THE ADVANTAGES OF DEHULLED SOYBEAN MEAL IN THE LIFE CYCLE NUTRTION OF PIGS

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For many years the soybean crushing industry produced primarily 44% protein soybean meal (regular SBM), which contains hulls. This meal was the standard soybean meal traded on the Chicago Board of Trade (CBOT). However, with the demand for higher energy diets, particularly for poultry production, and in improvement in processing techniques the crushing industry begin producing dehulled soybean meal (DHSBM), also sometimes referred to as "high pro" soybean meal. DHSBM also became the preferred soybean meal for use by the swine industry in the US, and today it has become the standard soybean meal traded on the CBOT. However, the swine industry in many parts of Asia continues to utilize regular SBM.

The acceptance or rejection of any "new" ingredient is dependent upon a number of factors, as indicated in Table 1.

Table 1. Factors affecting the relative value of DHSBM.

"Obvious Factors"
1. Price of the ingredient vs. the price of competitive ingredients; 2. Nutrient content of the ingredient vs. that of competitive ingredients;
"Subtle Factors"
1. Nutrient content and price of "non-competitive" ingredients; 2. Stage of livestock production for which the feed will be utilized; 3. The genetic capacity of the animal for growth, or other productive traits; 4. Environmental temperature; 5. Whether you are a feed manufacture, livestock producer, or integrated livestock producer.

This paper attempts to establish the advantages of DHSBM in the life cycle nutrition of pigs as affected by the factors given in Table 1.

1. OBVIOUS FACTORS

1.1 Price of the ingredient vs. the price of competitive ingredients

1.2 Nutrient content of the ingredient vs. that of competitive ingredients.

These two factors are very obvious and are considered together. DHSBM competes with regular soybean meal, other plant protein as well as animal protein sources. As indicated, regular SBM is commonly accepted as the standard protein ingredient in most of Asia, while DHSBM is the standard protein ingredient in the US. Basically DHSBM is regular SBM, but without the hulls. Thus, it is higher in protein, amino acids and energy (DE/ME) than regular SBM. Many buyers price protein ingredients solely on the cost per unit of protein, and do not take into account the higher amino acid and ME/DE values. This is especially true if a purchasing department rather than the nutrition department is making the purchase. Thus, the full value of DHSBM frequently is not given adequate consideration in the purchasing decisions. For example, SBM contains 43.8% crude protein and DHSBM contains 47.5% crude protein (NRC, 1998). However, it contains approximately 7% more of many essential amino acids, 6% more ME and over 50% less fiber than regular SBM (Table 2). In fact, it is the latter two items, higher ME and lower crude fiber, which make it especially attractive for baby pigs and lactating sows. In addition the higher protein content “frees space in the diet” for other ingredients such as grain which in turn helps to produce a higher energy diet.

Table 2. Comparison of the nutrient content of SBM and DHSBM[a]

Nutrient	Reg. SBM	DHSBM	% difference
Crude Protein	43.8	47.5	+8.44
LYS	2.83	3.02	+6.73
MET	0.61	0.67	+9.84
M+C	1.31	1.41	+7.63
THR	1.73	1.85	+6.94
TRY	0.61	0.65	+6.67
VAL	2.06	2.27	+4.85
DE	3,490	3,685	+5.59
ME	3,180	3,380	+6.29
Fiber	7.5	3.5	–53.33

[a] *(NRC, 1998)*

Based on the data in Table 2 DHSBM would have a value of 6 to 8% greater than regular SBM. However, its true value is much better assessed by the less obvious factors or subtle factors.

In addition DHSBM also competes with fish meal, and sometimes meat and bone meal. Fish meal is higher in protein than soybean meal, but its energy value is considerably less. For example Anchovy meal, main fish meal from Peru and Chile, contains only 2,695 kcal ME/kg (3,230 DE) compared to 3,380 kcal ME (3,685 DE) for dehulled soybean meal (NRC, 1998). Meat and bone meal contains only 2,225 kcal ME (2,440 DE). Meat and bone meal also has a lower content of many of the essential amino acids that does soybean meal, especially DHSBM (NRC, 1998).

Fish meal and meat and bone meal also have a higher content of phosphorus and available phosphorus than soybean meal. However, as phytase is becoming commonly accepted for use in feed formulation the importance of phosphorus in the animal proteins is becoming less important.

2. SUBTLE FACTOR

2.1 Nutrient content and price of “non-competitive” ingredients

A "non-competitive” ingredient would be the grain and/or possibly grain byproduct component of the complete feed. This aspect would almost never be considered by a purchasing department, but should be obvious to the nutritionist. Diets are formulated to meet specific specifications for energy, amino acids, etc. Grain is the major supplier of the energy in the diet. However, if the corn has 1 or 2% higher moisture content than normal, or other factors which lower its energy content, then the energy content of the protein ingredient becomes more important in maintaining existing formula specifications with a minimal increase in the formula cost. Table 3 compares the nutritive value of corn as given by NRC (1998) and that given by China Feed Data Base Information Center (1998) for corn from Mainland China.

Using the nutrient contents given in Tables 2 and 3 and the ingredient prices for Taiwan (Appendix), Table 4 illustrates the influence of corn quality on formula cost and relative value of regular and DHSBM, fish meal and meat and bone meal in a diet for a 20-50 kg pig. The nutrient requirements are based on NRC (1998). These ingredient prices are used throughout this paper.

Table 3. Comparison of the nutritive content of corn of varying quality.

