ARIZONA AND NEW MEXICO DAIRY NEWSLETTER

COOPERATIVE EXTENSION
The University of Arizona
New Mexico State University

November 2007

THIS MONTH'S ARTICLE:

The Impact of Heat Stress on Pre- and Postpartum Periods that Impact Reproductive Performance: Causes, Consequences and Solutions

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Reprinted from the 2007 Dairy Cattle Reproduction Conference
Denver, CO
November 2 - 3, 2007

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Dairy Calf & Heifer Seminar

February 6, 2008

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Hilton Garden Inn
Phoenix Airport

The Impact of Heat Stress on Pre- and Postpartum Periods that Impact Reproductive Performance: Causes, Consequences and Solutions

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INTRODUCTION

Worldwide, heat stress (**HS**) negatively impacts all cattle, including dairy cows. The annual economic impact of HS on American animal agriculture has been estimated at $2 billion, with the dairy industry alone accounting for $900 million of this loss. Several factors may further increase the dairy industry's vulnerability to HS related problems. First, HS will increase in magnitude as global warming continues to occur (Hulme, 1997). Secondly, the world's population growth is fastest in tropical and subtropical regions (Roush, 1994), and it is logical to assume that a greater proportion of the world's food animals will live in these hotter climates. Lastly, the dairy industry has continued to focus on selecting for production traits which, in turn, may increase the dairy cow's susceptibility to HS.

Heat stress does not have to last for months to have profound negative impacts, but can occur in days, even in temperate climates. For example, during a heat wave in 2006, California dairy producers lost an estimated $1 billion in milk and animals. In 1999, during a severe heat wave, Nebraska producers lost more than $20 million in cattle deaths and performances losses. Between July 11 and 12, 1995, a combination of heat and humidity caused the deaths of over 3,700 cattle in a thirteen county area of western Iowa (Collier and Zimbelman, 2007). This economic loss is a direct result from HS reducing such things as milk production, reproductive performance, milk quality, heifer growth, and increasing cow and calf mortalities and health-care costs.

Heat stress occurs over a wide combination of solar radiation levels, ambient temperatures, and relative humidity. This is further aggravated by metabolic heat production (generated by the cow herself). Generally, it is assumed that a cow becomes more sensitive to HS as milk production increases due to elevated metabolic heat production. Selectively breeding dairy cows for increased milk yield has increased the cows' susceptibility to HS thereby compromising summer production and reproduction. In addition, selecting for milk yield reduces the thermoregulatory range of the dairy cow (Berman et al., 1985) and magnifies the seasonal depression in fertility caused by HS (Al-Katanani et al., 1999). Consequently, strategies should be initiated to lessen the severity of HS on reproduction in both the dry and lactating dairy cow.

CAUSES AND CONSEQUENCES OF PREPARTUM HEAT STRESS ON REPRODUCTION

Traditionally, dry pregnant cows are provided little protection from HS because they are not lactating and it is incorrectly assumed they are less prone to HS. Additional stressors are imposed during this period due to abrupt physiological, nutritional, and environmental changes. These changes can increase the cows' susceptibility to HS and have a critical influence on postpartum cow health, milk production and reproduction. The dry period is particularly crucial since it involves mammary gland involution and subsequent development, rapid fetal growth, and induction of lactation. Heat stress during this time period can affect endocrine responses that may increase fetal abortions, shorten the gestation length, lower calf birth weight, and reduce follicle and oocyte maturation associated with the postpartum reproductive cycle. Prepartum HS may decrease thyroid hormones and placental estrogen levels, while increasing non-esterified fatty acid concentrations in blood; all of which can alter growth of the udder and placenta, nutrients delivered to the unborn calf, and subsequent milk production (Collier et al., 1982a). Collier et al. (1982b) reported that dairy cows experiencing HS during late gestation had calves with lower birth weights and produced less milk than cows not exposed to HS. This was associated with a reduction in circulating thyroxine, prolactin, growth hormone, and glucocorticoid concentrations. Other researchers have suggested that cooling dry cows may increase birth weights, improve colostrum quality, decrease calving related health disorders and increase subsequent milk production. (Avendano-Reyes et al., 2006; Wolfenson et al., 1988). Feed intake and metabolic rate are adversely affected by HS during the immediate prepartum period, and this may adversely affect the ability of the dairy cow to ramp up production postpartum.

