Feeding Growing-Finishing Pigs For Profit - Main Concepts And New Opportunities

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Introduction

The current low pork prices force us to look at means to reduce the cost of producing pork. For various reasons close attention is paid to the main aspects of feed preparation and feed utilization:

- Feed cost is the single largest cost-factor.
- Feeding programs can generally be altered without too much effort or cost.
- Feed costs per pig vary considerably between farms, which implies that there is room for improvement for many.

On a typical farrow to finish operation, close to 75% of total feed is consumed by grower-finisher pigs and more than 50% by pigs over 60 kg body weight. Furthermore, in typical pig diets energy and protein contribute to more than 85% of the ingredient cost. In this paper the emphasis will be on feeding management of grower-finisher pigs, and on the optimum energy and amino acid levels in grower-finisher pig diets.

First, the new publication ‘Nutrient Requirements of Swine’ from the National Research Council (NRC) in the US will be reviewed. Then, means to obtain information required to generate estimates of nutrient requirements for different groups of grower-finisher pigs - consistent with the NRC publication - will be discussed. Finally, some other important aspects of feeding management are briefly reviewed.

▪ A Brief Overview Of The 10th Edition Of "Nutrient Requirements Of Swine" From NRC (1998)

This benchmark publication is produced about once every 10 years and summarizes our current knowledge on nutrient requirements for the various classes of swine. In this publication recent swine nutrition research is reviewed and estimates of nutrient requirements for the various classes of swine are provided. A total of 39 nutrients that are essential to pigs are considered: energy, 12 amino acids, 1 fatty acid, 13 vitamins and 12 minerals. In addition, information is provided on the mean nutrient composition of the main pig feed ingredients, as well as on feed additives, water, and nutritional means the reduce the excretion of nutrients with pig manure. A committee of about 10 professors from across North America prepared this publication. Dr. Phil Thacker from the University of Saskatchewan was the Canadian representative on the committee.

The following can be considered the main features of this publication:

1. It is unbiased. The publication is prepared by a credible group of scientists and based on solid scientific information that has been published in the literature up to about the middle of 1997. It is not influenced by any commercial organization that may have some interest in promoting specific ingredients, nutrients, feed additives, or feeding program.

2. In the publication a factorial (modelling) approach is used to generate estimates of nutrient requirements for sows and growing-finishing pigs. The committee has recognized that there is a large amount of variability in performance potentials between different groups of pigs and that performance levels should be considered when generating estimates of nutrient requirements. For example, for growing-finishing pigs estimates of lean growth rates, feed intake and body weight are required to generate estimates of nutrient requirements. For nursing sows, estimates of litter growth rates, body weight, and either average feed intake or anticipated body weight changes during lactation are required. The publication includes a C.D. that contains easy to use computer programs - simple models - to generate estimates of nutrient requirements for the various classes of swine.

3. The methods that are used to generate factorial estimates of nutrient requirements are clearly described. There are no 'secrets' in the publication and all assumptions are clearly described. This allows the user to judge the validity and the appropriateness of the models that were used to generate estimates of nutrient requirements.

Clearly this publication will serve as a basis for the development of many feeding programs in commercial pork production. In addition, it will stimulate the development of research programs in areas where information is identified to be lacking. However, during the development of this publication some important choices had to be made, in particular in regards to the required complexity of the models to generate estimates of nutrient requirements. On one hand, the committee's goal was to make the models as simple as possible. This minimizes the amount of information required to generate estimates of nutrient requirements and makes the models easy to apply under a wide range of conditions. On the other hand, the committee wanted to make the models as accurate as possible. The latter increases the required complexity of the model, increases the need for a detailed description of animal and environmental factors that affect the animals' response to nutrient intake, and will make it more difficult to apply the model. This choice should be considered when evaluating the potential use of models under commercial conditions. The NRC model for growing-finishing pigs is simpler than dynamic pig growth models that have been developed by modelling groups (Black et al., 1986; TMV, 1991; Moughan et al., 1995; PPGM, 1997) or some of the larger feed companies.

Important technical aspects of the new NRC publication are:

Feedstuff Evaluation

Energy

The available energy content in feedstuffs is expressed as either digestible energy (DE), metabolizable energy (ME), or net energy (NE). In contrast to DE and ME systems, the NE system reflects that pigs use energy derived from some digested nutrients (e.g. fiber, protein not used for lean growth) less efficiently than energy derived from other digested nutrients (e.g. fat, starch, or protein used for lean growth) (Noblet et.al., 1994, CVB, 1998). For this reason, NE systems are used increasingly for formulating pig diets. The relative energy value of feedstuffs, and thus the relative nutritive value differs between DE, ME and NE systems (Table 1). Unfortunately, for some feedstuffs, such as corn and barley, there are substantial differences between NE values listed in NRC (1998) and other feeding tables such as CVB (1998) (Table 1). Moreover, the relative NE values in NRC (1998) are not consistent with differences in fiber and fat contents between feedstuffs (Noblet et al., 1994). The NE values listed in NRC (1998) should thus be interpreted with caution. In addition, the NE requirements of the various classes of pigs are not given.

