Reducing the Impact of Heat Stress on Dry Cows and Fresh Cows

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Introduction

Summer heat compromises a lactating cow's performance from different perspectives, such as decreased feed intake, altered metabolism, reduced milk production, impaired reproductive performance and increased disease incidence (Fuquay, 1981; Kadzere et al., 2002; West, 2003). Compared with lactating cows, dry cows produce less metabolic heat (West, 2003) and have a higher upper critical temperature (Hahn; 1997). Thus, heat stress management for dry cow is often overlooked, but substantially influences the cow's future performance. To avoid the negative impact of heat stress on dry cows, appropriate cooling should be applied during the entire dry period. Nutritional supplementation during dry and transition period may also be utilized to improve cow performance during the summer but more research need to be conducted in this area. This paper will focus on the impact of prepartum heat stress on performance during the dry period and the subsequent lactation performance. Treatments discussed in this manuscript were applied during the prepartum period only; after calving, all animals were managed in the same manner with cooling.

Prepartum Heat Stress Effects on Feed Intake and Metabolic Adaptation

Heat stress decreases dry matter intake (**DMI**) of dry cows, but to a lesser extent compared with lactating cows. Relative to cooled cows (**CL**), the non-cooled heat-stressed (**HS**) cows have ~15% decrease in DMI during the dry period (Table 1). As a result, they gain less body weight during the prepartum period partly due to the slower fetal growth (Tao et al., 2011). In addition to the reduced feed intake, heat stress alters the cows' metabolic responses. Recent studies suggest that, even a 30% decrease in DMI, heat-stressed cows have blunted adipose tissue mobilization in early (Lamp et al., 2015) and mid-lactation (Wheelock et al., 2010), and enhanced the whole body glucose utilization in mid-lactation (Wheelock et al., 2010) compared with pair-fed cows under thermo neutral condition. However, during the dry period, heat stress affects the cow's metabolism differently. Heat stress has no impact on the cow's adipose tissue mobilization (Lamp et al., 2015) and glucose clearance after a glucose tolerance test (Tao et al., 2012) during the dry period, presumably because of a lower energy demand for fetal growth compared with lactating. In contrast, relative to those under thermal neutrality with similar intake, the heat-stressed dry cows have more pronounced protein mobilization perhaps to support the fast fetal growth during late gestation (Lamp et al., 2015). Prepartum cooling improves feed intake before calving, and it has no carryover

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effects on cow's DMI in early lactation (first 2-3 weeks postpartum) but increases the concentrations of nonesterified fatty acids (**NEFA**) and beta hydroxybutyric acid (**BHBA**) in blood (do Amaral et al., 2009; Tao et al., 2012) and peripheral tissue insulin resistance (Tao et al., 2012) to support the higher milk production. However, on the other hand, as the lactation advances, prepartum cooled cows will consume more feed relative to non-cooled prepartum cows in order to meet the nutrient demand for higher milk production.

Prepartum Heat Stress Effects on Mammary Development and Subsequent Milk Production

Late gestation heat stress has profound effects on milk production in the subsequent lactation. When active cooling (such as soakers and fans) is applied during the entire dry period, compared with HS cows, prepartum CL cows produce ~ 4 kg/d (12%) more milk in the next lactation (Table 2). Additionally, this increase in milk yield by cooling dry cows persists through the entire lactation, indicating an improved mammary function rather than the metabolically related galactopoietic effect (such as bovine somatotropin). On the other hand, when cows are cooled only during the close-up period, the increase in following milk yield is still apparent but to a lesser extent. From limited studies, relative to HS, the close-up CL cows have ~ 2.2 kg/d (5.8%) increase in milk yield during the next lactation (Table 2). This positive effect of prepartum cooling on subsequent lactational performance can be attributed to the improved mammary growth during the late gestation. The dry period is characterized by extensive mammary involution during the first couple weeks after dry off and the following mammary growth (Capuco et al., 1997), and heat stress influences both cellular processes. Indeed, HS cows have lower mammary cell proliferation ~2-3 weeks before calving compared with CL (Tao et al., 2011), which is partly due to a lower placental production of estrone-sulfate (Collier et al., 1982). Although often overlooked, mammary involution, including apoptosis and autophagy, during the early dry period may be important in modulating subsequent mammary growth and milk production. A recent study conducted at the University of Florida showed that the mammary gland of the HS cow has reduced autophagy during the early dry period compared with CL (Ramirez-Lee et al., 2015). The result from this study suggest that heat stress blunts mammary involution after dry-off, which perhaps negatively affects the subsequent period of mammary growth and milk production; however, more research is needed to evaluate this hypothesis. Relative to multiparous cows, prepartum cooling of nulliparous heifers has received less attention and only two publications have compared the lactational responses from applying heat abatement during summer to heifers (~1 month before calving). In general, prepartum cooling of nulliparous have shown less consistent benefits to subsequent lactation (Table 2), although, more controlled studies are warranted.

