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Invited review: Heat stress effects during late gestation on dry cows and their calves

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ABSTRACT

In dairy cattle, late gestation is a critical period for fetal growth and physiological transition into the next lactation. Environmental factors, such as temperature and light, exert dramatic effects on the production, health, and well-being of animals during this period and after parturition. The aim of this review was to introduce effects of heat stress during late gestation on dairy cattle, and discuss the biological mechanisms that underlie the observed production and health responses in the dam and her fetus. Relative to cooled cows, cows that are heat stressed during late gestation have impaired mammary growth before parturition and decreased milk production in the subsequent lactation. In response to higher milk yield, cows cooled prepartum undergo a series of homeorhetic adaptations in early lactation to meet higher demand for milk synthesis compared with heat-stressed cows, but no direct effect of environmental heat stress on metabolism exists during the dry period. Prepartum cooling improves immune status of transition cows and evidence suggests that altered prolactin signaling in immune cells mediates the effects of heat stress on immune function. Late-gestation heat stress compromises placental development, which results in fetal hypoxia, malnutrition, and eventually fetal growth retardation. Maternal heat stress may also have carryover effects on the postnatal growth of offspring, but direct evidence is still lacking. Emerging evidence suggests that offspring from prepartum heat-stressed cows have compromised passive immunity and impaired cell-mediated immune function compared with those from cooled cows.
Key words: heat stress, late gestation, lactation, fetus

INTRODUCTION

Late gestation is a critical period in the production cycle of food animals. In dairy cattle, for example, the fetus grows at the fastest rate and accumulates approximately 60% of its birth weight during the last 2 mo of gestation (Bauman and Currie, 1980). The dry period or nonlactating interval before parturition in dairy cows is also of importance, as extensive mammary gland growth and cell turnover occur before parturition and influence future milk production (Capuco et al., 1997; Sorensen et al., 2006). In the absence of a dry period, dairy cattle produce significantly less milk in the next lactation (Bachman and Schairer, 2003; Grummer and Rastani, 2004). Moreover, the transition period from late gestation to early lactation is characterized by immune dysfunction (Mallard et al., 1998), negative energy balance (Goff and Horst, 1997; Drackley, 1999), and increased incidence of health and metabolic disorders (Goff and Horst, 1997; Mallard et al., 1998). Given the physiological challenges cows experience under the best of conditions, management of external factors are critical to additional negative influences on the cow during this period.

Environmental factors, such as light and temperature, exert dramatic effects on the cow during the dry period (Dahl and Petitclerc, 2003; Collier et al., 2006; Bernabucci et al., 2010) and thus can be manipulated and used as management tools to improve animal production, immune competence, metabolism, and overall well-being. The effects of photoperiod during the dry period have been reviewed recently (Dahl et al., 2012); thus, this review will focus on effects of heat stress during late gestation on dairy cattle.

HEAT STRESS EFFECTS DURING LATE GESTATION IN COWS

One well-recognized environmental factor that limits production of dairy cattle is elevated ambient temperature. It is well described in lactating dairy cows that thermal stress is related to decreased feed intake, altered metabolism, compromised lactational performance, increased disease incidence, and impaired reproductive performance (Fuquay, 1981; Kadzere, et al., 2002; West, 2003). Compared with lactating cows, dry cows generate less metabolic heat (West, 2003) and have a higher upper critical temperature (Hahn, 1999). But environmental thermal stress still influences the

