January 2003

Omega-3 Fatty Acids and Swine Reproduction - A Review

Duane Reese
University of Nebraska - Lincoln, dreese1@unl.edu

Omega-3 Fatty Acids and Swine Reproduction — A Review

Duane E. Reese[1]

Summary and Implications

A literature review was conducted to examine the role dietary omega-3 fatty acids may play in swine reproduction. Omega-3 fatty acids are not normally present to any great extent in practical swine diets, but they are increasingly important in human and pet health. Swine nutritionists have focused primarily on the effect omega-3 fatty acids may have on litter size, piglet preweaning mortality, and boar fertility. Feeding omega-3 fatty acids to sows has not generally improved litter size. Piglet preweaning mortality may be improved by omega-3 fatty acid supplementation provided sows are allowed to farrow naturally (without induction). Boar fertility seems to be positively influenced by feeding omega-3 fatty acids. The optimum amount of omega-3 fatty acids to add to breeding herd diets, which aspect(s) of the reproductive cycle they should be provided for best results, and the preferred sources require greater clarification.

Introduction

The role of fat and oil in sow diets received considerable attention by researchers 20 to 30 years ago. Interest was centered on improving piglet preweaning survival and reducing the nutrient drain experienced by lactating sows. Those investigations showed that supplemental fat provided to the sow prefarrowing generally improves preweaning survival, but its role in reducing nutrient drain during lactation is less meaningful. Fat and oil has basically served as a source of energy in swine diets.

Fats and oils consist of fatty acids. Each fat or oil source has a unique fatty acid profile that distinguishes one fat or oil source from another. Nutritionists have been examining the health benefits of specific fatty acids, especially omega-3 fatty acids, in pet and human health for several years. More recently, the role of omega-3 fatty acids in swine reproduction has been investigated and pork producers are presented with the option to include omega-3 fatty acids in their swine diets. The purpose of this paper is to review published research results that pertain to omega-3 fatty acids and swine reproduction.

Background on Fatty Acids

Fatty acids vary in length from two to 22 carbon chains. Some fatty acids are saturated meaning they lack double bonds in their carbon chain while others are unsaturated and have from one to six double bonds in their carbon chain. The final carbon atom at one particular end of the carbon chain is called the "omega" carbon. This carbon atom is usually designated as "n." Polyunsaturated fatty acids (fatty acids with more than one double bond) are classified according to the location and number of double bonds that they contain. Omega-3 fatty acids (n-3) contain their first double bond at the third carbon atom while omega-6 fatty acids (n-6) have their first double bond at the sixth carbon atom in the carbon chain (Figure 1).

Table 1 shows the fatty acid profile of several fat and oil sources. The name of each fatty acid is listed along with a description of its structure (number of carbon atoms and number of double bonds in its chain) and its type (n-3, n-6, etc). The omega-3 fatty acids are linolenic; eicosapentaenoic, (EPA); and docosahexaenoic, (DHA). Linseed (flax) is the most abundant source of linolenic acid; canola oil is the next best source, while negligible amounts are found in the other sources of fats and oils. In contrast, fish oils are the only sources of the other two omega-3 fatty acids (EPA and DHA). It is evident from this table that practical swine diets in the USA contain an abundance of linoleic acid (from corn) and

