

Fat Utilization for Pigs: A Review

J.H. Cho and I.H. Kim

Department of Animal Resource and Science, Dankook University,
Cheonan, 330-714 Choongnam, Korea

Abstract: The available energy in utilizable fats and oils is about 2.25 times that from utilizable carbohydrates (although, there is a considerable range in values), they supply essential fatty acids can have an influence on carcass quality and are useful in reducing dust and promoting palatability of compound diets. There are two kinds of oil sources. First, the major sources of vegetable oil are as follows: soya beans, palm, sunflower seed, rape seed, coconut, cotton seed. Second, the major sources of animal fats are as follows: cattle tallow sheep fat, pig lard and fish oils. For pigs, fats include decrease feed intake and increased palatability, growth rate, feed efficiency and carcass fat.

Key words: Fat sources, utilization, diets, pigs, growth rate, carcass fat, Korea

INTRODUCTION

The supplementation of fat could result in diminution of feed intake and growth performance to weaned pigs. According to researchers, fat inclusion improves fatty acid digestibility in weaned pigs (Frobish *et al.*, 1970), ADG and G/F (Crampton and Ness, 1954; Lawrence and Maxwell, 1983). There was a consistent improvement in growth rate and reduction in feed intake and improvement in feed: gain when fat is added to the diet of growing/finishing pigs. It does not appear that levels of inclusion of fats up to 10% will significantly decrease the efficiency of digestion in pigs. Although, opinion on this is hotly contested and some authorities suggest that DE value is likely to fall off at levels of above 7% inclusion of fat in the diet. Thus, the effective DE value of fats may fall with level of inclusion, giving a quadratic rather than a linear change in DE value of diets with increasing levels of add fat. Fat based on the less digestible and more saturated tallows and the less well used free fatty acids are the most likely to show the phenomenon of the DE value being reduced as level of dietary fat inclusion increases (Whittemore, 1998).

In pigs, dietary fat can slow the rate of passage (Cunningham *et al.*, 1962) and improve the digestibility (Lewis and Southern, 2001) of other feed components, especially carbohydrates thus enhancing the assumed DE of the carbohydrate fraction of the diet and attributing to the fat a remarkable energy value because the presence of diet fat can improve the efficiency of use of the assumed total diet DE, it is technically possible for the DE values for fats in pig diets to be equal to or above the gross energy value.

OVERVIEW OF THE PATHWAYS OF LIPID METABOLISM

Lipogenesis in the pig occurs primarily in adipose tissue (O'Hea and Leveille, 1969) with very little contribution of the liver. Most of the fat deposition in market pigs occurs during the finishing phase. Lipogenic enzyme levels increase with age in various fat depots in the pig (Mourot *et al.*, 1995). In the nursery phase, lipid deposition is in the range of 30-50 g day⁻¹ and is similar to that of protein deposition. In the finishing phase, lipid deposition is in the range of 250-450 g day⁻¹. On a typical corn-soybean meal diet with 3-5% added fat, at least half of the daily lipid deposition is accounted for by de novo lipogenesis and presumably is achieved by glucose liberated from cornstarch as a source of carbon for lipogenesis (Pettigrew and Moser, 1991).

Addition of fat to the diet inhibits de novo lipogenesis in the pig as well as in other species (Allee 1985). In non-ruminant species, this results in a change in adipose tissue fatty acid composition that reflects the fatty acid profile of the diet. The only concern here is that with unsaturated fat sources such as soybean oil or fish oil, the physical properties of carcass fat can become undesirable. In rodents and other species, the degree of inhibition of lipogenesis is directly related to the degree of unsaturation in the fat source (Herzberg and Rogerson, 1988).

Thus, fish oil is more potent than corn oil which is more potent than lard in inhibition of lipogenesis (Cho and Kim, 2010). This does not seem to be true in the pig. Allee *et al.* (1971) reported that 10% dietary corn oil or tallow had similar inhibitory effects on adipose tissue

lipogenesis. Smith *et al.* (1996) found that lipogenesis in adipose tissue of pigs fed various fatty acids was less than in the cornstarch-fed controls, palmitate was more potent than either mono (palmitoleic/myristoleic or oleic) or polyunsaturated (linoleic) fatty acids. Fat metabolism in the growing pig was reviewed by Farnworth and Kramer (1997).