Prepartum Heat Stress Effects on Immune Function and Disease Incidence

Immune dysfunction is well characterized during the transition period and partly responsible for the increased disease incidence in early lactation. Various studies indicate that prepartum heat stress exaggerate the dysfunctional immune system during late gestation and early lactation. Compared with prepartum CL cows, HS cows have higher blood count of leukocyte but smaller proportion of CD4+ T lymphocyte (Gomes et al., 2014). Also, immune cells of HS cows have weaker proliferative response and TNFα production when stimulated by a mitogen in vitro (do Amaral et al., 2010), suggesting a compromised cell-mediated immunity. The humoral immune response is also altered by heat stress during the transition period. After challenged with ovalbumin, the HS cows have less IgG production during the dry period (do Amaral et al., 2011) and early lactation (Gomes et al., 2014) compared with CL cows. In addition, the nonspecific innate immunity is impaired by prepartum heat stress as evidenced by the lower ability of neutrophils from HS cows to phagocytize and destroy pathogens relative to those from CL cows in early lactation (do Amaral et al., 2011).

With the compromised immunity during the transition period, it is expected that the prepartum HS cows would experience a higher disease incidence during early lactation. When comparing dry period seasonal effects on the occurrence of health disorders in the first 60 DIM in Florida, Thompson et al. (2012) found that cows dried off in the hot months (June, July and August) had increased incidences of mastitis, respiratory problems and retained fetal membranes in early lactation compared with those dried in cool months (December, January and February). Although confounded with the seasonal effects during early lactation and photoperiod during the dry period, these data may suggest the negative impact of prepartum heat stress on future disease susceptibility. In contrast, in the controlled experiments, studies (Santos et al., 2014; Thompson et al., 2014a) suggest that prepartum CL cows have similar incidence of diseases in early lactation but a slight increase in the incidence of metritis. The increase in metritis incidence is unexpected considering the improved measures of immunity of CL compared with HS cows during the transition period, but deserves further investigation.

Prepartum Cooling and Body Temperature

Evaporative cooling is by far the most efficient approach to minimize the negative impact of heat stress during the dry period on dairy cows. Active cooling including sprinklers and fans is widely used to abate heat from lactating cows, but not often applied in dry cow barns, especially during the for far-off period. However, successful decrease in the dry cow's body temperature by cooling results in a significant return on investment. In a free stall setting, implementation of active cooling effectively reduces dry cow's body temperature by ~ 0.4 °C (0.7 °F; 102.7 vs. 102.0 °F, Table 3) and respiration rate by 21 breath/min (72 vs. 51 breath/min), which are much smaller compared with the difference (~ 1.0 °C = 1.6 °F) of body temperature between non-cooled and cooled lactating cows, but enough to elicit the strong positive influence on subsequent lactation milk production.

Feeding Betaine-Containing Molasses to Transition Dairy Cows During Late Summer

Nutritional supplementation of heat-stressed lactating cows has been widely studied, but the related research for dry cows under heat stress is somewhat limited, especially during the far-off period. Betaine, also called tri-methyl glycine, is a natural compound either produced endogenously by choline oxidation (Zeisel, 2013) or found in feed ingredients, such as sugar beet solubles, which has the most abundant betaine content (Eklund et al., 2005). Betaine has two main functions in an animal's body. It is a powerful osmolyte to reduce dehydration and stabilize protein when a cell is under stress condition. Additionally, it serves as a methyl donor when fed to animals and is a key component in one carbon metabolism (Eklund et al., 2005; Bertolo and McBreairty, 2013). Supplementing 100 g/d rumen-unprotected betaine increased milk production in mid-lactation cows (Peterson et al., 2012) under a thermal-neutral condition. However, its role in transition dairy cows, especially during summer, remains unknown.

