily gain, kg	0.84	0.86
Ave. daily feed, kg	2.38	2.49
Feed conversion[a]	2.84	2.94
Carcass index	107.1	107.1
Lean yield, %	49.6	49.4
P2 backfat, mm	17.3	17.3

[a] Canola meal different from soybean meal, $P < 0.05$
Source: de Lange, J.F. Patience and D. Gillis. 1993. Is added biotin required in barley-based diets for growing - finishing pigs? Prairie Swine Centre Annual Report. pp. 35 - 38.

Canola Meal	
DE	3100
Crude Protein	37.7
Lysine	2.16
Digestible Lysine	1.60
Digestible Threonine	1.12
Digestible Tryptophan	0.29
Calcium	0.63
Phosphorus	1.01

Canola meal is complementary to other feedstuffs used in swine diets and in particular, represents a good "fit" with peas and other pulse crops. The relatively higher sulphur amino acid content of canola helps to offset the low TSAA content of peas, while the high energy in peas counters the lower DE value of canola meal. Because conditions that favour the growing of canola are also desirable for peas, the two crops represent an excellent complementary pair from the perspective of both swine nutrition and crop selection.

Several research trials conducted at various institutions across Canada have shown that canola meal can be used as part or all of the supplementary protein in diets fed to breeding stock. Research trials conducted at the University of Alberta showed no reduction in litter size, birth weight or weaning weight when canola meal was fed to sows for two successive parities. Therefore it would appear that canola meal can be used as the sole source of supplementary protein in diets fed to breeding stock. If high energy lactation diets are desired, extra fat will be needed to compensate for canola's low energy content. However, care should be taken to ensure that sows are gradually adapted to diets containing canola meal and not replace all of the soybean meal in the diet abruptly by canola meal.

In summary, canola meal is a high quality product and when properly utilized and priced competitively, can reduce feed costs. Using typical feed grain and protein supplement prices, canola meal is competitive with soybean meal if it can be purchased at about 65-75% of the cost of soybean meal (47% protein) on a unit weight basis. When available at this price, even conservative nutritionists should feel comfortable allowing canola meal to provide 25% of the supplementary protein in starter diets (18+ kg), 50% in grower and lactation diets and 100% of the supplementary protein in finishing and gestation diets.

Further Reading and References

Hickling, D. 1993. Canola meal: Feed industry guide. Canola Council of Canada, Winnipeg, MB. 26 pp.

Canola Seed: Full Fat

Considerable interest has been shown recently in the possibility of incorporating whole canola seed into swine diets. Dry growing conditions, early frosts and other weather conditions may result in the production of off-grade canola seed which is unsuitable for crushing or export. This seed can be salvaged as a feed ingredient.

Unprocessed canola seed contains approximately 40% oil and 20% crude protein. Therefore, it can be regarded as a high energy, relatively high protein supplement. The level of other nutrients are similar to those found in canola meal modified only by the dilution effect of the oil.

Canola Seed: Full Fat	
DE	4750
Crude Protein	20.7
Lysine	1.20
Calcium	0.39
Phosphorus	0.64

The addition of fat to swine diets has been shown to increase growth rates and improve feed conversion efficiency for growing pigs. In addition, the reproductive performance of sows has been shown to improve as a result of fat supplementation. Unfortunately, there are many mechanical problems associated with adding fats and oils to swine diets, especially on farms using mix mills. However, many of these problems can be overcome through the use of whole canola seed as a fat source. Since canola seeds are very small, a fine screen is required. The experience of some farmers indicates that a 1/8" screen in good condition will result in a reasonably good grind; some whole seeds may pass through, but they represent a small portion of the total.

There is little information available on the nutritional value of whole canola seed for starter pigs. However, it would appear that the performance of starter pigs may be enhanced as a result of including whole canola seed in starter diets. The results of one feeding trial conducted at the University of Alberta are presented in Table

4-16. This data indicates that the inclusion of 15% canola seed resulted in improved growth and increased efficiency. However, at higher levels of inclusion, the palatability of the diet appeared to decrease and as a consequence, performance declined.

Table 4-16. Performance of Starter Pigs Fed Diets Containing Whole Canola Seed.

	Control	15% Canola	30% Canola
Average Daily Gain (g)	498	512	415
Average Daily Feed (g)	638	649	615
Feed Conversion	1.28	1.26	1.48

Adapted from Shaw and Aherne, 1987, Univ. Alberta 66th Ann. Feeders Day Report. pp. 7-9.

The results of a feeding trial in which whole canola seed was included at 0, 3, 6, 9, 12 or 15% of the diet of growing pigs are shown in Table 4-17. In general, growth rates were improved at all levels of inclusion but the optimum inclusion level appeared to be about 6% of the diet. However, it may be possible to include whole canola seed at levels of up to 15% of the diet without any adverse effects on pig performance.

It is important to note that the above experiment utilized soybean meal as its source of additional dietary protein. Addition of a myrosinase source such as whole canola seed to a diet containing canola meal as the protein supplement could lead to glucosinolate hydrolysis. This may result in a reduction in performance. Therefore, it is recommended that whole canola seed not exceed 10% of the total diet if canola meal is present.

There does not appear to be any published information on the effects of feeding whole canola seed to breeding stock. Therefore, until more information is available regarding the effects of feeding whole canola seed on reproductive performance, diets fed to pregnant or lactating sows should not contain whole canola seed.

Table 4-17. Performance and Carcass Composition of Pigs Fed Diets Containing Whole Canola Seed.

	Dietary Level of Canola Seed (%)					
	0	3	6	9	12	15
Average Daily Gain (kg)	0.67	0.72	0.73	0.70	0.70	0.70
Average Daily Feed (kg)	2.09	2.17	2.10	2.19	2.03	2.04
Feed Conversion	3.11	3.01	2.87	3.12	2.90	2.91
Dressing Percentage	76.5	77.1	77.1	78.2	76.7	77.0
Carcass Grade	101.8	101.0	102.7	99.5	101.8	99.7
Backfat (cm)	3.2	3.2	2.9	3.4	3.0	3.3

Adapted from Castell and Falk, 1980. Can. J. Anim. Sci. 60:795-797.

Corn

Corn (*Zea mays*) sometimes referred to as maize and related products have been popular ingredients in swine diets for many years. Corn first became a popular swine ingredient in Ontario when new cultivars made it agronomically more feasible about 30 years ago. The high yields achieved in areas capable of growing corn quickly translated into more pounds of pork per acre than barley and the switch to corn was thus inevitable. However, its early introduction was met with a certain degree of scepticism, due to concerns about carcass grades. Proper diet formulation, and in particular maintaining proper amino acid to energy ratios, soon overcame such resistance. Pig diets based on corn, soybean meal and premix have become widely accepted and have become standards against which many alternative diets are compared. This does not imply that corn (and soybean meal) based diets should always be the diet of choice. In many parts of the world, equivalent of better performance is achieved in pigs fed diets that contain feedstuffs other than corn as compared to pigs fed corn based diets. For example, starch in corn is not as well digested by young, newly weaned piglets as the starch in oats or barley. However, corn is fed as the main feed ingredient in diets for millions of pigs and will continue to be a major feed ingredient in the future.

Because of its high energy content, pigs perform well on diets based on corn. Carcass quality is not impaired, as evidenced by the fact that average carcass indexes in Ontario or Quebec, where corn is the predominant grain, are no poorer than those in regions where corn is not used. The carcass fat from pigs fed on corn will be different than the fat of pigs fed wheat or barley; it will be slightly softer and perhaps yellower in colour. The softer consistency reflects the content and quality of fat in corn. Corn contains approximately 3.5% fat which is substantially higher than that in barley and wheat that contain approximately 1.7% fat. The fat that is present in corn tends to be highly unsaturated and soft (oily) as well; the colour is due to the presence of a pigment called cryptoxanthin. In some parts of the world, this colour is considered undesirable and white varieties of corn are preferred.

Corn	
DE	3550
Crude Protein	8.5
Lysine	0.26
Dig. Lysine	0.17
Dig. Threonine	0.21
Dig. Tryptophan	0.04
Calcium	0.02
Phosphorus	0.25

The protein content in corn is low and of poor quality. Lysine and tryptophan are the first and second limiting amino acids, respectively, for swine. The reason for the poor quality of the protein is that zein, the main storage form of protein in the kernel, is a poor source of many essential amino acids.

The amino acid content of corn can be predicted using regression equations based on crude protein. These equations can be found in chapter 3.

Varieties of corn that are higher in protein and more specifically in lysine have been bred. The lysine content in these varieties is approximately 30% higher than in conventional corn. The original high lysine varieties, and in particular Opaque 2, were not widely accepted because of poor agronomic characteristics, such as yield and disease resistance. However, more recently newer varieties have been developed that have better yielding characteristics. Commercial hybrids of these new varieties will become available over the next few years. In addition new varieties of corn with extremely high fat contents (up to 10%) may become available in the future. The DE content of these varieties may be as much as 10% higher than those in conventional corn.

Perhaps the greatest concern surrounding the use of corn in swine diets is its susceptibility to molds, especially when wet weather arrives during critical growing stages. The actual mold does not appear to be the problem; the fungi may consume some nutrients in the kernel, but the effect on feed quality is questionable. Corn so moldy that the kernels could hardly be separated, has been fed to pigs with no adverse affects on performance. However, when the mold produces a mycotoxin, such as vomitoxin or searalenone, the effects on swine can be very serious. Reproductive performance of sows appears to be most susceptible, so that some pork producers have switched to barley-based diets for the breeding herd. This is not necessarily a practical solution, since barley can also be infected, and lactation diets based solely on barley as the basal grain may contain insufficient energy to support maximum milk production.

If a suspected outbreak of mycotoxicosis occurs, there is reason to believe that an increase in the nutrient (energy, protein and vitamin) content of the diet will be beneficial. Minimize other stressors in the environment also since the pig is less capable of dealing with them. A broad spectrum antibiotic at therapeutic levels is recommended for the same reason. The best course of action is to remove the suspect feed until a proper analysis has been carried out to determine if mycotoxicosis is the cause of the problem. A variety of feed additives are currently being evaluated as potential treatments for mycotoxicosis. A more thorough discussion on mycotoxins appears in chapter 11.

Corn normally must be artificially dried to prevent deterioration during storage or stored as a wet grain, either treated with a preservative or held in an oxygen limiting structure. Drying of corn must be carefully controlled to prevent loss of nutritive value. Research has shown that drying corn at temperatures of up to 110°C to a final moisture content of 12-15% will have no effect on pig performance. Exceeding 150°C drying temperature will reduce acceptability to the pig.

On a dry matter basis, there is little difference in the nutritive value of high moisture or dry corn. Phosphorus is more available from high moisture corn. As vitamin E tends to degrade faster in high moisture corn than in dry corn, higher fortification with vitamin E may be required in high moisture corn based diets. Otherwise, the decision of which storage method to use will depend on the relative costs and convenience of the two systems. For more information on high moisture cereal grains see "high moisture barley" earlier in this chapter.

As with other cereal grains, variation in the feeding value of different samples of corn, due to differences in variety, growing, harvesting, and drying conditions can be expected. It is, however, surprising how little research has been conducted to determine variation in feeding value of different samples of (sub-standard) corn. Based on research with chickens, which are more sensitive to changes in feeding value than pigs, it can be concluded that corn bushel weight is a poor indicator of feeding value of individual corn samples. This is supported by the observations made on starter pigs (Table 4-18). These results suggest that some samples of immature dried corn with an extremely low bushel weight can support levels of performance similar to that in pigs fed regular corn. Unlike in barley and wheat, fibre levels in corn are generally low and do not vary much between samples. Fibre is thus also a poor predictor of feeding value of corn samples. The best predictor of feeding value may be the starch content. In high fat corn varieties, the fat content should be considered as well. In regular corn, the starch content is approximately 60%, while it may be as low as 50% in some samples of corn. Based on the French and Dutch net energy

Table 4-18. Nutritional Value of Immature Corn (different bulk density) for Starter Pigs Fed Corn-Soybean Meal Based Diets.

	Bulk density (lbs/bu)	Gain (kg/day)	Feed intake (kg/day)	Feed efficiency
Control 1*	57.4	.55	1.32	2.40
Control 2**	58.7	.57	1.42	2.49
Variety A#	50.6	.59	1.38	2.34
Variety B#	43.7	.60	1.41	2.35
Variety C#	43.6	.48	1.24	2.58
Variety D#	45.7	.51	1.23	2.41

*1991 Ontario harvest; ** 1992 Indiana harvest; #immature dried corn harvested between Dec 4, 1994 and Jan. 12, 1993. Adapted from Patterson et al., 1993, J. Anim. Sci. 71 (supplement 1): 157 (abstract).

systems it could be derived that the DE content will be reduced by 20 Kcal/kg per percent reduction in starch content. This relationship should be confirmed in well controlled studies. As mentioned earlier, the amino acid content of different corn samples may be predicted from the amino acid content.

Additional Reading and References

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Adams, K.L. and A.H. Jensen. 1987. High-fat maize for pigs and sows. Anim. Feed Sci. Techn. 17:201-212.

Corn By-Products

While the major portion of the corn crop is destined for use in livestock feeds, some is destined for further processing. Three industries use corn as raw material: the wet millers who produce starch and oil for human use, the dry millers who produce grits, meal and flour, and the fermentation industry. In all cases, between 25 and 35% of the corn used this way will be returned in processed form to the livestock industry as feed ingredients.

Corn gluten feed and meal are by-products of the wet milling industry. During wet milling, the raw corn is soaked or steeped to soften the kernel and facilitate separation of gluten, protein and germ. Steep water may be collected and sold as animal feed. It is rich in protein and B-vitamins. The steeped corn is then de-germinated (removes the germ which may be sold as corn germ meal); all that is remaining at this point is the starch, gluten and hulls. The hulls are removed and the residual centrifuged to separate starch from gluten. The corn starch is destined for the human food trade while the gluten is used as animal feed. For every 100 kg of corn milled, there will be 62-68 kg of starch, 3 kg of oil and the remainder will be corn gluten meal, corn gluten feed and corn germ meal.

Corn gluten feed consists primarily of the corn hull mixed with some corn germ. Due to its high fibre and low energy content, poor amino acid balance and digestibility it is more favoured in cattle rations than in swine rations. It contains approximately 23% protein, 64% lysine and 3000 Kcal DE per kg. If included in swine diets the inclusion level should be less than 5% in starter and nursing sow diets and 20% in growing finishing pig diets. Corn gluten feed has been successfully used at high inclusion levels in dry sow diets.

Corn Gluten Meal	
DE	4150
Crude Protein	60.0
Lysine	1.03
Calcium	0.06
Phosphorus	0.38

Corn gluten meal is actually two products, containing either 41 or 60% crude protein. The former is generally a mixture of the 60% material and corn gluten feed. Thus, the 41% meal is lower in energy as well as protein compared to the 60% meal. Compared to corn, 60% protein corn gluten meal is richer in energy and crude protein. However, like the parent material, the balance of amino acids is poor with lysine and tryptophan being most limiting.

Corn gluten meal can be used in the diet of market hogs or sows at levels of 20-30% of the diet without affecting palatability or performance, assuming proper adjustments for nutrient composition are made. Indeed, higher levels are possible with careful ration formulation. Corn gluten feed will be used to a much lesser extent it at all, due to its lower energy content.