Few studies have investigated effects of cooling dry cows on subsequent fertility postpartum. Florida researchers demonstrated that postpartum cows with shade during the dry period had increased blood levels of prostaglandin F metabolite, ovarian volume, diameter of the largest follicle and corpus luteum, and percentage of ovaries with a corpus luteum compared to cows with no shade (Lewis et al., 1984). However, days to first ovulation and estrus, days open, and services per conception were unaltered by prepartum HS. Another study also concluded that there was no difference in services per conception, days open, or days to first estrus for dry cows either with prepartum shade or no shade (Collier et al., 1982b).

Many studies reporting a negative effect of HS on subsequent fertility were published over 20 years ago when the average milk yield was much less than it is today. In addition, our cooling systems and knowledge of proper cooling (when, where, and to what extent) to reduce HS has increased substantially. More recently, Avendano-Reyes et al. (2006) concluded that cooling dry cows with shades, fans, and water spray vs. cows with only shade decreased services per conception and days open, and increased milk yield during the postpartum period. In 2006, Urdaz et al. observed that dry cows with feed line sprinklers, fans and shade compared to cows with only feed line sprinklers had an increased 60 d milk yield with no difference in body condition score (**BCS**) changes, incidence of postparturient disorders, or serum nonesterified fatty acid concentrations. In this study, reproductive parameters were not measured; however, cooling dry cows with shades, fans, and sprinklers compared with only sprinklers improved total 60 d milk production by 185.5 lb/cow, and increased estimated annual profits by $2,131/cow (based on milk only).

The problem of *carry over* effects from summer HS to fall fertility may be accentuated due to HS during the dry period. It is well known that a period of approximately 2 months is needed for low autumn fertility to be restored to the level prevailing in the winter. It takes approximately 40-50 d for antral follicles to develop into large dominant follicles and ovulate (Roth et al., 2001). If HS occurs during this time period both the follicle and oocyte inside the follicle become damaged. Once ovulation occurs, the damaged oocyte has reduced chances of fertilizing and developing into a viable embryo. Cooling dry cows may reduce HS effects on the antral follicle destined to ovulate 40-50 d later, which coincides with the start of most breeding periods, and possibly increases first service conception rates.

SOLUTIONS FOR REDUCING NEGATIVE EFFECTS OF PREPARTUM HEAT STRESS

The greatest opportunity to reduce the negative effects of HS during both the pre- and postpartum periods is through cooling. As mentioned above, cooling dry cows with feed line sprinklers, fans and shades proved to be beneficial for reducing services per conception, days open, and increasing milk yield with a significant return on investment compared to cows with either shades alone or feed line sprinklers alone (Avendano-Reyes et al., 2006; Urdaz et al., 2006).

In addition to proper cooling, changing management decisions may help reduce the severity of HS in areas of intermittent heat waves. For instance, at dry-off, many cows receive vaccines that can cause a fever spike which, when coupled with HS, can cause body temperature to rise above normal (101.3-102.8 ºF). In the 2006 California heat wave, many cows died (not only in the fresh pen as expected) within the first few days of dry off (personal unpublished observations). Possibly, during severe heat waves it would prove beneficial to delay vaccinations at dry-off if the dry pen does not contain adequate cooling.

CAUSES AND CONSEQUENCES OF POSTPARTUM HEAT STRESS ON REPRODUCTION

As mentioned earlier, genetic selection for milk production has increased metabolic heat output per cow. This has considerably increased the lactating dairy cows' susceptibility to HS. In addition, the first several days to weeks following calving, the cow is vulnerable to infectious diseases and metabolic disorders. These stress factors, coupled with physiological, nutritional, and environmental changes occurring at calving, can reduce reproductive performance.

Energy Balance

Many experiments indicate HS reduces both feed intake and milk yield, and this decreased feed intake has been recognized as one of the main reasons for reduced milk yield. Recently, a study conducted at the University of Arizona demonstrated Holstein cows subjected to HS in mid-lactation had an immediate reduction (approx. 11 lb/d) in dry matter intake (**DMI**) with the decrease reaching nadir at approximately d 4 and remaining stable thereafter (Figure 1).