Table 1. Estimated digestible energy (DE), metabolizable energy (ME) and net energy (NE) for selected feedstuffs according to NRC (1998) and NE values according to CVB (1998).

	Available energy (Kcal / kg)			
	DE	ME	NE	
			NRC	CVB
Corn	3525 (100)	3420 (100)	2395 (100)	2552 (100)
Wheat, HRS	3400 (96)	3250 (95)	1925 (80)	2347 (92)
Barley	3050 (86)	2910 (85)	2340 (98)	2201 (86)
Wheat middlings	3075 (87)	3025 (88)	1560 (65)	1467 (57)
SBM, dehulled	3685 (105)	3380 (99)	2020 (84)	1950 (76)
Canola meal	2885 (82)	2640 (77)	1610 (67)	1487 (58)
Peas	3435 (97)	3210 (94)	2195 (92)	2294 (90)
Soybeans, heat proc.	4140 (117)	3690 (108)	2880 (120)	2842 (111)
Animal fat - beef	8000 (227)	7680 (224)	4925 (205)	

Amino Acid Availability

The availability of amino acids is expressed in true standardized ileal amino acid digestibilities. In feedstuffs that are not heat treated, this is clearly the best means to express amino acid availabilities. Unlike apparent digestibilities that were included in the old publication (NRC; 1988), true digestibilities are additive in mixtures of feedstuffs. The latter is a prerequisite for proper feed formulation. The NRC (1998) values for true ileal amino acid digestibilities for selected feedstuffs appear reasonably consistent with these from other tables such as CVB (1998) (Table 2). In heat-treated feedstuffs, true ileal amino acid digestibilities may over-estimate the actual amino acid availabilities (Batterham et al, 1993). As a result of heat treatment, lysine may react with other feed components, which renders some of the true ileal digestible lysine unavailable to the pig. A relatively simple technique is now available to measure amino acid availabilities in a wide range of heat-treated feedstuffs (Rutherfurd and Moughan, 1995). Differences between true ileal amino acid digestibilities and availabilities are not considered in NRC (1998).

Phosphorus Availability

The availability of phosphorus, determined in slope-ratio assays relating bone characteristics to phosphorus intake levels, is given for most feedstuffs. Unfortunately, the large amount of information of phosphorus digestibility in feedstuffs that has been generated in Western Europe has been ignored. A direct comparison between NRC and CVB values indicates some important differences in phosphorus availability for ingredients that are routinely used in Western Canada (see Table 2, de Lange et al., 1999, this proceedings). This requires some further attention.

Insert table 2

Ingredient variability

For each feedstuff only average available nutrient contents are provided in the NRC (1998) feed composition tables. Variability in feeding values due to differences in growing conditions (climate, soil type, fertilizer programs), plant varieties, or processing are basically not considered. However, based on protein contents the total contents of key amino acids (lysine, threonine, methionine, methionine + cysteine, tryptophan) can be predicted. Furthermore, a prediction equation is provided that allows for a reasonable prediction of the DE content of feedstuffs from proximate analyses. This equation appears reasonably accurate in explaining differences in DE content between feedstuffs. However, the equation requires estimates of crude fiber contents in the feedstuffs or diets, while crude fiber contents in the feedstuffs are no longer listed in the feed composition tables. The following equation, based on neutral detergent fiber (NDF) content, may be used as an alternative (Noblet et al., 1994):

DE (Kcal / kg dry matter) = 4168 + 1.91 * CProtein + 3.82 * Cfat - 3.59 * NDF - 9.08 * Ash;
(the contents of Cprotein, Cfat, NDF and Ash are all given as g per kg drymatter)

This equation may be more useful than the one given in the NRC publication. It is easier to measure NDF than crude fiber levels, and the equation based on NDF is slightly more accurate than the equation based on crude fiber.

These generalized equations are unlikely to be sufficiently sensitive to explain variability in DE content between different samples of the same feedstuff. The latter is important for the production of feeds of a consistent quality and that result in consistent and predictable levels of animal performance. Equations are, or will become, available to predict the DE content of specific batches of Canadian feedstuffs from relative simple measurements on representative samples (de Lange et al., 1993; Fairbairn, 1997, de Lange et al., 1998).

Estimating Nutrient Requirements For Growing-Finishing Pigs

Factors Determining Nutrient Requirements

For growing-finishing pigs, the three main factors that affect nutrient requirements - body weight, fat-free lean gain and feed intake - are considered (Table 3). Requirements are expressed as either daily amounts (g/d) or as concentrations in the diet (%).