Corn distillers dried grains are derived from the fermentation industry, the most prominent of which is the alcohol industry. Actually two by-products are made available to the livestock industry: corn distillers dried grains with solubles and corn distillers dried grains. Over the last years the production has changed from primarily distillers (dried) grain to distillers (dried) grain mixed with solubles. Both of these products contain approximately 27% crude protein. Although both can be used effectively by the swine industry, the majority is destined for use in cattle rations because the type of protein is particularly attractive to high producing animals especially dairy cattle. An additional concern with using distillers grains, as in many by-products, is the variability in the product. For example, in a recent survey of only eight samples of distillers dried grains with solubles, the lysine content varied between .43 and 90% Odour and colour seem to be important in determining the feeding value; light coloured samples that are free of burnt or smoky odour, are more likely to have good nutritional properties. Inclusion levels of distillers dried grain with solubles of up to 5% in starter diets, 20% in grower-finisher diets and 40% in dry sow diets appear to have little effect on animal performance when diets are properly formulated and when good quality products are used.

Corn Distillers Grain	
DE	3450
Crude Protein	27.6
Lysine	0.79
Calcium	0.12
Phosphorus	0.65

The energy content of distillers dried grains with solubles is approximately equal to that of corn. Like the parent material, the amino acid profile of the protein is not well suited to the pig and thus needs to be used in concert with a good quality protein supplement. Although calcium and phosphorus levels are higher than corn, the differences are of only marginal economic benefit.

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Table 4-19. Effect of Bushel Weight on Rate and Efficiency of Growth and on Digestibility of Energy in Corn.

Relative Change[1] Corn Bushel Weight	Rate of Gain	Feed Efficiency	Digestible Energy
Alberta			
60 (100)	100	100	100
56 (93)	103	99	101
55 (92)	96	99	99
54 (90)	100	99	99
54 (90)	97	99	97
Manitoba			
59 (100)	100	100	100
58 (98)	96	101	101
58 (98)	99	99	99
57 (97)	99	100	9
53 (90)	98	99	100

[1] Comparisons were carried out by arbitrarily setting the values for the highest bushel weight at 100 and calculating each parameter as a percentage of the highest bushel weight sample. Thus, in an Alberta sample, the 56 lb corn had a bushel weight that was 93% of the highest sample, but birds grew 103% as fast as the birds on the heaviest corn, they converted the feed at 99% that of birds on the heaviest corn, and had a DE value of 101% that of the heaviest corn.

Adapted from Campbell, 1981, Proc. Western Nutr. Conf. pp 238-242.

Dried Bakery Product

Dried bakery product, as its name suggests, is reclaimed waste from bakeries. Because it has been cooked during the manufacturing of the original baked goods, this product is an excellent ingredient for swine, especially for young pigs whose digestive abilities are not yet fully developed. The cooking degrades the starches and renders them more available to the pig resulting in fewer problems with digestive upset.

However, because dried bakery product represents waste materials, it often lacks uniformity; its contents reflect the materials manufactured at the time and place of collection. This lack of uniformity has compromised interest by the swine industry. Also, since many bakery products are rich in salt, the by-products also contain a lot of salt. Excess salt is not desirable in the diet of young pigs. Many bakery products are also sweet, so dried bakery products tend to be highly palatable.

Dried Bakery Product	
DE	3975
Crude Protein	10.0
Calcium	0.15
Phosphorus	0.25

If it can be purchased at a good price and its nutrient composition can be characterized with reasonable accuracy, dried bakery product offers considerable opportunity in swine rations. Levels of up to 30-40% of the diet would not be considered excessive, providing salt does not become too high and assuming the material has been properly analysed with respect to nutrient composition. Because of cost, dried bakery product is best used in starter diets.

Fababeans

Fababeans (*Vicia faba*) are an annual belonging to the legume family and are related to the garden broad bean. Initially most of the crop was grown for silage, but in recent years more than 75% of the crop has been grown for grain. The average crude protein content of fababeans is approximately 24 - 30%. Fababean protein is relatively high in lysine but like most legume seeds, it is deficient in methionine. A high level of cystine partly overcomes the methionine deficiency and therefore, supplementation of diets containing fababeans with synthetic methionine has not proven to be beneficial. The balance of other amino acids appears fine.

Fababeans have a digestible energy content between that of soybean meal and barley. The fat content of fababeans is low (1.5%), which partially accounts for its lower digestible energy. Fababean oil contains a high content of unsaturated fatty acids which can lead to the early development of rancidity after the seed has been ground. Therefore, processed fababeans should not be stored more than a week before use. The relatively high crude fibre content of fababeans (8%) can also account for its lower digestible energy content.

Fababeans are a relatively poor source of calcium and are low in iron and manganese. In fact, extra supplementation of manganese is required if a diet contains a large proportion of fababeans. The vitamin content of the fababean is lower than that found in soybean meal or canola meal and therefore, diets containing a high level of fababeans may require a specially formulated premix in order to supply a balanced ration.

Fababeans contain a relatively high level of trypsin inhibitor although the level of trypsin inhibitor in fababeans is lower than the level found in raw soybeans. The presence of this trypsin inhibitor may cause a reduction in the digestibility of protein in diets containing fababeans. However, the level of trypsin inhibitor can be reduced by autoclaving (steam heating under pressure) fababeans at 120°C for 30 minutes.

Fababeans	
DE	3150
Crude Protein	26.7
Lysine	1.62
Calcium	0.12
Phosphorus	0.49

Another undesirable factor is hemagglutinin which has been found to be present in fababeans at a level of 2900 to 4200 rabbit RBC units per gram. The corresponding values for soybeans, wheat and barley are 650, 50 and 5 units. Autoclaving at 120°C has also been shown to reduce the activity of the hemagglutinins in fababeans.

Fababeans contain between 0.3 and 0.5% tannin. The presence of these tannins may lead to a reduction in feed intake when high levels of fababeans are fed to swine. In addition, the digestibility of protein and energy may be reduced as a result of the presence of these tannins.

As a result of the anti-nutritional factors present in fababeans, it is recommended that fababeans not be used to supply 100% of the supplementary protein required to provide a balanced diet for swine. Although there has not been a great deal of research conducted to determine the value of including fababeans in starter pig diets, the few reports available suggest that fababeans should not be included at a level in excess of 15% of the diet (Table 4-20). At higher inclusion levels, there appears to be problems with palatability and as a consequence of the lower feed intake, growth rates are impaired.

Table 4-20. Performance of Starter Pigs (10-25 kg) Fed Graded Levels of Fababeans.

	Level of Fababean (%)				
	0	10	15	20	25
Daily Gain (kg)	0.55	0.54	0.54	0.48	0.51
Daily Feed (kg)	1.27	1.24	1.20	1.11	1.17
Feed Conversion	2.31	2.31	2.22	2.31	2.30

Aherne et al. 1977, Can. J. Anim. Sci. 57: 321-328.

The adverse effects of including high levels of fababeans in the diet of the growing pig are clearly demonstrated by the results of a feeding trial conducted at the University of Alberta (Table 4-21). As the level of fababeans in the diet increased, daily gain and feed conversion efficiency decreased. The decrease in performance was particularly evident at levels of inclusion greater than 20% of the diet.

The effects of including fababeans in breeding stock diets has received little attention. However, Danish workers have reported a significant reduction in litter size both at birth and weaning when fababeans are included at high levels in gestation diets (Table 4-22). Milk protein content and yield have also been reported to be reduced when fababeans are included at high levels in lactation diets. Caution should also be exercised when feeding fababeans to pregnant sows as fababeans generate stomach gases and may cause constipation. For these reasons, fababeans should not be used at levels greater than 15% in diets for breeding stock.

Table 4-21. Performance of Grower Pigs (16-45 kg) Fed Diets Containing Fababeans.

	Fababean Level (%)					
	0	10	15	20	25	30
Daily Gain (kg)	0.68	0.66	0.65	0.65	0.61	0.58
Feed Intake (kg)	1.87	1.94	1.89	1.90	1.98	1.95
Feed/Gain	2.75	2.92	2.89	2.94	3.25	3.40

Aherne et al., 1977, Can. J. Anim. Sci. 57: 321-328.

Table 4-22. Effect of Fababeans on Reproductive Performance.

	Fababeans (%)		
	0	17	34
Pigs Born Alive	12.0	10.5	9.7
Birth Weight (kg)	1.4	1.4	1.4
Pigs Weaned (8 weeks)	9.2	8.3	8.1
Weaning Weight (kg)	19.1	19.0	19.6
Milk Yield (kg/day)	6.3	5.5	5.2
Dry Matter (%)	19.0	18.9	18.6
Protein (%)	7.1	7.0	6.5
Fat (%)	5.5	5.6	5.7

Nielsen and Kruse, 1973, Livest. Prod. Sci. 1: 179-185.

In summary, fababeans have much to offer as a protein supplement and a considerable reduction in feed costs may be achieved by their inclusion in the diet. However, inclusion at too high a level will impair animal performance. It is recommended that fababeans not be included at levels greater than 15% in starter diets, 20% in grower diets and 15% in diets fed to breeding stock.

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Field Peas

Field peas (*Pisum sativum, arvense*) are primarily grown for human consumption and used mainly in soup. Peas, or splits can be used quite effectively as a livestock feed when available at a sufficiently low price. In swine diets, field peas are most often utilized to replace a portion of the protein supplement but may also replace part of the cereal grain in the diet.

At 22 - 29% crude protein, field peas are intermediate in protein content between cereal grains and conventional protein sources. They are a good source of lysine and appear to be adequate in all other essential amino acids with the exception of methionine and tryptophan.

The digestible energy content of field peas (approximately 3372 kcal/kg) is higher than most commonly used feedstuffs. A high concentration of easily digested starch is one of the major factors accounting for this high digestible energy content.

The fat content of field peas (1.2%) is low and crude fibre levels in the field pea (5.8%) are approximately the same as those found in barley.

Field peas contain higher levels of both calcium and phosphorus than the common cereal grains. However, field peas are very deficient in vitamin E and selenium and care should be taken to ensure that the diet is supplemented with these two nutrients when field peas are included at high levels in swine diets.

Field Peas	
DE	3400
Crude Protein	23.4
Lysine	1.50
Digestible Lysine	1.25
Digestible Threonine	0.62
Digestible Tryptophan	0.16
Calcium	0.09
Phosphorus	0.50

Peas, like other pulse crops, contain some anti-nutritional factors which will affect pig performance if present at high enough levels. The presence of a trypsin inhibitor is likely the most important. The trypsin inhibitor content of spring seeded varieties of field peas is generally between 2.3 and 5.5 TIA (trypsin inhibiting activity) units/mg DM (dry matter) while winter varieties generally average between 8.9 and 15.9 TIA units/mg DM. Field peas are also reported to contain 80 units of hemagglutinating activity and between 3.8 and 7.0 mg/kg of cyanogenetic glycosides. Although these anti-nutritional factors can be inactivated by heat, they are usually not present at high enough levels to reduce performance and therefore, are not generally considered when formulating diets for swine.

There has not been a great deal of research conducted to determine the value of including field peas in starter pig diets. However, the few reports available suggest that field peas can be included in starter diets up to a level of 15% of the diet without affecting performance. At higher levels of inclusion, feed conversion starts to decline. Inadequate tryptophan levels are suggested to be the cause of the reduction in performance. Therefore, careful balancing of the diet for amino acids may permit even higher levels of inclusion.

There is much more data available on the effect of including field peas in the diet of growing pigs. The results of a feeding trial conducted at the Agriculture Canada Research Station in Brandon in which the performance of pigs fed a control diet containing 12.3% soybean meal as the protein supplement was compared with that of pigs fed diets containing peas at 11, 22 or 33% of the diet are shown in Table 4-23. Pigs fed diets containing field peas gained as well as those fed the control diet at all levels of inclusion. No significant changes were observed in carcass quality as a result of feeding peas. Therefore, it would appear that field peas can be used as the sole source of supplementary protein in the diet of growing pigs without adversely affecting rate of gain or feed efficiency.

Table 4-23. Performance of Pigs (27-95 kg) Fed Peas as a Replacement for Soybean Meal.

	Level of Pea Substitution (%)			
	0	11	22	33
Daily Gain (kg)	0.88	0.89	0.83	0.86
Daily Intake (kg)	2.65	2.58	2.59	2.55
Feed Efficiency	3.01	2.90	3.12	2.96
Backfat (mm)	16.1	15.5	15.7	15.2

Castell et al., 1988. Can. J. Anim. Sci. 68: 577-579.

There has been a considerable amount of interest recently in the use of protein supplements made up of a blend of field peas and canola meal. Canola meal is a good source of sulphur containing amino acids while peas are a superior source of lysine. As a consequence, these two ingredients are particularly compatible. Experimental evidence indicates that the performance of pigs fed a blend of these two protein sources is superior to that of pigs fed either ingredient alone (Table 4-24).

Table 4-24. Performance of Growing-Finishing Pigs (25-90 kg) Fed a Mixture of Peas and Canola Meal.

	SBM	C[1]	P[2]	1/3P 2/3C	2/3 P 1/3 C
Daily Gain (kg)	0.82	0.84	0.81	0.85	0.88
Daily Feed (kg)	2.32	2.44	2.38	2.53	2.62
Feed Efficiency	2.83	2.89	2.93	2.94	2.98
P2 Fat Depth (mm)	11.7	11.9	12.2	11.7	12.5

[1] Canola Meal
[2] Field Peas
Castell and Cliplef, 1993. Can. J. Anim. Sci. 73: 129-139.

There is limited information on the effect of feeding field peas to breeding stock. In one trial, field peas were included at levels as high as 15% in gestation diets and 25% in lactation diets without affecting prolificacy or the number and weight of weaned piglets. However, other trials have reported reductions in litter size when a level of 10% of field peas was included in diets fed during gestation and lactation. Therefore, until further work is conducted, it may be wise to limit field peas to no more than 10% of diets fed to breeding stock.

In summary, field peas have much to offer as a protein supplement and a considerable reduction in feed costs may be achieved by including them in swine diets. However, for best results it is recommended that field peas not be used at levels higher than 15% for starter pigs and 10% for breeding stock. For growing pigs, it would appear that field peas can be used to completely replace the soybean meal in the diet.

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Grain Dust

Grain dust is normally considered a nuisance if not an outright health and safety hazard in grain handling facilities. Yet, studies in the United States suggest it is potentially a very good ingredient, reflecting in nutrient composition, the parent material. The possible exceptions are fibre and ash which tend to be somewhat elevated relative to the parent grain. Grain dust contains slightly more lysine than the parent material. For example, wheat dust contains 24% more lysine than the wheat it came from. A summary of one study (Table 4-25) illustrates the difference between dust and parent grains. One note of caution is the observation that considerable non-protein nitrogen may be present in the dust so that crude protein analysis may over-estimate the true feeding value. Handling the product tends to be a major frustration because it is bulky and not easily conveyed by conventional grain handling equipment. Lack of uniformity is also a concern.

Table 4-25. Comparison of the Composition of Grain Dust and Parent Grains.

	Wheat		Corn		Soybean	
Nutrient	Grain	Dust	Grain	Dust	Grain	Dust
Moisture (%)	8.3	8.2	9.5	10.4	6.3	7.4
CP (%)	12.7	11.3	10.4	7.9	37.7	12.4
Ash (%)	1.7	21.2	1.3	4.9	4.9	20.0

Adapted from Hubbard et al., 1982, Cereal Chem. 59:20-22.