To investigate the potential impact of supplementation of betaine containing diet during the dry and transition period, a study (Monteiro et al., 2015) was conducted at the University of Georgia-Tifton Campus during late summer 2014. In early September, cows were randomly assigned to betaine or control groups either at dry off (n = 10/treatment) or 24 d before calving (n = 8/treatment) based on their previous mature equivalent milk yield. Cows were fed common diets supplemented with either a 28% CP molasses-based liquid supplement made from sugar cane or a 28% CP liquid supplement made of molasses from sugar cane (67%) and condensed beet solubles containing ~30% betaine (33%) for control and betaine cows, respectively, until 8 weeks postpartum. The liquid supplement was fed at a rate of 1.1 and 1.4 kg DM/d for pre and postpartum cows, respectively. Dry cows were housed in the same free-stall barn without supplemental cooling and lactating cows were cooled by misters and fans and milked thrice daily. Feed intake was recorded daily during the entire experimental period and plasma samples were harvested weekly from a subset of animals. For those enrolled at close-up, no treatment effects were observed for milk production and composition, feed intake, and blood metabolites during pre- and postpartum periods. In contrast, cows that received betaine diets starting at 56 d before the expected calving date had improved milk production (44.2 vs. 41.5 kg/d), milk fat concentration (4.78 vs. 4.34%), and 3.5% FCM (50.0 vs. 47.0 kg/d) during the first 8 weeks postpartum compared with control cows; however, no change in DMI was detected during both pre- and postpartum periods. As a consequence, betaine-fed cows had increased plasma concentrations of NEFA and BHBA during the early lactation. However, the experimental period for dry cows in this study spanned from Sep to Nov, 2014, and the environmental condition (average temperature and humidity index or THI < 68) during this period was not suitable to conclude the potential impact of betaine containing diet during the summer time. Thus, supplementation of betaine containing molasses during dry and lactating period improves performance during early lactation, but the potential impacts of feeding betaine to transition cows during hot summer need to be further studied.

Conclusions

It is important to recognize the negative impacts of dry period heat stress on cow performance, immunity and metabolism, and the significance of prepartum cooling in transition cow management. A special attention should also be given during the early dry period to ensure a smooth transition from lactating to non-lactating stage. In addition to cooling, other strategies, such as nutritional supplements, should be explored to future overcome the negative impacts of prepartum heat stress.

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Table 1. Summary of studies on effects of prepartum heat stress (HS) and cooling (CL) on dry matter intake (DMI)

	DMI, kg/d			
Period	HS	CL	Difference (kg or %)	Reference
Dry	11.3	12.2	0.9 or 8%	Adin et al., 2009
Dry	12.0	14.1	2.1 or 18%	do Amaral et al., 2009
Dry	8.4	9.8	1.4 or 17%	do Amaral et al., 2011
Dry	8.9	10.6	1.7 or 19%	Tao et al., 2011
Dry	10.2	11.1	0.9 or 9%	Tao et al., 2012
Dry	10.4	12.3	1.9 or18%	Thompson et al., 2014b
Average	10.2	11.7	1.5 or 15%	

Table 2. Summary of studies on effects of late gestation heat stress (HS) or cooling (CL) on milk production

	Milk production			
Period	HS	CL	Difference (kg or %)	Reference
Dry	37.2	40.7	3.5 or 9%	Wolfenson et al., 1988
Dry	25.4	28.1	2.7 or 11%	Avendaño-Reyes et al., 2006
Dry	39.3	41.4	2.1 or 5%	Adin et al., 2009
Dry	26.2	33.7	7.5 or 29%	do Amaral et al., 2009
Dry	32.2	34.5	2.3 or 7%	do Amaral et al., 2011
Dry	28.9	33.9	5.0 or 17%	Tao et al., 2011
Dry	43.2	45.6	2.4 or 6%	Thompson et al., 2011
Dry	27.7	34.0	6.3 or 23%	Tao et al., 2012
Dry	30.2	33.8	3.6 or 12%	Thompson et al., 2014b
Average	32.3	36.2	3.9 or 12%	
Close-up	38.7	40.1	1.4 or 4%	Urdaz et al., 2006
Close-up	32.1	33.5	1.4 or 4%	Adapted from Wang et al.,2010
Close-up	36.9	38.7	1.8 or 5%	Adapted from Gomes et al.,2013
Close-up	40.5	44.6	4.1 or 10%	Karimi et al., 2015
Average	37.0	39.2	2.2 or 6%	
Late gest.	23.3	25.6	2.3 or 10%	Adapted from Wang et al.,2010
Late gest.	25.1	25.5	0.4 or 2%	Adapted from Gomes et al.,2013
Average	24.2	25.6	1.4 or 6%	

Table 3. Summary of studies on effects of prepartum heat stress (HS) and cooling (CL) on rectal temperature (RT, °C) and respiration rate (RR, breaths/min)

	RT			RR			
Measurement	HS	CL	Diff.	HS	CL	Diff.	Reference
1400h	39.2	38.8	0.4	---	---	---	Wolfenson et al., 1988
1400h	39.3	39.0	0.3	74	67	7	Avendaño-Reyes et al., 2006
1500h	38.8	38.5	0.3	57	45	12	Adin et al., 2009
1430h	39.2	38.8	0.4	---	---	---	do Amaral et al., 2009
1430h	39.4	39.0	0.4	78	56	22	do Amaral et al., 2011
1430h	39.4	39.0	0.4	78	46	32	Tao et al., 2011
1430h	39.9	39.4	0.5	78	45	33	Thompson et al., 2014b
1430h	39.3	39.0	0.3	69	48	21	Tao et al., 2012
Average	39.3	38.9	0.4	72	51	21	

SESSION NOTES