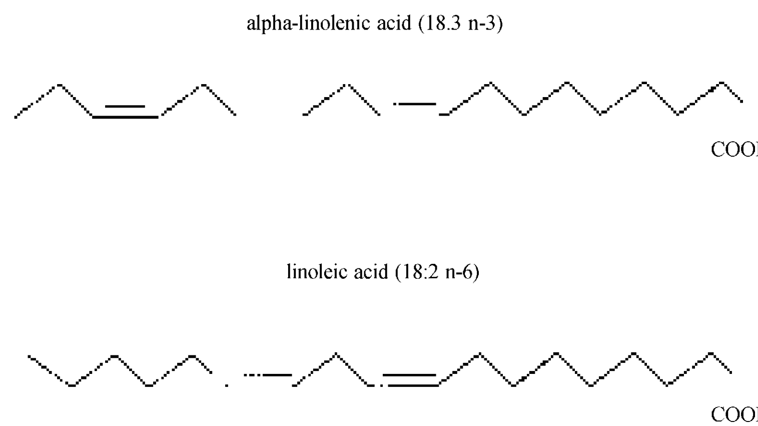

Figure 1. Structure of alpha-linolenic acid (an omega-3 fatty acid) and linolenic acid (an n-6 fatty acid). A carbon atom is located at the end of each line. Double lines indicate location of double bonds in the carbon chain.

Table 1. Fatty acid composition of fats and oils (%).[a]

Name	Lauric	Myristic	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	α-Linolenic	Arachidic	Gadoleic	Arachidonic	Eicosapentaenoic (EPA)	Docosahexaenoic (DHA)
Structure (no. carbons: no. double bonds)	12:0	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	20:4	20:5	22:6
Type				n-7		n-9	n-6	n-3		n-9	n-6	n-3	n-3
Canola oil		0.1	4.1	0.3	1.8	60.9	21.0	8.8	0.7	1.0			
Coconut oil	47.1	18.5	9.1		2.8	6.8	1.9	0.1	0.1				
Corn oil		0.1	10.9	0.2	2.0	25.4	59.6	1.2	0.4				
Cottonseed oil	0.1	0.7	21.6	0.6	2.6	18.6	54.4	0.7	0.3				
Linseed (flax) oil			5.3		4.1	20.2	12.7	53.3					
Olive oil			9.0	0.6	2.7	80.3	6.3	0.7	0.4				
Palm oil	0.3	1.1	42.9	0.2	4.6	39.3	10.7	0.4	0.3				
Palm kernel oil	48.2	16.2	8.4		2.5	15.3	2.3		0.1	0.1			
Peanut oil		0.1	11.1	0.2	2.4	46.7	32.0		1.3	1.6			
Safflower oil		0.1	6.8	0.1	2.3	12.0	77.7	0.4	0.3	0.1			
Soybean oil		0.1	10.6	0.1	4.0	23.2	53.7	7.6	0.3				
Sunflower oil		0.1	7.0	0.1	4.5	18.7	67.5	0.8	0.4	0.1			
Sunflower oil (high oleic)		3.7	0.1	5.4	81.3	9.0		0.4					
Beef tallow	0.1	3.2	24.3	3.7	18.6	42.6	2.6	0.7	0.2	0.3			
Chicken fat	0.1	0.8	25.3	7.2	6.5	37.7	20.6	0.8	0.2	0.3			
Lard (pork fat)	0.1	1.5	26.0	3.3	13.5	43.9	9.5	0.4	0.2	0.7			
Milk fat	3.1	10.8	28.8	2.5	13.3	27.6	2.5	1.6	0.1	0.1			
Anchovy oil		10.6	16.1	11.4	2.8	10.2	1.0	0.4	0.4	0.5	1.7	24.6	9.8
Cod liver oil		6.2	10.5	7.4	1.6	14.3	0.9	0.5		18.6	0.4	12.8	8.0
Menhaden oil		8.6	21.2	10.6	3.3	15.0	7.0	1.3	0.4	1.2	1.9	13.41	1.4
Salmon oil (wild)		5.3	15.8	9.3	3.3	15.5	3.4	1.0	2.5	1.0	0.3	16.6	13.4
Sardine oil		6.7	18.9	8.8	3.4	17.1	1.1	0.1	0.1	2.5	1.6	19.1	11.0

[a]Adapted from Timothy Carr, University of Nebraska, 2002.

only trace amounts of omega-3 fatty acids.