Component	Corn, US[a]	Corn, Grade 1 PRC[b]	Corn, Grade 2 PRC[b]
Dry matter, %	89	86	86
ME, kcal/kg	3,420	3,289	3,308
DE, kcal/kg	3,525	3,390	3,410
Crude Protein, %	8.3	8.7	8.0
Lysine, %	0.26	0.24	0.24
Methionine, %	0.17	0.18	0.16
M+C, %	0.36	0.38	0.34
Tryptophane, %	0.29	0.30	0.30
Threonine, %	0.06	0.07	0.06
Valine, %	0.39	0.38	0.36

[a] NRC (1998)   [b] China Feed Data Base Information Center (1998)

Table 4. Effect of corn quality on dietary energy and relative value of soybean meal and other protein sources.

	Corn quality		
Ingredient, %	NRC	Ch, H	Ch, M
Corn	70.0	70.1	63.5
DHSBM	26.8	26.6	33.5
Vit. & Min.	3.18	3.30	2.97
Phytase	0.02	-	0.03
ME	3,350	3,210	3,200
DE	3,510	3,360	3,350
Shadow prices, NT$/kg[a]			
Reg SBM	6.99	6.83	5.61
Fish meal (65%)	9.88	9.08	6.33
M&B meal	8.62	8.67	9.27

[a] Price at which an ingredient would begin to enter the diet.

From Table 4 we can see that it is possible to obtain a diet with 3,350 kcal ME/kg (3,510 DE) utilizing DHSBM and NRC quality corn. The importance of this high energy level will be discussed later. The relative value of the other protein ingredients is shown by their shadow prices. In this diet regular soybean meal would be worth only NT$6.99/kg, about 14% less than the value of DHSBM. Fish meal (65%) would only be worth NT$9.88 and meat and bone meal NT$8.62.

However, when the quality (energy content) of the corn decreases we either have to accept a lower energy level, which may affect performance, or it is necessary to add fat (tallow/ soy-bean oil) to the diet. Specialized equipment is needed to add tallow. For feedmills that have equipment to heat the tallow and spray it into the mixer this is not a problem. However, for on farm mixing this is very difficult and probably not practical, except for very large-scale farms. Even adding oil is difficult and very inefficient unless you have equipment to spray it into the mixer. On the other hand, by using DHSBM it is possible to help keep the energy level at or near the level suggest by NRC (1998) without using tallow or soybean oil. The relative value of regular SBM declines to NT$6.83 (approximately 17% less than DHSBM) and fish meal to NT$9.08, while the relative value of meat and bone meal remains at about NT$8.67.

However, when the low quality corn is used the energy value drops dramatically unless fat is added to the diet. In fact DHSBM enters the diet at a very high level as a source of energy and the value of regular SBM declines to only NT$5.61/kg (30% less than DHSBM). The value of fish meal declines to only NT$6.33, while the value of meat and bone meal increases to NT$9.27. This diet would be very high in protein and is not practical. It is simply included to illustrate what happens when you try to use poor quality ingredients and how utilizing poor quality ingredients further increases the value of DHSBM compared to other protein ingredients.

It was indicated phytase is becoming popular to help lower the need for supplemental phosphorus. Note that it came into two of the diets.

This clearly illustrates the point that the quality and/or availability of other ingredients, particularly the energy ingredients, has a strong influence over the relative value of DHSBM in maintaining formula specifications and feed quality.

2.2 Stage of livestock production for which the feed will be utilized

The pig's nutrient requirements change base upon the stage of production. DHSBM's role and relative value also varies with the stage of development in the life cycle of the pig. This is a very important consideration, especially for weanling pigs and lactating sows.

While lysine and the other essential amino acids are important for ADG, FCR and lean growth, frequently the most limiting nutrient, especially for lean growth in modern genetic pigs that are capable of very high lean growth, is energy. This is particularly true for pigs from weaning through 50 kg, and may extend to heavier weights for very lean meat pigs, which have also been developed for improved feed efficiency. These pigs tend to have reduced feed consumption (Kanis, 1990). However, the energy requirement for growth, especially lean meat gain, may actually have increased.

2.2.1 Weanling Pigs

We know that modern genotypes are capable of growing very rapidly and are very efficient producers of lean meat. For example, it definitely is feasible to produce 100 kg pigs in 130 – 140 days. However, the growth performance of pigs from weaning through 9-10 weeks of age is critical in determining subsequent weight for age relationships and as such ultimate carcass weight and quality. While the young pig has a high potential for growth there are numerous factors that influence the extent to which this potential is expressed, especially in the young pig.

Energy requirements: There is considerable scientific and commercial evidence suggesting that pigs weighing 4-5 kg at weaning respond positively in terms of growth rate to dietary ME levels up to 3,400 kcal/kg (3,585 DE) (Campbell, 1999). Leading universities in the US recommend, as practical transition diets, ME levels of 3,370 to 3,460 kcal/kg (DE 3,530-3,625). This compares to the 3,265 kcal ME/kg (3,400 DE) indicated by NRC (1998).

There is also considerable evidence to indicate that **available** lysine levels as high as 4.0 to 4.5 g/Mcal ME (4.7 to 5.3 g total lysine/Mcal ME; 3.4-3.8 g available lysine/Mcal DE, or 4.0-4.5 g total lysine/Mcal DE) (Campbell, 1999, Reese *et al*., 1995, Holden *et al*., 1996).

