Research article

Developmental programming of production and reproduction in dairy cows

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Home messages:

- Prenatal factors can play a critical role in the developmental programming of production and reproduction in dairy cows.
- Maternal parity can affect milk production and the reproductive performance of the offspring.
- Maternal exposure to heat stress during gestation can affect milk production and reproductive performance of the offspring.

Keywords: Developmental programming, Milk production, Reproductive performance, Ovarian reserve, Dairy cows

Introduction:

The concept of developmental programming, which refers to the effect of environmental factors during fetal and/or neonatal life on the normal physical and physiological function of an individual during adulthood, was initially popularized by Dr. David Barker (Barker, 2004). Afterwards, numerous studies demonstrated the role of developmental processes in the health and disease of various organs and bodily systems in humans, particularly in metabolic and cardiovascular conditions, over the recent decades (Padmanabhan et al. 2016). Furthermore, the impact of prenatal factors has been detected on the development of reproductive organs and ovarian reserve (Yao et al. 2021). In this context, the importance of developmental factors in livestock has also been the primary focus of some studies over the recent years and a number of prenatal factors have been identified to be associated with reproductive performance and markers of ovarian reserves, including concentration of anti-Müllerian hormone (AMH) and antral follicle count (AFC), in cattle (Akbarinejad et al. 2017, 2018, 2019, 2020; Tenley et al. 2019; Succu et al. 2020; Bafandeh et al. 2023; Makiabadi et al. 2023). The focus of this review is to summarize data partitioning to the effect of maternal parity and maternal exposure to heat stress during gestation on the developmental programming of production and reproduction in dairy cows.

Maternal parity:

Maternal parity is one of the factors which has been recognized to influence fetal programming in cattle (Akbarinejad et al. 2018; Tenley et al. 2019; Succu et al. 2020; Wathes, 2022; Bafabdeh et al. 2023). To begin with, nulliparous and primiparous dams have been observed to give birth to lighter calves as compared to multiparous dams, and this effect has been partly attributed to the fact that nulliparous and to some extent primiparous cows are still growing and partitioning part of their nutritional intake to their own requirements for growth (Akbarinejad et al. 2018; Wathes, 2022). In addition, offspring born to multiparous dams have been reported to be more fertile compared with offspring born to nulliparous and primiparous dams (Akbarinejad et al. 2018). With respect to biomarkers of ovarian reserves, Akbarinejad et al. (2018) found that the concentration of AMH was greater in offspring born to multiparous dams than those born to nulliparous and primiparous dams in Holstein cows. Tenley et al. (2019), moreover, observed that Angus heifers with older dams had a greater number of primordial follicles and AFC than those with younger dams. Succu et al. (2020) also indicated that AMH concentration and AFC were greater in heifers born to primiparous dams than those born to nulliparous dams, but AMH concentration and AFC in heifers born to multiparous dams were not different from those in heifers born to nulliparous and primiparous dams in their research. More recently, Bafandeh et al. (2023) reported that nulliparous and young multiparous dams gave birth to the lightest and heaviest calves, respectively, and the calves born to primiparous and old multiparous dams were in-between in this regard. The milk production of offspring constantly declined with the increase in maternal parity, which could have resulted from the improvement in genetic merits of herds by intensive genetic selection for increment in milk yield over various generations (Bafandeh et al. 2023). The greatest reproductive performance was found in the offspring of old multiparous dams, and this phenomenon could partly be attributed to their lower milk production and higher concentration of AMH (Bafandeh et al. 2023).

Maternal exposure to heat stress during gestation:

Maternal exposure to heat stress is another prenatal factor recognized to influence the production, reproduction and markers of ovarian reserves (Monteiro et al. 2016; Akbarinejad et al. 2017; Succu et al. 2020). In this context, Monteiro et al. (2016) reported that heifers whose dams were exposed to heat stress during the last 6 weeks of pregnancy, as compared with heifers whose dams were cooled during the same period of pregnancy, had more services per pregnancy at day 30 following insemination, were less probable to reach first lactation and produced less milk up to 35 weeks of their first lactation period. Further, Akbarinejad et al. (2017) found that maternal exposure to heat stress during the first, second and third trimesters of gestation led to diminished reproductive performance in offspring and exposure of dams to heat stress during the second and third trimesters of gestation culminated in lower concentration of AMH in the resultant offspring. More recently, Succu et al. (2020) evaluated AMH, AFC and fertility in heifers born to dams having conceived in summer, which were exposed to heat stress during the first trimester of pregnancy, and in winter, which were exposed to heat stress during the third trimester of pregnancy, and indicated that summer-conceived offspring had lower AMH and AFC than winter-conceived offspring, yet age at first insemination, pregnancy and parturition as well as services per conception were comparable between these two groups. More recently, Makiabadi et al. (2023) found that the late stage of gestation was the critical period for the negative influence of maternal exposure to heat stress on the birth weight of offspring. Additionally, they showed that exposure of dams to heat stress during the early to mid-stage of gestation, particularly the first month after conception, could decrease milk production in the offspring (Makiabadi et al. 2023). Furthermore, the early stage of gestation was recognized as the critical period for the negative effect of in utero heat stress on the ovarian reserves of offspring (Makiabadi et al. 2023). Nevertheless, a distinct temporal pattern for the negative effect of parental heat stress on reproductive variables was not found in the current study (Makiabadi et al. 2023).

Conclusion:

Cows with greater longevity could be valuable resources to improve fertility in dairy herds, even though the potential of their offspring for milk production may be lower than the offspring of younger cows. In this sense, given that there are usually few numbers of these cows in dairy herds (De Vries and Marcondes, 2020), and they might suffer from degenerative changes of the uterus and other parts of the reproductive tract, which hinder their own pregnancy, these cows could serve as donors in programs of embryo transfer so as to propagate the number of cows with greater genetic merits for fertility in dairy farms. Indeed, low fertility and short life span of cows, high rate of culling and the corresponding costs are serious concerns of the dairy industry worldwide, and this strategy may help improve fertility in herds with reproductive issues. Herein, it should be mentioned that the applicability of this strategy depends on the economic disciplines of the herd and whether the primary priority of the herd is fertility and longevity or milk production. The results of this research showed the offspring of these dams had inferior milk production in spite of their superior reproductive performance. This strategy, therefore, could not be an appropriate approach for herds with the primary focus on increasing milk production.

The critical window for the negative influence of prenatal heat stress on developmental programming varied among different organs and systems. With regard to developmental programming of productive performance, the first month of gestation appeared to be the most sensitive stage to adverse effects of in utero heat stress. Previous studies suggested the application of cooling strategies during the first week post-conception in order to improve the pregnancy rate after insemination because as the pregnancy advances beyond 7 days, the negative effect of heat stress on embryonic survival dwindles (Hansen, 2009). Yet it seems that extension of the intensive cooling up until one month after insemination might help the offspring achieve their potential for milk production. With respect to developmental programming of reproductive performance, however, the results were not as conclusive as they were for milk production. Perhaps, one reason for this phenomenon could be the fact that multiple factors, including the quantity of milk production itself, can influence the success of reproduction and these factors which can impact fertility do not necessarily have the same temporal pattern of developmental programming during fetal period, and in turn, they may have different windows of sensitivity to in utero heat stress. As a result, the entire period of gestation might be critical for the developmental programming of the reproductive performance of offspring. Yet the mechanism(s) whereby in utero heat stress exerts its negative effect on the fertility of offspring might be different during various stages of pregnancy.

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