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Optimizing gilt mammary development to increase future milk yield

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Summary

Sows do not produce enough milk to sustain optimal growth of their litters. This is particularly important when considering the current hyperprolific sow genetic lines. Mammary development needs to be considered to improve potential milk yield. One can only attempt to stimulate mammogenesis during periods when rapid mammary development is already ongoing. There are two such periods before lactation starts, namely, from three months of age until puberty, and from 90 days of gestation until farrowing. Early studies showed that a 20% feed restriction from 90 days of age until puberty drastically reduces mammary parenchymal tissue mass. Yet, in a more recent study, sow milk yield was not altered following a 10% or 20% feed restriction, or a 25% dietary fibre addition from 90 days of age to breeding. This absence of effect was likely due to the greater feed intake of control gilts in that recent study compared with the older studies, and suggested that feed intake of growing gilts can be reduced to 2.7 kg/d (but not 2.1 kg/d) without detrimental effects on future milk yield. During prepuberty, inclusion of the phytoestrogen genistein in the diet increases the number of mammary parenchymal cells. During late gestation, feeding very high energy levels may have detrimental effects on mammary development and subsequent milk production. Feed intake throughout gestation is also important because of its effect on body condition, with gilts that are too thin (< 16 mm backfat thickness) in late gestation showing less mammary development. A 40% increase in lysine intake via inclusion of additional soybean meal to the diet of gilts from days 90 to 110 of gestation increased mammary parenchymal mass by 44%. Increasing circulating concentrations of the growth factor IGF-1 during late gestation also increased mammary parenchymal mass by 22%. Current data clearly demonstrate that feeding management before lactation can be used to enhance mammary development, hence future milk yield.

Keywords: feeding, gestation, mammary development, pig, prepuberty

It is known that piglet growth rate is limited by milk supply (Harrell et al., 1993), hence it is essential to develop management and nutritional strategies to increase sow milk yield. One avenue that needs consideration to achieve such a goal is mammary development. This is most important because the number of mammary cells present at the onset of lactation has a major impact on potential sow milk yield (Head and Williams, 1991). Attempts to stimulate mammogenesis must be done during a period where there is already ongoing development of mammary tissue. In swine, there are three stages of rapid mammary accretion. The first stage is from 90 d of age until puberty, during which there is a four- to sixfold increase in mammary DNA (Sorensen et al., 2002a). Puberty in itself has a stimulatory effect on mammogenesis, leading to a 51% increase in parenchymal tissue mass of gilts (Farmer et al., 2004). The second stage of rapid mammary development is during the last third of gestation. (Sorensen et al., 2002a), during which there is a shift in mammary composition from a high lipid to a high protein content (Ji et al., 2006). The third and last stage of rapid mammary development is during lactation (Kim et al., 1999).

Hormones and mammary development

Estrogens are essential for mammary development, both at puberty (Farmer et al., 2004) and in late gestation (Kensinger et al., 1982). These last authors showed a positive correlation between circulating estrogen concentrations and DNA concentrations in mammary tissue of gilts on day 110 of gestation. An attempt was therefore made to stimulate mammary development in gilts by providing a dietary source of estrogen. When 2.3 g/d of the phytoestrogen genistein was added to a standard soya diet of growing gilts from 90 to 183 d of age, there was a 44% increase in mammary parenchymal cells at the end of the treatment period (Farmer et al., 2010).

Prolactin is another hormone that stimulates mammary development of growing gilts and it is also

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essential for mammary development during late gestation (Farmer and Petitclerc, 2003). Giving injections of recombinant porcine prolactin to gilts for 28 d starting at 75 kg body weight doubled the amount of mammary parenchyma at the end of the treatment period (Farmer and Palin, 2005). Creating a state of hyperprolactinemia with a pharmacological agent in late-pregnant gilts led to greater differentiation of mammary epithelial cells and to a 21% increase in milk yield the following lactation (VanKlompenberg et al., 2013). The plant extract silymarin (from *Silybum marianum,* generally known as milk thistle) is known for its hyperprolactinemic properties. Yet, even though feeding silymarin to late-pregnant gilts increased circulating prolactin concentrations by 51.8% 4 d after the onset of treatment, this increase was transient and not important enough to have beneficial effects on mammary development (Farmer et al., 2014a).

Increasing circulating concentrations of the growth factor IGF-1 (insulin-like growth factor-1) in gilts from days 90 to 110 of gestation stimulated their mammary development both in terms of parenchymal tissue mass and composition (Farmer and Langendijk, 2019). This increase was achieved by injecting porcine recombinant somatotropin but there may be feed additives that could be used for such means. Studies are currently ongoing in that area.

Nutrition and mammary development

Growing gilts are generally fed ad libitum, however, the very fast growth rate of current genetic lines and the high incidence of leg problems leading to lameness entices producers to reduce feed intake in certain periods of growth. Restricting feed intake of growing gilts by 20% (Farmer et al., 2004) or 26% (Sorensen et al., 2002b) from 90 d of age until puberty was shown in early studies to significantly reduce mammary development. Timing of the feed restriction is crucial because when done earlier (from 28 d to 90 d of age) it had no impact on mammary development, whereas when done from 90 d until 5 ½ mo of age it led to significant decreases in mammary tissue mass, mammary DNA and mammary RNA (Sorensen et al., 2006). In a more recent study, sow milk yield was not altered following a 10% or 20% feed restriction, or a 25% dietary fibre addition (diluting dietary energy by 5%) from 90 d of age to breeding (Gregory et al., 2023). This absence of effect may be due to the greater feed intake of control gilts in that recent study compared with the older studies. Such a difference in feed intake was likely brought about by genetic selection for faster growing pigs, and it appeared that feed intake of growing gilts can be reduced to 2.7 kg/day (but not 2.1 kg/d) without detrimental effects on their future milk yield.