In the growing-finishing pig model, the effects of some environmental factors on nutrient requirements are represented as well. In particular, the model includes effects of environmental temperature on feed intake and maintenance energy requirements, and the effects of stocking density on feed intake. However, as feed intake is affected by many animal, feed, and environmental factors, and their interactions, extreme care should be taken when interpreting the effects of these environmental factors on feed intake and nutrient requirements generated using the NRC model (Chapple, 1993; Forbes et al., 1989; Verstegen et al., 1987).

Table 3. Effects of body weight, fat-free lean gain and feed intake on true ileal digestible lysine (Lys) and threonine (Thr) and available phosphorus (av. P) requirements when fed a diet containing 3400 kcal/kg DE and according to NRC (1998).

	Feed intake 90% of NRC			**Feed intake 80% of NRC**		
	Lys (%)	Thr (%)	Av. P (%)	Lys (%)	Thr (%)	Av. P (%)
Fat-free lean gain (g/d)	**30 kg body weight**					
400	1.09	.68	.24	1.07	.68	.24
350	.96	.61	.24	.94	.60	.24
300	.83	.53	.24	.81	.52	.24
	75 kg body weight					
400	.81	.52	.17	.87	.56	.17
350	.71	.46	.17	.76	.49	.17
300	.62	.40	.17	.66	.43	.17

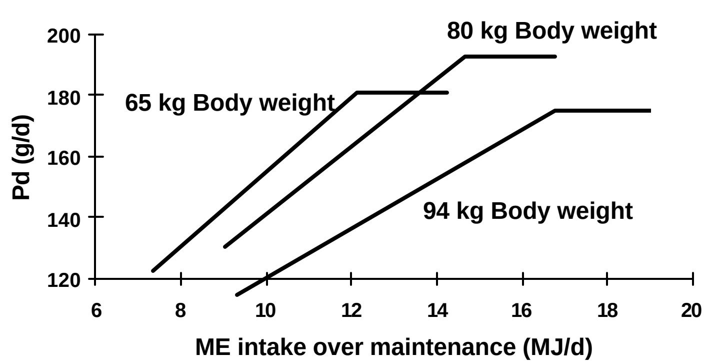
Requirements are estimated for one point in time and for an individual pig that may represent the average of a group of pigs. The width of the body weight range over which diets are fed is not considered. For example, estimated nutrient requirements of a group of pigs fed one diet between 50 and 70 kg body weight are considered to be the same as those of a group of pigs fed one diet between 20 and 100 kg body weight. This is because the average body weights for these two groups of pigs are the same. These characteristics make the NRC growth model a static, deterministic model. This is in contrast to more complex, dynamic models that move through time. In dynamic models, nutrition utilization and growth is calculated over short time periods, generally over individual days, and performance over longer time periods is calculated from the cumulative results of subsequent short time simulations. These dynamic models are a better representation of nutrient utilization than the NRC model, as they consider nutritional history - and as a result, compensatory growth - and responses to changes in nutrient intake as pigs grow.

The NRC model generates estimates of nutrient requirements only; it does not allow for the prediction of pig responses to levels of nutrient intake that are below the estimated requirements. In commercial pork production, it does not make economic sense to always meet the pig’s nutrient requirements. For a proper cost-benefit analyses of alternative feeding strategies, a prediction of pig performance at levels of nutrient intake that are below requirements is essential. This applies in particular to phase feeding programs for growing-finishing pigs.

Response Of Growing-Finishing Pigs To Energy Intake

In the NRC (1998) model the relationship between energy intake and lean gain – or body protein deposition – is represented using a linear plateau concept (Figure 1). Lean gain increases linearly with increasing energy intake levels until a plateau is reached. The pig's performance potential or the intake of another nutrient may determine the plateau. These concepts are well established. In addition, the effect of body weight on the relationship between energy intake and lean gain or body protein deposition is included in the NRC (1998) model (Figure 1). This confirms recent findings that pigs have to become fatter as they grow heavier and/or when energy intake levels increase, even when energy intake limits lean gain (Schinckel and de Lange, 1996). However, the relationship between energy intake and lean gain differs between pig genotypes and is not closely related to lean gain potentials (Mohn and de Lange, 1998). Unfortunately, the relationship between energy intake and lean gain can not be adjusted in the NRC model; it is directly linked to lean gain potentials and environmental temperatures. The importance of the relationship between energy intake and lean gain in growing-finishing pigs has been underestimated and deserves more attention (Schinckel and de Lange, 1996; see the next section on feed intake as well). The effect of energy intake on nutrient requirements will be discussed in the following sections on lean gain and feed intake

Figure 1. Effect of body weight on the relationship between energy intake and body protein deposition (Pd) in cross-bred boars (Quiniou et al., 1995).