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performance of cows during late gestation and negative effects carry over to the next lactation. For example, Figure 1 summarizes the monthly milk production from 2007 to 2010 and the typical ambient temperature within a year at Okeechobee, Florida, the top-ranked county for dairy cows in the state. From May to August, milk production in Florida declines as air temperatures (and relative humidity) rise. This phenomenon can be explained by decreased lactational performance due to chronic thermal stress in lactating dairy cows. However, it is also clear that the lowest or highest monthly milk production in Florida does not coincide with the highest (July and August) or lowest ambient temperature (January). Instead, cows in Florida produce the lowest amount of milk in September and the most milk in March. Thus, a 2-mo lag between milk yield and air temperature appears consistently in the annual pattern. This observation suggests that, in addition to a direct effect on milk production during lactation, the thermal status of dry cows has a carryover effect on performance in the subsequent lactation. Indeed, cows exposed to heat stress during the dry period have decreased milk production in the next lactation (Wolfenson et al., 1988; do Amaral et al., 2009). In addition to the residual effects on milk production in the next lactation, thermal status of dry cows also affects immune and metabolic function of cows and alters fetal growth and postnatal calf development. Studies comparing the response of heat-stressed and thermoneutral dry cows under controlled environmental chamber conditions are lacking. Thus, the knowledge discussed in current review is extracted from experiments that compare heat-stressed cows and cows under heat stress abatement during the dry period. It is important to mention that cooling applied in those studies does not completely eliminate heat strain on the cows but it is a realistic way to study the biology of heat stress and a feasible intervention under normal management conditions. However, if available, studies conducted in tightly control environmental conditions at other stages of the lactation cycle of cows, or in other species will be specifically indicated in the current review.

Late-Gestation Heat Stress Effects on Lactation Performance and Mammary Function

As summarized in Figure 2, late-gestation heat stress has a profound effect on milk production in the subsequent lactation compared with milk production of cows that are cooled. Under normal management, complete abatement of heat stress during the summer is unlikely; however, a decrease in body temperature by active cooling during the dry period results in significant improvement in milk production in the next lactation. Indeed, regression analysis of published data from heat-stressed and cooled cows during late gestation reveals a significant correlation between afternoon rectal temperature in late gestation and milk production in the next lactation (Figure 3). Other factors also affect the effect of prepartum cooling on the milk production in the next lactation. Depending on the method and duration of prepartum cooling, dry dairy cattle have different milk yield responses in the next lactation. With limited cooling, such as shade (Collier et al., 1982b) or short-interval soaking in the middle of the day (Avendaño-Reyes et al., 2006), only modest increases in subsequent milk production were observed and the difference was not statistically significant. However, when more extensive cooling (shade, fans, and sprinklers) was provided to dry cows, milk production in the subsequent lactation was significantly improved (Wolfenson et al., 1988; do Amaral et al., 2011). The duration of prepartum cooling during environmental heat stress may also affect future lactational performance. Moore et al. (1992) studied the relationship between climatological data and milk production of cows that calved from July to September in Mississippi using regression analysis and found that exposure to heat stress during last 30 d of gestation was too short to elicit any effect on milk production in the next lactation. However, in a controlled study (Urdaz et al., 2006), actively cooled cows in the last 28 d of gestation had improved milk yield in the first 60 d of lactation compared with noncooled cows.

Therefore, little question exists that heat stress during the dry period decreases subsequent milk production. Additionally, the lactation curves of prepartum cooled cows are consistently higher than those of heat-stressed cows in the next lactation (do Amaral et al., 2009).

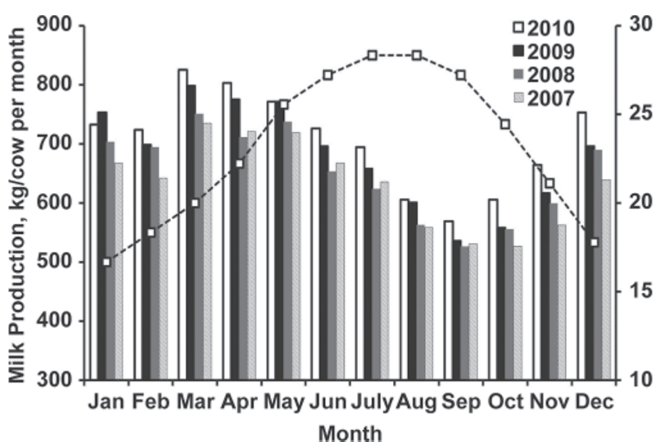

Figure 1. Monthly milk production in Florida (bar graph; data from Florida livestock, dairy, and poultry summary, 2010; USDA-NASS. 2011) and typical air temperature within a year in Okeechobee, Florida (line graph; data from http://www.weather.com/weather/wxclimatology/monthly/34972).