Energy and protein intakes

During the growing-finishing period (from 90 d of age until puberty), reducing dietary crude protein from 18.7% to 14.4% did not affect mammary development. Neither amount of parenchymal tissue nor composition of mammary parenchyma were altered (Farmer et al., 2004). This suggests that total feed intake is more important than protein intake to ensure proper mammary development of growing gilts. In pregnant gilts, increasing dietary energy from 5.76 to 10.5 Mcal ME/d from day 75 of gestation until the end of gestation decreased mammary parenchymal weight, and total parenchymal DNA, RNA and protein (Weldon et al., 1991). On the other hand, increasing protein intake (330 vs. 216 g CP/d) had no effect on any of the measured variables of mammary development (Weldon et al., 1991). This absence of effect of protein intake was later corroborated by Kusina et al. (1999a) who showed that lysine intakes of 4, 8 or 16 g/d from days 25 to 105 of gestation did not alter mammary parenchymal tissue mass or composition at the end of gestation. However, the 4 and 8 g/d treatments failed to support maximal milk yield in the subsequent lactation (Kusina et al., 1999b).

In a recent study, feeding 40% more lysine than current recommendations (20.6 g/d instead of 14.7 g/d) to sows from day 90 of gestation until farrowing, increased piglet weight gain in the following lactation (Che et al., 2019). One possible explanation for this positive outcome was enhanced mammary development due to greater intake of amino acids. When a similar 40% increase in lysine intake (from 18.6 to 26.0 g/d) was done from days 90 to 110 of gestation, and gilts were then euthanized to obtain mammary tissue, an effect on mammary development was evident. Gilts fed 26.0 g/d of SID lysine had 44% more mammary parenchymal tissue than gilts fed 18.6 g/d (Farmer et al., 2022). These data indicate that the use of a two-phase feeding strategy for pregnant gilts, whereby dietary lysine is increased as of day 90, could benefit potential milk yield in the subsequent lactation.

Energy source

The impact of feeding flaxseed on mammary development of gilts was investigated (Farmer et al., 2007), both because of its high content of polyunsaturated fatty acids (PUFA) and its high concentration of secoisolariciresinol diglycoside. The latter is a precursor for lignin formation, which could be beneficial for mammary development due to its estrogenic activities (Adlercreutz et al., 1987). Dietary supplementation with 10% flaxseed from 88 until 212 d of age led to expected changes in circulating fatty acid concentrations but had no beneficial effects on mammary development in pubertal gilts. However, when diets were supplemented with 10% flaxseed from day 63 of gestation until the end of lactation, it tended to increase mammary parenchymal mass of the female offspring at puberty and increased parenchymal protein content (Farmer and Palin, 2008). This was a first demonstration of such an *in utero* effect in pigs. Howard (1995) also looked at the effect of providing supplemental PUFA using soybean oil in late pregnancy. Gilts were fed a corn-soybean diet that was supplemented or not with 5% soybean oil from days 75 to 105 of gestation. Neither parenchymal tissue weight nor composition were altered by treatment.

Body condition and mammary development

The first demonstration that body condition can affect mammary development in pigs was provided by Head and Williams (1991). Body composition of gilts was altered by manipulating protein and energy intakes during gestation to create two groups of animals. Obese (36 mm backfat) and leaner gilts (24 mm backfat) had similar weights of mammary tissue at the end of gestation but there was a threefold reduction in mammary DNA concentration in obese gilts. The body conditions used in this last study do not reflect what is currently seen in pig herds. A study was therefore carried out to investigate the potential effect of more representative body conditions on mammary development in late gestation. Gilts of similar body weights at mating were fed different amounts of feed throughout gestation to achieve three levels of backfat thickness on day 109 of gestation, namely, 12-15 (lean), 17-19 (medium) and 21-26 (fat) mm. Mammary parenchymal tissue mass was significantly reduced in lean gilts, being 1059, 1370 and 1444 g for lean, medium and fat gilts, respectively (Farmer et al., 2016a). Therefore, within this new range of body conditions, being too thin (12-15 mm backfat) at the end of gestation was detrimental for mammary development whereas showing medium (17-19 mm) or fat (21-26 mm) body conditions had no negative impact.

Interestingly, results were different when body conditions of late-pregnant gilts varied because backfat thickness already differed at mating and differences were maintained throughout gestation. When gilts of three ranges of backfat thicknesses at mating (lean: 12-15, medium: 17-19, and fat: 21-26 mm) were fed varying feeding levels in order to maintain these backfat thicknesses until the end of gestation, mammary parenchymal tissue mass was not affected by treatment (Farmer et al., 2016b). These studies emphasize the importance of nutrition during gestation for mammary development and demonstrate that underfeeding should be avoided to ensure maximal amount of parenchymal tissue mass. This was corroborated in a comparative study where relations between backfat thickness and mammary development were investigated in late-pregnant gilts (Farmer et al., 2017). Care into avoiding thin gilts also has the added advantage of positively influencing sow longevity (Ocepek et al., 2016).

Overall, current findings show that feeding management of gilts can affect their mammary development, hence potential milk yield. There are two periods during which rapid mammary accretion takes place before lactation starts and these are crucial because they are when nutrition can be effectively used to alter mammary development. They are from 90 d of age to puberty and from 90 d of gestation to farrowing.

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