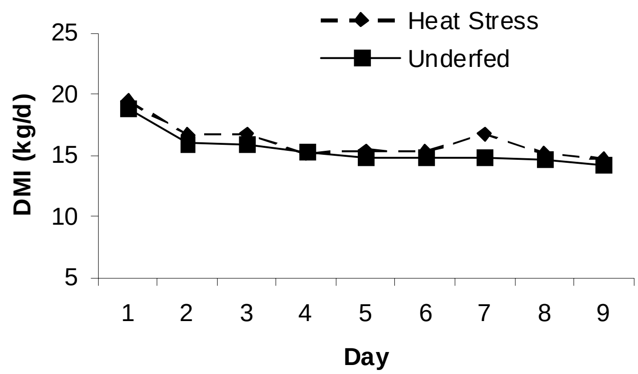

Figure 1. Effects of heat stress and pair-feeding thermal neutral lactating Holstein cows on dry matter intake. Adapted from Rhoads et al., 2007

Milk yield was reduced by approximately 31 lb/d with production steadily declining for the first 7 d and then reaching a plateau (Figure 2). A second group of cows housed under thermal neutral conditions and pair-fed to the same level as the HS cows also had a reduction in milk yield of approximately 13 lb/d, but milk production reached its nadir at d 2 and remained relatively stable thereafter (Rhoads et al., 2007; Figures 2). This indicates the reduction in DMI can only account for approximately 40-50 % of the decrease in production when cows are heat stressed, and approximately 50-60 % can be explained by other HS induced changes to the endocrine/metabolic systems regulating maintenance costs, mammary cell function, and nutrient partitioning.

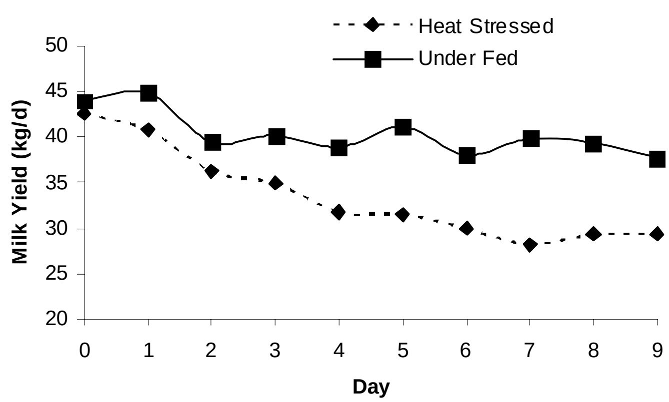

Figure 2. Effects of heat stress and pair-feeding thermal neutral conditions on milk yield in lactating Holstein cows. Adapted from Rhoads et al., 2007.

The changes in the endocrine system not only affect milk yield, but impact reproductive performance. The lactating dairy cow first directs nutrients to growth (2 to 3 year old cows), maintenance, and lactation before supplying the reproductive organ with nutrients for ovarian function and embryo growth. In a similar experiment as the one described above, HS induced negative energy balance (approx. 4-5 Mcal/d) and the same effect occurred in the under-fed group. (Wheelock et al., 2006; Figure 3). Several studies indicate that lactating dairy cows losing greater than 0.5 units BCS within 70 d postpartum had longer calving to first detected estrus and (or) ovulation interval (Butler, 2000; Beam and Butler, 1999). Garnsworthy and Webb (1999) reported the lowest conception rates in cows that lost more than 1.5 BCS units between calving and insemination. In addition, Butler (2000) reported that conception rates range between 17 and 38 % when BCS decreases 1 unit or more, between 25 and 53 % if the loss is between 0.5 and 1 unit, and is > 60 % if cows do not lose more than 0.5 units or gain weight.

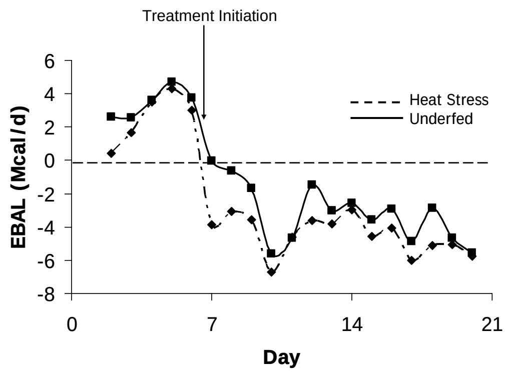

Figure 3. Effects of heat stress and pair-feeding thermal neutral conditions on calculated net energy balance in lactating Holstein cows. Adapted from Wheelock et al., 2006.