Contamination can also be a problem. Molds may become associated with the dust from elevators and other inadvertent contamination from various chemicals and solvents used in the grain equipment must be monitored. This may pose a health threat not only to pigs eating it, but also to persons working in the barn and thus exposed to the dust.

Except for these very important concerns, grain dust would appear to offer opportunities for feed savings if the feed mill or farmer is willing to invest some time and money in developing the expertise required to formulate and manufacture appropriate diets.

Grain Screenings

Grain screenings are not normally considered for use in swine diets. The product is highly variable and thus difficult to characterize sufficiently for precise diet formulation. Since screenings are often available at a very reasonable price, they should not be ignored. However, they should be used with caution.

There are a number of classes of screenings available, generally from brokers or directly from terminal elevators. Wheat screenings (No. 1 wheat screenings, wheat feed screenings) are the best quality of screenings available. They are obtained from the cleaning of wheat, and as such will often contain considerable quantities of broken or small wheat kernels. These are obviously quite satisfactory for inclusion in swine diets. They will also contain weed seeds such as wild buckwheat, wild oats, cow cockle, lady's thumb, mustard and others. Table 4-26 compares the chemical composition of five samples of wheat screenings compared to a sample of typical whole wheat.

Considering the origin of the product, wheat screenings appear to be relatively consistent from sample to sample and contain an excellent nutrient profile. Crude protein and ether extract levels are higher than wheat, while fibre on average is only slightly higher than wheat. Thus, one would suspect that such a material would have a digestible energy content of at least that of wheat and probably 5% higher. The gross amino acid composition is also encouraging, with lysine, threonine and total sulphur amino acids (methionine plus cystine) above that of wheat. Since no estimate of availability was given, one must be cautious in assigning available amino acid levels any higher than those found in wheat. Thus, if the product is palatable, it could be used in the diet of growing pigs and adult swine at up to 40% of the total diet.

Grain screenings tend to be of somewhat lower feeding value than wheat screenings. No. 1 grain screenings are of approximately the same feeding value as barley. Canola screenings, consisting of only about 10% whole canola with the remainder chaff, dust and weed seeds, is inferior to barley. Digestibility studies suggest canola screenings have about 60% of the feeding value of barley. Mixed feed oats are in essence wild oats (86% of total) and are of only slightly better value than rapeseed screenings. Refuse screenings are about equal to mixed feed oats.

In summary, the better quality screenings (No. 1 wheat screenings and No. 1 feed screenings) can be used in swine diets, provided palatability concerns related to noxious weed seeds can be addressed. No. 1 wheat screenings are approximately equivalent to wheat and No. 1 feed screenings are approximately equal to barley in terms of energy and perhaps slightly better in terms of amino acids. The use of other screenings in swine diets will lead to reduced performance due to lower energy content unless adjustment in other ingredients is made. Their use would not normally be recommended in the diets of lactating sows, weanlings or growing pigs.

Table 4-26. Chemical Composition of Five Samples of Feed Wheat Screenings Compared to Wheat.

	Wheat Typical Analysis	Wheat Screenings Avg.	Wheat Screenings S.D.[1]
Crude protein	12.20	13.60	0.90
Ether extract	1.60	5.30	1.70
Crude Fibre	2.60	3.40	0.70
Ash	1.40	2.20	0.20
Calcium	0.04	0.11	0.03
Phosphorus	0.31	0.37	0.02
Lysine	0.33	0.41	0.03
Threonine	0.28	0.36	0.02
Total Sulphur Amino Acids	0.35	0.42	0.02

Grain Screenings No. 1 Wheat	
DE	3250
Crude Protein	12.9
Lysine	0.37
Calcium	0.04
Phosphorus	0.32

Grain Screenings No. 1 Feed Wheat	
DE	3100
Crude Protein	11.2
Lysine	0.39
Calcium	0.07
Phosphorus	0.29

Lentils

Lentils (*Lens culinaris*) are a pulse crop suited to cool temperate regions, exhibiting only moderate resistance to drought or high temperature. The major varieties grown in western Canada are Laird and Eston. Lentils are grown for sale to the human food market but on occasion, become available at a competitive price to pork producers due to market conditions or as a result of frost damage, seed damage or aschocyta blight. Discoloration during storage is also a concern, since it results in reduced grades. Tannins, concentrated in the seed coat, oxidize as the seed ages in storage causing the seed coats to darken. It is advised that lentils be stored at a moisture content no higher than 16% to prevent deterioration during storage. If drying is required, temperatures should not exceed 43°C.

The chemical composition of lentils is influenced by the cultivar seeded and the growing conditions prior to harvesting. The crude protein content of lentils (25.7%) is intermediate to cereals and soybeans. Like all pulse crops, lentils are a relatively poor source of sulphur amino acids but are rich in lysine. Care must be taken in swine rations, especially those for the young pig, to ensure that sulphur containing amino acids are not deficient. About 7% of lentil protein is non-protein nitrogen and the percent nitrogen in protein is 5.72%. Raw lentils contain trypsin and chymotrypsin inhibitors, although it appears that these are of a sufficiently low concentration to offer no difficulties when fed to swine at up to 30% of the total diet. The lipid content is not high, but is rich in linoleic acid, an essential fatty acid in the diet of the pig. This may be particularly important in areas where coarse grains such as wheat and barley are fed, since they contain much less linoleic acid than diets based on corn.

Lentils	
DE	3065
Crude Protein	24.6
Lysine	1.63
Calcium	0.08
Phosphorus	0.33

Lentils are a very acceptable feedstuff for swine. Even if slightly frost damaged and infested with aschocyta, incorporation into diets at 30% will cause no problems provided they are properly formulated with respect to energy and essential amino acid content (particularly methionine). On the basis limited research, it appears that aschocyta-infestation of lentils has little if any adverse effect on pig performance or health.

Table 4-27. Effects of Feeding Cull Lentils on Digestibility and Pig Performance (23-100 kg).

	Content of Lentils (%)			
	0	10	20	30
Apparent Digestibility (%)				
Dry Matter	79	79	78	79
Energy	80	80	78	79
Nitrogen	78	78	75	76
Performance (23 to 100 kg)				
Daily Gain (kg)	0.82	0.83	0.86	0.86
Daily Intake (kg)	2.53	2.48	2.56	2.58
Feed Efficiency	3.09	2.99	2.98	3.00

Bell and Keith, 1986 Can. J. Anim. Sci. 66: 529-536.

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Molasses

Molasses is a by-product of the manufacturing of sugar from either sugar cane or sugar beets. Thus, molasses is often referred to as beet molasses or cane molasses. Beet molasses is higher in crude protein (7-11% versus 3-4%) than cane molasses. Beet molasses contain slightly more (4%) energy than cane molasses but the latter tends to contain more calcium (0.8-1.0% versus 0.1%).

Molasses - Beet	
DE	2475
Crude Protein	7.1
Calcium	0.10
Phosphorus	0.02

Molasses is becoming a much more difficult product to obtain in adequate quantities at a competitive price and thus is not generally used in swine rations. There are exceptions, however. Sometimes, molasses will be used at a rate of 3-5% of the diet for sows to help prevent constipation and enhance feed intake. Other ways of reducing constipation are available, so using molasses will depend on the personal preference of the farmer and his nutritionist.

Typically, molasses contains about 22-25% moisture. Energy content is about 12-15% less than that of oats; therefore, use of molasses in swine diets will reduce energy and crude protein content unless other adjustments to the formula are made.

Oats

Oats (*Avena sativa*) are not widely utilized as an energy source for use in swine production. The main reason for their lack of use is the fact that they contain a very high hull content which lowers their digestibility and limits their nutritive value for swine. However, when economics dictate, they may find a place in diets fed to pigs during the various stages of the production cycle.

Oats contain approximately 11.5% crude protein (N x 6.25) and this protein is of reasonably high quality, having a better balance of amino acids than any of the other grains. They are still deficient in lysine, threonine and the sulfur containing amino acids. However, in contrast to most cereal grains, selection for an increase in protein content will not decrease protein quality. In this regard, oats are unique among cereal grains since the lysine level of grain is not inversely related to its protein content.

Oats contain approximately 10% less digestible energy than barley and about 20% less energy than wheat and corn. The main reason for the reduction in energy content is the fact that oats contain almost 11% crude fibre. This fibre is not digestible by the pig and its presence also impairs the digestibility of other nutrients contained in the grain.

Oats contain almost twice as much fat as barley and wheat. This fat is distributed throughout the endosperm, germ and aleurone layer of the oat kernel with very little fat present in the pericarp (outer layer). Oats also contain a very active lipase (fat splitting enzyme) which is present almost entirely in the pericarp of the oat kernel. Fortunately, the enzyme does not normally come in contact with the fat since this could lead to the development of rancidity. However, when the oat kernel is broken or ground, the lipase in the pericarp is brought into contact with the oat fat and free fatty acids are released. As a consequence, ground oats are far more likely to spoil than are other cereal grains and care should be taken not to process them too far in advance of when they are required.

Oats	
DE	2800
Crude Protein	10.8
Lysine	0.40
Digestible Lysine	0.26
Digestible Threonine	0.19
Digestible Tryptophan	0.08
Calcium	0.10
Phosphorus	0.35

Since oats are low in energy, they are not recommended as a good source of carbohydrate in starter diets. For example, when oats replace corn at levels between 0 and 50% (Table 4-28a) in diets fed to pigs from 5 - 18 kg, both growth rate and feed conversion suffer. This reduction in performance may reflect the pigs' inability to consume sufficient oat diet to meet their energy requirements for optimal growth. The gains are therefore slower and less efficient.

The adverse effects of including oats in diets fed to growing pigs are clearly demonstrated by the results of the experiment presented in Table 4-28b. It can be seen that as the level of oats in the diet increases, average daily gains decrease and the amount of feed required per pound of gain increases. Clearly, if any reasonable level of performance is desired, oats should not be included in grower diets.

Table 4-28a. Effect of Substituting Oats for Corn on the Performance of Weaner Pigs.

	Level of Oats (%)					
	0	10	20	30	40	50
Daily Gain (kg)	0.35	0.36	0.33	0.30	0.30	0.30
Daily Feed (kg)	0.68	0.68	0.67	0.67	0.61	0.64
Feed Conversion	1.94	1.89	2.03	2.10	2.03	2.13

Watts and Moser, 1981, Nebraska Swine Report. pp 5-6.

Table 4-28b. Effect of Substituting Oats for Corn on Grower Pig Performance.

Level of Oats (%)	0	29	60	95
Daily Gain (kg)	0.80	0.70	0.63	0.57
Daily Intake (kg)	2.93	2.95	2.77	2.71
Feed Conversion	3.67	4.20	4.44	4.77

Jenson et al., 1959, J. Anim. Sci. 18: 701-709.

Oats may be successfully used in diets fed to gestating sows. During gestation, it is recommended that the energy intake of sows be restricted. Therefore, the lower energy content of oats is a desirable feature. However, it is recommended that oats constitute no more than 50% of diets fed to sows during gestation. During lactation, oats should not be fed at all.

Feeding oats may also be of value if a swine operation is experiencing problems with gastric ulcers. Several experiments have suggested that oats may have some value in protecting growing pigs against ulcers. The protective effect of the oats is believed to be due to an alcohol-soluble fraction contained in the hulls.

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Oats: Naked

Since the high fibre content of oats is the major factor detracting from its use as a livestock feed, a considerable amount of effort has been extended to try and reduce the crude fibre content of oats. Plant breeders in several countries have recently developed varieties of naked oats and these new cultivars would appear to have considerable potential for use in swine production. The most popular naked oat currently available in Canada is the cultivar Tibor.

Hulless oats are not really hulless. They do have a hull but it is much more loosely attached than with conventional oats and is blown away in the field during combining. Therefore, the crude fibre content of hulless oats (2.7%) is much lower than conventional oats (10.7%). As a consequence, the digestible energy content of hulless oats is much higher than that of conventional oats. In addition, the oil content is also higher in hulless oats (7.5% versus 4.7%) than conventional oats. Due to the increase in oil, it is wise to supplement diets containing naked oats with higher levels of vitamin E to avoid problems with rancidity.

The crude protein content of hulless oats is also higher than conventional oats. Hulless oats have a good balance of amino acids with lysine and methionine being the only amino acids not present in adequate amounts to meet the requirements. Vitamins and minerals are generally present at a slightly higher level than in conventional oats as a result of removing the diluting effect of the hull.

Despite the improvement in the nutritional composition of hulless oats, it would appear that they still cannot be utilized as the sole cereal source in diets fed to weaner pigs. The results of an experiment in which naked oats were compared with corn and wheat for pigs from 25 - 56 days of age are shown in Table 4-29. All diets were adjusted with dried skim milk and fish meal so they provided 26% protein, 1.4% lysine and 17 MJ DE/kg. However, both daily gain and feed efficiency were poorer for pigs fed the diets containing hulless oats. The poorer performance for the weaner pigs fed naked oats has been attributed to the presence of a high level of beta-glucan, a gummy polysaccharide which interferes with digestion.

Table 4-29. Comparison of Naked Oats and Other Cereal Grains as an Energy Source for Weaner Pigs (25 - 56 days).

	Naked Oats	Oat Flakes	Wheat	Corn
Daily Gain (g)	381	434	472	433
Daily Intake (g)	575	625	651	601
Feed Conversion	1.51	1.44	1.38	1.39

Fowler, 1985, Pig Farming Suppl. pp 45-52.

Naked oats can be used with a high degree of success in diets fed to growing pigs. The results of one experiment in which naked oats were used to replace 0, 30, 65 or 97% of the corn and soybean meal in diets fed to pigs from 32 - 98 kg are shown in Table 4-30. It can be seen that growth rates were similar at all rates of inclusion while there was a tendency for feed efficiency to be improved as the level of naked oat in the diet increased. Dressing percentage was slightly improved in the naked oat diets but the carcasses tended to be fatter as the level of naked oat in the diet increased.

Table 4-30. Performance of Market Hogs Fed Naked Oats (32 - 79 kg).

	0	30	65	97
Daily Gain (kg)	0.82	0.84	0.83	0.84
Daily Intake (kg)	2.61	2.59	2.40	2.36
Feed Conversion	3.18	3.09	2.89	2.81
Dressing Percent	77.40	76.90	78.50	78.40
Backfat (mm)	32.60	32.60	32.20	33.40
Carcass Grade	104	104	103	104

Morris and Burrows, 1986, Can. J. Anim. Sci. 66: 833-836.

Several experiments conducted with naked oats and growing pigs have almost completely removed the supplementary protein from the diet without significantly affecting performance. This implies that the amino acid profile of naked oats is adequate to meet the requirements of the growing pig. Therefore, the potential exists for a substantial reduction in feed costs should naked oats be used at high levels in swine diets.

Naked oats have been grown successfully in Canada. However, in some years, the hulls were not as effectively removed by combining as hoped. Yields have also been disappointing at times. If the agronomic problems can be resolved though, naked oats should have an excellent future in swine diets.

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Oat Groats

Oat groats are obtained by mechanically dehulling oats. The removal of the highly fibrous hull from the oat seed greatly improves the nutritive value of the resulting product. Oat groats are considered to be one of the most palatable and easily digested feedstuffs available for use in swine production.