BIOLOGICAL EFFECTS OF FAT SOURCES

Composition of the growth and performance of pigs fed diets with and without added fat demonstrates a number of properties of fat. Because of the greater energy density of fat compared with carbohydrates and proteins, one of the most pronounced effects of fat is a decrease in absolute feed intake. This effect is largely accounted for by the effect of fat on the energy density of the diet. When intakes are expressed on an energy basis for example, the intake is similar (Azain *et al.*, 1991, 1992).

In the digestive tract, fat has the effect of slowing passage rate (Cunningham *et al.*, 1962). This effect is the opposite of what is seen with fiber in the diet. Because passage rate is reduced, the digestibility of other nutrients is improved. This is referred to as the extra-caloric effect of fat. As an example, in nursery pigs, apparent ileal digestibility of crude protein improved from 80.7-83.3% as fat increased from 3.2-12.2% in the diet (Li and Sauer, 1994). Individual amino acids in the large intestine, supporting the role of passage rate in the small intestine as the basis for the improvement.

Because of their lower heat increment and greater efficiency in utilization, animals fed diets where fat has been substituted for an equivalent metabolizable energy in the form of carbohydrate will generally have greater net energy available to them. In growing pigs, this is seen as a slight increase in growth and an increase fat. The lower heat increment of fat can be an advantage in warm climates where feed intake is compromised. Several studies suggest improved performance in heat-stressed pigs fed high-fat diets (Stahly and Cromwell, 1979; Coffey *et al.*, 1982; Stahly, 1984).

Digestibility of the fat or lipid in sow's milk is >90%. Digestibility of fat in starting diets is reduced during the 1st week post-weaning but increase with age and gradually returns to the 90% range by 4-6 weeks post-weaning (Wiseman, 1984; Cera *et al.*, 1988). Post-weaning, digestibility of shorter-chain saturated or long-chain unsaturated fatty acids is better than that of long-chain saturated fatty acids (Cera *et al.*, 1989). Cera *et al.* (1988) reported that digestibility of corn oil was 79% in 6 kg pigs during the 1st week post-weaning. Digestibility improved to 89% in the 4th week post-weaning. At least part of the

increase in digestibility is associated with increased pancreatic lipase production during the post-weaning period (Cera *et al.*, 1990). Values for lard and tallow were 68 and 85 and 65 and 83 at week 1 and 4, respectively.

Digestibility of all types of fat increased with time but unsaturated sources were consistently more digestible. In general as fatty acid chain length increases, digestibility is reduced. Digestibility increases as double bonds are introduced (Stahly, 1984; Desouza *et al.*, 1995; Doreau and Chilliard, 1997). Furthermore, there are positional effects within the triglyceride molecule. Saturated fatty acids are more digestible when on the number 2 position of glycerol as compared with the 1 or 3 position (Small, 1991).

Since, the fatty acid profile of sow's milk is similar to that of lard, a saturated fat source, it is somewhat surprising that fat digestibility decrease at weaning. At least a portion of the difference in digestibility of milk fat vs. the fat provided in a starter diets can be accounted for by the form in which fat is present as lipid droplets enclosed in a phospholipid monolayer. This form which is structurally similar to that of circulating lipoproteins is likely very compatible with the formation of micelles and consequently digestion by pancreatic lipase. Fat in dry diets is not in such an easily accessible form. Studies (Desouza *et al.*, 1995; Jones *et al.*, 1992) reported that effect of emulsifiers such as lecithin and lysolecithin on fat digestibility in weaning pigs indicate that in general, the emulsifiers improved fat digestibility but have no detectable effect on growth performance. In one study (Jones *et al.*, 1992), tallow digestibility was improved from 81% without emulsifier to 88% by the addition of lecithin as 10% of the fat in the diet. Another study examining the effect of lecithin addition on digestibility of diets containing soybean oil concluded that although, lecithin improved nitrogen and feed efficiency, it did not specifically affect fat digestibility (Overland *et al.*, 1993).