Lysine Requirements

The lysine requirements generated by the NRC (1998) model are quite high as compared to other models (Table 4). This is entirely due to the assumed efficiency of using absorbed available lysine intake for body protein deposition, which is low in the NRC (1998) model. The latter implies that for pigs with extremely high lean gains the discrepancy between the NRC and the other models will increase even further. There is little need to add safety margins when formulating diets based on lysine requirements derived from the NRC (1998) model, and in multiple phase feeding programs in particular.

Table 4. Estimated apparent ileal digestible lysine allowances for a 50 kg pig with a protein deposition rate of 130 g/d and consuming 2.2 kg of a diet containing 3150 kcal DE/kg.

	Apparent ileal digestible lysine (%)
Moughan et al., 1987	.54
Stranks et al., 1988	.59
Fuller et al., 1989	.43
TMV, 1991	.62
Moughan, 1989	.65
Whittemore, 1993	.58
NRC, 1998	.68

Requirements for other Amino Acids

The requirements of other essential amino acids are derived from the lysine requirements for maintenance and lean gain based on fixed amino acid to lysine ratios for these two processes. The net result is that the optimum dietary threonine to lysine ratios and methionine plus cysteine to lysine ratios increase with body weight and decline with increases in lean gains at a given body weight (Table 3). These concepts are well established. However, the actual ratios that are suggested for finisher pigs remain to be properly tested. The effect of body weight on the optimum amino acid ratios may be larger that suggested in the NRC publication. Moreover, diet ingredient composition may impact these ratios.

Requirements For Vitamins and Minerals

The requirements for vitamins and minerals of growing-finishing pigs have not changed from the previous NRC (1998) publication. This reflects the lack of solid research to better define the effects of environmental stresses and lean gains on requirements for vitamins and minerals in growing-finishing pigs. According to NRC (1998) vitamin and mineral requirements, when expressed as concentrations in the diet, are not affected by lean gains and feed intake levels (Table 3; av. P). This is quite surprising. Bone growth, and thus the requirements for calcium and phosphorus are closely associated with lean gain.

Furthermore, pigs with high lean gains generally have better feed efficiencies and tend to have lower feed intakes. If NRC (1998) recommendations are followed, pigs with higher lean gains will have lower intakes of vitamins and minerals per kg of body weight gain, and likely per day as well, than pigs with lower lean gains. It appears more reasonable to keep the daily intake of vitamins and minerals constant and to calculate target diet vitamins and mineral levels as daily requirements divided by anticipated feed intake. This will result in increases in diet vitamin and mineral levels as feed intake levels decline. Moreover, vitamin and mineral levels may be increased in diets for growing-finishing pigs with high lean gains. The adjustment may be in direct proportion with lean gains or diet lysine levels, certainly not higher. The latter applies to available phosphorus and calcium in particular. Finally, given the small contribution of vitamins and micro-minerals (copper, zinc, iron, manganese, iodine, selenium) to total nutrient costs in pig diets, the actual levels of these nutrients in practical diets are generally considerably higher, often more than double, than the NRC (1998) recommendations. The latter may be appropriate, as environmental stresses and exposure to diseases are likely to increase requirements for vitamins and micro-minerals.

▪ Establishing And Interpreting Average (Fat-Free) Lean Gains And Lean Gain Curves

Lean gain is closely related to daily gain, feed efficiency and carcass quality. The value of increasing lean gain is substantial. An increase in lean gain of only 5% represents an increase in profit of at least $1.50 per pig. Furthermore, lean gain is closely related to body protein deposition, the main determinant of dietary amino acid requirements and one of the main determinants of energy requirements. An estimate of the average fat-free lean gain over the entire growing-finishing period is essential when models are used for generating nutrient requirements. In Canada, the range in average lean gains is likely between 300 and 425 g/d.

In Canada, for the calculation of average fat-free lean gains for groups of pigs the following information is required:

- average body weight (kg) when pigs enter the growing-finishing barn,
- average hot carcass weight (kg),
- average lean content (%) in the carcass (unfortunately this is now given as a percentage of cold carcass sides, rather than the hot carcass; see assumption 2 below), and
- the average number of days required to grow pigs from initial to final body weight.

Two assumptions are required:

1. The lean content in pigs at the initial body weight. This value is unlikely to vary much between pig genotypes at body weights between 15 and 30 kg. It can be predicted from body weight using the following equation (derived from NPPC, 1994; some corrections are included for fat contents in dissected lean):

lean content (kg) = 0.441 x live body weight (kg) - 1.751.

2. The difference in weight between the weight of the hot carcass and cold carcass sides. This represents the weight of the head, feet, kidney, leaf fat and some drip losses that may occur. Based on the results of the Ontario Pork Carcass Appraisal project (data from more than 1700 pigs) the weight of the cold carcass sides can be predicted using the following equation:

weight of cold carcass sides (kg) = 2.400 + 0.867 x hot carcass weight (kg).