The crude protein content of oat groats is higher than that of unhulled oats as a result of removing the diluting effect of the hull. The digestible energy content of oat groats is also 35 - 40% higher. The protein quality of oat groats is considered to be fairly high with lysine and threonine being the only amino acids not present in sufficient amounts to meet the requirements of the growing pig.

Oat Groats	
DE	3725
Crude Protein	16.0
Lysine	0.50
Calcium	0.10
Phosphorus	0.40

The major factors determining the use of oat groats in swine rations are cost and availability. It takes almost 160 kg of oats to produce 100 kg of oat groats. When the initial purchase price of oats is combined with the cost of dehulling, the selling price demanded by oat groat manufacturers is higher than can be justified on the basis of their nutrient content. Therefore, oat groats are generally used only in the higher priced diets such as creep feeds and starter diets. This will depend on local conditions and the pricing policy of suppliers.

Potatoes and Potato Products

Potatoes (*Solanum tuberosum*) are grown primarily for human consumption. However, surplus potatoes, potatoes unfit for human consumption, and potato by-products (from the production of potato starch, french fries or potato chips) are available for use as swine feed ingredients.

Fresh potatoes contain only about 20-22% dry matter. Because potatoes are almost all starch, they are very high in energy but very low in crude protein. More than half of the nitrogen present is in the form of non-protein nitrogen and therefore is not protein at all. Essentially then, potatoes are a source of energy.

Potatoes	
DE	3350
Crude Protein	7.7
Lysine	0.40
Calcium	1.20
Phosphorus	0.85

A major drawback with feeding fresh potatoes is the low dry matter content (18 to 25%); when large quantities are fed to pigs, bulkiness will limit nutrient intake. In addition, raw potatoes contain anti-nutritional factors (chymotrypsin inhibitors and solanine; the latter in green potatoes in particular) that make them unpalatable to pigs. Cooking or steaming potatoes effectively inactivates these anti-nutritional factors and at the same time enhances the digestibility of starch.

The crude protein content of potatoes are low. More than half of the nitrogen present is in the form of non-protein nitrogen and therefore is not protein at all. However, the actual protein that is present in potatoes is of an extremely high quality. Purified potato protein is widely used in the human food industry; its high price prohibits its use in diets for (starter) pigs.

On a dry matter basis the feeding value of cooked potatoes is similar to that of cereal grains. The digestible energy is 3370Kcal/kg while the crude protein content is 10.9%.

Potatoes are very low in magnesium. Since magnesium is not usually supplemented in standard swine diets, special attention should be paid to this mineral to ensure it is not deficient (ie. Supplementation of the diet may be required).

Potatoes can be used effectively in the diet of pigs, although there are notable limitations. Raw potatoes contain solanin, especially in the sprouts; this is believed to be partly responsible for the poor digestibility and palatability of raw potatoes. Cooking improves digestibility and removes factors that inhibit digestive enzymes. However, the water used for cooking should be discarded and not fed to pigs because it contains the water-soluble solanin. Cooked potatoes are an excellent energy source, containing more energy than corn or wheat. The digestibility of gross energy in the pig is 96% compared to 85%-88% for wheat and corn.

Some researchers have developed feeding regimes for swine, allowing free choice access to cooked potatoes and limit-feeding a 19% protein concentrate at the rate of about 1.14 kg per pig per day.

Raw potatoes can only be fed to dry sows, where 6 kg of potato can replace 1 kg of barley with additional protein supplementation. Raw potatoes have been fed to finishing pigs, but when 25% of dietary dry matter was supplied by potatoes, significant reductions in performance were observed. Cooked potatoes are accepted by all classes of swine. However, due to the water content and its high bulk it is not recommended for starter pigs. Recommended maximum inclusion levels (dry matter basis) are 30% for growing pigs. Recommended maximum inclusion levels (dry matter basis) are 30% for growing pigs., 50% for finishing pigs and 25% and 50% for nursing and dry sows respectively.

The two main potato by-products that could be used as swine feed ingredients are potato steam peel and potato chips. Potato steam peel is a by-product of potato processing where the peel is removed after processing. It contains typically 15% dry matter, and 3400 Kcal/kg, 16% protein, and .05% lysine on a dry matter basis. This product can be included at up to 20% (dry matter basis) in grower-finisher pig diets. Substandard potato chips will be high in energy (typically 30% fat as they are cooked in oil; DE content of 5250 kcal/kg) and low in protein (typically 6.5% protein). It is a highly palatable ingredient that can be included at levels up to 15% in starter diets and 25% in diets for grower pigs, dry and nursing sows. Because of the high fat content and fat quality (oily) it is recommended that the inclusion level in the finisher diet be restricted to 10% or less.

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Rye

From an agronomic point of view, rye (*Secale cereale*) is an attractive crop for Western Canada. It produces higher yields of grain than other cereals particularly on poor quality, sandy soils, and assists in better management of the soil by minimizing soil erosion. Rye is traditionally sown in the fall making more effective use of water during spring runoff and allowing for a more equitable distribution of a farmer's workload due to its early harvest.

Unfortunately, the market for rye has been limited due to several toxic factors which can reduce its nutritional value. If the detrimental effects of these anti-nutritional factors could be overcome, it would make available to the swine industry an alternative feed resource from a previously little used product.

The energy level of rye is intermediate to that of wheat or barley, while the crude protein (N x 6.25) content is similar to barley and oats but lower than wheat. It supplies a reasonable balance of amino acids and contains roughly the same amount of lysine as barley or wheat. Relative to the requirements of the growing pig (20 - 50 kg), only lysine, threonine and the sulfur containing amino acids are not present in sufficient quantity to meet requirements. However, these total values must be interpreted with caution since the availability of the amino acids in rye are approximately 5 - 10% lower than those in barley and wheat.

Rye supplies approximately the same amount of calcium (0.06%) and phosphorus (0.32%) as other cereals. A specialized premix should not be necessary if rye is used as the major energy source in a swine ration. The content of other minerals and vitamins would also appear to be similar to those found in other cereals.

Rye is susceptible to contamination and infection from several undesirable fungi, the most important of which is ergot. Ergot may contain 10 or more toxic alkaloids including ergotamine, ergotoxine and ergonovine (see Ch. 11). Although ergot has been shown to reduce the performance of pigs fed rye, it is important to realize that ergot is a fungus contaminating rye and not a factor inherent to the rye itself. New varieties of rye have recently been developed which are much more resistant to ergot infestation. Examples of these ergot resistant varieties are Puma, Musketeer, Cougar and Kodiak. When these varieties are fed, ergot is far less likely to be a problem than with the more traditional cultivars of rye.

Recent research has indicated that rye also contains high levels of soluble pentosans and these pentosans may pose a greater problem than the presence of ergot. Pentosans are normal constituents of the cell wall and are related to hemicellulose but are more soluble. They result in a highly viscous intestinal fluid that interferes with digestion.

Another compound found in rye which was believed to reduce pig performance is a fat-soluble, growth inhibiting substance called 5-n-alkyl resorcinol. However, the most recent work on rye tends to discount the importance of alkyl resorcinol as a factor contributing to the poor performance of pigs fed rye.

Most recommendations concerning the nutritional value of rye are based on the older varieties of rye which were often contaminated with ergot. These recommendations may no longer be valid since ergot is present at much lower levels in the newer varieties of rye. As a consequence, the potential to use rye in swine diets may be greater than was previously realized.

Rye is relatively unpalatable. Feed intakes of pigs fed rye-based diets are generally 10% lower than those of pigs fed a barley-based diet. The specific factor causing the reduced intake has not been identified although a simple increase in the dustiness of the ration has been implicated. Since weaner pigs are often reluctant to eat solid feed, a feedstuff of questionable palatability should not be included in a starter diet. Therefore, it is suggested that rye not be used in diets fed to starter pigs.

Rye would appear to have much more potential for use in diets fed to growing pigs. The results of one experiment in which grower pigs were fed either a barley or a rye-based diet are shown in Table 4-31. Pigs fed diets in which ergot-free rye was utilized as the sole energy source in the diet gained approximately 5% slower than did pigs fed a barley based diet. However, it took significantly less feed to put on a pound of gain using the rye-based diet. This improvement in feed efficiency may provide sufficient incentive to encourage the incorporation of rye into swine diets, particularly when the cost of other cereal grains is high.

The reduction in performance which occurs as a result of feeding ergot-free rye has been attributed to the presence of soluble pentosans. Supplementation of diets containing rye with an enzyme capable of breaking down these pentosans has been shown to produce a modest improvement in pig performance. As a consequence, there is not much difference in the performance of pigs fed enzyme-supplemented, rye-based diets and those fed barley. Therefore, it would appear that when prices warrant, enzyme- supplemented rye can be used as 100% of the cereal portion of a swine diet without a significant reduction in pig performance.

Table 4-31. Effect of Enzyme Supplementation on the Performance of Growing Pigs (20-98 kg) Fed Rye.

	Control	Rye	Rye & Enzyme
Average Daily Gain (kg)	0.79	0.76	0.78
Average Daily Feed (kg)	2.19	2.02	2.05
Feed Conversion	2.74	2.64	2.64

Thacker et al., 1991. Can. J. Anim. Sci. 71: 489-496.

There is very little information concerning the feeding value of ergot-free rye in diets fed to breeding stock. Until further research is conducted, it may be wise to limit the inclusion of rye to no more than 25% of the diet during gestation and to avoid feeding rye to sows during lactation.

The nutritive value of rye for swine can be improved by processing. Since dustiness is a problem when rye is fed, producers are advised to utilize a coarser grind (< 4 - 5mm screen) when processing rye for use in swine rations. Supplementation with low levels of (0.5 to 2.0%) fat or vegetable oil may also help to reduce the dustiness. In addition, the nutritional value of rye for pigs has been shown to be substantially improved by pelleting.

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Soybeans: Full Fat

The soybean, a legume, is one of the oldest cultivated crops known to mankind. But only over the last 50 years has the potential of soybeans as a source of oil and protein in human and animal diets been fully recognized. It is estimated that soybeans account now for close to 80% of the supplemental protein used in cereal grain based diets for non-ruminants in North America. Although full-fat soybeans and soybean meal are the main products of interest to swine producers, recent developments in further processing of soybean products have resulted in the production of protein concentrates (containing approximately 70% crude protein on a dry matter basis) and isolates (containing approximately 70% crude protein on a dry matter basis) and isolates (containing approximately 90% crude protein on a dry matter basis). These products have favourable nutritional characteristics. However given the high cost of these products, they should only be considered for use in milk replacer or in highly complex (pre-) starter diets.

Although commercial soybean meal manufactured from raw soybeans by cooking and removal of the oil represents by far the major product used in swine diets, full fat beans are also used. With 18% fat, they provide more energy and are therefore particularly desirable in the manufacture of starter of lactation diets. For farmers mixing their own diets, full fat beans offer a vehicle for adding fat to high energy diets without investing in expensive fat handling equipment. The use of full-fat soybeans means that growers can feed the product on site rather than selling the beans and buying back the meal.

Heating raw soybeans helps to improve their nutritive value by destroying anti-nutritional factors such as trypsin inhibitor.

Soybeans: Full-fat	
DE	4200
Crude Protein	37.2
Lysine	2.25
Calcium	0.25
Phosphorus	0.59

Raw soybeans contain various anti-nutritional factors (ANF). The major ANF's are a group of proteins called trypsin inhibitors, which interfere with trypsin, a digestive enzyme produced by pigs. Other ANF's in soybeans include hemagglutinis (lectins), saponins and lipoxidase. Due to the presence of these ANF's it is not recommended to feed raw beans to most classes of pigs. It depresses growth and feed efficiency in growing pigs (starters, growers and finishers). In nursing sows it reduces feed intake and as a result increases body weight losses and reduces litter growth rates. Only dry sows are able to perform well when fed raw beans. Recently some varieties of soybeans have been developed that contain lower levels of some of the ANF's and that are superior in feeding value compared to conventional beans. However, even when these new varieties are fed raw to starter and grower pigs, animal performance is reduced.

Fortunately, most of these ANF's can be inactivated, and animal performance can be improved when beans are heated prior to feeding. However, soybeans can be overheated as well. Excessive heat destroys various amino acids (in particular lysine) and can thus also reduce the feeding value of full-fat beans. Means to heat beans include roasting, extruding, jet sploding (exposing beans to heated air) and micronizing (using radiant heat). Heating methods that can be considered on the farm are roasting and extruding. During roasting, beans should be heated between 3 and 5 minutes and the target temperature should be approximately 120°C. When extruding, the target exist temperature should be approximately 130°C. It should be noted that these alternative heat treatments are not equally effective and that the effectiveness of heat treatment is determined by many variables including: duration, temperature, pressure during heating, rate of cooling, composition of the bean (moisture and oil) and particle size. As a result, there can be considerable variation in the feeding value of heat treated soybeans. For example, the data in Table 4-32 indicate that the DE content of roasted beans may be as much as 12% lower than that in extruded full-fat soybeans.

Table 4-32. The Effect of Heat Treatment on the Digestible Energy Content of Soybeans.

Heat treatment	DE content (MJ/kg dry matter)
Extruding	5020
Jet sploding	4780
Micronizing	4680
Roasting	4420

Derived from Marty et al., Can. J. Anim. Sci. 73:411-419.

A laboratory assay that can be used to routinely check the adequacy of heat treatment of full fat soybeans in the urease test. In this test the activity of urease, an enzyme that breaks down urea and that is present in raw soybeans, is monitored. This enzyme is a protein and is, just like the trypsin inhibitors, inactivated when heat treated. The urease activity, measured in change in pH (acidity) in a standard solution should not exceed .20 units. Unfortunately there is not yet an accepted procedure that can be used to determine whether beans have been over-heated. The most reliable method is still an objective evaluation of colour and odour. The heat treated product should be light in colour (devoid of dark, burned particles) and small "nutty" rather than burned.

If full-fat beans are to be used, one must consider the extra energy supplied in the diet. Remember that full-fat beans contain about 12% more energy than high protein (dehulled) soybean meal. Failure to maintain the proper ratio of essential amino acids, in particular lysine, to energy will result in reduced growth rates, feed efficiency and in the case of finishing pigs in reduced carcass lean yields.

The inclusion of heated full fat soybeans in starter pig diets has not resulted in consistent improvements in performance in comparison to soybean meal based starter diets. In some studies, and in particular when roasted full fat beans were used, starter pig performance was in fact reduced when heated full fat beans where fed. This may be the result of incomplete inactivation of ANF's, or an insufficient rupturing of the cells in the seed during roasting. It should be noted that, given the immaturity of the digestive system, starter pigs will be more sensitive than any other class of swine to insufficient processing of full-fat soybeans. When extruded beans are used to replace soybean meal in starter pig diets, pig performance is generally improved. Extruded beans can effectively replace all of the soybean meal in starter pig diets.

In growing-finishing pig diets heated full fat soybeans can supply all of the supplemental protein in cereal grain based diets. Feeding roasted full fat soybeans will result in slight improvement in growth rate and feed efficiency as compared to feeding soybean meal, but not to the same extent as the feeding of cereal grain, soybean meal and supplemental fat (Table 4-33). Apparently roasted beans are not equivalent to a mixture of soybean meal and soybean oil, even for growing-finishing pigs. A concern with using full fat soybeans as the sole source of supplemental protein in finishing diets is its effect on the content and quality of the fat in the carcass. In particular, in pigs with unimproved lean growth potential, and increase in daily energy intake due to increases in dietary energy density, may increase carcass fatness and thus reduce lean yield. Carcass fat is certainly softened when full fat soybeans are fed. This has been associated with a paler colour of the meat and in several instances, to a reduced acceptability by the consumer of pork. The results of some studies indicate that the inclusion level of full fat beans should not exceed 10% in corn-based finishing pig diets in order to maintain pork quality. As barley and wheat contain less fat than corn, this would be equivalent to approximately 20% in barley or wheat based diets.