Research results

Sow Nutrition

Researchers have focused primarily on the role fatty acids may play in litter size and piglet preweaning mortality. In 1970 Canadian researchers fed 30 gilts either a wheat/barley-soybean meal control diet, the control diet with 4 % safflower oil (rich source of linoleic acid) or the control diet with 4% olive oil (rich source of oleic acid) from the day of first estrus through to day 35 of gestation (gilts were mated on their second estrus). Diet had no effect on ovulation rate, but there were 2.7 to 3.2 more embryos present in gilts that were fed either olive or safflower oil compared to those fed the control diet. Also, there was approximately 26% more DHA in embryos from sows fed the supplemental oils. The DHA was initially thought to have originated from the oleic or linoleic acid additions to the diet; however, more recently is has been established that DHA is formed from linolenic acid, not from linoleic acid . Although an omega-3 fatty acid source was not provided to the gilts in this experiment, these results suggest that it may be valuable to increase the DHA content of the embryo.

Also, in 1970 Ohio State University researchers fed gilts either a corn-soybean meal control diet or the control diet with 6% whole fish meal for two successive reproductive cycles. Treatment diets were fed from 30 days prior to breeding until weaning following the second lactation period. Litter size (total and born alive) was significantly higher in sows fed the fish meal supplemented diet (Table 2). Sows fed the fish meal supplemented diet farrowed 133 more live pigs during the course of the experiment than sows fed the control diet.

However, in 1974 researchers from the University of Illinois suggested that these responses were likely due to better selenium nutrition in the fish meal-fed sows (fish meal is high in selenium). The diets used in the Ohio State study contained no supplemental vitamin E or selenium. The fish meal supplemented diet in the Ohio State study probably contained 0.15 ppm additional selenium assuming fish meal contains 2.2 ppm selenium. The addition of selenium to practical sow diets has generally not improved litter size, therefore it is unlikely that the selenium provided by the fish meal had much role in the improved reproductive rate observed by the Ohio State researchers. Also, the control and fish meal diets contained similar amounts of fat (2.34 vs 2.61%), suggesting that the fish meal contributed only a small

(Continued on next page)

amount of omega-3 fatty acids to the diet. Therefore, it is not clear what contributed to the increase in the reproductive rate observed in the Ohio State study.

In the University of Illinois study, researchers fed sows either a corn-soybean meal control diet or the control diet with 3% menhaden fish meal for two successive gestation periods. The diets were fortified with vitamin E (10 IU/lb), but no selenium. Litter size (total and born alive) was not affected by diet.

In 1995 Virginia researchers fed 86 gilts either a corn-soybean meal control diet, the control diet with 4 % coconut oil (rich source of lauric, myristic, and palmitic acid), the control diet with 4% soybean oil (supplied linolenic acid), or the control diet with menhaden oil (rich source of EPA and DHA). The diets were fed from day 10 to 17 after the first estrus to day 37 to 45 after breeding. Gilts were mated on their third estrus. Also, a total of 46 sows were fed the diets beginning day 1 postweaning until day 37 to 45 of gestation. Overall there was no significant difference in fetal survival rate due to treatment. However, in one of the two gilt trials, fetal survival rate was improved by providing menhaden oil (93.7 vs 78.8%, respectively).

In 1998 Scottish researchers fed 14 sows a diet supplemented with either 3% soybean oil or tuna oil (rich source of DHA) from d 90 to 94 of gestation through to day seven of lactation. Sows were induced to farrow on d 113 of gestation. Piglet viability decreased with tuna oil feeding. In humans gestation length is increased when the intake of omega-3 fatty acids is increased. The authors suggested that the "natural" gestation length might be longer for sows fed tuna oil; thus, piglets from soybean oil-fed sows may have been more mature at farrowing. Results also indicate that feeding tuna oil increased the proportion of long chain fatty acids in the tissues of piglets at birth.