EFFECT OF FATS FOR ANIMAL CARCASS FAT

The adipose tissue of pigs reflects the diet fatty acid composition as fatty acids are absorbed largely unchanged and frequently deposited directly into carcass fat (Seerley *et al.*, 1978; Madsen *et al.*, 1992; Miller *et al.*, 1990). Accordingly, the use of unsaturated vegetable oils in pig diets will result in enhanced levels of linoleic acid in pig fat. In addition, it is because long chain unsaturated fatty acids can be incorporated directly or with little change, into animal adipose tissue that they have such high net energy values.

Body fat synthesis from dietary fat is about 90% efficient whereas body fat synthesis from carbohydrate is

only about 70% efficient as a result the ratio of net energy to digestible energy is about 0.85 for fats and oils and 0.75 for carbohydrate (Whittemore, 1998). A high dietary level of linoleic acid will produce high linoleic adipose tissue in pigs levels can increase from a normal 10-15% linoleic acid in adipose tissue up to 30-40% linoleic acid with a consequent dramatic softening of the carcass fat (Monziols *et al.*, 2007).

The addition of fats into diets will not, on that account alone, make pigs fat. Pigs have the propensity to become fat if appetite is enhanced to the extent that energy is consumed in excess and diet fats will usually enhance appetite. Similarly, excess energy may be consumed if the energy density of diets is increased and diet fat additions will increase energy density. Pigs will grow fat if there is insufficient protein in the diet and if incorrectly valued, fat additions may upset the intended energy:protein ratio (Chiba *et al.*, 1991).

EFFECTS OF FAT ON GROWTH PERFORMANCE

Addition of fat to a diet has characteristic effects on performance and carcass characteristics. These include decrease feed intake and increased palatability, growth rate, feed efficiency and carcass fat. The magnitude of the performance changes is influenced by the stage of production. Pettigrew and Moser (1991) performed meta-analyses summarizing the effects of dietary fat in the various phases of production in the first edition of this book. Summaries for the use of fat in staling, growing-finishing and sow diets were reported. In all three categories, the effects of added fat were categorized into studies in which the calorie:protein ratio was maintained or where it was not adjusted.

Because of the increased energy density of fat (relative to protein or carbohydrate) and the ability of animals to regulate intake based on energy content of a feed, it is necessary to increase protein content to ensure adequate amino acid intake when fat is added. Although, direct evidence of the effect of failure to maintain calorie:protein ratio on carcass quality and performance is limited (Allee, 1985) the practice is widely accepted.

The magnitude of the reduction in intake was greater than that of gain and thus, the gain/feed ratio was also significantly improved in pigs fed supplemental fat (Tokkach *et al.*, 1995; Cromwell, 2006). There have been numerous studies investigating the effects of fat type and source on performance in the nursery published since, the Pettigrew and Moser review. In general these support the observation that efficiency is improved and that the effects on intake and gain are less obvious (Tokkach *et al.*, 1995). Discrepancies among studies in their conclusions

about the magnitude of the effect of fat in performance of nursery pigs are likely due to combination of differences in the type of fat, other dietary ingredients such as the source of protein or copper and age or genetic background of the pigs.

In growing-finishing pigs, the main effects noted with fat supplementation are improved gain and efficiency, decreased intake and increased carcass fat (Baudon *et al.*, 2003; Apple *et al.*, 2004). These responses to dietary fat are independent of whether the calorie/protein ratio of the diet is adjusted. The decreased intake in older pigs is a more consistent response than in nursery pigs, particularly when the dietary fat level exceeds 3%. At <3% added that intake increased slightly with added fat. This suggests that gut capacity in nursery age pigs, rather than energy may have limited intake in these studies. Pettigrew and Moser (1991) reported that the increase in backfat thickness was actually greater when diets were adjusted for energy density. The increase was 0.12 ± 0.03 cm with no adjustment and 0.27 ± 0.7 with adjustment.

By far the greatest interest in the use of fat in swine diets has centered around sow nutrition. Seerley *et al.* (1974) observed that fat addition during late gestation resulted in improved neonatal survival. Subsequent studies suggested that the effects were most likely accounted for by greater energy stores in the pig at birth that resulted in a greater ability to sustain life until adequate nutrition was obtained from the sow (Seerley *et al.*, 1974; Pettigrew, 1981). At birth, pigs have <2% body fat and very low liver glycogen contents. Fat feeding during late gestation increases neonatal energy stores although, the changes are small and not consistent. On theory, fatty acids or ketone bodies, generated from acid oxidation and the dam, cross the placenta and provide an energy source for the developing fetus. They also spare glucose use as an energy source and result in increased liver glycogen synthesis and storage. A more reproducible response to fat feeding late in gestation and lactation is an increase in the level of fat and thus the energy density of both colostrum and milk (Seerley *et al.*, 1974; Pettigrew, 1981).

