Fats in pig diets: beyond their contribution to energy content

R.G. Campbell

United Feeds, PO Box 108, Sheridan, Indiana 46069 USA, rcampbell@unitedfeeds.com

Summary

This paper describes the results and implications of recent studies on the effects of level and type of dietary fat on performance of growing pigs and reproducing sows. In the USA, the concept of fat has changed from one of a feed ingredient to one of a means for enhancing the performance of pigs in the final weeks of the commercial production process. The results presented in the paper demonstrate how the addition of fat to high–energy diets increases growth rate and improves feed efficiency to a level in excess of that which would be expected from the increase in dietary energy content alone. The inclusion of dietary fat during a specific period of growth affects subsequent performance. When fat is removed from the diet, the pig continues to eat as though the diet still contains fat. The consequent effect is a transitory reduction in growth rate that can persist for as long as seven weeks. These results call into question the nutritional strategies that are currently used for growing pigs in most parts of the world. The paper briefly discusses the effects of fibre and fat on pig performance and those of n–3 polyunsaturated fatty acids on sow reproduction. A number of examples are given which show that a reduction in the ratio of n–6 fatty acids to n–3 fatty acids in the diets of lactating sows and the diets of gilts before mating increased subsequent litter size. Taken together, these results suggest that fat has a lot more to offer nutritionists and the pig industry than a high–energy ingredient. The mechanisms underlying the apparent extra calorific value of fat in diets for growing pigs and the effects of n–3 fatty acids on reproduction remain to be established. Nevertheless, recent research sheds a new light on concepts of fat and offers a simple strategy for enhancing the efficiency and profitability of pig production.

Keywords: pigs, sows, reproduction, fat, n–3 polyunsaturated fatty acids, growth performance

Introduction

Fat is included in pig diet formulations on the basis of DE content, price and occasionally, iodine number. In Australia, fat is often included in diets for younger pigs. Because of its price, fat is either used at lower levels or removed from diets for older or heavier pigs due to the belief that these pigs are less responsive to high–energy diets. However, these strategies fail to recognize the potential effects of high–energy diets—especially those that contain added fat—on growth rate, throughput and feed efficiency. These factors are not considered in least–cost diet formulations, but there is increasing evidence that dietary fat can be used as a strategic nutrient rather than as an ingredient in diets for heavier pigs. Strategic use of fat can facilitate flexibility in the management of weaner– grower– and finisher–pig facilities. There is also evidence the effect of fat on growth rate and feed efficiency exceeds that which would be expected from energy content alone. We have also observed a 5–7% improvement in the feed efficiency of pigs offered diets with added fibre plus fat compared to control diets with the same DE content. This effect is not taken into consideration when formulating diets on a least–cost basis.

There is increasing evidence that type of fat can affect reproduction and there is increasing interest in the effects of n–3 polyunsaturated fatty acids on sow and finisher pig health and performance. In this paper, I have briefly reviewed the latest experimental data on the effects of amount and type of fat on performance of growing–finishing pigs and sows and explore their commercial and scientific implications.

Effects of dietary energy and fat on the performance of growing pigs

The effects of energy intake on the partitioning of energy between protein and fat metabolism are well–

established (Black and Griffiths 1975; Campbell 1988). Protein deposition increases linearly with increasing energy intake and then plateaus. The slope of the linear component of the relationship and the stage at which a plateau is reached are affected by liveweight, genotype and gender. The effects of energy intake on growth and carcass composition are also well–established (King *et al*. 2004). During the linear phase of the relationship between growth rate and energy intake, body fat and carcass fat thickness increases in a curvilinear manner. The effects of dietary energy content are less predictable and energy concentration should not be confused with energy intake. Increased energy intake will always improve growth performance. An increase in dietary energy content may have no effect on growth performance because the pigs often adjust feed intake to maintain a constant energy intake. Even when energy content does affect energy intake, the effect on growth performance is small. Nevertheless, energy demand under commercial conditions is affected by a variety of factors including gender, health and temperature. The general belief that young pigs respond better to high–energy diets than older or heavier pigs is often not substantiated by responses under commercial conditions. Under commercial conditions, the energy demand of younger animals seems to be reduced to a greater extent than that of older pigs. In the USA, fat is seldom added to diets fed during the first 14–21 days after weaning, but is commonly added to the diets fed from 80–125 kg liveweight. Part of the reason for this is that animal fat is poorly digested by newly–weaned pigs and, even at liveweights of 15–30 kg, the effect on growth is small and of doubtful economic benefit.