In 2000, Scottish researchers assigned 30 sows to one of three treatments from three to four days post breeding to weaning. Corn/wheat-based diets were supplemented with either 1.75% corn oil (rich source of n-6 fatty acids), 1.75% tuna oil, or 1.75% of a combination of corn and linseed oil (rich source of linolenic acid) and fed during gestation. During lactation sows continued on the same diets except 1.75% additional corn oil was added to each diet. Sows were induced to farrow on day 113 of gestation. Fewer piglets from corn oil-fed sows died or were removed from the experiment prior to weaning than from other sows (6.4, 28.3 and 25.5% for corn, tuna and linseed oil, respectively). The authors speculated that inducing the sows to farrow may have resulted in piglets from sows offered omega-3 fatty acids to have been born more prematurely in respect to the natural gestation length of the sow.

In 2001, Scottish researchers fed 198 sows either a wheat-based control diet or the control diet containing 1.65% salmon oil (rich source of EPA and DHA) from day three post mating to weaning. Sows were weaned at 21 to 28 days of lactation and returned to a standard commercial diet. Subsequent conception rate, farrowing rate and litter size were recorded. Sows were not induced to farrow. There were no differences in total litter size or in the number pigs born alive (Table 3). Preweaning mortality was lower for piglets from salmon-fed sows than control sows (10.2 vs 11.7%) even though they were lighter at birth (3.2 vs 3.4 lb). No difference was observed in litter weaning weight. Gestation length was longer for the salmon oil-fed sows (115.9 vs 115.4 d). The authors speculated that gestation length was increased because of a reduction in the amount of arachidonic acid available for synthesis of prostaglandin, a hormone involved in parturition. This reduction may have also contributed to lower piglet birth weight. During the subsequent gestation period, no differences in mean conception (95%) and farrowing (78%) rates, or in litter size (control, 11.8; salmon oil, 12.4) were observed.

In order to make practical use of fish oil in sow diets to improve piglet mortality it is necessary to establish the amount of fish oil to add to sow diets which results in an increase in DHA in the piglets while minimizing a decrease in arachidonic acid. Other Scottish researchers have determined that 1% salmon oil in the sow diet will meet these criteria in piglet brain tissue.

Table 2. Effect of whole fish meal on sow reproductive performance.[a]

Item	Control	Control + 6 % whole fish meal
No. litters produced[b]	65	74
Total pigs born/litter[c]	7.9	8.7
Pigs born alive/litter[c]	7.4	8.3
Total no. pigs born alive	481	614
Piglet birth weight, lb	2.7	2.8
Pigs weaned/litter	6.5	7.1

[a]Palmer et.al., 1970.
[b]Fifty-four gilts were assigned to each treatment at the beginning of the experiment.
[c] $P < 0.05$.

Table 3. Effect of salmon oil in sow diets.[a]

Item	Control	Control + 1.65% salmon oil
No. of sows	84	114
Total pigs born	11.9	12.3
Pigs born alive	11.6	11.8
Piglet birth weight, lb[b]	3.4	3.2
Preweaning mortality, %	11.7	10.2
Gestation length, d [b]	115.4	115.9
Litter weaning weight, lb	172.3	177.3

[a]Rooke et.al., 2001.
[b] $P < 0.05$.

Boar Nutrition

Pig spermatozoa contains a significant amount of DHA. It is probable that DHA is essential for optimal fertility in the boar. Supplemention of boar diets with omega-3 fatty acids may improve sperm characteristics and litter size. That has been the focus of four studies.

In 1999, Norwegian researchers used 29 boars to determine the effect of a daily dose of 75 ml of cod liver oil (source of EPA and DHA) on resistance to cold shock and on freezability of boar semen. Cod liver oil was supplemented for 12 weeks. The concentration of DHA increased in the semen from boars given the cod liver oil from 25.5 to 32.1%; no change in the fatty acid composition of semen from the unsupplemented boars was observed. Despite the higher content of DHA in the semen from cod liver oil-fed boars, their semen did not withstand cold shock or freeze better than that from control boars.