The pig survival response to fat in the gestation diet was only evident when litter survival rates were <80-85% for the control groups. At the time these studies were conducted, this was typical of the industry. By current production standards, a 90% survival rate is to be expected (USDA, 1995) and thus the benefits of added fat will be less obvious. The sow feeding program is a complex consideration of birth weight, survival, lactation performance and subsequent reproductive performance. Greater energy intake during gestation, either by increasing energy density (added fat) or simply increasing intake is generally associated with reduced intake during

lactation (Coffey *et al.*, 1994; Weldon *et al.*, 1994). Reduced energy intake during lactation leads to increased sow weight loss and days to estrus.

CONCLUSION

Conversely, fat feeding during lactation is associated with reduced sow body weight and backfat losses and a decrease in the weaning to estrus interval (Pettigrew and Moser, 1991). In two studies examining the effect of increased lactation diet nutrient density, there was no benefit of higher nutrient density (Coffey *et al.*, 1994; Dove and Haydon, 1994) on survival rates. In both studies, weaning weight was improved as a result of fat addition to the lactation diet. Recent research indicates that the increase in weaning weight of pigs from sows fed fat during gestation is accounted for by an increase in carcass fat of the pigs (Tilton *et al.*, 1999). This study also suggests that based on earlier research (Friend, 1974), an increase in fat at weaning is likely to be associated with increased fat at market weight.

REFERENCES

- Allee, G.L., 1985. The interaction of dietary protein and energy on swine performance. Proceedings of the Georgia Nutrition Conference for the Feed Industry, February 13-15, 1985, Atlanta, Georgia, pp: 136-141.
- Allee, G.L., D.H. Bnaker and G.A. Leveille, 1971. Influence of level of dietary fat on adipose tissue lipogenesis and enzymatic activity in the pig. *J. Anim. Sci.*, 33: 1248-1254.
- Apple, J.K., C.V. Maxwell, L.K. Rakes, S. Hutchison, W.A. Wallis, J.D. Stephenson and Z.B. Johnson, 2004. Effects of dietary fat source and length of fat consumption on performance and carcass composition of growing-finishing swine. *Arkansas Anim. Sci. Depart. Report. Res. Series.*, 535: 30-34.
- Azain, M.J., K.D. Bullock, T.R. Kasser and J.J. Veenhuizen, 1992. Relationship of mode of porcine somatotropin administration and dietary fat on the growth performance and carcass characteristics of finishing pigs. *J. Anim. Sci.*, 70: 3086-3095.
- Azain, M.J., R.W. Seerley, J.O. Reagan and M.K. Andersen, 1991. Effect of a high-fat diet on the performance response to porcine somatotropin (PST) in finishing pig. *J. Anim. Sci.*, 69: 153-161.
- Baudon, E.C., J.D. Hancock and N. Llanes, 2003. Added fat in diets for pigs in early and late finishing. Kansas State University, Agricultural Experiment Station and Cooperative Extension Service. Swine Day, pp: 155-158. <http://krex.k-state.edu/dspace/handle/2097/2091>.
- Cera, K.R., D.C. Mahan and G.A. Reinhart, 1988. Weekly digestibilities of diets supplemented with corn oil, lard or tallow by weaning swine. *J. Anim. Sci.*, 66: 1430-1437.
- Cera, K.R., D.C. Mahan and G.A. Reinhart, 1989. Apparent fat digestibilities and performance responses of postweaning swine fed diets supplemented with coconut oil, corn oil or tallow. *J. Anim. Sci.*, 67: 2040-2047.
- Cera, K.R., D.C. Mahan and G.A. Reinhart, 1990. Effect of weaning, week postweaning and diet composition on pancreatic and small intestinal luminal lipase response in young swine. *J. Anim. Sci.*, 68: 384-391.
- Chiba, L.I., A.J. Lewis and E.R. Peo Jr., 1991. Amino acid and energy interrelationships in pigs weighing 20 to 50 kilograms: II. Rate and efficiency of protein and fat deposition. *J. Anim. Sci.*, 69: 708-718.
- Cho, J.H. and I.H. Kim, 2010. Fish meal-nutritive value. *J. Anim. Physi. Anim. Nutr.*, 10.1111/j.1439-0396.2010.01109.x
- Coffey, M.T., B.G. Diggs, D.L. Handlin, D.A. Knabe, C.V. Maxwell, P.R. Noland, T.J. Prince and C.L. Cromwell, 1994. Effects of dietary energy during gestation and lactation on reproductive performance of sows: A cooperative study. *J. Anim. Sci.*, 72: 4-9.
- Coffey, M.T., R.W. Seerley, D.W. Funderburke and H.C. McCampbell, 1982. Effect of heat increment and level of dietary energy and environmental temperature on the performance of growing-finishing swine. *J. Anim. Sci.*, 54: 95-105.
- Crampton, E.W. and O.M. Ness, 1954. Ameal mixture suitable as the entire ration to be self-fed dry to pigs weaned at ten days of age. *J. Anim. Sci.*, 13: 357-364.
- Cromwell, G.L., 2006. Rendered Products in Swine Nutrition. In: Essential Rendering, Meeker, D.L. (Eds.). National Renderers Assoc, Alexandria, VA, pp: 141-157.
- Cunningham, H.M., D.W. Friend and J.G.W. Nicholson, 1962. Note on re-entrant fistula for digestion studies in pigs. *Canadi. J. Anim. Sci.*, 42: 112-113.
- Desouza, T.R., J. Peiniau, A. Mounier and A. Aumaitre, 1995. Effect of addition of tallow and lecithin on the diet of weanling piglets on the apparent total tract and ileal digestibility of fat and fatty-acids. *Anim. Feed Sci. Technol.*, 52: 77-91.
- Doreau, M. and Y. Chilliard, 1997. Digestion and metabolism of dietary fat in farm animals. *Br. J. Nutr.*, 78: S15-S35.
- Dove, C.R. and K.D. Haydon, 1994. The effect of various diet nutrient densities and electrolyte balances on sow and litter performance during two seasons of the year. *J. Anim. Sci.*, 72: 1101-1106.