For example, in a growing-finishing pig unit, pigs are entered at 26 kg body weight, pigs require, on average, 110 days to reach market weight, have an average hot carcass weight of 86 kg and a lean yield of 60.5%. In this example, the amount of lean in the pig's body at initial body weight is 9.715 kg (0.441 x 26 - 1.751). The weight of the cold carcass sides is 76.962 kg (2.400 + 0.867 x 86). The amount of lean in the carcass is 46.562 kg (76.962 x 60.5/100). The lean gain is 335 g/d ([46.562 - 9.715] / 110 = 0.335 kg/d x 1000).

To convert this average lean gain to average fat-free lean gain, average lean gain should be multiplied by .90. This value indicates that dissected lean according to the Canadian carcass grading system contains approximately 10% fat. Both intra-muscular, as well as some extra-muscular fat contribute to this 10%. Unfortunately, little information is available on how this fat content varies between types of pigs in Canada. It should be remembered that the trimmed belly and some of the ribs are considered part of dissected lean in Canada. The belly contains approximately 30% fat and contributes to about 20% of the weight of dissected lean. In the above example the average-fat free lean gain is 302 g /d (335 x 0.90).

In these calculations the main source of potential errors is in the estimation of lean content in the cold carcass sides. Based on the conformation of the carcass, there may be some systematic differences between the actual and estimated lean content in the carcass for various pig (geno-) types. Estimation of the amount of lean in the carcass may be improved by dissecting out one of the prime cuts (loin) or by obtaining multiple real time ultrasound measurements on the carcass (e.g. Hicks et al., 1998; Swensen et al., 1998).

As multiple phase feeding programs are developed, it is essential that the lean gains, and feed intakes are determined at the various stages of growth, i.e. that lean gain and feed intake curves are established. Furthermore, for determining the optimum shipping weight, the change in lean gain around the slaughter weight should be determined as it determines the change in carcass value and the cost (amount of feed required) to produce the marginal increments in carcass lean content (Porkma$ter, 1997).

Lean gain curves can be established using three different methods:

1. Calculate the average lean gains, as indicated above, and combine this with a standard lean gain curve shape to establish the actual lean gain curves. This is the easiest method and is used in the new NRC (1998) model. This is also the least preferred method as it ignores differences in the shape of lean gain curves between different growing-finishing pig units.

2. Establish a growth curve by relating body weight versus time in the barn based on measurements on at least 40 pigs. On at least 40 of these pigs, make serial B-mode real time ultrasound measurements at least four, preferably 5, different body weights that are equally spread out over the entire growing-finishing phase. This is to estimate the lean content at each of these body weights (Schinckel and de Lange, 1996). Relate lean content to body weight using mathematical functions such as the allometric function (lean content = a x $[\text{body weight}]^b$; where a and b are mathematical parameters). Based on this allometric relationship, growth curves can be converted to lean gain curves. The main sources of error in this approach are the inaccuracies of the real time ultrasound measurements and the prediction of lean contents of real time ultrasound measurements at the various body weights. Relationships between real time ultrasound measurements and body lean content differ between lines of pigs (Schinckel and de Lange, 1996; Hicks et al., 1998). When this method is used, experienced people should be involved in obtaining and interpreting the data. This is the preferred method for establishing lean gain curves.

3. Establish a growth curve, based on at least 4 equally spread data points that relate body weight to the number of days in the barn and with observations from at least 40 pigs per data point. Combine this information with an actual feed intake curve (see the next section) and run this through a dynamic pig growth model. Then adjust the lean gain curve 'inside' the model to fit a predicted growth curve to the actual growth curve. This approach is very sensitive to assumptions about maintenance energy requirements and to the accuracy of the feed intake curve. This approach requires access to dynamic models that are more complex than the static NRC (1998) model.

Care should be taken with the interpretation of lean gain curves. Various factors, including genotype, sex, environmental stresses (health status, crowding) and nutrient intake affect observed lean growth rates. Lean gains have medium to high heritabilities and disease can reduced lean growth rates by more than 30% (de Lange and Schreurs, 1995; Black et al., 1995). Furthermore, lean gain is generally affected by different factors at the various stages of growth. At lower body weights, when daily lean gains are increasing with increasing body weight, lean gain is generally determined by nutrient intake and most often by energy intake. Ideally, lean gain curves should be established under conditions where nutrient intake is unlikely to limit lean gains. Pig growth models such as the NRC (1998) model may be used to identify whether nutrient intake affects lean gain and to identify whether an increase in nutrient or energy intake increases lean gain.

