Long-Chain Polyunsaturated Fatty Acids

Subjects: Zoology

Contributor: Robert Roszkos

The effects of long-chain polyunsaturated fatty acids (LC PUFAs) have been frequently investigated in sows because the profitability of pig production depends mainly on reproduction performance. According to the results of the previous studies, n-3 fatty acids can postpone the time of parturition, decreasing the synthesis of prostaglandins, which are necessary for uterus contraction during labour. These effects could also be useful during the post-weaning period when low prostaglandin levels are indispensable for embryo survival. The n-3 fatty acids fed during the lactation period secreted in milk, may improve piglet performance. Despite the numerous previous field trials, there are no current feeding recommendations available for PUFAs in swine nutrition. In finding the appropriate dose of n-3 PUFAs in terms of sow nutrition, the n-6 PUFAs levels in the given feeds must be taken into account to ensure that there are no significant reductions in the final n-6/n-3 ratio.

Keywords: swine ; nutrition ; n-3 fatty acids ; reproduction

1. Introduction

long-chain polyunsaturated fatty acids (LC PUFAs) have been a focus of scientific research and practical nutrition for a long time. LC PUFAs are composed of at least 18 carbon atoms and contain at least two unsaturated double bonds in their acyl chain. PUFAs are classified according to the position of the first double bond, relative to the terminal methyl group. Consequently, the short names given to PUFAs show how far the first double bond is from the end of the molecule (e.g., the third carbon atom in the case of n-3 and sixth in the case of n-6 PUFAs) [1].

Among the various LC PUFAs, linoleic acid (LA; C18:2, n-6) and α-linolenic acid (ALA; C18:3, n-3) are considered essential for vertebrates because they are unable to synthesize them and must be acquired from their diet[2].

LC PUFAs have diverse effects in the body. They are involved in building the outer membranes of cells (phospholipid bilayer), preserving cell integrity and the fluidity of membranes supporting some intracellular signal transduction mechanisms. They are involved in the biosynthesis of certain hormones (e.g., prostanoids) and immune processes[3]. Moreover, they can affect the expression of specific genes that play a role in the regulation of lipid metabolism and cholesterol synthesis [4].

2. The Biological Function of LC PUFAs in Reproduction

According to Wathes et al. [5], LC PUFAs influence the reproductive performance in such a way that they positively affect follicle development and the expression of genes encoding the enzymes necessary for the formation of prostaglandins and sex steroids. The pig oocyte has high levels of LC PUFA, particularly the n-6 fatty acids, such as LA and ARA, indicating a local role in actively producing PGs[6].

LC PUFAs can pass through the placenta into the foetus and can be excreted through sow milk [7]. Due to a selective transportation process through the placenta, mainly from the second trimester onwards, a much higher concentration of ARA and DHA can be found in the foetus than in maternal blood in humans and swine [8].

3. LC PUFAs in Practical Swine Nutrition

3.1. Effects during the Prenatal Period

The n-6 fatty acids play many physiologically essential roles in the body. For example, the rate of embryo growth is directly connected to the amount of ARA. Since the presence of EPA and DHA is considered to depress the synthesis of ARA-derived PGs, they may decelerate the growth of embryos at the end of pregnancy and postpone the term of birth. The n-3 LC PUFAs that are unrelated to eicosanoid synthesis can affect myometrial contractions through direct impacts

on ion channels and cell signalling, which can also elongate the duration of gestation. This influence of LC PUFAs on the different ion channels of muscle cells is quite well-documented in human models[9]. Several researchers also found that the administration of n-3 LC PUFAs during the gestation period increases the length of pregnancy in swine[10].