Likewise, pigs from 10 kg to 25 kg also require high energy, high lysine:energy ratios for rapid growth, good feed efficiency and rapid lean growth. Nam and Aherne (1994) reported that the lysine:energy ratio to produce maximum weight gain (612 g/day) in pigs from 10 to 25 kg was 4.16 g/Mcal of ME (3.98 g/Mcal of DE). While they did not measure lean growth directly, based on response surface analysis, a ratio greater than 4.16 g lysine/Mcal ME is required to maximize lean growth.

Ingredient selection: is also more critical for the younger animals, and animal protein supplements (milk products, high quality blood meal, and fish meal) should be used to help reduce the level of vegetable protein. However, inclusion of SBM in the transition diet of pigs weaned at 21 days of age is important to accustom the pig's digestive system (Friesen *et al*., 1993). Inclusion of high levels of SBM in the transition diet may reduce ADG gain slightly during the first 14 days post-weaning. However, pigs that received transition diets without SBM and are then placed on a starter diet with a high level of SBM experienced "post-weaning lag" between 14 and 35 days post-weaning.

Friesen *et al*. (1993) suggested that the transition diet for pigs weaned at 21 days of age should contain 15-22.5% SBM (DHSBM). However, based upon cost of other ingredients such as select fish meal, high quality blood meal, plasma protein, edible grade whey, *etc*. it may be more economical to utilize 25-30% DHSBM in the transition diet. DHSBM is preferred over regular SBM and other vegetable proteins because of its higher protein content and lower fiber content.

Based on these guide lines for nutrient requirements Table 5 shows the comparative formulation cost and relative value of DHSBM and regular SBM in a transition diet limiting soybean meal to 25 and 30% of the diet.

From the data in Table 5 it is obvious that in high quality transition diets DHSBM lowers the cost of formulation, especially if soybean meal is limited to 25% of the diet. While the difference in cost when the formula contains 30% SBM appears to be small, NT$0.10, the price of regular SBM would have to decline to NT$7.1/kg before the formulation cost would be the same as when DHSBM cost NT$8.2. Thus, in this case the real value of DHSBM is 15% more than that of regular SBM.

It also reduces the amount of plasma protein and/or blood meal required. For purposes of this illustration regular fish meal was utilized. It would be preferable to use select Menhaden fish meal in the transition diet, but this would increase the cost considerably. Utilizing DHSBM also reduces the level of tallow required to meet the energy level.

For the starter diets utilizing DHSBM it is possible to formulate a diet containing 3,285 kcal ME/kg (DE 3,440) without the addition of fat (Table 6). Regular soybean oil would just begin to enter the diet at a price of NT$7.5. However, its inclusion rate would be less than 0.5%, and the price would have drop to NT$6.4 before it would be utilized at a higher inclusion rate. Thus, in a high quality, corn-soybean meal diet the true value of DHSBM is over 20% greater than regular soybean meal. For regular SBM to have a value of 90% that of DHSBM would require the addition of high levels of tallow (including equipment for heating the tallow and spraying it onto the pellets).

Table 5. Advantage of DHSBM in transition diets.

Ingredient, %	Reg. SBM	DHSBM	Reg. SBM	DHSBM
Corn	33.18	35.43	29.52	32.24
SBM	25.0	25.0	30.0	30.0
Whey	20.0	20.0	20.0	20.0
Fish meal (65%)	10.0	10.0	10.0	10.0
Blood meal	3.0	3.0	2.3	1.3
Plasma protein	1.2	0.5		
Meat & bone	0.7	0.3	1.1	1.0
Tallow	5.4	4.2	5.7	4.1
Vit. & Min.	1.23	1.29	1.1	1.1
ZnO_2	0.25	0.25	0.25	0.25
Met	0.04	0.03	0.03	0.01
NT$/kg	14.59	13.70	12.80	12.70
ME, kcal/kg	3,400	3,400	3,400	3,400
DE, kcal/kg	3,560	3,560	3,560	3,560
Dig lys	1.52	1.52	1.52	1.52

On the other hand, the price of fish meal would have to decline to NT$10.70 and meat and bone meal to NT$7.86 before they would begin to enter the diet.

As noted if regular SBM is used the diet is slightly cheaper. However, the energy level is decreased and as previously discussed this can result in reduced growth rate and lean growth. By the shadow price DHSBM would begin to enter the diet at a price of NT$8.00 and at a price of NT$8.20 (present price) it would replace all of the regular SBM giving a higher energy diet.

If the diets are produced by a feedmill with the capability of spraying fat onto the pellet then I would recommend increasing the energy level to 3,300 kcal ME/kg (3,455 DE). As noted in the transition diets, in this case the value of DHSBM vs. regular soybean meal and the animal proteins is increased.

Table 6. Advantage of DHSBM in starter diets.

Ingredient, %	DHSBM	Reg. SBM
Corn	57.11	54.33
SBM	39.4	42.2
Vit. & Min.	3.43	3.44
Lys	0.03	
Phytase	0.03	0.03
ME, kcal/kg	3,285	3,200
DE, kcal/kg	3,440	3,350
Dig lys	1.12	1.12
NT$/kg	7.15	6.90
Shadow prices, NT$/kg		
Reg. SBM	7.60	
DHSBM		8.00
Fish meal (65%)	10.70	15.48
M&B meal	7.86	8.45

These diets appear to be very expensive. However, as indicated the performance from weaning through 9-10 weeks of age is critical in subsequent performance. Table 7 provides an estimate of expected feed consumption and performance.