▪ Establishing And Interpreting Feed Intake Curves

The importance of establishing feed intake curves has been addressed in previous years at the Banff Pork Symposium (1996, 1997). For a complete discussion on interpreting and manipulating feed intake curves, the reader is referred to these and other articles. Feed intake can have substantial impacts on animal performance and profits. Furthermore, for establishing effective feeding programs estimates of feed intake are important. The simulation results presented in Table 5 clearly indicate that pigs with unimproved lean gain potentials deserve to be feed restricted, while feed intake in pigs with improved lean gain potentials should be maximized. The data also suggest that the cost of sub-optimal feeding programs can be very substantial.

Pork production is most efficient, and generally most profitable, when energy intake is just sufficient for pigs to express their lean gain potential. When energy intake is lower than this, energy intake drives lean gain and feed efficiency. In this situation, energy intake should be maximized, diet nutrient levels should be established based on nutrient to energy ratios (Table 3; pigs at 30 kg body weight), and energy intake has only minor effects on the lean to fat ratio in the pigs body. When energy intake is higher than that required to just maximize lean gain, a further increase in energy intake will result in an increase in body fat deposition only. This, in turn, will result in a poorer carcass quality and feed efficiency. In this situation, nutrient levels should be determined based on daily requirements and estimated feed intakes (Table 3; 75 kg body weight). Energy intake is likely not limiting lean gain in pigs over 60 kg body

Table 5. Interactive effects of feed intake, pig lean gain potentials and feeding programs on pig performance and profits*.

	Unimproved pig type			Improved pig type	
Feed allowance, % of NRC	100	80		100	80
Feeding program	Optimal	optimal	sub-optimal**	optimal	optimal
Lean gain, g/d	340	290	265	415	330
Gain, g/d	793	643	606	920	714
Avg. days to market	108	133	141	93	120
Days per rotation	122	147	155	107	134
Feed : Gain	2.97	2.93	3.12	2.54	2.61
Dressing %	80.55	79.75	80.10	79.7	79.23
Carcass lean yield, %	57.48	60.50	59.12	60.68	62.44
Carcass index	104.2	109.4	107.5	109.6	110.95
Feed cost, $ / pig	48.07	49.17	50.26	43.65	44.87
Margin, $ /pig	-3.48	-.07	-2.92	5.62	5.22
Margin, $/pig place/year	-10.42	-.18	-6.87	19.16	14.23

*Based on: performance between 20 and 105.5 kg body weight; 5% feed wastage; 1% mortality; 14 open days per rotation; standard deviations on carcass lean yield and carcass weight of 2% and 4 kg, respectively; weaner pig price $55.00; variable costs per pig $15.00; price per kg carcass at index 100: $1.30; corn ($130/tonne), soybean meal (47.5% CP;$310/tonne) and premix (3% inclusion; $600/tonne) based diets in a 2 phase feeding program; mixed costs are $15/tonne; diets are switched at 65 kg body weight. For all feeding programs, diet soybean meal levels have been adjusted to maximize profit for each pig type and feeding level.

**For the suboptimal feeding program, diet soybean meal levels are the same as the optimum diet soybean meal for this pig type at the high feed allowance. Margin ($/pig) is calculated as: carcass value - feed costs - weaner pig price - variable costs per pig. Margin ($/pig place per year) is calculated as: $/pig x 365 / days per rotation. Calculations are conducted using PPGM - Purina Pork Growth Model (1997).

weight and in pigs with medium or unimproved lean gain potentials. However, in modern pig genotypes energy intake may limit lean gain up to market weight (e.g. Schickel and de Lange, 1996; Mohn and de Lange, 1998). Unfortunately, there is insufficient information about the relationship between body weight, energy intake and lean gain in the main pig genotypes. A simple means to get an indication of this relationship is to compare the carcass lean content in the fastest growing pigs to that in pigs with average growth rates. If these are similar, energy intake is likely limiting all the way up to market weight. If the first pigs are the fattest pigs, energy intake is unlikely to limit lean gain in finishing pigs. In the latter case a restriction in feed intake will result in improvements in carcass lean content, feed conversion ratio and profit per pig (Table 5).

Reasonable feed intake curves can be established when feed intake is measured accurately in representative monitoring pens over at least a two week period and at least three different stages of growth that are equally spread over the growing-finishing period. For each body weight range, feed intake and body weight data should be obtained from at least two feeders with at least 40 pigs per body weight range. The highest body weight range should be as close to market weight as possible. Relatively simple and inexpensive devices are now available to measure feed disappearance in individual feeders. As an alternative to measuring feed intake in representative monitoring pens, feed intake may be determined for an entire room or barn if these are managed on an all in-all out basis. The latter requires that feed deliveries and inventories, as well the total number of pigs in inventory is monitored accurately and frequently. Computer programs such as GrowthMaster, PorkMa$ter or more recently the PigWin program may be used to derive actual feed intake curves from the various observations. In GrowthMaster and PorkMa$ter feed intake curves are expressed as a % of voluntary feed intake according to NRC (1988, 1998).