- Famworth, E.R. and J.K.G. Kramer, 1997. Fat metabolism of dietary fat in farm animal. *Br. J. Nutr.*, 78: S15-S35.
- Friend, D.W., 1974. Effect on the performance of pigs from birth to market weight of adding fat to the lactation diet of their dams. *J. Anim. Sci.*, 63: 1073-1081.
- Frobish, L.T., V.W. Hays, V.C. Speer and R.C. Ewan, 1970. Effect of fat source and level on utilization of fat by young pigs. *J. Anim. Sci.*, 30: 197-202.
- Herzberg, G.R and M. Rogerson, 1988. Hepatic fatty acid synthesis and triglyceride secretion in rats fructose- or glucose- based diets containing corn oil, tallow or marine oil. *J. Nutr.*, 118: 1061-1067.
- Jones, D.B., J.D. Hancock, D.L. Harmon and C.E. Walker, 1992. Effects of exogenous emulsifiers and fat sources on nutrient digestibility, serum lipids and growth performance in weanling pigs. *J. Anim. Sci.*, 70: 3473-3482.
- Lawrence, N.J. and C.V. Maxwell, 1983. Effect of dietary fat sources and level on the performance of neonatal and early weaned pigs. *J. Anim. Sci.*, 57: 936-942.
- Lewis, A.J. and L.L. Southern, 2001. *Swine Nutrition*. 2nd Edn., CRC Press LLC., USA.
- Li, S. and W.C. Sauer, 1994. The effect of dietary fat content on amino acid digestibility in young pigs. *J. Anim. Sci.*, 72: 1737-1743.
- Madsen, A., K. Jakobsen and H. Mortensen, 1992. Influence of dietary fat on carcass fat quality in pigs: A review. *Acta Agric. Scand.*, 42: 220-225.
- Miller, M.F., S.D. Shackelford, K.D. Hayden and J.O. Regan, 1990. Determination of the alteration in fatty acid profiles, sensory characteristics and carcass traits of swine fed elevated levels of monounsaturated fats in the diet. *J. Anim. Sci.*, 68: 1624-1631.
- Monziols, M., M. Bonneau, A. Davenel and M. Kouba, 2007. Comparison of the lipid content and fatty acid composition of intermuscular and subcutaneous adipose tissues in pig carcasses. *Meat. Sci.*, 76: 54-60.
- Mourot, J., M. Kouba and P. Peiniau, 1995. Comparative study of *in vitro* lipogenesis in various adipose tissues in the growingpig (*Sus domesticus*). *Comp. Biochem. Physiol.*, 111: 379-384.
- O'Hea, E.K. and G.A. Leveille, 1969. Significance of adipose tissue and liver as sites of fatty acid synthesis in the pig and efficiency of utilization of various substrates for lipogenesis. *J. Nutr.*, 99: 338-344.
- Overland, M., M.D. Tokach, S.G. Cornelius, J.E. Pettigrew and J.W. Rust, 1993. Lecithin in swine diets. I: Weanling pigs. *J. Anim. Sci.*, 71: 1187-1193.
- Pettigrew, J.E. and R.L. Moser, 1991. Fat in Swine Nutrition. In: *Swine Nutrition*, Miller, E.R., D.E. Ullrey and A.J. Lewis (Eds.). Butterworth-Heinemann, Stoneham, MA.