Table 4-33. Performance of Growing-finishing Pigs Fed Roasted Beans as the Sole Supplemental Protein Source in Corn-based Diets

	SBM	Roasted Soybeans	SBM and oil*
Daily gain (kg)	.89	.89	.92
Daily intake (kg)	2.81	2.76	2.64
Feed conversion	3.16	3.10	2.86

* The amount of oil and soybean meal added to the diet resulted in similar total protein and fat contents to that in the roasted soybean meal based diet; derived from Cromwell et al., 1990. J. Anim. Sci. 68 (suppl. 1):112.

The advantage of including heat-treated full-fat beans in sow diets appears quite similar to advantages of alternative high energy sow diets (chapter 6). Due to their maturity, sows are better able to utilize nutrients from full fat soybeans, even if they are not heat treated properly.

Additional Reading and References

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Soybean Meal

Since soybean meal is now used so extensively in swine diets, it is difficult to imagine that its early introduction was fraught with problems due not only to legitimate anti-nutritional factors but also false perceptions about its quality. The presence of anti-nutritional compounds covered in the previous section focused attention on the soybean's limitations rather than its potential. However, research into the proper handling and utilization of soybeans soon overcame the early problems. As a result, soybean meal has been a staple in swine diets since the 1940's.

Soybean meal gained acceptance in part because it complemented corn so well in the diet of the pig. It is high in energy and is a rich source of the amino acids such as lysine and tryptophan that are lacking in corn. The calcium content may vary among suppliers from as low as 0.25% to over 1.00%, due to the use of limestone in some cases to enhance its flowability. This poses no particular problem provided appropriate adjustments are made to the overall formula to ensure that calcium:phosphorus ratios in the final diet are maintained in the acceptable range. Also, as limestone use rises, the concentration of other nutrients such as amino acids and energy will fall.

Soybean meal is produced from raw soybeans by removing the oil and grinding the remaining flakes. Different processes may be involved. The most commonly used are pre-press solvent where oil is literally squeezed from the seed before solvents are added to remove the remaining fat, or solvent extraction alone.

Two types of soybean meal are currently available: high protein or dehulled and the lower protein, non-dehulled products. Dehulled meal contains less hull and as a consequence, is richer in protein, amino acids and energy than the meal containing the hull. Because of their widely differing nutrient composition, it is important to define which meal one is talking about. For example, the protein content of the dehulled meal is about 47% while that of the standard meal is 44.0%. Energy levels are approximately 5% higher and lysine about 10-15% higher in the dehulled product.

Soybean Meal: 44% CP	
DE	3500
Crude Protein	44.3
Lysine	2.86
Digestible Lysine	2.40
Digestible Threonine	1.29
Digestible Tryptophan	0.46
Calcium	0.29
Phosphorus	0.61

Soybean meals: 48% CP	
DE	3675
Crude Protein	47.5
Lysine	3.18
Digestible Lysine	2.70
Digestible Threonine	1.44
Digestible Tryptophan	0.50
Calcium	0.29
Phosphorus	0.60

The amino acid content of soybean meal can be predicted using regression equations based on crude protein. These equations can be found in chapter 3.

A variety of tests are available to evaluate the quality of soybean meal. Moisture, protein and calcium analyses are recommended to ensure that guaranteed minimum (protein content) and maximum levels (hull and limestone content) are met and to estimate amino acid content. The urease test may be used to ensure that the anti-nutritional factors in the soybean meal are sufficiently inactivated (see previous section on full-fat soybeans). Residual hexane content may also be tested. An objective evaluation of colour will provide a reasonable indication of product quality as well. A darker quality suggest that the protein quality is reduced and that further laboratory tests may be required (amino acid analyses; protein solubility in potassium hydroxide).

Soybean meal is often used as the sole source of supplemental protein in swine diets. In the diet of newly weaned pigs, dried milk products such as whey or skim milk are preferred due to the nature of the young piglet's digestive system. However, for all other classes of swine a consistent and known quality of soybean meal can support good levels of animal performance if used as the sole source of supplemental protein. In fact, choosing the amount of soybean meal to use will depend mainly on price and availability.

Sunflower Meal

Sunflowers (*Helianthus annuus*) are grown in southern Manitoba, Saskatchewan and in the northern Plains States of the U.S., in part for the oilseed market and, to a lesser extent, the confectionary market. The two are distinct in terms of the varieties of sunflowers grown. Confectionary sunflower seeds will not be used for oil production.

Sunflower meal has not gained the same degree of prominence in swine diets as other protein meals, reflecting not so much nutritional problems, but rather the availability of seed for crushing. It appears to be readily accepted by pigs. From a nutritional perspective, dehulled sunflower meal represents a good product with considerable potential in swine diets.

Sunflower Meal: Dehulled	
DE	3115
Crude Protein	40.5
Lysine	1.39
Digestible Lysine	1.03
Digestible Threonine	0.97
Digestible Tryptophan	0.35

Three types of sunflower meal are available. Dehulled sunflower meal contains about 38% crude protein; for swine, it is far superior to the standard meal which generally contains less than 30% crude protein and is very high in crude fibre. A third product, partially dehulled sunflower meal, is intermediate between the two. It contains about 32% crude protein. The fibre content varies dramatically between the three meal from about 14% in the dehulled meal to 25 - 30% in the standard meal. Consequently, the energy content of the various sunflower meals varies widely. Even dehulled sunflower meal has more than twice as much fibre as dehulled soybean meal, so that it contains slightly less digestible energy than barley. The standard meal contains less energy even than wheat bran and much less than oats. Any discussion of sunflower meal must differentiate between the three types.

The amino acid profile of dehulled sunflower meal is poor in comparison to soybean meal, largely because lysine is much lower and threonine, another important amino acid in barley and wheat based diets, is somewhat lower. Of additional concern is the fact that the availability of lysine from sunflower meal is about 15% less than that from soybean meal; threonine is also slightly less available. The replacement of soybean meal with sunflower meal in barley-based diets will require adjustment for both available lysine and threonine content.

Fortunately it is the dehulled meal that is produced in Manitoba and it often becomes available at a competitive price. It is produced by the pre-press, solvent process. It can be used to completely replace soybean meal in swine diets, especially those for gestating sows and the late growing stage (above 65 kg) where energy concentration is not so critical. In early growing diets and lactation diets, a drop in energy content will reduce productivity so that care is required in replacing even part of the soybean meal with sunflower meal. In medium to high energy diets, such as starter and lactation formulations, added fat and an increase in total dietary protein or synthetic amino acids to adjust for lower available lysine and threonine levels, is advised.

Standard and partially-dehulled sunflower meal must be used with even greater caution; because of the very low energy concentration and high crude fibre content, even partially-dehulled sunflower meal should not be used to supply more than half of the required supplemental protein in market hog diets. Neither meal should be used in lactation or starter diets because the energy content is too low.

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Sunflower Seeds

Interest in the sunflower as a crop has increased tremendously in recent years. This interest is based on the fact that the oil contained in the sunflower seed supplies a very high level of polyunsaturated fatty acids. Therefore, sunflower oil is highly sought after as a vegetable oil for human consumption. However, not all sunflower seeds are suitable for the production of oil or for use as confectionery seeds. As a consequence, whole sunflower seeds are sometimes available for use as a livestock feed.

Sunflower seeds can be considered as high in energy and medium in protein content. They contain on average of about 40% oil, 20% crude protein and 29% crude fibre. The high crude fibre level arises because of the thick hull on the sunflower seed. Unfortunately, there is little information concerning the levels of other nutrients in the entire sunflower seed.

The results of one experiment in which sunflower seeds were fed to weanling pigs from four to eight weeks of age are presented in Table 4-34. In this experiment, inclusion of 6.5 or 13% sunflower seeds improved the average daily gain of the weaner pigs while the addition of 26% sunflower seeds depressed performance. The reduction in growth rate was associated with a reduced feed intake suggesting that the high crude fibre content of the sunflower seed limits its usefulness in starter diets. In addition, supplementation with synthetic lysine did not appear to be beneficial. A maximum of 10% sunflower seeds is therefore recommended in starter diets.

Table 4-34. Effect of Feeding Sunflower Seeds on the Performance of Weaner Pigs.

	Sunflower Seeds (%)				
	0	6.5	13.0	26.0	26.0
Added Lysine	-	-	-	-	+
AD G (kg)	0.61	0.63	0.63	0.55	0.56
Daily Feed (kg)	1.15	1.16	1.18	1.03	1.04
Feed Conversion	1.88	1.84	1.87	1.87	1.86

Adams et al., 1982, Univ. Ill. Agric. Exper. Station Report. pp. 1-4.

From an experiment in which sunflower seeds were fed to growing pigs (Table 4-35), it can be seen that there was a linear increase in growth rate as the level of sunflower seeds in the diet increased. However, as the level of sunflower seed in the diet increased, carcasses become fatter, firmness decreased and bacon sliceability became much more difficult. It appears that market hogs should not be fed diets containing above 10% sunflower seeds because of deleterious effects on carcass quality and that results are improved by feeding unprocessed seeds since heating reduces digestibility.

Table 4-35. Performance of Growing Pigs Fed Graded Levels of Sunflower Seeds.

	Sunflower Seeds (%)			
	0	2.5	5	10
Average Daily Gain (kg)	0.71	0.74	0.76	0.80
Average Daily Feed (kg)	2.36	2.46	2.53	2.60
Feed Conversion	3.32	3.34	3.28	3.30
Carcass Firmness[1]	3.70	3.30	3.00	2.50
Bacon Sliceability[2]	1.10	1.40	1.65	2.40
Iodine Number[3]	55.77	58.17	64.18	71.04

[1]Range of 1 to 5 with 1 the softest and 5 the firmest.
[2]Range of 1 to 5 with 1 being the best and 5 the worst.
[3]Hartman et al., 1983, S. Dakota State 27th Ann. Swine Day. pp.8-13.

Sunflower seeds have been fed successfully to sows during the last week of gestation and during early lactation. The most dramatic effect observed as a result of feeding sunflower seeds was a linear increase in the percentage of milk fat. However, piglet weaning weight and percentage survival were unaffected by dietary treatment. Some palatability problems were observed at inclusion levels greater than 25% and therefore it would seem wise to limit the level of sunflower seed to less than 25% of the diet.

In summary, the high crude fibre content of the sunflower seed limits its usefulness in starter diets and a maximum of 10% sunflower seed is therefore recommended. As the level of sunflower seed in the diet of the growing pig increases, carcasses become fatter, carcass firmness decreases and bacon sliceability becomes more difficult. Therefore, it would appear that market hogs should not be fed diets containing more than 10% sunflower seed. Finally, palatability problems have been observed at levels of greater than 25% in diets fed to breeding stock.

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Triticale

Triticale (*Triticale hexaploide*) is a relatively new, synthetic, small grain crop produced by crossing durum wheat with rye. The goal of plant breeders in developing triticale was to combine the high crude protein and digestible energy content of wheat with the high yields and protein quality of rye. Its name is derived by combining *Triticum*, the botanical name for wheat, with *Secale*, the botanical name for rye.

Triticale has not been a major crop in Canada and therefore, large quantities of triticale have not been fed to livestock. However, from time to time, significant quantities of triticale become available and can be successfully utilized as an energy source in swine diets.

One of the most attractive features of triticale is its relatively high digestible energy content. For pigs, the digestible energy content has been estimated to be approximately equal to wheat and corn. A relatively low crude fibre content (2.4%) is one of the factors accounting for this high energy level.

The crude protein content of triticale has been reported to vary considerably, depending on the cultivar and growing conditions, with protein contents ranging from 11.8 - 22.5% being reported. The average is about 16%. Triticale has a better balance of amino acids for pigs than most other cereals, although this may be quite variable depending upon variety. Most amino acids tend to be present at a level intermediate to that of durum wheat and rye. As is typical of most cereal grain proteins, triticale is low in cystine, methionine, threonine and lysine. Lysine is the first limiting amino acid in triticale while threonine is reported to be the second limiting amino acid. The availabilities of amino acids in triticale exceed those of barley by approximately 5 - 10%.

Like rye, triticale tends to be susceptible to ergot infestation (see chapter 11). Also, as is the case with rye, it is important to remember that ergot is a fungus contaminating the grain and not a factor inherent to the grain itself.

New varieties of triticale have recently been developed which are much more resistant to ergot infestation than were the older cultivars of triticale. Examples of ergot resistant varieties are Welsh and Carmen. When these varieties are fed and the ergot concentration of the diet is kept below 0.1%, it is unlikely that any ergot-related problems will develop for growing pigs fed triticale.

Several other anti-nutritional factors have been isolated in triticale. Perhaps the most important is the presence of a high level of typsin inhibitor which has been shown to tie up the enzyme trypsin and reduce the digestibility of dietary protein. There is a great deal of variation in the level of trypsin inhibitor among varieties of triticale (Table 4-36) and therefore producers should strive to obtain cultivars with a low trypsin inhibitor levels.

Table 4-36. Trypsin Inhibition Levels in Spring Triticale[1].

Variety%	Trypsin Inhibition
Carman	64.05 $\pm$ 7.18
Welsh	79.59 $\pm$ 8.71
Triwell	72.00 $\pm$ 3.72
*75L021	70.30 $\pm$ 0.86
*79P439	65.60 $\pm$ 1.97

[1]Acceptable level of inhibition for hogs equals 60% inhibition or less.
Adapted from Metzger, 1982. Unpublished Data. Corvallis, Oregon.

Soluble pentosans have also been identified in triticale. It is postulated that pentosans form complex bonds with the albumen fraction of the cereal protein and thus decrease the digestibility of the diet. It is also suggested that pentosans increase diet bulkiness as a result of their water binding capacity in the gastrointestinal tract and thus depress feed intake.

Other factors which have been identified in triticale include alkyl-resorcinols and tannins. However, the levels of these factors are generally low and therefore, their presence is usually of little consequence in formulating diets for swine.

In evaluating triticale as an energy source for swine, it is important to differentiate between problems associated with ergot and problems associated with the grain itself. As stated earlier, triticale with an ergot level above 0.1% should not be fed to growing swine. Ergot-infested triticale should not be fed to the breeding herd. Therefore, the remaining discussion shall relate to ergot-free triticale.

Some scientists have reported that triticale is relatively unpalatable for starter pigs. Others observed no problems. Since starter pigs are often reluctant to eat solid feed feedstuffs of questionable palatability triticale should be used with caution. Should it be used, then it is recommended that initially it not be included at more than 25% of the total diet.

Triticale can be successfully utilized as an energy source for growing swine. Most of the early work with triticale indicated that it was relatively unpalatable and as a consequence, most nutritionists have limited it to about 50% of the cereal portion of the diet. However, more recent work with ergot-free triticale indicates that triticale is comparable in feeding value to both wheat and corn (Table 4-37). Therefore, it may be possible to include triticale at higher levels than was previously recommended. Producers who wish to feed it are advised to start with about 25% triticale in the diet and gradually increase the level. The performance of the pigs should be monitored closely to ensure that no problems arise. Some producers who have fed triticale have reported problems with excessive dust. This problem can be addressed by using a coarser screen size when grinding or by incorporating 2 - 5% fat into the ration. Pelleting the ration would also be beneficial.