The potential advantages of high–energy diets for heavy pigs were demonstrated by Henman *et al*. (1999) who offered five diets ranging in DE content from 12.0–15.2 MJ/kg to 63 kg pigs for 42 days. Dietary DE content had no effect on feed intake but DE intake increased by 22.4% over the range 12.0–14.4 MJ/kg. This was associated with a 16.3% increase in growth rate and an 8.3% increase in carcass weight. Carcass P2 fat thickness also increased with increasing dietary DE content but the effect was not significant when carcass weight was used as a covariate. These results have important economic implications because there are few strategies that can generate similar performance improvements under commercial conditions. When extrapolated to 1,000–head finisher barns, these data suggest that raising DE content from 12.0 MJ/kg to 14.4 MJ/kg would increase carcass weight by 6,200 kg and reduce the mass of feed required by 6,600 kg. The economic impacts of strategies such as this and the consequent effects on effluent output are rarely taken into account when decisions are made regarding dietary energy levels for finisher pigs. The value of this strategy has largely been underestimated or ignored in Australia, where complimentary strategies such as the use of intact males and the administration of exogenous porcine somatotropin (PST) are practiced. Both strategies reduce back–fat thickness, which further increases the value of the extra carcass weight produced.

The effects of the addition of fat to diets of high DE content are shown in Table 1. In this experiment, castrated male pigs (initial liveweight = 91 kg) were offered a corn–soy diet with or without 5% fat. The pigs were housed in a 1,200–head barn in groups of 29 and the diets were offered *ad libitum* for 44 days.

Table 1 The effects of the addition of fat to corn–soy diets on the performance of barrows (R.G. Campbell, unpublished).

	Added fat (%)	
	0	5
DE (MJ/kg)	14.5	15.4
Growth rate (g/d)	718^b	791^a
Feed : gain	4.21^b	3.74^a
Carcass weight (kg)	94.5^b	97.2^a

Row means with different superscripts are significantly different (P<0.05)

In this experiment, the DE content of the unsupplemented diet was similar to that for which Henman *et al.* (1999) reported near–maximum performance. Despite this, growth rate was increased when DE was increased from 14.5 MJ/kg to 15.4 MJ/kg by the addition of fat. The improvement in feed efficiency (12.6%) was considerably higher than the relative difference in DE content between the diets (6.2%). This finding is consistent with other experiments in which fat was added to increase dietary energy content, and suggests that fat is used more efficiently for energy metabolism than is commonly accepted. For example, we recently found that the addition of 6–8% soy hulls plus sufficient fat to make the diet isoenergetic (DE basis) with a corn–soy control diet resulted in significantly faster growth rate of pigs growing from 72–120 kg and from 75–95 kg. Feed efficiency was improved by 5%. We have seen similar effects in younger pigs, and diets for pigs of 15–30 kg liveweight now commonly include additional fibre and fat. The addition of animal fat to corn–soy diets for heavy pigs also alters the dietary ratio of omega–6 fatty acids to omega–3 fatty acids and may affect immune responses. We are currently investigating the effects of omega–3 fatty acids and omega–6 fatty acids per se on animal health and performance. Because diets used in Australia contain more fibrous ingredients than those used in the USA and have lower omega 6– to omega–3 fatty acid ratios, the results discussed here may not be directly applicable to the Australian pork industry. Nevertheless, the implications are independent of what ingredients are used and need to be considered in ingredient descriptions of least–cost programs and in diet formulations.

The results of a second trial on the impact of added fat and DE content on the performance of finisher pigs are shown in Table 2. In this experiment, barrows and gilts (initial live mass = 46.8 kg) were offered corn–soy diets with 0, 3, 6 or 9% added fat for 84 days. The pigs were housed in groups of 18 in well–ventilated barns containing 260 pigs each. As this environment was considered excellent, the additional fat was not expected to have a marked effect on growth performance. In contrast, growth rate responded linearly to increasing dietary DE content, and feed efficiency improved by 2–6 percentage points in excess of what was expected from the relative increase in DE content. In this experiment, increasing dietary DE content from 14.5–16.4 MJ/kg increased carcass weight by 4.6 kg but no had no effect on the back–fat thickness of castrated males. Back–fat thickness of females increased when the percentage of supplementary fat was increased from 6% to 9%. Although the latter level of added fat is not commercially feasible, any change in carcass fatness would have to be taken into account. The feed required to produce the additional carcass weight was reduced by 14 kg/pig, which is equivalent to 14,000 kg for a 1,000–head barn. The effects of high–energy diets on growth performance and profit will depend on stocking density, cost of fat, fibre content of the diet, change in carcass fat thickness per unit lean mass (price) and other environmental factors that we have yet to understand fully. Nevertheless, given that overheads represent some 40–55% of the total cost of production, high–energy diets for heavy pigs represents an easy means of reducing fixed costs and increasing income. Profitability indices such cost per unit gain, diet cost or cost per unit DE will not reflect the impact of high–energy diets, especially high fat diets, on profit. A more appropriate measure is profit per pig or profit per barn. Simulation models such as Auspig do not accurately predict the effects of dietary energy content on growth rate at present. This is because the mechanisms underlying the DE responses shown in the two preceding tables are unclear. Because of the potential impact on profit and flexibility, more research needs to be directed to this aspect of finisher pig nutrition.