- Pettigrew, J.E., 1981. Supplemental fat for periparturient sows: A review. *J. Anim. Sci.*, 53: 107-117.
- Seerley, R.W., J.P. Briscoe and H.C. McCampbell, 1978. A comparison of poultry and animal fat on performance, body composition and tissue lipids of swine. *J. Anim. Sci.*, 46: 1018-1023.
- Seerley, R.W., T.A. Pace, C.W. Foley and R.D. Scarth, 1974. Effect of energy intake prior to parturition on milk lipid and survival rate, thermostability and carcass composition of piglets. *J. Anim. Sci.*, 38: 64-70.
- Small, D.M., 1991. The effects of glyceride structure on absorption and metabolism. *Ann. Rev. Nutr.*, 11: 413-434.
- Smith, D.R., D.A. Knabe and S.B. Smith, 1996. Depression of lipogenesis in swine adipose tissue by specific dietary fatty acids. *J. Anim. Sci.*, 74: 975-983.
- Stahly, T.S., 1984. Use of Fats in Diets for Growing Pigs. In: *Fats in Animal Nutrition*, Wiseman, J. (Ed.). Butterworths, London, pp: 313-331.
- Stahly, T.S. and G.L. Cromwell, 1979. Effect of environmental temperature and dietary fat supplementation on the performance and carcass characteristics of growing and finishing swine. *J. Anim. Sci.*, 49: 1478-1488.
- Tilton, S.L., P.S. Miller, A.J. Lewis, D.E. Reese and P.M. Ermer, 1999. Addition of fat to the diets of lactating sows: I. Effects on milk production and composition and carcass composition of the litter at weaning. *J. Anim. Sci.*, 77: 2491-2500.
- Tokach, M.D., J.E. Pettigrew, L.J. Johnston, M. Overland, J.W. Rust and S.G. Cornelius, 1995. Effect of adding fat and/or milk products to the weaning pig diet on performance in the nursery and subsequent grow-finish performance. *J. Anim. Sci.*, 73: 3358-3368.
- USDA., 1995. *Swine'95*. Part I: Reference of 1995 Swine Management Practices, Animal and Plant Health Inspection Service. Veterinary Services, Washington, DC., USA.
- Weldon, W.C., A.J. Lewis, G.F. Louis, J.L. Kovar, M.A. Giesemann and M.L. Miller, 1994. Postpartum hypophagia in primiparous sows: I. Effects of gestation feeding level on feed intake, feeding behavior and plasma metabolite concentrations during lactation. *J. Anim. Sci.*, 72: 387-394.
- Whittemore, C.T., 1998. *The Science and Practice of Pig Production*. 2nd Edn., Blackwell Publishing Ltd., London, ISBN-13: 978-0632050864, Pages: 640.
- Wiseman, J., 1984. Assessment of the Digestible and Metabolizable Energy of Fats for Non-Ruminants. In: *Fats in Animal Nutrition*, Wiseman, J. (Ed.), Butterworths, London, pp: 277-297.