Typical levels of feed intake, feed allowances minus feed wastage, are about 90% of NRC but may vary between 70 and 100% of NRC. If feed intake levels are below the average, check feed quality, feeder type and settings, water availability, environmental temperature, animal health, and pig genotype. The effect of sex on feed intake differs between pig genotypes; it may vary between 3 and 15% and increases with body weight.

▪ Effect Of Animal Variation On Nutrient Requirements - Phase And Split-Sex Feeding

Unfortunately, there is considerable variation in body weight, growth rate, lean gain, and feed intake within groups of pigs. As a result the actual nutrient requirements differ between individual pigs within a group, even though they may be fed the same diet. For example, in Table 6 the lysine requirements for various pigs are estimated. These values are based on coefficients of variation in body weight and lean gain of 10%, which is typical within groups of pigs. For the development of effective phase feeding and split-sex feeding programs, this variability should be minimized. Based on the results in Table 6, growing pigs should be grouped based on lean gain potentials; in growing pigs variability in lean gain has a much bigger impact on nutrient requirements than body weight or gender. A reasonable means to do this is to separate pig genotypes and to look at past performance, i.e. to sort pigs based on weight per age as they enter the growing barn. In finishing pigs, the gender effect becomes relatively more important. In grower diets for gilts the lysine to energy ratio should be about 5% higher than in grower diets for barrows, while in the finisher diets this difference may increase to as much as 15%. It should be noted that split-sex feeding will improve the efficiency of using space in the barn as barrow pens can be turned over faster than gilts pens. Based on the animal and economical conditions described under Table 5, split-sex feeding in a 2 phase feeding program will increase profits per pig by about $1.00 and profit per pig place per year by about $3.00. As the effect of gender on lean gain and feed intake differs between pig genotypes, these values may differ between pig units.

According to Table 6, the effect of body weight on nutrient requirements is smaller than the effects of either lean gain or gender. Therefore it does not make sense to have multiple phase feeding programs when the gilts and barrows are mixed or when there is considerable variation in lean gain within groups of pigs. Furthermore, additional improvements in profitability become smaller with each additional feed that is introduced. For example, based on the animal and economical conditions described in Table 5, the improvement in profit per pig and profit per pig place per year are just over $2 per pig and $6 per pig place per year if the optimum 1 phase feeding program is replaced by the optimum 2 phase feeding program. These values are about half of this when comparing a 2 to a 3 phase feeding program, about $1 per pig and $3 per

Table 6. Effect of body weight, sex, and fat-free lean gain on estimated lysine requirements for growing and finishing pigs

	True digestible lysine Requirements (% in diet)
Growing pigs:	
30 kg gilt; avg fat-free lean gain of 325 g/d (BASE)	.87 (100)
33 kg gilt; avg fat-free lean gain of 325 g/d (+10% BW)	.85 (98)
30 kg gilt; avg fat-free lean gain of 357 g/d (+10% lean gain)	.95 (109)
30 kg barrow; avg fat free lean gain of 312 g/d	.83 (95)
38 kg gilt; avg fat-free lean gain of 325 g/d	.83 (95)
Finishing pigs:	.67 (100)
75 kg gilt; avg fat-free lean gain of 325 g/d (BASE)	.63 (94)
82.5 kg gilt; avg fat-free lean gain of 325 g/d (+10% BW)	.73 (109)
75 kg gilt; avg fat-free lean gain of 357 g/d (+10% lean gain)	.56 (83)
75 kg barrow; avg fat free lean gain of 312 g/d	.56 (83)
98 kg gilt; avg fat-free lean gain of 325 g/d	

pig place per year, and about half of that again when comparing a 3 to a 4 phase feeding program. This should be weighed against the risk of slight errors in feed preparation and in estimating nutrient requirements. As the number of diets in a phase feeding program increases, the safety-margins (i.e. differences between dietary nutrient supply and nutrient requirements) are becoming smaller. As a result, errors in feed formulation and preparation are more likely to reduce animal performance and profits as the number of diets in phase feeding programs is increased.

▪ Effect Of Alternative Management Strategies On Profit

Profitability in the growing-finishing barn is affected by many factors. In addition to those discussed in the previous sections, feed ingredient evaluation, least cost feed formulation, finess of grinding, mixing accuracy, effects of health on pig performance, and shipping strategies should be considered. The relative values of alternative management strategies to increase income per pig place per year are presented in Table 7. These values are based on Canadian conditions as presented in the footnotes of Table 5. The basis for these calculations is a group of pigs with an average lean growth potential (maximum lean gain 395 g/d), average feed intake levels (feed allowance is 95% of voluntary feed intake according to NRC 1998 and 5% feed wastage), performance between 20 and 109 kg of body weight, optimum two phase feeding programs for each alternative, the standard Ontario carcass grading system, 1% mortality, 14 open days per rotation (difference between days per rotation and the average days to market for a group of pigs), high health status and a good environment.