Table 7. Estimated feed consumption and performance of pigs from weaning[a] to market.[b]

Phase	wt., kg	kg feed per phase	% feed usage	feed/gain	days	ADG g/day
Transition	5.5-7	1.5	0.5	1.1	8	188
Starter	7-20	27	8.9	1.8	34	382
Grower I	20-35	32	10.6	2.2	18	833
Grower II	35-55	51	16.9	2.8	20	1,030
Finisher I	55-77	73	24.1	3.2	24	927
Finisher II	77-110	118	39.0	3.7	38	870
Total		302.5	100	2.9	142	736

[a] *21-day weaning*
[b] *Goodband et al. (1994)*

Using a feed cost for the DHSBM diets in Tables 5 and 6 the total feed cost for the transition and starter phase would be NT$213.60 (1.5 x 13.70 + 27 x 7.15). As the pig approaches market weight of 100 kg or more feed consumption of a corn-soy diet would be approximately 3.2 kg/day. Based on the current prices this diet might be expected to cost about NT$5.52/kg. Each kilogram of additional gain during the nursery would be expected to decrease the days to market by 1.15 days (1 ÷ 0.870). At a feed consumption of 3.2 kg and NT$5.52/kg feed, each kg additional gain in the nursery equals a feed savings of NT$17.66 per day (3.2 × 5.52) in the finishing period. The average daily gains from weaning to 20 kg presented in table 7 are very modest. With high quality diets the ADG could easily be 30% greater. This would reduce the time to 20 kg form 42 days about 32 days. These types of gains can be achieved in practice. The reduction of 10 days represents a savings of NT$176.60 in the finishing period. This essentially pays for the entire cost of the feed during the nursery period. Further savings can be made by feeding two starter diets; i.e. Starter I from about 7 or kg to 12 kg and Starter II from 12 kg to 20 kg. This would be very typical of the feeding program used in the US and by large commercial farms in Australia.

Furthermore, results from a series of feeding trials in China comparing DHSBM with regular soybean meal in diets for weanling and growing pigs clearly showed a 9.5 to 13% economic advantage for DHSBM (Bushman, 1997; Shi, personal communication).

2.2.2 Growing Pigs (20-50 kg)

There is evidence that, within limits, growing pigs adjust their voluntary food intake to achieve a constant energy intake (Owen and Ridgman, 1967, 1968). However, the ability to compensate for low energy diets increases with live weight (Owen and Ridgman, 1967). Furthermore, feed intake is not affected by energy levels of up to 3,310 kcal ME/kg (3,465 DE) for pigs between 25 and 50 kg live weight (Campbell and Taverner, 1988). Similarly Savidge *et al*. (1984) reported a continual increase in the voluntary energy intake of pigs between 25 and 55 kg with increase in dietary DE concentration up to 3,585 kcal/kg (3,425 ME).

There is also evidence that high fiber in the diet may affect growth of growing pigs even though the diet contains a high level of energy (Campbell and Taverner, 1986). They utilized diets containing 8% crude fiber and 1% to 10% fat. The ME content of the diets ranged from 2,695 to 3,335 kcal ME/kg (2,820-3,490 DE). There was no difference in feed consumption up to the inclusion of 5% fat in the diet, 3,015 kcal ME/kg (3,155 DE). In a second trial (Campbell and Taverner, 1988) they utilized diets ranging from 2,695 to 3,450 kcal ME/kg (2,820-3,610 DE). The crude fiber decreased from 5% in the low energy diet to 2.4% in the high-energy diet. Feed intake was not affected up to an energy level of 3,310 kcal ME/kg (3,465 DE). This diet contained only 2.5% crude fiber. Weight gain continued to increase up to the highest energy level. The maximum energy intake and growth rate were 7% and 26% higher, respectively than when the high fiber diets were utilized.

They concluded that feed intake and growth rate suggest that the pig's demand for energy, and consequently its response to dietary energy concentration, is affected by dietary fiber concentration. They also concluded that between 20 and 50 kg the pig's demand for energy, which is largely a reflection of its capacity for tissue growth, lies somewhere between 6,620 and 7,070 kcal ME/day (6,930-7,405 DE). Average daily feed intake for pigs in this weight is approximately 2.0 kg. Thus, unless given a diet containing nearly 3,310 kcal ME/kg (3,465 DE) the growing pig is unable to satisfy its demand for energy or to fully express its growth potential.

Restricting daily energy intake by limit feeding is a common practice in many Asian countries. However, data from modern genotypes strongly support the fact that restricted feeding reduces growth rate and lean growth, especially during the growing period.

Haydon *et al*. (1989) reported a study in which pigs were either fed *ad libitum* from 20 kg to 110 kg, or restricted to 15% or 30% of *ad libitum* intake. The *ad libitum* diets contained 3,320 and 2.1 g lysine/Mcal ME in the growing period (20-50 kg). The diets that were restricted contained a similar energy level, but more lysine. This was done in an attempt to keep the daily intake of lysine as close as possible between the three groups. The pigs were slaughtered at different weights (50, 80, 95 and 110 kg) to determine the effect of restricted feed during different periods of growth. The results during the growing period (20-50 kg) are presented in Table 8. Results from the finishing period and combined growing and finishing period are discussed in the section Finishing Pigs.

It is obvious that restricting feed intake (energy) reduced ADG and the time to reach 50 kg (nearly 1 wk at 15% restriction and 2 wk. at 30% restriction). Restricting feed did increase percentage of lean cuts. However, the lean growth, as indicated by increase in lean cut gain/day, was significantly greater in the *ad libitum* fed pigs. *Ad libitum* feeding also resulted in better feed efficiency both for live weight gain and lean gain. The lysine:enegy ratio used in this trial, especially in the *ad libitum* diet was much lower than presently recommended and this may have limited lean growth.

