Vitamin D3 and its metabolites in sow fertility and performance

The number of piglets born alive, litter size at birth, and the number of weaned piglets per sow per year are reproductive traits with great economic impact on the profitability of pig production. Achieving high farrowing rates throughout the sow's life, along with litter uniformity, are great challenges in high prolific sows.

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Increasing litter size generally results in a reduced piglet uniformity, which causes more competition between litter mates. Differences in body weight among piglets generally increase until weaning. Therefore, uniformity at birth is important.

Even though litter size has markedly increased during the last decade, the number of piglets weaned per sow per year did not show the same trend, due to increased embryonic and piglet mortality.

This has different reasons:

- It can be related to insufficient uterine capacity, which might lead to embryonic mortality or intrauterine growth retardation.
- It can also be a result of the farrowing process, which is longer for large litters.

A prolonged farrowing process increases the risk of asphyxia of the piglets and delays access to colostrum resulting in lower piglet vitality.

This can be reduced by supporting muscle contractions of the sow during farrowing (uterus, pelvic muscle) by providing sufficient calcium.

Another important parameter to achieve optimal production performance is the number of litters per sow per year.

Sows must be inseminated at the first oestrus after weaning. Success is measured by a low rate of sows returning to oestrus.

For successful insemination, the physiological condition of the sow needs to be in a state to:

- Facilitate fertilisation of the mature egg.
- Prepare the uterus for embryo implantation.
- Maintain pregnancy after successful fertilisation.

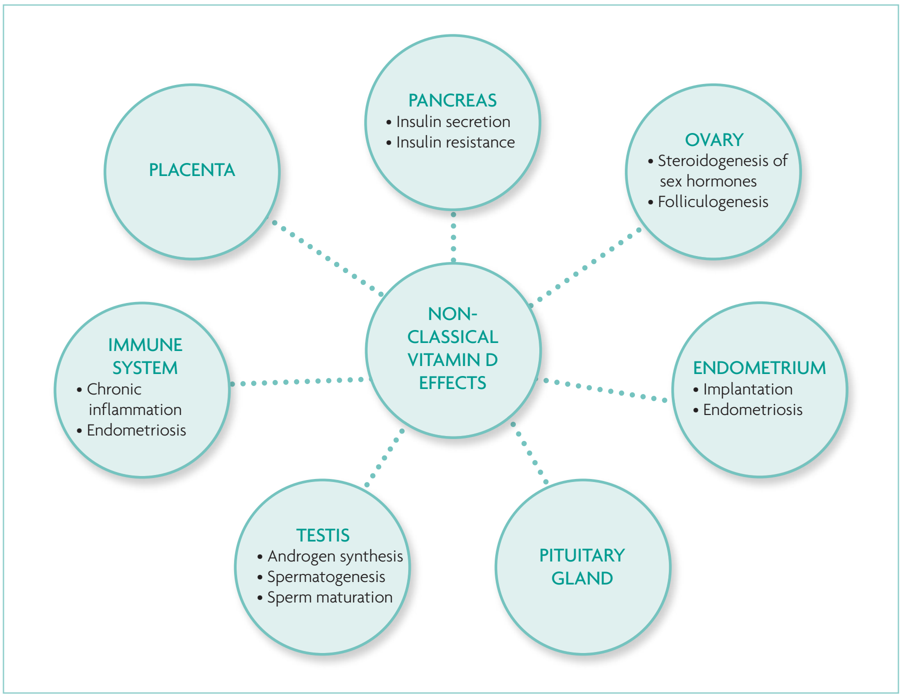

Fig. 1. Effects of $1,25(OH)_2D_3$ on various tissues related to fertility (Lerchbaum et al, 2012).

A high rate of sows returning to oestrus disrupts the smooth running and the financial status of a sow farm.

It is important to minimise the rate of return to oestrus through good management, proper sow nutrition, control of body weight loss during lactation and insemination practice.

Vitamin D3 and its metabolites have a direct effect on fertility

In pig nutrition, little is known about the vitamin D3 requirements for reproduction. However, it is known that various reproductive organs in male and female pigs contain vitamin D3 receptors (VDR) and are therefore influenced by 1,25-dihydroxycholecalciferol ($1,25(OH)_2D_3$), the metabolically active form of vitamin D3.