Provided that the proper two phase feeding program is in place, improving pig lean gain potentials and reducing the impact of disease on animal performance are the most effective means to improve profits in the growing-finishing barn. Furthermore, close attention should be paid to feed preparation, and to finess of grinding in particular. The simulation results also indicate that it is more important to pay attention to shipping strategies, i.e. reducing variation in carcass weights and determining the optimum shipping weight, than to develop multiple phase feeding or split-sex feeding programs. The optimum shipping strategy is determined by the carcass grid and performance of pigs around the time of slaughter. The optimum strategy is likely to vary between different pig units and provinces. Programs such as PorkMa$ter and PigWin may be used to determine the optimum shipping strategy for individual pig units.

Table 7. Estimated values of alternative management strategies for growing-finishing pigs under Canadian conditions (Adjusted from Marty, 1998; based on model simulations using PPGM, 1997).

Strategy	Comparison	Difference from base $/pig place/yr
High health status	High vs low[1]	22
	High vs compromised[1]	12
Correct final body weight	109 vs 105 kg	7
	109 vs 114 kg	6
Minimal variation in carcass weight	STD[2] of 4 vs 6 kg	9
Superior pig genotype /	395 vs 310 g/d	17
maximum lean gain	440 vs 395 g/d	7
Correct feed particle size	650 vs 1250 um grain[3]	13
Low feed wastage	5 vs 11%	9
	5 vs 8%	5
Phase feeding	2 vs 1 phase(s)	6
	3 vs 2 phases	3
Optimum mixing accuracy	$\pm$ 10%[4]	6
Split-sex feeding	Barrows and gilts separate vs mixed	3

[1] For pigs with a low health status the maximum lean gain is assumed to be 30% lower, feed intake 12% lower, maintenance energy requirements 8% higher, and mortality 2% higher than in pigs with a high health status; for pigs with a compromised health status the maximum lean gain is assumed to be 20% lower, feed intake 6% lower, maintenance energy requirements 4% higher, and mortality 1% higher than in pigs with a high health status (de Lange and Schreurs, 1995; Black et al., 1995).

[2] Variation in carcass weights is expressed based on the standard deviations (STD; about 66% of carcass weights are within the mean carcass weight $\pm$ 1 x STD). This variation, combined with variation in carcass lean yield, determines the distribution of carcasses over the various cells in the carcass grading grid and thus average carcass value. Based on results from Ontario Pork, typical STD for carcass weights and lean yields are about 5 kg and 2%, respectively.

[3] Difference in diet DE content due to change in finess of grinding is 9% (e.g. Wondra et al., 1995).

[4] changing the inclusion level of the protein source and premix every 10 kg of body weight gain to either 10% above or 10% below the optimum inclusion level.

▪ Summary

In April 1998, the National Research Council (NRC) published the 10th edition of ‘Nutrient Requirements of Swine’. In this publication our current knowledge about nutrient requirements of swine is summarized. The publication includes various models that can be used to estimate nutrient requirements for different classes of swine based on body weights, performance levels and some environmental conditions. The main strengths and weaknesses of the NRC publication and the growing-finishing pig model were reviewed. For estimating nutrient requirements for growing-finishing pigs estimates of body weight, average lean gains and feed intake are required. Average lean gains can be calculated from growth rates, carcass weight and carcass lean yield. For manipulating average lean gains, factors that determine lean gain at the various stages of growth - energy intake, intake of amino acids and other nutrients, pig performance potentials, environmental stresses - should be identified. Provided that a proper two phase feeding program is in place, the main determinants of profitability in growing-finishing pig units - in approximate order of importance - are: effects of disease on expression of lean gain potentials, lean gain potentials, feed particle size, shipping strategies, feed wastage, phase feeding, feed mixing accuracy, and split-sex feeding.

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Table 2. True digestibilities in selected pig feed ingredients according to NRC (1988) and CVB (1998).

	True ileal digestibility (%)									
	Lysine		Threonine		Tryptophan		Methionine		Cysteine	
	NRC	CVB	NRC	CVB	NRC	CVB	NRC	CVB	NRC	CVB
Corn	78	76	82	80	84	76	90	87	86	81
Wheat	81	84	84	86	90	88	90	90	90	90
Barley	79	76	81	80	80	77	86	82	86	80
Wheat middlings	89	68	88	60	91	75	93	73	91	72
SBM, dehulled	90	89	87	86	90	88	91	90	87	83
Canola meal	78	74	76	71	75	71	86	81	83	70
Peas	88	81	83	76	81	70	84	74	79	68
Soybeans, heat processed	86	83	83	79	82	82	85	82	80	75