Table 4-37. Performance of Grower Pigs Fed Diets Containing Triticale, Wheat or Corn (18-98 kg).

	Triticale	Wheat	Corn
Average Daily Gain (kg)	0.90	0.90	0.84
Average Feed Intake (kg)	2.78	2.80	2.57
Feed Conversion	3.09	3.11	3.06

Jilek and Barnett, 1981, Univ. Florida 26th Ann. Swine Field Day Res. Report. pp. 32-34.

There is very little information concerning the feeding value of triticale in diets fed to breeding stock. Until more research is conducted to determine the nutritive value of triticale for breeding stock, a limit of 25% of the total diet is suggested.

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Wheat

Wheat (*Triticum aestiuum*) is grown primarily for the human food market and is used in livestock diets only when market conditions or quality discounts make it economical to do so. However, feed grade wheat, destined specifically for the animal feed market, is also grown in various parts of Canada. From an animal feed perspective, there is no difference between red or white wheat varieties, nor between those seeded in the spring or fall. There are slight differences between hard and soft wheat; the former tend to have more protein, a higher content of essential amino acids, although a slightly inferior profile, and less energy. However, both soft and hard wheat support equal performance in growing pigs (Table 4-38) and in starter diets (Table 4-39). Studies of new varieties of feed wheat, such as the Prairie Spring Wheat variety Biggar or dwarf wheat have not revealed any serious problems, suggesting they can be used in swine diets according to nutrient composition without concern. Differences in feeding value between different samples of wheat are more attributed to variation in growing and harvesting conditions that to differences between the various varieties of wheat. In general, when amino acids are properly balanced with energy, wheat makes an excellent feed ingredient for swine feed. Dustiness may be a problem, especially for producers more familiar with barley diets. Coarser grinding or the addition of 0.5 to 2.0% fat to the diet will prove helpful.

Table 4-38. Comparison of Hard and Soft Wheat in the Diet of Pigs from 61-121 kg.

	Wheat	
Item	Hard	Soft
Avg Gain per Day (kg)	0.81	0.84
Avg Feed per Day (kg)	2.96	3.10
Feed Conversion	3.67	3.69

Adapted from Hinens, 1982, Kansas St. Univ. Swine Day. pp. 104-107.

Table 4-39. Replacement of Hard Red Spring Wheat with Soft Wheat in Pig Starter Diets.

	Percent soft wheat			
	0	20	40	60
Initial wt, kg	7.1	7.4	7.2	7.2
Ave. daily gain, kg	0.46	0.47	0.51	0.48
Ave. daily feed, kg	0.67	0.68	0.71	0.68
Feed conversion	1.45	1.45	1.39	1.41

Adapted from Magowan and Aherne, 1987, Proc. Western Nutr. Conf. pp 125-127.

Wheat contains approximately 10% more digestible energy (DE) than barley and only slightly less energy than corn. However, and as discussed in Chapter 3, there can be considerable variation in the DE content of various wheat samples. This is especially the case when wheat is harvested prematurely and/or under poor conditions. For example, a recent study at the Prairie Swine Centre indicates that differences in DE content between wheat samples can be as high as 300 Kcal/kg or 10% of the mean DE content. This would result in differences of feed efficiency of 10%. A means to predict the DE content of individual wheat samples is based on chemical analyses (in particular dry matter, fibre and protein) and using mathematical equations such as the following:

DE (Kcal/kg of dry matter) = 3584 + 38.3 x Protein content (% in dry matter) - 16.0 NDF content (% in dry matter).

Bushel weight is a poor predictor of the feeding value of individual wheat samples. The results of studies conducted at Prairie Swine Centre indicate that there were basically no differences in DE content between samples that had bushel weights of 53 and 62 lbs. Only when the bushel weight was below approximately 53 lb, was a significant reduction in DE content noted. Actual animal performance studies suggest that the feeding value of wheat with bushel weights less than 56 should not be discounted at all, and wheat with bushel weights lower than that can be fed to pigs over 65 kg with appropriate adjustments of formulas.

The amino acid content of wheat is substantially higher than that in corn and similar to that in barley. In comparison to corn, wheat contains approximately 50% more lysine and triple the amount of tryptophan. This reduces the need for supplemental protein in wheat-based diets as compared to corn-based diets. In some samples of wheat the protein content can be as high as 16%, especially when growing conditions are dry. It should, however, be stressed that the quality of protein (amino acid balance) in wheat is poor. For example, the lysine content expressed as a percentage of crude protein (N X 6.25) present in wheat is approximately 2.9% which is less than half of that in soybean meal. In addition there are important differences in the protein quality between wheat, barley and corn. In spite of the differences in protein content between wheat and barley there are basically no differences in the lysine content. Failure to recognize these differences in protein quality, by formulating diets based on crude protein (N x 6.25) rather than amino acid levels, will result in sub-optimal pig performance. A final point is that the amino acid to energy ratio should be considered as well. In particular, when wheat replaces barley in pig diets.

The actual amino acid content in individual wheat samples is largely affected by the protein content in individual wheat samples and can be predicted based on the mathematical equations presented in chapter 3. These equations indicate that an increase in protein does not result in a proportional increase in many of the essential amino acids such as lysine. The changing protein content reflects largely the change in the amount of gluten present; gluten is rich in non-essential amino acids and is a poor source of essential amino acids such as lysine.

The contents of minerals and vitamins in wheat are not sufficiently different from those in corn and barley to warrant major changes in diet formulation.

The feeding value of wheat as compared to that in corn and barley, is directly the result of differences in digestible energy and amino acid contents between these cereal grains. The results of many studies indicate that performance of pigs fed wheat based diets is similar to that of pigs fed corn based diets, provided that the proper dietary amino acid to energy ratios are maintained. When comparing wheat to barley-based diets, feed efficiency is generally close to 10% better in the wheat-based diets. Differences in growth rates between pigs fed barley and wheat based diets will depend on the body weight of pigs. In starter pigs it is generally 10% higher on wheat based diets and the difference tends to become smaller as pigs grow heavier. As finishing pigs are able to compensate for changes in dietary energy density, by adjusting voluntary feed intake, difference in growth rate in finishing pigs fed either barley or wheat based diets are small and can often not be detected.

The choice of cereal grain in properly formulated pig diets should purely be driven by economical considerations. In diets for starter, grower and finisher pigs wheat can be used as the sole cereal grain. In many practical nursing sow rations, the inclusion levels of wheat can be as high as 50%. There is no need for high energy ingredients such as wheat in dry sow rations. However, provided that attention is paid to feed processing and feeding management, the inclusion level of wheat can also be 50% in the dry sow diet.

When wheat is used as a pig feed ingredient close attention should be paid to feed processing and in particular to the fineness of grinding.

Wheat should not be ground too finely since it becomes very floury and palatability may suffer. Finely ground wheat does not flow as well in self-feeders and the incidence of stomach ulcers may also increase with a fine grind. For growing swine, most studies have demonstrated that rolled wheat will perform as well as coarsely ground wheat in the diets of market hogs. Results of one representative study revealed that rolling was better than grinding, and that pelleting was the best of all treatments. This particular study revealed that both hard and soft wheat responded in the same manner to processing treatment. It may be difficult to obtain and maintain a uniform feed mixture with rolled wheat, so a medium grind (approximately 4.5 mm to 6.4 mm screen) is recommended. If stomach ulcers become a problem the addition of 5-10% whole oats in pelleted rations, or coarsely ground oats in mash rations generally solves the problem.

Off grade wheat often becomes available to the animal feed market and questions arise about its suitability for swine. Studies conducted at the Prairie Swine Centre indicate that the DE content, of frost damaged wheat is similar to that in normal wheat. This would suggest that the actual feeding value of frost damaged wheat is similar to that of regular wheat as well. The results of a France study (Table 4-40) indicate that the feeding value of wheat that was partially sprouted was the same, or even slightly better, than that of regular soft wheat.

Table 4-40. Performance of Starter Pigs Fed Either Sprouted or Regular Soft Wheat.

	Control[1]	Sprouted[2]	Sprouted[3]
Daily intake (kg)	.87	.90	.87
Daily gain (kg)	.45	0.50	.51
Feed Conversion	1.94	1.81	1.71

[1] Soft wheat (Fidel)
[2] Soft wheat (Fidel), based on visual inspection - 15% sprouted
[3] Hard wheat (Cando), based on visual inspection - 20% sprouted
Adapted from Gatel and Bourdon, 1989. Pig news and Information 10 (vol 2): 159-160.

Scabby wheat, having been infected with the mold *Fusarium graminearium*, has been shown in feeding trials to reduce growth rate in swine. In starter pigs, 1 ppm of vomitoxin in Fusarium-contaminated hard wheat was sufficient to impair growth rate in the first week on the trial. There was some compensation as the time on test progressed, but even after three weeks, vomitoxin at 2.4 ppm reduced rate and efficiency of gain. Removal of the contaminated grain from the diet did not result in compensatory gain, indicating that losses due to moldy wheat will permanently increase the number of days to market.

Wheat is processed into flour for human consumption and generates by-products which can be successfully used in swine diets. The wheat kernel consists of 85% endosperm, 13% bran and 2% germ. The objective of flour milling is to separate the endosperm from the bran and germ in as efficient a manner as possible. On average, by-products represent only about 28% of the total grain milled, indicating that the process is quite efficient. Typically, the by-products include wheat shorts, wheat middlings, red dog and wheat bran, with bran accounting for about 50% of the total. Although Canada exports much of its wheat and mills a relatively small portion domestically, flour milling by-products are still available to the livestock industry. The naming of these materials is confusing because of little consistency world wide. For example, Canadian wheat shorts are roughly equivalent to American middlings. In some countries, they may also be called wheatings, thirds or coarse middlings.

The greatest problem associated with the use of these milling by-products in animal feed is the lack of uniformity due to mixing of fractions. Some bran is always included in wheat shorts, but increasing the extent will decrease energy content and alter the amino acid profile. Bulk density has been proposed as a gauge of nutritional value, since it would change as the proportion of various fractions changes.

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Wheat Bran

Wheat bran consists mainly of the outer husk of the wheat kernel. Because of its high fibre content, bran is low in digestible energy and is inferior even to oats in this regard (Table 4-41). Because of its relatively low energy content, wheat bran is not an ingredient of choice in swine diets.

Wheat Bran	
DE	2475
Crude Protein	15.5
Lysine	0.59
Digestible Lysine	0.32
Digestible Threonine	0.25
Digestible Tryptophan	0.16
Calcium	0.12
Phosphorus	1.16

Where constipation is a concern, especially in sows around the time of farrowing, bran at 5-15% of the total diet can be most helpful. Nutritionists must ensure that when adding fibre to the diet and thus reducing constipation, the sow's need for energy is not compromised. Lactation may be a time when constipation is most likely, but it is also the time when energy demands are very high. Consequently, bran should be matched with oil or some other concentrated energy source in the diet to ensure that the sow's energy intake is satisfactory.

Wheat Shorts

Wheat shorts consist of fine bran and parts of the endosperm from the original wheat kernel. Because of the endosperm fraction, wheat shorts contain less crude fibre and more energy than bran. In terms of energy content, wheat shorts are approximately equivalent to barley and contain somewhat higher levels of crude protein, lysine and threonine. (See Table 4-41.)

Wheat Shorts	
DE	3140
Crude	17.5
Lysine	0.70
Digestible Lysine	0.50
Digestible Threonine	0.32
Digestible Tryptophan	0.18
Calcium	0.10
Phosphorus	0.85

Wheat shorts are potentially a very good ingredient for swine diets; pellet mill operators like them because they tend to improve pellet durability. Potential concerns in using wheat shorts in pig feeds include the variability of the product and the high fibre level. Recommended maximum inclusion levels of wheat short are 10% for starter pigs and approximately 40% for grower-finisher pigs and sows. However, when diets are properly balanced for energy and amino acid contents and when a good consistent quality of wheat shorts is used, animal performance can be maintained at inclusion levels higher than the recommended maximums. If the diet is not pelleted, dustiness could become a problem, so that either the proportion of shorts should be reduced or fat added to the diet to settle the dust.

Table 4-41. Typical Specifications for Wheat and its By-products

Ingredient	Crude Protein	Fat	Fibre
	Minimum (%)		Maximum (%)
Wheat[2]	13.6	1.7	2.7
Bran[1]	14.0	3.5	12.5
Shorts[1]	15.0	4.0	8.0
Middlings[1]	15.5	2.5	4.5
Germ[1]	25.0	9.0	2.5

[1] Millfeed Manual, Millers' National Federation.
[2] Appendix 1.

Wild Oat Groats

Despite intensive efforts at chemical and cultural control, wild oats (*Avena fatua*) continue to contaminate a large proportion of the grain produced in Western Canada. Approximately 40% of the dockage assessed on locally produced cereal grains and as much as 1% of the total harvest of grain is comprised of wild oats. Due to their black-coloured hull, wild oats must be removed before the grain can be exported or processed for human consumption. Over 200,000 tonnes of wild oat seeds are separated annually at commercial seed cleaning plants across Canada.

Wild oats have traditionally been marketed as Mixed Feed Oats and have been utilized almost exclusively in diets fed to ruminants. The presence of a highly fibrous hull limits their usefulness in diets formulated for monogastrics. However, a technique for dehulling wild oats has been developed recently and the dehulled kernels, commonly called groats, may have considerable potential to replace domestic oat groats in diets fed to poultry and swine.

Wild oat groats contain significantly higher levels of crude protein in comparison with domestic oat groats (19.9 versus 15.5%). Despite large differences in protein content between the wild and

Table 4-42. Performance of Starter Pigs (7 - 25 kg) Fed Various Oat Products[1].

	Wheat	Oat Groat	Feed Oats	Wild Oat Groat	Wild Oat Flake
Average Daily Gain (kg)	0.39	0.39	0.38	0.37	0.35
Average Daily Feed (kg)	0.64	0.65	0.65	0.61	0.60
Feed Conversion	1.64	1.62	1.70	1.64	1.70

Thacker and Sosulski, 1994. Anim. Feed Sci. Technol. 46: 229-237.

[1] Diets based on 25% oat product added at the expense of wheat.

domestic oat groats, there would appear to be little difference in amino acid composition between common and wild oat protein. With the exception of lysine and threonine, all of the essential amino acids are present in sufficient quantity to meet the requirements of the starter pig (10 - 20 kg).

Wild oats contain a higher level of ether extract than domestic oat groats (7.8 versus 6.3%). Chemical analysis has shown that almost 90% of the lipid in wild oats is in the form of triglycerides. These triglycerides are highly unsaturated with the oleic, linoleic and linolenic acid levels being 46, 35 and 2%, respectively, of the total fatty acids. The polyunsaturated fatty acids are desirable nutritionally, but they are also subject to oxidative instability during storage especially after seed grinding.