Table 8. Effect of restricted feeding on performance of growing pigs (20-50 kg).[a]

Item	Feeding regime		
	Ad lib	15% restriction	30% restriction
ADG	0.798	0.686	0.573
Feed/day, kg	1.98	1.7	1.43
FCR	2.49	2.49	2.68
Days to wt	37.6	43.7	52.4
Lean cut, %	65.12	66.11	68.32
lean cut gain, kg/day	0.597	0.555	0.470
Feed/kg lean cut gain	3.32	3.06	3.05

Hayden (1989)

More recently, Bikker *et al*. (1995) clearly demonstrated that restricting feed consumption of a nutrient dense diet, 3,445 kcal ME/kg (3,610 DE), and 3.28 g lysine/Mcal ME (3.13 g/Mcal DE), in high lean, growing gilts significantly decreased ADG, feed efficiency and carcass gain. The control gilts, fed *ad libitum*, consumed 1.8 kg of feed daily, 6,205 kcal ME (6,500 DE), and had an ADG of 1,075 g. This compares to an ADG of only 959 g when feed consumption was restricted by 13%. Furthermore there was no difference in backfat and the control gilts took 3 days less to reach 45 kg.

These studies clearly show that *ad libitum* feeding of high energy diets (3,300-3,400 kcal ME/kg; 3,450-3,560 kcal DE) may be required for optimum performance of growing pigs. They also show the importance of keeping fiber levels to a minimum. The advantage of DHSBM and its relative value in high energy, growing diets is well illustrated by the formulas using DHSBM in Table 4.

Because a wide range of energy levels are utilized in the commercial swine industry it is also important to express the lysine (amino acid) requirements in terms of energy content of the diet. The lysine requirement for ADG and feed efficiency in high lean, growing pigs is 2.94 g/kcal ME (2.81 g/kcal DE) (Bikker *et al*., 1994; Lawrence *et al*., 1994; Batterham *et al*., 1990). However, for lean growth the requirement is at least 5% higher than for ADG, 3.1 g total lysine/kcal ME (2.95 g/kcal DE) (Bikker *et al*., 1994), and may be as much as 12% higher than the requirements for ADG and feed efficiency (Batterham *et al*., 1990).

2.2.3 Finishing Pigs

While lean growth in growing pigs appears to be linear throughout the growing period, and high levels of energy and amino acids are required during this period, there appears to be a plateau in lean growth for unimproved finishing pigs (Campbell *et al*., 1985; Dunkin *et al*., 1986). Also in the trial reported by Haydon *et al* (1989) when the pigs were taken to 110 kg there was no advantage in lean growth in the period from 95 to 110 kg for the *ad libitum* fed pigs. However, up to 95 kg there still was an advantage in favor of *ad libitum* feeding. In terms of days from 20-95 kg *ad libitum* feeding resulted in the pigs reaching 95 kg in 86, 101 and 126 days, respectively, for the *ad lib*, 15% restriction and 30% restriction. Furthermore, *ad libitum* feeding resulted in significantly greater lean growth per day in all periods up to 95 kg. However, from 95 to 110 kg there was no advantage in lean growth for the *ad libitum* fed pigs, and the feed efficiency, both for ADG and lean gain, was better in the pigs restricted to 15% of *ad libitum* feeding. On the other hand, *ad libitum* feeding still resulted in improved lean growth with little or no difference in feed efficiency for gain or lean growth vs. the pigs restricted to 30% of *ad libitum* feeding. The results indicate that the pigs in this trial did reach a plateau in lean growth after 95 kg.

However, with today's improved genetics even heavier pigs of an improved strain may not reach a plateau (Bikker *et al*., 1996; Campbell, 1999; King and Campbell, personal communication).

In trials conducted by Bunge Meat Industries (Campbell, 1999) reported that protein deposition increased linearly in gilts between 80 and 120kg with increasing energy intake to the highest level tested (*ad lib* feeding a diet containing 3,310 kcal ME/kg (3,465 DE), and total 10,992 kcal ME/day (11,443 DE). ADG and FCR were 1.040 kg/day 2.76, respectively. The available lysine level was 2.7 g/Mcal ME (2.3 g/Mcal DE). Backfat was only 15.9 mm. Obviously these pigs were very superior genetically. In another trial pigs from 54 to 112 kg live weight were fed *ad libitum* with diets ranging in energy content from 2,695 to 3,490 kcal ME/kg (2,820-3,665 DE). The highest energy level resulted in the best feed efficiency, and greatest dressing percent. ADG was 1.017 kg.

King and Campbell (personal communication) using high performing pigs demonstrated that for gilts from 80 to 120 kg increasing energy consumption resulted in a linear increase in protein deposition (Figure 1). They also reported that the lysine requirement for lean growth in high performing gilts from 80 to 120 kg is 1.80 g available lysine/Mcal ME or total lysine 2.11 g (1.72 g and 2.02 g, respectively for DE).