3.2. Effects in the Postpartum Period: Pre-Weaning Growth and Mortality of Piglets

Studies reporting the effects of n-3 PUFAs on the pre-weaning performance of piglets remain controversial[11]. Some researchers found no significant difference between pre-weaning growth or the mortality of piglets when sows were fed with control or n-3 fatty acid-supplemented diets [12][13][14][15]. A very recent study found that litter birth weight and pre-weaning mortality was impaired when 1% salmon oil was added to gestation and lactation diets beside soya oil as a control supplementation [16]. However, some researchers experienced an improvement in the performance parameters of current and subsequent parturition when sows were fed the n-3 PUFAs supplemented diet during the lactation period. Rooke et al. [17] and Mateo et al.[18] reported that piglet weight at weaning was higher than the control if the sows were fed a diet supplemented with n-3 PUFAs from fish oil or marine algae during the second half of gestation. Luo et al. [19] also reported an improved daily weight gain of piglets (0 to 21 days of age) when sows were fed a 70 g/kg fish oil-supplemented diet during lactation. Innis[20] found the same effect in human infants and suggested that n-3 LC PUFA was a pivotal factor for the growth of children. Lavery et al. [21] fed sows with soya and fish oil from day 105 of gestation to weaning and, although there was no effect of oil type on the number of total born, born alive and piglets stillborn, there was a tendency for a reduced pre-weaning mortality rate for sows offered a diet containing salmon oil. These litters also had an increased litter weight gain in the second part of lactation.

4. LC PUFAs Improve Reproduction Parameters in the Context of Modern Sow Nutrition

According to human, animal and field studies, it seems that n-3 PUFAs, fed during the gestation period, lead to increased lengths in pregnancy times due to a negative impact on ARA production, which exhibits a linear correlation with embryo size. Without the induction of farrowing (e.g., with PGF2α), n-3 PUFA administration may not negatively influence the birth weights of piglets, as foetuses have more time (some days) to develop before parturition. Supplementation with n-3 PUFAs during the lactation period may improve the quality of ovarian follicles, thereby improving the survival rate of embryos and the subsequent litter size, as was demonstrated by several studies, when there was an ongoing subclinical deficiency in this nutrient. These biological reproductive effects will be reinforced if supplementation is elongated until the end of the first trimester of gestation when ovulation, fertilization, and implantation occur, and the skeletal frame of embryos develop. During this period, the effect of n-3 PUFA on follicle maturation and progesterone synthesis via CL size could help to maintain the pregnancy and reduce the rate of early embryo loss, which is specific to pigs.

Besides reproduction aspects, n-3 LC PUFAs are also transferred into the bodies of suckling piglets through colostrum and sow milk, helping to provide these essential nutrients of piglets in high-performance modern herds.

In case of deficiency, it seems that n-3 PUFAs could have favourable impacts on performance parameters during the whole production cycle of the sow, but especially during the lactation period, when piglets could also benefit from the supplementation directly. In other production periods, the dose, basal sow diet, and n-6/n-3 PUFA ratio may have a significant influence on the outcome.

As there are no current feeding recommendations available for PUFAs in swine nutrition, more research is required with standardized metabolic trials and comparing the different practical feeding situations for the establishment of PUFAs, including n-6/n-3 ratio requirements. More studies should be performed to find a threshold for PUFAs requirements that does not improve production and reproduction results further. The appropriate dose of n-3 PUFA in sow nutrition and the n-6 PUFA levels in the feeds must be taken into account to ensure that there are no significant reductions in the n-6/n-3 ratio. Despite the previous field trials, further examinations will be needed to certify the assumptions and conclusions of this review.

References

1. Williams, C.A.; Dietary fatty acids in human health. *Ann. Zootech.* **2000**, *49*, 165–180, .
2. Di Pasquale, M.G.; The essentials of essential fatty acids. *J. Diet. Suppl.* **2009**, *6*, 143–16, .
3. Stillwell, W.; Wassall, S.R.; Docosahexaenoic acid: Membrane properties of a unique fatty acid. *Chem. Phys. Lipids* **2003**, *126*, 1–27, .