There is an active lipase in the pericarp of the wild oat. The lipase is not in contact with the lipids in the intact kernel but crushing or milling the seed will result in hydrolysis of the triglycerides into free fatty acids, even at relatively low seed moisture levels. The free fatty acids are much more susceptible to oxidation into rancid, bitter breakdown products than the intact triglyceride. Therefore, it is essential to steam the groats thoroughly to destroy the lipases in the bran before proceeding to process the groat into feed products. Once the enzyme has been inactivated, the dry milled products can be stored for several months without a significant breakdown of lipids, especially if cool temperatures are maintained.

The performance of starter pigs fed diets containing wild and domestic oat groats and flakes is presented in Table 4-42. In this experiment, the control diet was based on wheat and soybean meal while the remaining diets contained 25% domestic oat groats, wild oat groats, toasted oat flakes or toasted wild oat flakes added at the expense of wheat. All diets were formulated to contain approximately 20% crude protein and synthetic lysine was added so that all diets supplied approximately 0.9% lysine.

The growth rate of pigs fed diets containing either wild oat groats or wild oat flakes was similar to that obtained with domestic oat groats and flakes. Toasting and rolling of oat groats or wild oat groats did not appear to improve their nutritional value. The results of this experiment indicate that one may include up to 25% wild oat groats in starter diets without any adverse effects on performance. Based on the high cost of wild oat groats, there would appear to be little potential for including them in grower diets or in diets fed to breeding stock.

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Fats and Oils

Fats and oils are a very concentrated source of energy, often containing 2.5-3.0 times the energy of cereal grains. They also tend to be more expensive per calorie than cereal grains and thus are used only where higher energy levels are required, such as those for weanling pigs, lactating sows of fast growing market hogs. They are also used to supply essential fatty acids, to suppress dust, facilitate pelleting and reduce wear in feed manufacturing equipment. In fact, as the swine industry has developed, and expectations for increasingly higher standards of performance rise, fat usage in pig diets has increased.

Whenever fat is added to swine diets, careful adjustment of other nutrients, especially amino acids, is required to ensure the diet remains balanced with respect to nutrient to energy ratio's and in particular amino acid to energy ratio's. If, through the addition of fat to the diet, the energy content is raised without proper adjustments of the dietary amino acid levels, then animal performance will be sub-optimal. In market hogs carcass index, growth rates and feed efficiency will be reduced and nursing sows will not increase their milk production. As fat is added to the diet, daily feed intake is generally slightly reduced, but the pig will consume more energy per day, up to a maximum that will be determined by the diet and by such factors as genetics and environmental temperature.

Like many branches of nutrition, fats have a specific set of terminology that helps to describe their nutritive value. Most fats are present in a compound called a triglyceride (see Figure 4-2). It is made up of three fat chains called fatty acids, that are linked together at one end like tines on a fork. If the fatty acids are not linked together but exist as single units, they are called free fatty acids. Some fats contain only two fatty acids linked together with the third position occupied by another compound such as a phosphorus compound.

The chemical and nutritional characteristics of all fats are dictated by the individual fatty acids. Some are 'loose structures and thus are soft at room temperature. Vegetable oils are liquid at room temperature because they contain many of these 'loose' or unsaturated fatty acids. Other fatty acids are very firm and are hard at room temperature. They are called saturated fatty acids. Tallow contains a high proportion of saturated fatty acids; for this reason, tallow must be heated to liquefy it so that it can be mixed properly into the diet. Oil is generally the term used to describe fats that exist as a liquid at room temperature. Tallow and lard are solid at room temperature and thus are not oils. Fatty acids are described not only as saturated or unsaturated, but also short- or long-chained. This refers to the physical length of the fatty acid molecule. The significance of these terms, from a nutritional perspective, is explained below.

In some respects, fatty acids are to fat what amino acids are to protein. However, there are some major differences. Only two fatty acids are essential in the diet (linoleic, a member of the w-6 family of polyunsaturated fatty acids and linolenic, a member of the w-e family of polyunsaturated fatty acids), whereas there are ten essential amino acids. Also, proteins contain only amino acids while fats contain fatty acids plus other compounds, like glycerol, sugar and phosphorus.

The requirements for essential amino acids in pigs are not well established. For example, there is still considerable debate on the efficiency with which

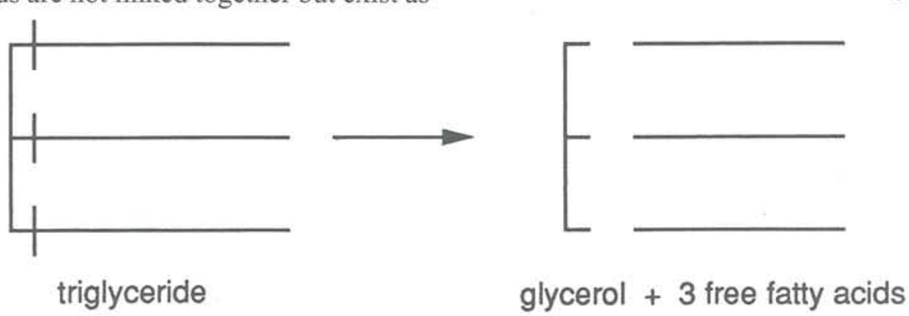

Figure 4-2. Triglyceride.

pigs can convert linolenic acid pigs to other polyunsaturated fatty acids that belong to the family of w-3 fatty acids, and that are essential for normal animal metabolism. Some studies suggest that the ratio of w-6 to w-3 fatty acids in the diet is as important for the conversion of these w-3 fatty acids (see "essential fatty acids" in chapter 3).

The term fat is very general, referring to a group of ingredients including animal fats, vegetable oils and related compounds. Feed fats can be divided into six general categories: animal fat, poultry fat, blended feed grade animal fats, blended animal and vegetable fats, feed grade vegetable fats and soapstocks. Animal fat refers to rendered fats from beef or pork by-products. It includes packing house offal and supermarket trimmings. Because beef fat (tallow) tends to be constant regardless of the diets fed to cattle, it tends to be more consistent in terms of fatty acid profile that pork fat (lard) which depends on the diets fed to pigs.

Poultry grease is the rendered fat from poultry offal. Blended animal fats may include mixtures of pork lard, beef tallow, poultry grease and possibly restaurant grease. Blended animal and vegetable fats may include proportions of the above mentioned animal fats plus fats of plant origin. Vegetable oils are derived from the refining of vegetable fats such as soybean oil, canola oil or corn oil. Soapstocks, also called foots, contain products not wanted in oils destined for the human food trade including free fatty acids.

Good quality tallow or poultry grease may contain no more than 15% free fatty acids, while soapstocks contain approximately 50% free fatty acids. They can be used in the manufacture of soap or as a fat supplement in animal diets. Soapstocks are separated from the higher grade of oils by the addition of an alkali which causes them to settle out, allowing the still liquid oils to be removed. The precipitate is then re-suspended by adding an acid; for this reason, they are sometimes called acidulated fatty acids. In concentrated form, they are quite corrosive, and must be used with care in the feed manufacturing process. Once they are diluted in the feed, they have proven to have excellent feeding value. In terms of fatty acid composition, they are quite similar to the parent vegetable oil.

High grade vegetable fats are not commonly used in swine diets due to cost. On the prairies, crude canola oil is sometimes used by individual farmers who mix their own feed because it is easy to handle in a simple mill. Tallow and lard as well as by-product fats are commonly used in swine diets, although vegetable fats may be preferred due to higher energy and essential fatty acid content.

A variety of chemical tests can be carried out on fats to determine their nutritional quality. Melting point refers to the temperature at which the material changes from a solid to a liquid. Vegetable fats with a high proportion of 'loose' or unsaturated fatty acids have a low melting point, meaning they are liquid at room temperature. Fats of animal origin such as lard and tallow, have a lower proportion of unsaturated fatty acids, and thus a higher melting point. Consequently, they are solid at room temperature and must be heated before being added to the feed mix.

Undesirable impurities in fats can be measured. These include moisture (water, should be less than 1%), insolubles (skin, hair, bone; should be less than .5%) and unsaponifiable matter (should be less than 1%). As undesirable impurities rises, energy content is reduced. Free fatty acid content is not a good criteria of quality. Once triglycerides enter the gut, they are converted to free fatty acids. However, it the fat source normally has a low free fatty acid concentration and it suddenly rises, it is a sign that deterioration has occurred.

One inexpensive test conducted by some commercial laboratories is the iodine value analysis. It determines the proportion of unsaturated and saturated fatty acids and thus helps to determine uniformity of fat supply. A change in iodine number would reflect a change in the composition of the fat and thus indicate a need to discuss product source with the supplier. Table 4-43 illustrates how changing fatty acids in the fat can alter iodine value. A hypothetical fat containing 50% oleic acid and 50% linolenic acid would have an iodine value of 1.8 while another fat, with equal portions of palmitoleic, oleic and linoleic acids would have an iodine number of 1.22.

Table 4-43. Estimating Iodine Value from Fatty Acid Composition of a Fat.

Fatty Acid	Multiply by:
C14:1 Myristoleic	1.10
C16:1 Palmitoleic	1.00
C18:1 Oleic	0.90
C18:2 Linoleic	1.80
C18:3 Linolenic	2.70

Other factors that are considered include colour and odour. A relatively recent concern surrounding feed grade fats is safety, or more specifically, freedom from compounds that make the product a health hazard. Well-publicized examples of such compounds as PCB's (polychlorinated biphenyl: poisonous environmental pollutants which tend to accumulate in animal tissues) contaminating feed grade fats has focused new attention on this subject. Quality-conscious feed companies know that there is no such thing as a cheap source of fat and avoid special "deals" that might come along. If farmers are buying fat ingredients, they would be well advised to follow the same thinking.

All fat supplements, irrespective of quality or source, must contain an antioxidant to prevent rancidity. Common antioxidants include propyl gallate, BHT (butylate hydroxytoluene), GHA (butylate hydroxyanisole) and ethoxyquin. Failure to use properly stabilized fats will reduce palatability and could compromise the pig's status with respect to vitamin E and selenium Since rancid fat in the diet leads to damage of cell membranes, this situation must be avoided. If a poor grade of fat is suspected, additional vitamin E and selenium should be added to the diet. The rancidity of fats can be evaluated by determining the peroxide value. This value should not exceed 5.0 milli-equivalent per kg. Raw oil in seeds, such as canola or soybeans, contain natural antioxidants such as vitamin E. However, these may deteriorate during fat extraction procedures and artificial antioxidants are required.

It is important to use a correct energy value for fats used in swine diets. In some cases, 10-15% of the total energy in the diet may be supplied by such fat ingredients so errors must be avoided. A number of factors can influence the digestibility of feed fats and thus their contribution to the energy content of the diet. Long chain saturated fatty acids are not well accepted by the intestinal tract and are poorly digested unless mixed with unsaturated fatty acids which make them more compatible with the digestive processes. Thus the ratio of unsaturated:saturated fatty acids will help to indicate the digestibility of a fat source.

The iodine number, which estimates the ratio of unsaturated:saturated fatty acids, is therefore very useful to the nutritionist. Fat digestibility appears to be maximized when the unsaturated:saturated ratio is 2.0 or above. Digestibility falls rapidly below 2.0 and at 1.0, digestibility is reduced by about 20%. Short-chain fatty acids, whether or not they are unsaturated are well accepted by the gut and are therefore well absorbed. Fibre in the diet reduces the digestion of fat due to an increase in rate of passage. It has been estimated that for every 1% crude fibre in the diet, fat digestion is reduced by 1.3 to 1.5%. In Table 4-44 the digestible energy contents of selected fats and oils are summarized. It should be noted that in net energy systems the available energy content of fats and oils, relative to that in other ingredients is much higher than in digestible energy systems (chapter 3). This is because dietary fat can be incorporated directly in body fat (even in very lean pigs a substantial amount of essential body fat needs to be deposited) or in milk fat and at low heat increments of feeding. The relative feeding value of fats is thus more accurately represented in net energy than in digestible energy systems.

It is difficult to suggest minimum and maximum inclusion levels of fat in pig feeds. With the exception of newly weaned piglets, pigs are able to utilize added fat at inclusion levels that exceed 10%. However, at inclusion levels that are higher than 6-8% it becomes difficult to process and handle feed (bridging in bins and feeders). Given the (high) cost per unit of energy, the economics of using fat should be considered as well.

Table 4-44. Digestible Energy Content of Selected Fat Sources.

Fat	Saturated Fat %	Unsaturated Fat %	Energy	
			Digestible	Metabolizable
			Kcal/kg	
Vegetable Origin				
Canola Oil	6	94	8800	7300
Soybean Oil	16	84	8800	7275
Soapstocks[1]	--	--	7850	7150
Animal Origin				
Grease (Poultry)	29	71	8625	8200
Lark (Pork)	43	57	7850	7550
Tallow (Beef)	51	49	8200	7900

Apendix, Table 1.

[1] Depends on the origin of the soapstock.

The results of studies where the effect of added fat in diets for starter pigs has been evaluated have been inconsistent. In many studies no or little change in growth rate or feed efficiency has been observed during the first two weeks following weaning. This may be attributed to the reduced digestibility and the piglets inability to metabolise some types of fats, in particular highly saturated, long chain fatty acids. Fat utilization will be improved when medium chain fatty acids (such as these in coconut oil) or when unsaturated fats (oils are used).

Fat can be included at high levels in diets for pigs that are older than 6 weeks. In diets for starter and grower pigs the inclusion of fat will increase both the energy content of the diet and the daily energy intake. The value of added fat is thus determined by improvements in both feed efficiency (basically proportional to increases in dietary energy density if diets are properly balanced for nutrient to energy ratios) and in growth rate (basically proportional to dietary energy density as well). As finishing pigs are better able to adjust for changes in dietary energy density (by adjusting daily feed intake), the value of added fat in finishing diet should be based on improvements in feed efficiency only.

A potential concern with the inclusion of large quantities of fat in the finishing diet is the direct relationship between the quality of dietary fat and carcass fat. As more unsaturated fat is included in the diet for finishing pigs, carcass fat will become softer, more prone to oxidation (to become rancid). This will affect colour, shelf life and consumer acceptance of fresh pork products. Some recommendations are to maintain the total oil content below 5% in finishing diets. In practical terms this means that in a corn-based diet the inclusion level of full fat soybeans should not exceed 10% (or less than 2% added oil), and that in a barley based diet the inclusion level of full fat canola seed should not exceed 7.5% (or less than 3% added oil).

The inclusion of fat in nursing sow diets has been proven to be beneficial in many studies. In a recent comprehensive review of the available literature conducted by researchers at the University of Minnesota, fat in the sow's diet increased litter weaning weights in 18 out of 24 studies, and lactation weight loss in the sow was reduced in 11 out of 15 studies (Table 4-45). In some studies the response to fat in the sows diet was small.

Table 4-45. Summary of Responses to Supplemental Fat in Sow Diets.

Item	Responses Positive	Responses Negative	Response	Total No. of Comparisons
Piglet survival (%)*	14	6	2.7%	369
Lactation feed intake (kg/d)	3	16	-.2 kg/d	833
ME intake (Mcal/d)	19	0	1.24Mcal/d	834
Litter weaning weight (kg)	18	6	1.65 kg	1150
Lactation weight change in sows (kg)	11	4	1.5 kg	697

* When treatment mean survival is less that 80% and when more than 1000 g of fat was fed to the sow prior to farrowing; derived from Pettigrew and Moser, 1991.