The organs and tissues that are shown in Fig. 1 are all important to increase the chances of successful insemination and pregnancy, and thus in reducing sows returning to oestrus.

Vitamin D3 metabolism

To become active, vitamin D3 needs to undergo a two-step conversion. The first step happens in the liver and the second in the kidney to deliver the bioactive form $1,25(OH)_2D_3$. Beside the conversion in the kidney, which provides the circulating $1,25(OH)_2D_3$, some tissues and cell types are also able to locally produce $1,25(OH)_2D_3$. $1,25(OH)_2D_3$ interacts with the VDR to exert its biological functions.

The functions of vitamin D3 can basically be divided into:

- Maintenance of Ca homeostasis in the body by upregulating Ca absorption from the gut and Ca exchange in bones.
- Fertility, immunity, muscle growth and function. Research has shown that the VDR is present in many different tissues. It is currently known that >200 genes are affected by $1,25(OH)_2D_3$. In addition, $1,25(OH)_2D_3$ influences signalling cascades in different cells.

It has been observed that $1,25(OH)_2D_3$ is

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important for ovulation, implantation, placentation and in immune modulation during pregnancy. Furthermore, vitamin D_3(-metabolites) play a role in the maternal-conceptus crosstalk and the maintenance of the pregnancy. The latter can also be mediated by immunomodulatory functions of $1,25(OH)_2D_3$.

- **Ovulation and fertilisation**

In ovarian tissue, $1,25(OH)_2D_3$ stimulates the secretion of sexual hormones like estradiol. Together with the role of calcium in follicular development and ovulation, $1,25(OH)_2D_3$ stimulates oocyte activation to prepare the maturing egg for fertilisation.

- **Implantation**

There are strong indications that $1,25(OH)_2D_3$ increases uterine weight and induces the preparation of the uterus to be ready for pregnancy, thus supporting a successful implantation of the blastocyst (early embryonic state).

- **Placentation**

The placenta is formed during gestation, allowing nutrients to be transferred from the mother to the foetus. The placenta expresses VDR at early stages of pregnancy. Current data suggests an important role for vitamin D_3 in placental physiology and the modulation of the antimicrobial and anti-inflammatory immune activity.

As $1,25(OH)_2D_3$ does not readily cross the placenta, the placenta and mostly the foetal kidney express the enzyme 1α-hydroxylase that converts $25(OH)D_3$ to $1,25(OH)_2D_3$ in foetal tissues, which contributes to foetal circulating levels of $1,25(OH)_2D_3$.

Supplementation of a natural vitamin D_3 metabolite

A simple way to support the vitamin D_3 metabolism on top of the usual vitamin D_3 supplementation is to provide a source of $1,25(OH)_2D_3$. There are some specific plants such as waxy-leaf nightshade (Solanum glaucophyllum) that naturally produce $1,25(OH)_2D_3$ in a glycosidic form.

The glycosides are cleaved in the gut by the intestinal microflora and free $1,25(OH)_2D_3$ gradually becomes available for absorption, ensuring a continuous effect and a high safety margin. It was demonstrated that plant-based $1,25(OH)_2D_3$ from Solanum glaucophyllum is safe up to 20x the recommended dose.

A trial was performed with the objective to evaluate the effect of Solanum glaucophyllum (Panbonis) supplementation on the performance of sows from eight different pig farms. There were an average of 795 DanBred sows per farm and the reproductive performance was recorded during half a year. Panbonis was supplemented in gestating and lactating sow diets at 100g/t on top of the normal commercial feed from January to June. The comparison with the unsupplemented control was started in April, when all sows had Panbonis supplemented diets during at least a full gestation period. Data recorded from April-June of the previous year served as the control.

Results indicate that sows had a higher number of piglets born alive with Panbonis. On average, sows fed Panbonis in gestation and lactation diets produced 0.9 extra weaned piglets per sow/year and 0.7 additional pigs of 30kg of body weight per sow/year with an FCR significantly reduced.

Additionally, it was shown in a different trial that milk composition and milkability were improved by Panbonis. ■

References are available from the authors on request