4. Donald B. Jump; N-3 polyunsaturated fatty acid regulation of hepatic gene transcription. *Current Opinion in Lipidology* **2008**, *19*, 242-247, 10.1097/mol.0b013e3282ffaf6a.
5. David S. Rosero; R. Dean Boyd; Mark McCulley; Jack Odle; E. Van Heugten; Essential fatty acid supplementation during lactation is required to maximize the subsequent reproductive performance of the modern sow. *Animal Reproduction Science* **2016**, *168*, 151-163, 10.1016/j.anireprosci.2016.03.010.
6. Smits, R.J.C. The Functional Role and Requirement for Long-Chain Omega-3 Polyunsaturated Fatty Acids in Breeding Gilts and Sows. Ph.D. Thesis, The University of Adeliade, Adelaide, Australia, 2011.
7. S. Sampels; J Pickova; A Högberg; M Neil; Fatty acid transfer from sow to piglet differs for different polyunsaturated fatty acids (PUFA). *Physiological Research* **2010**, *60*, 113–124, .
8. Francine De Quelen; Gaëlle Boudry; Jacques Mourot; Linseed oil in the maternal diet increases long chain-PUFA status of the foetus and the newborn during the suckling period in pigs. *British Journal of Nutrition* **2010**, *104*, 533-543, 10.1017/s0007114510000772.
9. Fredrik Elinder; Sara I. Liin; Actions and Mechanisms of Polyunsaturated Fatty Acids on Voltage-Gated Ion Channels. *Frontiers in Physiology* **2017**, *8*, 43, 10.3389/fphys.2017.00043.
10. Rooke, J.A.; Sinclair, A.G.; Edwards, S.A.; Cordoba, R.; Pkivach, S.; Penny, P.C.; Penny, P.; Finch, A.M.; Horgan, G.W.; The effect of feeding salmon oil to sows throughout pregnancy on pre-weaning mortality of piglets. *Anim. Sci.* **2011**, *73*, 489–500, .
11. Sofie Tanghe; Stefaan De Smet; Does sow reproduction and piglet performance benefit from the addition of n-3 polyunsaturated fatty acids to the maternal diet?. *The Veterinary Journal* **2013**, *197*, 560-569, 10.1016/j.tvjl.2013.03.051.
12. Sampels, S.; Pickova, J.; Hörgber, A.; Neil, M. Fatty acid transfer from sow to piglet differs for different polyunsaturated fatty acids (PUFA). Physiol. Res. 2011, 60, 113–124.
13. R. J. Smits; B. G. Luxford; M. Mitchell; M. B. Nottle; Sow litter size is increased in the subsequent parity when lactating sows are fed diets containing n-3 fatty acids from fish oil1. *Journal of Animal Science* **2011**, *89*, 2731-2738, 10.2527/jas.2010-3593.
14. Smits, R.J.; Luxford, B.G.; Mitchell, M.; Nottle, M.B. Sow litter size is increased in the subsequent parity when lactating sows are fed diets containing n-3 fatty acids from fish oil. J. Anim. Sci. 2011, 89, 2731–2738.
15. Papadopoulos, G.A.; Maes, D.G.D.; Van Weyenberg, S.; van Kempen, T.A.T.G.; Buyse, J.; Janssens, G.P.J. Peripartal feeding strategy with different n-6:n-3 ratios in sows: Effects on sows' performance, inflammatory and periparturient metabolic parameters. Br. J. Nutr. 2009, 101, 348–357.
16. McDermott, K.; Icely, S.; Jagger, S.; Broom, L.J.; Charman, D.; Evans, C.; Miller, H.M.; Supplementation with omega-3 polyunsaturated fatty acids and effects on reproductive performance of sows. *Anim. Feed. Sci. Technol.* **2020**, *267*, 114529, .
17. J.A. Rooke; A. G. Sinclair; Sandra Edwards; Feeding tuna oil to the sow at different times during pregnancy has different effects on piglet long-chain polyunsaturated fatty acid composition at birth and subsequent growth.. *British Journal of Nutrition* **2001**, *86*, 21-30, 10.1079/bjn2001363.
18. R. D. Mateo; J.A. Carroll; Y. Hyun; S. Smith; S. W. Kim; Effect of dietary supplementation of n-3 fatty acids and elevated concentrations of dietary protein on the performance of sows. *Journal of Animal Science* **2009**, *87*, 948-959, 10.2527/jas.2008-0964.
19. Jie Luo; Feiruo Huang; Chenglin Xiao; Zhengfeng Fang; Jian Peng; Siwen Jiang; Responses of Growth Performance and Proinflammatory Cytokines Expression to Fish Oil Supplementation in Lactation Sows’ and/or Weaned Piglets’ Diets. *BioMed Research International* **2013**, *2013*, 1-9, 10.1155/2013/905918.
20. Sheila M Innis; Human milk: maternal dietary lipids and infant development. *Proceedings of the Nutrition Society* **2007**, *66*, 397-404, 10.1017/s0029665107005666.
21. Anna Lavery; P. G. Lawlor; Helen M. Miller; Elizabeth Magowan; The Effect of Dietary Oil Type and Energy Intake in Lactating Sows on the Fatty Acid Profile of Colostrum and Milk, and Piglet Growth to Weaning. *Animals* **2019**, *9*, 1092, 10.3390/ani9121092.