The addition of fat to the late gestation diet may not increase birth weight but will reduce the energy stores in the piglet at birth. The addition of fat had a positive effect on piglet survivability in 14 out of 20 experiments (Table 4-45). This was especially the case when birth weights were low and pre-weaning mortalities were high (more than 20%). The effects are more due to fat per see rather than to the increase in the daily energy intake prior to farrowing. An additional benefit of fat in the gestation diet is that the fat content of colostrum is increased. In order to get these benefits, sows should consume approximately 1 kg of fat in the week prior to farrowing. In a direct comparison, medium-chain fatty acids in the gestation diet appeared more effective than long-chain fatty acids from soybean oil in reducing pre-weaning mortality.

As in growing-finishing pigs, it is extremely important to maintain a proper balance between amino acid and energy intake in nursing sows. A deficiency in protein during lactation maybe more detrimental to sow reproductive performance than a deficiency in energy.

Due to a more efficient utilization of energy derived from digested fat as compared to that from cereal grains and protein sources, and due to the associated reduction in body heat production, the inclusion of fat in swine diets tends to reduce the effect of heat stress on feed intake and animal performance.

Table 4-46. Fat Content - Common Feed Ingredients.

Ingredient	Percent fat[1]
Cereal Grains	
Barley	2
Corn	4
Oats	5
Wheat	2
Fat-rich	
Canola seed	40
Soybean seen	18
Meat and bone meal	9

[1] As defined by ether extraction.

Fat can be added to swine diets indirectly, avoiding the need to install expensive fat handling equipment. High fat ingredients such as whole seed canola or soybeans have been used by many producers. Table 4-46 indicates the quantity of fat contained in such ingredients, as compared to commonly used cereal grains. To add 2% fat to a diet, canola seed containing 40% oil should be added to the diet at the rate of 50 kg/t (5%). The same quantity of fat would require 110 kg/t of soybeans (11%). If such high fat, and therefore high energy feeds are used, adjustments to the amino acid content of the diet may be required. For example, if 2% fat is added to the diet, crude protein should also increase by about 0.5%.

The amount of added fat required to adequately suppress dust has not been determined. A minimum of 0.5% has been recommended, although some producers are adding as much as 2% fat. Many commercial feed manufacturers have specialized fat handling equipment that allows them to add fat to the outside of the pellet. This has proven to be effective in reducing visible dust in the barn.

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Mineral Ingredients

Minerals are added to the diet when the basal ingredients fail to meet the requirement of the pig. Thus, it is rare to supplement potassium or magnesium since basal ingredients supply more than sufficient amounts of these nutrients. However, calcium, phosphorus, sodium and chloride are routinely added to practical diets. Common mineral supplements are illustrated in Table 4-47a and Table 4-47b.

Table 4-47. Typical Analysis (%) of Common Mineral Ingredients Used in Swine Diets.

Table 4-47a.

Macrominerals Ingredient	Calcium	Phosphorus	Sodium	Chloride	Potassium	Magnesium
			-percent-			
Dicalcium phosphate	17.0	21.0	-	-	-	0.6
Monosodium phosphate	-	26.0	19.0	-	-	-
Disodium phosphate	-	22.0	32.0	-	-	-
Mono-dicalcium phosphate	15-23	18-27	-	-	-	-
Deflourinated phosphate	31.0	18.0	5.0	-	-	-
Limestone	38.0	-	-	-	-	0.2
Salt	-	-	39.3	60.4	-	-
Sodium Bicarbonate	-	-	27.4	-	-	-
Potassium bicarbonate	-	-	-	-	39.0	-
Potassium chloride	0.1	-	1.0	47.0	50.0	0.1
Magnesium oxide	1-6	-	-	-	-	51-59
Ammonium chloride	-	-	-	65.0	-	-
Potassium magnesium sulfate	-	-	-	-	18.0	11.0

Table 4-47b.

Microminerals Ingredient	Iron	Zinc	Copper	Manganese	Iodine	Selenium
			-percent-			
Calcium iodate	-	-	-	-	62	-
E.D.D.I.	-	-	-	-	80	-
Copper carbonate	-	-	55	-	-	-
Copper oxide	-	-	75	-	-	-
Copper sulphate H_20	-	-	25	-	-	-
Ferrous carbonate	36-45	-	-	-	-	-
Ferrous oxide	57	-	-	-	-	-
Ferrous sulphate H_20	20-22	-	-	-	-	-
Manganese carbonate-	-	-	-	45	-	-
Manganous oxide	-	-	-	55-65	-	-
Manganese sulphate	-	-	-	27-28	-	-
Potassium iodide	-	-	-	-	68	-
Sodium selenate	-	-	-	-	-	40
Sodium selenite	-	-	-	-	-	45
Zinc Oxide	-	70-80	-	-	-	-
Zinc sulphate	-	36	-	-	-	-

Note: Actual nutrient composition may vary, depending on the supplier. Nutrient composition should be confirmed by chemical analysis. Different sources may vary in mineral availability, especially for copper and iron. Refer to text for details.

Probiotics

Probiotics are a relatively new concept in the regulation of intestinal bacteria. They have been widely touted as an alternative to the use of antibiotics in swine rations. They are supposed to have the opposite effect to antibiotics on the intestinal microorganisms in the digestive tract. Whereas antibiotics control the microbial population in the intestine by inhibiting or destroying microorganisms, probiotics actually introduce live bacteria into the intestinal tract.

Both beneficial and potentially harmful bacteria can normally be found in the digestive tract of swine. Examples of harmful bacteria are Salmonella, Esherichia coli, Clostridium perfingens and Campylobacter sputorum. Not only can these bacteria produce specific diseases known to be detrimental to the host but through competition for essential nutrients, they can also decrease animal performance. In contrast to the effects of these disease causing microorganisms, bacteria such as Lactobacilli and the vitamin B-complex producing bacteria can be beneficial to the host. By encouraging the proliferation of these bacteria in the intestinal tract, it can be possible to improve animal performance.

The ideal situation would be to always have specific numbers of beneficial bacteria present in the intestinal tract. However, physiological and environmental stress can create an imbalance in the intestinal flora of the tract allowing pathogenic bacteria to multiply. When this occurs, disease and poor performance may result. Probiotics increase the numbers of desirable microflora in the gut thereby swinging the balance towards a more favourable microflora.

The mode of action of probiotics has not been clearly defined. It has been suggested that probiotics increase the synthesis of lactic acid in the gastrointestinal tract of the pig. This increased production of lactic acid is postulated to lower the pH in the intestine, thereby preventing the proliferation of harmful bacteria such as E. coli. The decrease in the number of E.coli bacteria may also reduce the amount of toxic amines and ammonia produced in the gastrointestinal tract. In addition, there are reports which suggest that probiotics may produce an antibiotic-like substance and also stimulate the early development of the immune system of the pig.

Despite a considerable amount of study, the research conducted to determine the value of probiotics in swine diets has been inconclusive. The results of one experiment conducted to determine the effects of probiotics in starter diets are shown in Table 4-48. The results of this experiment are typical of most of the research conducted with starter pigs, with most researchers reporting slight improvements in daily gain and feed efficiency as a result of probiotic inclusion. However, this is not always the case and several researchers have reported the opposite effect.

Table 4-48. Performance of Starter Pigs Fed Diets Containing a Probiotic.

	Control	Probiotic
Average Daily Gain (g)	263	270
Average Daily Feed (g)	599	594
Feed Conversion Efficiency	2.28	2.20

Pollmann et al., 1980, J. Anim. Sci. 51: 577-581.
Probiotic = Probios (MuLabs Division, Pioneer Hybrid International).

Some of the reasons for the variability of results include the fact that the viability of microbial cultures may be dependant on storage method, strain differences, dose level, frequency of feeding, species specificity problems as well as drug interactions. The difficulty in maintaining a viable lactobacillus culture in swine feeds may also partially explain the inconsistency in research results. It is well documented that temperature, humidity, change in pH and various antibiotics will decrease the viability of lactobacillus cultures.

The value of adding probiotics to diets fed to growing pigs would appear to be questionable based on experimental data such as that shown in Table 4-49. Some researchers have speculated that probiotics may actually have some negative effects on pig performance during the growing phase by competing for nutrients with indigenous organisms of the digestive tract, decreasing carbohydrate utilization and increasing the intestinal transit rate of digesta. Therefore, although the theoretical concept of probiotics appears promising, the documented evidence of their therapeutic value suggests that the search must continue for a workable alternative to antibiotics.

Table 4-49. Performance of Growing Pigs (23 -38 kg) Fed Diets Containing a Probiotic.

	Level of Probiotic (cfu/kg)			
	0	10^8	10^9	10^{10}
Daily Gain (kg)	0.61	0.61	0.63	0.65
Daily Feed (kg)	1.04	1.02	1.05	1.04
Feed Efficiency	1.69	1.66	1.66	1.60

Scheuermann, S.E., 1993. Anim. Feed Sci. Technol. 41: 181-189.

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Synthetic Amino Acids

Although the most common source of amino acids in swine diets is complete proteins such as soybean or canola meals, some can be provided by individual amino acids that are manufactured by bacterial culture. The most common example is L-lysine hydrochloride (HCI). Commercial products are 98% pure and contain 78.4% lysine in a form that is essentially 100% available to the pig. Other amino synthetic amino acids that are available, and increasingly at competitive prices, include: L-threonine (98% pure threonine in the product), DL-methionine (99% pure methionine in the product) and L-tryptophan (98% pure tryptophan in the product). There has been some data that suggest that synthetic amino acids, such as lysine HCI is used less efficiently than the lysine from soybean meal when pigs are fed once a day, but there is no difference at higher feeding frequencies or when pigs are fed ad libitum.

Synthetic amino acids, and in particular lysine HCI are sometimes referred to as a growth promotant. They are not. They are ingredients which supply the nutrient, lysine, and thus have no growth promoting properties. Growth may improve with the addition of lysine HCI to the diet if lysine is deficient. In this case, they merely improve the nutrient balance of the diet. Lysine HCI should only be purchased when it is economical. If lysine from lysine HCI is less expensive than lysine from other sources, they are worth considering. If they are more expensive, the alternative sources should be chosen.

When large quantities of synthetic amino acids are used it is important to consider the amount of energy supplied by amino acids as well. Just like in protein sources, such as canola meal and soybean meal, amino acids do contribute to the digestible energy content of ingredients. It can be estimated that the DE contents of L-lysine HCL, L-threonine, DL-methionine and L-tryptophan are 4970, 4250, 5750 and 4900 Kcal per kg of product respectively. The energy contents of synthetic amino will have an effect on their economic value in feed formulation systems and on the calculated energy content of diets that include synthetic amino acids.

Some alternatives to pure synthetic amino acids are available or will become available in the near future. Examples are methionine hydroxy analogue (MHA) and fermentation products that contain high concentrations of several essential amino acids. MHA can be used to replace methionine. It is available in a dry form (calcium - MHA, 93% MHA) or in liquid form (88% MHA). There is some controversy about the amounts of amino acids that are effectively supplied by these alternative products. For example, some research with poultry would suggest that MHA is approximately 75% effective in supplying methionine as compared to pure synthetic CL-methionine. Only a limited number have been conducted to study the effectiveness of these alternative sources of amino acids in swine diets.

Interestingly, as these amino acids become more economical, they provide another alternative to balancing swine diets. Rather than only selecting among the various protein meals, the opportunity will exist to consider the synthetic or free amino acids as another option. However, as diets change to include greater quantities of free amino acids in place of complete proteins, the need to carefully formulate **and** manufacture diets will increase. The room for errors will shrink because the over-formulation of the past will be replaced by greater precision. Eliminating wasteful excesses will be of great benefit to the industry, but it carries a significant price tag in terms of quality control.

Organic Acids

Organic acids are widely utilized to inhibit mold activity in stored feedstuffs as well as finished feed. By treating with organic acids, it is possible to harvest and store grains at a higher moisture content without spoiling. Propionic and acetic acids are the most commonly used acids for this purpose.

Some of the early research conducted to determine the nutritional value of acid-treated grains observed improvements in pig performance which could not be attributed solely to the antifungal properties of these acids. Therefore, a considerable amount of research has been conducted to try and improve rate of gain and feed efficiency through the use of organic acids.

Most of the research conducted with organic acids has been focused on improving their performance of starter pigs using fumaric, citric or propionic acid. Supplementation with organic acids at levels between 0.5 and 3.0% of the total diet has been shown to consistently improve feed efficiency while having little or no effect on growth rate. Typical research data is presented in Table 4-50.

Table 4-50. Effect Of Organic Acid Supplementation On Starter Pig Performance.

	Control	Propionic Acid (2%)	Fumaric Acid (2%)	Citric Acid (2%)
Diet pH	5.78	4.71	4.18	4.06
Average Daily Gain (g)	254	245	263	258
Average Daily Feed (g)	494	440	480	471
Feed Efficiency	1.94	1.79	1.83	1.82

Adapted from Giesting and Easter, 1985, J. Anim. Sci. 60: 1288-1293.

The mechanism by which the beneficial effects of organic acid supplementation are achieved has not been determined. However, it has been suggested that the reduction in dietary pH may increase the activity of pepsinogen, a pH-sensitive, protein digesting enzyme in the stomach. The reduction in dietary pH may also reduce gastric pH resulting in greater bacteriocidal activity in the stomach, thus reducing nutrient-robbing bacterial loads in the intestinal tract. Organic acids may also act as chelating agents which increase the absorption of minerals in the intestine of the pig. Finally, it has been suggested that the reduction in pH may slow gastric emptying, allowing greater time for proteolysis (digestion of protein) to occur in the stomach.

As pigs age, their ability to produce their own gastric acid is increased and therefore, there is little benefit in terms of growth rate or feed efficiency from supplementing the diets of growing pigs with organic acids. However, it may be possible to improve carcass traits through organic acid supplementation.

Recent evidence has suggested that methylmalony CoA, a breakdown product of propionic acid metabolism, inhibits some of the enzymes involved in fat synthesis. As a consequence, pigs fed high levels (3-9%) of propionic acid have been shown to have significantly lower levels of backfat than control pigs. Therefore, if the current consumer demand for reduced carcass backfat continues, propionic acid supplementation of diets fed to market hogs may increase in the future.

Feed Flavours

The use of flavors in animal feeds has increased considerably in the past decade as more attention is being paid to ingredient and diet palatability. This increase in feed flavour usage has been paralleled by a dramatic increase in the number of commercially available products ranging from simple spices and tonics to aroma modifiers, sweeteners, flavour intensifiers and artificial flavors.

Unfortunately, feed flavors tend to be incorporated into swine feeds because of marketing appeal and consumer preference rather than as a result of proven effectiveness. At present, very little is known about what specific flavors pigs find attractive and too often flavors are chosen for inclusion in swine feeds because they are attractive to the human palate rather than that of the pig. Even if a particular flavour has been shown to be preferred by swine in free choice or stimulus tests, this preference will not necessarily result in improved performance.

The end result is that although there are claims that such products will stimulate feed intake, very few studies have demonstrated a consistent improvement in feed intake or growth rate as a result of the inclusion of feed flavors in the diet. One researcher compared 129 different feed flavors to determine which specific flavors were preferred by pigs. Five of the flavors which were shown to be most preferred by pigs were then used in a feeding trial. None of the flavors significantly increased the feed intake or growth rate of starter pigs. Since there is a cost associated with the inclusion of flavors in the diet, it would be wise to avoid their use until further research is conducted and a more consistent response is obtained.

Additional Reading and References

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