The carryover effects of dietary fat on pig performance

Fat is traditionally included at high levels in diets for young pigs and is then gradually reduced and often removed from diets for pigs in the final stages of commercial production. Such strategies are based on the assumption that young pigs respond more to fat and high–energy diets than older pigs and that they do not get fatter, as older or heavier pigs do. There is evidence from trials conducted in the USA that casts doubt on the validity of this strategy because it does not take the effects of commercial environments on the growing pig's access to feed and its energy demand into account. However, we have recently found that the addition of fat at one stage of growth affects subsequent performance. We recently conducted a 2 × 2 factorial study in which pigs were offered diets plus 0% or 4% added fat for 42 days and 0% or 4% added fat for the subsequent 49 days. Pigs fed additional fat during the first period but not the second consumed the same amount of feed during the second period as pigs that were fed additional fat during both periods. They also consumed significantly less feed during period two than the controls (pigs that were not fed fat during period 1 or period 2). Pigs fed 4% fat and then 0% fat grew significantly slower during the second period than those fed the other diets. In contrast, feed efficiency was associated with DE content during both periods. These results, which have been repeated on a number of subsequent occasions, suggest that even small amounts of dietary fat have marked long–term effects on energy metabolism. In our experiments, pigs offered dietary regimes in which fat was added in one period ate as though the subsequent diet still contained fat. The effect tends to decrease with time but can last as long as seven weeks. The commercial implications of these findings are evident from Table 3, which shows the results of an experiment in which pigs (initial live mass = 15 kg) were offered corn–soy based diets with 2.0% or 4% added fat for 42 days and a common diet without added fat for 28 days thereafter. The addition of fat increased growth rate and weight at the end of the initial 49–day period. However, during the subsequent 28–day period, growth rate and feed intake were negatively related to the level of fat contained in the previous diet, and the liveweight advantage of the first period was not retained. Feed efficiency during the second period was not affected by the amount of fat added to the diets during the first period.

These results suggest that the traditional way in which fat is used in pig diets may not be cost effective. A better strategy may be to use little or no fat in diets

Table 2 The effects of the addition of fat to corn–soy diets on the performance of barrows.

	Added fat (%)				
	0	3	6	9	Significance
DE (MJ/kg)	14.5	15.2	15.8	16.4	
Daily gain (g)	881	901	936	955	*P*<05
Feed : gain	2.78	2.66	2.50	2.36	*P*<001
Carcass weight (kg)	93.1	95.0	95.9	97.7	*P*<05
Carcass lean (%)	53.4	53.5	53.5	53.2	*P*>05

fed to young pigs and to increase the level of added fat with age and weight. Such a strategy would prevent negative carryover effects on subsequent feed intake and growth rate and more effectively match dietary DE level to the increasing physical and environmental constraints to feed intake faced by pigs in commercial barns. We consider the worst–case scenario to be one in which fat is removed from the diet after pigs have been fed diets containing added fat; if you start including fat in the diet, keep it in.

Effects of dietary fatty acids on reproduction, health and performance

There are probably as many experiments showing negative responses to dietary fat for lactating sows as there are experiments showing positive effects. It would probably be correct to conclude that neither the fat content nor the DE content of diets fed to lactating sows has a significant effect on reproduction. However, there is evidence that the type of fat fed to lactating sows affects reproduction. In the fields of human nutrition and health there is increasing interest in the role of omega–3 fatty acids in the immune system and cardiovascular health. In many developed countries such as the USA, human diets are generally high in omega–6 fatty acids, and the ratio between omega–6 and omega–3 fatty acids exceeds 20 : 1. The ratio in corn–soy diets for growing pigs and sows is similar. We have investigated the effects of increased dietary levels of n–3 polyunsaturated fatty acids on reproduction and health of sows during lactation and gestation. The results of one experiment are shown in Table 4. In this experiment, the ratio of n–6 polyunsaturated fatty acids to n–3 polyunsaturated fatty acids was reduced from 18 : 1 to 6 : 1 using protected marine oils. The sows were offered the control and experimental diets from entry into the farrowing room until seven days post–weaning. An increased level of dietary n–3 polyunsaturated fatty acids during lactation significantly increased total litter size and the number of live–born piglets during the subsequent farrowing.