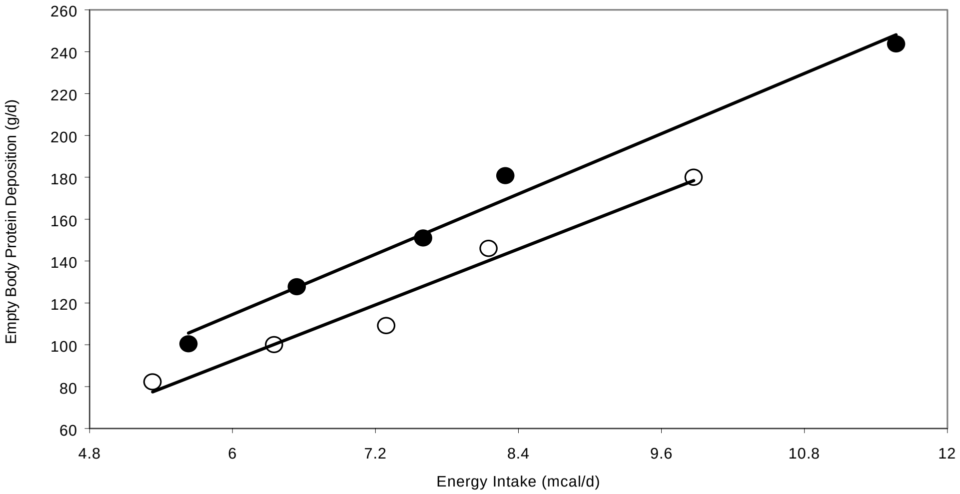

Figure 1. Relationship between protein deposition in the empty body of male (●) and female (○) pigs and digestible energy intake between 80 to 120 kg live weight (King and Campbell, personal communication)

Furthermore, Kanis (1990) reported that selection for leaner and more efficient pigs may result in pigs with a lower feed intake capacity. This increases the probability that the capacity for lean growth is greater than the pig's ability to consume low energy feed and consequently a plateau in lean growth may not be reached.

Thus, the ability to improve overall growth performance by the use of higher energy diets for finisher pigs should be borne in mind when developing flexible and profitable nutritional strategies for commercial producers. Because of its higher energy level DHSBM should definitely be considered as the protein source of choice for the production of higher, more efficient diets for high performing pigs.

For poorer genotypes a degree of feed/energy restriction may be the most profitable strategy in the short term, especially at heavier weights as illustrated in the trial reported by Haydon *et al.* (1989). The restriction however, should be imposed as late as possible in the animal's development and dietary amino acid levels should be adjusted accordingly. If feed/energy restriction is to be practiced, parametric formulation should be utilized to determine the most economical energy level in the diet (Bushman, 1998). Then, if it is necessary to restrict feed provide the optimum daily energy intake through restricted feeding. However, be sure to balance the amino acid:energy ratio. DHSBM normally enters diets formulated to optimum nutrient density.

2.2.4 Lactating Sows

Unfortunately, many swine producers overlook the importance of feed quality for the lactating sow. However, next to the transition and nursery feeds, the lactation feed is one of the most important concerns on any well-managed farm.

Within limits, milk production appears to be a demand-driven process where the pig's willingness, ability, to take milk from the sow determines the rate of production. Research at Iowa State University clearly demonstrated that the sow's capacity to produce milk is well beyond that previously estimated. The key point is that the sow will produce milk in response to demand.

Sows have an ability to produce adequate milk, even when fed low energy diets, by utilizing their own muscle and fat to obtain the nutrients needed for milk production. However, this results in excessive weight loss during lactation. Traditionally the approach to feeding sows was to allow them to loose significant weight during lactation, then regain the weight during gestation. The following table provides guidelines for adjusting feed intake and lysine requirements of gestating sows based on weight loss during lactation.

Table 9. Gestating sow adjustments of feed intake and lysine requirements.[a]

Wt. Loss, post-farrowing-weaning, kg	Feed, kg/day[b]	Lysine, %[b]
7	+0.135	0
14	+0.275	+0.01
20	+0.365	+0.02
27	+0.500	+0.03
34	+0.635	+0.04

[a] *Holden et al. (1996)*
[b] *Based on a corn-soybean meal diet.*

These differences may appear to be relatively small, approximately 135 g of feed/day for each 7 kg weight loss and an increase of 0.01% lysine. However, the gestation diet is consumed for about 121 days (post-weaning to farrowing). Thus, each 7 kg weight loss is equivalent to 16 kg of feed. For a sow loosing 15 kg of weight during lactation this is 32 kg, or 10 kg more feed than increasing feed consumption by 1 kg during the 21-day lactation. In addition it probably means a heavier weaning weight for the pigs, and a quicker return to estrus. In first litter sows it may also mean an additional 1 or more pigs born during the second litter.

From the above discussion it should be obvious that it is more economical to feed the sow properly during the lactation period. Consequently the goal of the sow feeding program should be to hold maternal weight loss to a minimum by providing the necessary nutrients through the lactation diet.

What are the dietary energy and amino acid needs of the lactating sow? Based on data from King (1991) a sow nursing 10 piglets requires 21,300 kcal ME (22,300 DE) and 52 g of digestible (60 g total) lysine daily. This agrees very closely with the NRC (1998) recommendations for a 175 kg sow (post-farrowing), nursing 10 pigs in a 21-day lactation period, and an ADG of 250 g by the baby pigs. The requirements as given by the NRC are presented in the following table.