In 2001 British researchers reported feeding 35 boars a diet with or without a supplement containing DHA and specific antioxidants (PROSPERM™). Due to the large number of double bonds in long chain, polyunsaturated fatty acids, an antioxidant is necessary to prevent oxygen from attacking the double bonds and altering the biological activity of the fatty acid. Four hundred and seventy-eight gilts were artificially inseminated with semen either from boars that received the dietary supplement or those that did not. Significant improvements were observed for conception rate (control, 83%; supplemented, 90%), number of pigs born alive (control, 10.2; supplemented, 10.6), and the number of pigs born alive per 100 services (control, 846; supplemented, 954). The supplement increased the proportion of DHA in boar spermatozoa.

In 2001, British and Italian researchers reported feeding 14 boars a diet with or without supplemental DHA and antioxidants (PROSPERM™) for 16 weeks. Sperm concentration increased (571 vs 695 million sperm cells per ml) when the supplement was provided. Similar to the previous study, the supplement increased the amount of DHA in spermatozoa.

Scottish researchers in 2001 fed 10 boars either a barley/wheat-rapeseed control diet or the control diet supplemented with 3% tuna oil. Both diets were supplemented with approximately 295 ppm α-tocopherol acetate (vitamin E) to serve as an antioxidant. Semen was collected at week 0, 3, 5, and 6 following initiation of the study. Tuna oil increased sperm viability and the proportion of spermatozoa with progressive motility and normal acrosome score. Also, tuna oil increased the proportion of DHA in sperm after 5 and 6 weeks of feeding.

In the studies where PROSPERM™ was provided to boars it is unclear which component of the product (DHA or the antioxidants) contributed to the observed improvement in semen characteristics and reproductive performance. The Scottish work, where the only variable in the study was the level of tuna oil in the diet, does suggest a role for supplemental DHA in the diet of boars.

Synthesis of EPA and DHA from Linolenic Acid

It is interesting from a scientific and practical standpoint to know whether pigs can make sufficient quantities of EPA and DHA from linolenic acid. If pigs can elongate linolenic acid sufficiently, pork producers could feed flaxseed or soybean oil and expect similar results to feeding fish oil. Some researchers have examined if piglet tissue levels of EPA and DHA are increased to the same extent by providing them preformed in the sow's diet vs adding linolenic acid to the diet. Virginia researchers concluded that the developing fetus was not able to elongate soybean oil linolenic acid and it was unable to obtain the same level of EPA and DHA from soybean oil as it did from menhaden oil. A subsequent trial in Scotland concluded that offering linseed oil as a source of linolenic acid to sows was ineffective at increasing EPA and DHA concentration in piglets. Therefore, to maximize benefits that EPA and DHA may impart on litter size and piglet mortality, it seems necessary to add them preformed to the diet. In practical situations, that can be accomplished only by adding fish oil or fish products to the diet.

Omega-3 fatty acid stability

As mentioned previously, omega-3 fatty acids are unstable and therefore easily loose their biological activity if not protected by antioxidants such as vitamin E or ethoxyquin. In some of research reviewed for this report, it is clear that attention was given to protect the omega-3 fatty acids from oxidation. It is possible that some of the variability observed in the response to omega-3 fatty acids in the published literature is due to differences in how well the omega-3 fatty acid sources were stabilized.

Conclusion

Omega-3 fatty acids appear to influence some aspects of swine reproduction. Given the large body of information that is available on the role of omega-3 fatty acids in humans and pets, it is becoming evident that the decision to add fat or oil to sow and boar diets should be based on more than just an energy source consideration. However, until results from studies that involve hundreds of sows or boars fed corn and soybean meal-based diets supplemented with omega-3 fatty acids are published, it is difficult to establish the economic value of omega-3 fatty acid supplements for sows and boars. Additional clarification is needed for: 1) the optimum amount of omega-3 fatty acids to add to breeding herd diets, 2) which aspect(s) of the reproductive cycle omega-3 fatty acids should be provided to enhance reproductive performance and piglet survival, and 3) the preferred sources of omega-3 fatty acids.

---

[1]Duane E. Reese is extension swine specialist in the Department of Animal Sciences. References are available from the author by request.