Spencer *et al*. (2004) reported similar effects in gilts fed diets with elevated levels of omega–3 fatty acids for 30–45 days prior to mating. Subsequent research has shown that the effect on litter size is associated with reduced embryonic mortality until day 36 of pregnancy (Webel *et al*. 2004). These results suggest that corn–soy diets are deficient in essential fatty acids for reproducing sows. We are currently investigating the effects of individual fatty acids on sow health and reproduction, although simply changing the ratio of n–6 fatty acids to n–3 fatty acids may be all that is required to elicit the responses described previously.

Conclusions

The formulation of diets on the basis of cost per tonne or cost per unit of energy is naïve and has allowed

Table 3 Growth performance of pigs (initial live mass = 15 kg) that were offered corn–soy diets with or without added fat for 42 days and a common diet without added fat for 28 days thereafter.

	Added fat (%)			
	0	2	4	Significance*
0–49 days				
Weight (kg)	44.4	44.7	45.9	Lin P<0.10
Daily gain (g)	663	677	691	Lin P<0.10
Feed intake (kg/d)	1.32	1.29	1.26	Lin P<0.10
Feed : gain	1.99	1.92	1.84	Lin P<0.05
50–77 days				
Weight (kg)	67.3	66.5	66.4	NS
Daily gain (g)	795	727	718	Lin P<0.05
Feed intake (kg/d)	1.98	1.91	1.83	Lin P <0.05
Feed : gain	2.53	2.54	2.54	NS

*Linear effect; NS, not significant (P>0.10)

Table 4 Effects of dietary n–3 polyunsaturated fatty acids during lactation on subsequent litter size of sows (Webel et al. 2003).

Treatment	Sows allocated	Sows farrowed	Total born	Born alive
Control	173	117	11.0[b]	10.3[b]
n–3 fatty acids	165	121	11.6[a]	10.8[a]

[a,b]treatment means within columns with different superscripts are significantly different (P<0.05)

potentially large improvements in profit and flexibility to be forgone. In the USA, fat is now used strategically. The addition of fat to diets consumed by pigs during the last 4–6 weeks of commercial production is an easy method for enhancing growth performance and reducing costs associated with feed delivery and milling.

There is increasing evidence that the efficiency of energy utilization and feed efficiency is increased when dietary DE is increased using fat rather than carbohydrates. Additional benefits may be had by including higher levels of NDF and fat in diets for grower–finisher pigs. Whether these effects are due to the more efficient use of fat for lipogenesis than carbohydrates or an effect of fat on rate of passage and nutrient availability is unknown. I tend to favour the former explanation but in heavier pigs, effects may be associated with the lower heat increment of fat or the impact of the ratio of n–3 fatty acids to n–6 fatty acids on immune function. The addition of fat to the diet may simply reduce dust and bacterial particles in the air, decreasing the production of pro–inflammatory cytokines. These factors warrant further investigation.

With the lean, efficient genotypes currently available, the addition of fat to a finisher diet will have little effect on carcass fat content or fat thickness. In the USA, barrows are more responsive to fat than gilts but an increase in carcass fat is seldom observed. Indeed, the addition of fat to diets fed to pigs from 90–125 kg actually increases loin depth and lean percentage.

Because of high grain costs and strict grading schedules, nutritionists in Australia and parts of Europe have tended to use diets containing more fibre and less energy than those used in North America. However, the addition of fat to diets for growing pigs actually reduces grain usage and allows greater efficiency to be achieved. You do not have to produce heavier pigs, although you should when prices are high; you can increase stocking density and produce more pigs at a lighter or ideal weight but still produce more weight per barn using added fat. This is an extremely effective way of improving profit and demonstrates the flexibility afforded by the use of fat.

At United Feeds, we take the fat content and fatty acid composition of all ingredients into account when formulating feeds. Diets for sows, nursery pigs and growing pigs are formulated on the basis of the n–6 polyunsaturated fatty acid to n–3 polyunsaturated fatty acid ratio and the latter is altered depending on the conditions under which the animals are housed. We also balance sow and nursery diets for certain other fatty acids. However, we are struggling with the question of how to describe the apparent ‘extra calorific’ value of fat per se, and are investigating this aspect in detail. At present, we rely on a simulation model to predict the effects of added fat on growth performance and profit, and have linked this with our formulation packages.

Fat warrants more consideration by nutritionists and researchers. It is somewhat strange that the more innovative research and its application to commercial situations have occurred in the USA. The USA already uses the highest dietary energy levels in the world for growing finishing pigs and has simple and consistent diets for lactating sows. The findings reported here may only apply to conditions in the USA, but this is unlikely. The results certainly are exciting and offer Australia a potentially new era of research and nutritional flexibility.

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