Table 10. Daily nutrient requirements of lactating sows.[a,b]

	Anticipated lactational wt. Change, kg					
	0	0	0	-10	-10	-10
	Daily wt. Gain of pigs, g					
Nutrient	150	200	250	150	200	250
ME, kcal/d	14,060	17,475	20,895	11,635	15,055	18,470
DE, kcal/d	14,646	18,205	21,765	12,120	15,680	19,240
Protein, %	16.3	17.5	18.4	17.2	18.5	19.2
Lys, Total, g	35.3	48.6	61.9	31.6	44.9	58.2
Lys, Dig., g	30.7	42.5	54.3	27.6	39.4	51.2
Met, total, g	8.8	12.2	15.6	7.9	11.3	14.6
M+C, total, g	17.3	23.4	29.4	15.7	21.7	27.8
Thr, total, g	23.0	31.1	39.1	20.8	28.8	36.9
Val, total, g	29.5	40.9	52.3	26.9	38.4	49.8

[a] *NRC (1998)*
[b] *Based on sow weight of 175 kg post-farrowing, 21-day lactation, nursing 10 pigs.*

It is very important to note that these requirements are in terms of **daily intake**, not percentage of the feed. The sow's feed consumption is influenced by a number of factors including environmental temperature, number of feedings per day, feeder design, etc. The latter, feeder design is extremely important (Taylor, 1990).

Recent research has shown the need to increase dietary lysine and valine as litter weaning weights increase (Richert *et al*., 1996, 1997; Johnston *et al*, 1993; Tokach *et al*., 1992, 1993; Tritton *et al*, 1993; Stahley *et al*., 1990; King *et al*, 1993). Increasing dietary lysine increased litter weaning weight by 4.2 kg and average weaned piglet weight by 0.3 kg, and reduced sow weight loss by 8.4 kg (Richert, 1997). This appears to be particularly important for first parity sows (Tokach *et al*., 1992; King *et al*., 1993; Richert *et al*., 1997).

Data on the response to valine indicates that the valine:lysine ratio in the diet should be 1:1 or possibly even higher. However, diets formulated using corn-soybean meal contain a ratio of approximately 0.85:1. Synthetic valine is not available commercially and thus, can not be added to the diet economically. Basically, this implies that synthetic lysine may not be as appropriate in lactation diets as this will further widen the valine:lysine ratio. Selection of high quality protein ingredients to maintain a high lysine level, and a valine level as high as possible is important. In areas where wheat is available at a reasonable price it can be used to increase the valine level in the diet. Wheat contains a ratio of 1.6:1 valine:lysine, compared to about 1.5:1 for corn. DHSBM contains a ratio of 0.75:1 vs. 0.73:1 for regular SBM.

In addition there is a strong positive relationship between weaning weight and post-weaning growth performance. Consequently there are considerable advantages associated with increasing the piglets weight at weaning. This is illustrated in Table 11.

Table 11. Effect of weaning weight at 25-29 days of age on the performance of piglets to 78 days of age.[1]

Wt at weaning, kg	78 day wt, kg	ADG, g
6.14 (n=1000)	30.4	454
7.95 (n=1000)	35.6	529

[1] *Campbell (1999)*

Since feed consumption varies and is influenced by a number of factors the nutrient requirements for the lactating sow are expressed in terms of g/day, kcal/day. The effect of feed consumption on percentage of nutrients in the diet is shown in Table 12.

Table 12. Energy and amino acids levels to meet nutrient requirements of lactating sows at varying levels of feed consumption.

Feed, kg/day	ME, kcal/kg	DE, kcal/kg	Lys,[a] %	Val, %	Thr, %
4.0	4,618	4,810	1.46	1.25	0.92
4.5	4,104	4,276	1.29	1.11	0.82
5.0	3,694	3,848	1.16	1.00	0.74
5.5	3,358	3,498	1.06	0.91	0.67
6.0	3,078	3,207	0.97	0.83	0.62
6.5	2,842	2,960	0.90	0.77	0.57
7.0	2,639	2,749	0.83	0.71	0.53
7.5	2,463	2,565	0.78	0.66	0.49

[a] *Total lysine.*

The relative value of feed ingredients in practical diets for lactating sows is presented in Table 13.

Table 13. Lactation diets

Ingredient, %	DHSBM	Reg. SBM
Corn	67.74	66.18
SBM	28.7	30.2
Vit. & Min.	3.53	3.6
Phytase	0.03	0.02
CP	19.2	18.7
ME, kcal/kg	3,287	3,223
DE, kcal/kg	3,440	3,375
Lys	1.06	1.04
Dig Lys	0.87	0.85
Val	0.92	0.87
Dig Val	0.57	0.53
Val:Lys	0.87	0.84

Utilizing DHSBM the diet would contain nearly 3,290 kcal ME/kg and 1.06% lysine. At a feed consumption of 5.6 kg per day this diet would provide the 18,470 kcal of ME and the amount of lysine require to support a high level of milk production (high weaning weight of the pigs) with 10 kg weight loss in the sow. To essentially prevent weight loss in the sow and still maintain maximum growth rate of the piglets it would require a feed consumption of about 6.35 kg. At the present price of NT$7.50/kg for regular SBM it would only enter the diet at 2% unless at least 1.5% tallow is added to the diet. Thus, DHSBM's real value is much closer to 9% than the 6 to 8% based on crude protein basis.

The shadow price for meat and bone meal and fish meal in this diet are NT$8.5 and NT$10.4, respectively. Thus, it is obvious that meat and bone meal and fish meal are not economical for lactating sows. This is mainly the result of their lower energy value, and also because of the utilization of phytase.

On the other hand, if DHSBM is not available the maximum energy level that can be obtained with regular SBM without the addition of fat is 3,225 kcal ME/kg. To support the same level of performance expected with the DHSBM diet feed consumption would have to be approximately 5.75 kg with 10 kg weight loss in the sow, but would have to increase to nearly 6.5 kg/day to prevent weight loss in the sow. This clearly shows the advantage of DHSBM in diets for lactating sows, especially in warmer environmental temperatures.

2.3 Genetic capacity of the animal

Subsequent to approximately 30 kg live weight intrinsic factors and in particular lean gain capacity, begin to play an increasingly important role in determining the performance capabilities and carcass characteristics of pigs.

In order of priority the factors affecting the performance and nutrient requirements of growing-finishing pigs are:

1. Genetics
2. Sex
3. Live weight

All three factors reflect or are associated with differences in lean gain capacity, or more correctly the relationship between lean gain and energy intake. The influence of genetics is well illustrated above (Finishing Pigs). High lean pigs have approximately a 5% higher requirement for lysine than medium lean pigs, which have approximately a 5% higher requirement than low lean pigs.

Also gilts are leaner than barrows and between 35 and 50 kg gilts require 5- 6% more lysine than a high lean barrow. However, between 50 and 110 kg they require as much as 15-20% more lysine. These increased lysine levels must also be accompanied by increases in the level of the other amino acids.

As is obvious from the discussion on weaning, growing and finishing pigs the lysine:energy ratio declines considerably as the pigs get older. This has led to the larger-scale producers practicing sex rearing and phase feeding as a part of their overall management strategy aimed at increasing profits. Also as lean growth rate increases the energy content of the diet becomes more important, as does the lysine:energy ratio and the requirements for the other essential amino acids. This in turns increases the value of DHSBM in relation to other ingredients.

2.4 Environmental temperature

Temperature has its major effect on energy demand and voluntary feed intake. For younger pigs and superior genotypes temperature per se has no effect on dietary amino acid requirements. The latter should be set relative to the energy content of the diet and growth performance manipulated by alleviating the adverse effects of temperature on energy demand and utilization.

For poorer genotypes and for barrows maximal protein deposition may lie within the appetite limits of the animal. Under these circumstances the pig's amino acid requirement is unaffected by energy intake beyond the point at which the genetic ceiling is achieved and dietary amino acid levels have to be adjusted to allow for changes in voluntary feed intake.

Excess protein and high fiber have also been shown to increase heat stress. Therefore, at house temperatures above 29^{o} C protein levels should be kept to a minimum without reducing the ratio of essential amino acids:energy ratio. Also fiber levels should be kept to a minimum; i.e. utilizing DHSBM and restricting the use of byproducts such as wheat bran. Depending on price and capability of the feedmill it also be desirable to add fat to the diet as an energy source. Fat has a lower heat increment than grains.

2.5 Feed manufacture, livestock producer, or integrated livestock producer

The acceptance or rejection of any new or alternate feed ingredient by feedmillers, swine producers and integrated swine producers is based on different factors. They each have different profit centers. This is especially true for the integrated producer whose bottom line is based on lean meat production. As indicated the lysine requirement for lean meat production is 5 to 10% higher than the requirement for ADG and feed efficiency. Also the energy requirement for high lean pigs is increased. Thus, it may well benefit the integrated producer to utilize high quality feed.

CONCLUSIONS

- ✓ Many buyers price protein ingredients solely on the cost per unit of protein, and do not take into account the higher amino acid and ME/DE values. These two factors are very important in formulating diets to meet the needs of today's high performing pigs.
- ✓ DHSBM's higher ME and lower crude fiber, which make it especially attractive for baby pigs and lactating sows.
- ✓ In high quality diets (high energy with proper amino acid:energy ratios) DHSBM's real value is 10 to 15% greater than that of regular SBM and may even be higher if fat can not be sprayed onto pellets for baby pigs.
- ✓ With the use of phytase the importance of phosphorus in the animal proteins is becoming less important. Thus, DHSBM is much more economical than fish meal and/or meat and bone meal.
- ✓ There is considerable evidence, both research and commercial, that today's high performing pigs grow faster and produce more lean meat when they are fed *ad libitum* with high energy diets with a high lysine:energy ratio. DHSBM is ideally suited for helping to formulate diets to meet the requirements for modern genotype pigs.
- ✓ The quality of "non-competitive" ingredients also affects the relative value of the protein ingredients. If low quality corn, or by-products are utilized, utilizing DHSBM becomes more important in helping to maintain feed quality.
- ✓ If fat or oil is inexpensive they can be used to help boost the energy content of feeds. However, for on farm mixing this is very difficult and probably not practical, except for very large-scale farms. Even adding oil is difficult and very inefficient unless you have equipment to spray it into the mixer. On the other hand, by using DHSBM it is possible to help keep the energy level at or near the level suggest by NRC (1998) without using tallow or soybean oil.

- ✓ Traditionally lactating sows were allow to loose a considerable amount of weigh, and then fed to regain their body weight in the succeeding gestation period. This is now known to be inefficient and uneconomical. Lactation diets need to be formulated to contain a high level of energy and high levels of essential amino acids. Because of its higher energy and amino acid content, DHSBM has become the protein ingredient of choice for lactation diets.

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APPENDIX

Ingredient prices used in least cost formulations for determining the relative value of DHSBM and regular SBM.

Ingredient	Price, NT$/kg
Corn	5.2
Regular SBM	7.5
DHSBM	8.2
Meat & bone	10.5
Fish meal (65%)	22.0
Fish meal (62.5%)	18.0
Tallow	9.0
Soybean oil	14.0
Blood meal	30.0
Plasma protein	150.0
Dical	10.0
Monocal	10.8
Limestone	1.1
Salt	2.0
Lysine	95.0
Premix	70.0
Phytase	180.0