Estrous Activity and Hormone Function

Heat stress reduces the length and intensity of estrus. For example, in summer, motor activity and other manifestations of estrus are reduced (Hansen and Arechiga, 1999) and incidence of anestrous and silent ovulations are increased (Gwazdauskas et al., 1981). Nebel et al. (1997) reported that Holsteins in estrus during the summer had 4.5 mounts/estrus vs. 8.6 mounts for those in winter. On a commercial dairy in Florida, undetected estrous events were estimated at 76 to 82 % during June through September compared to 44 to 65 % during October through May (Thatcher and Collier, 1986). Possible reasons for reduced estrous expression are from suppressed endocrine hormones such as luteinizing hormone and estradiol, important for follicle growth and triggering estrous behavior (Rensis and Scaramuzzi, 2003). However, it is unclear as to the effects HS has on endocrine function. To further exacerbate the problem, another possible reason for the reduction in expression of estrus is from reduction in physical activity, as a response to limit heat production.

Follicular Development and Dominance

Heat stress impairs follicle selection and increases the length of follicular waves; thus reducing the quality of oocytes and modulating follicular steroidogenesis (Roth et al., 2001). Summer HS has been shown to increase the number of subordinate follicles, while reducing the degree of dominance of the dominant follicle, and decreasing inhibin and estrogen levels (Wolfenson et al., 1995; Wilson et al., 1998). The HS-induced increase in duration of follicular dominance has been associated with a reduced fertility in beef heifers (Mihm et al., 1994). Ryan and Boland (1991) observed an increase in twinning rates in dairy cows during summer vs. winter. Summer HS reduces follicular dominance allowing more than one dominant follicle to develop explaining the increased twinning seen in summer months. As explained earlier, the follicle destined to ovulate emerges 40-50 d prior to ovulation. Therefore, HS occurring at anytime during this period can compromise follicular growth and steroidogenic capacity. In addition, either due to direct actions of elevated temperature or alterations of follicular function, the oocyte has potential to be compromised.

Oocytes and Fertilization

During summer, HS reduces pregnancy and conception rates, which can carry-over into the fall months (Wolfenson et al., 2000). Oocytes obtained from dairy cows during the summer HS period had reduced developmental competence *in vitro* (Rocha et al., 1998). Rutledge et al. (1999) also reported a decrease in the number of Holstein oocytes that developed to the blastocyst stage during July and August compared to cooler months. In both of these studies, fertilization rate was not affected by season, but the lower development following fertilization during summer was indicative of oocyte damage. When superovulated donor heifers were exposed to HS for 16 h beginning at the onset of estrus, there was no effect on fertilization rate. However, there were a reduced number of normal embryos recovered on d 7 after estrus (Putney et al., 1988a). This illustrates that a brief HS can still affect oocyte competence within the preovulatory follicle. In addition, exposure of cultured oocytes to elevated temperatures during maturation decreased cleavage rate and the proportion of oocytes that became blastocysts (Edwards and Hansen, 1997).

Early Developing Embryos

Heat stress can also affect the early developing embryo. When HS was applied from d 1 to 7 after estrus there was a reduction in embryo quality and stage from embryos flushed from the reproductive tract on d 7 after estrus (Putney et al., 1989). In addition, embryos collected from superovulated donor cows in summer months were less able to develop in culture than embryos collected from superovulated cows during fall, winter, and spring months (Monty and Racowsky, 1987). Drost et al. (1999) demonstrated that transfer of *in vivo* produced embryos from cows in thermoneutral conditions increased pregnancy rate in HS recipient cows compared to that of HS cows subjected to AI. Embryos appear to have developmental stages in which they are more susceptible to the deleterious effects of HS as shown *in vitro*. *In vitro* HS at the 2- to 4-cell stage caused a larger reduction in embryo cell number than HS at the morula stage (Paula-Lopes and Hansen, 2002). An earlier study also showed that HS caused a greater reduction in embryo development when applied at the 2-cell stage than the morula stage (Edwards and Hansen, 1997) or at d 3 following fertilization than at d 4 (Ju et al., 1999).

Latter Stages of Embryo Development

Not only can HS affect the oocyte and early embryo, it can also reduce embryo growth up to d 17, which is a critical time point for embryo production of interferon-tau. Adequate amounts of interferon-tau are critical for reducing pulsatile secretion of prostaglandin $F_{2\alpha}$; thus blocking CL regression and maintaining pregnancy. Biggers et al. (1987) indicated that HS reduced weights of embryos recovered on d 17 from beef cows. This reduction in embryo size was associated with reduced interferon-tau available to inhibit prostaglandin $F_{2\alpha}$ pulsatile secretion, which causes CL regression. Putney et al. (1988b) incubated embryos and endometrial explants obtained on d 17 of pregnancy at thermoneutral (39 °C, 24 h) or HS (39 °C, 6 h; 43 °C, 18 h) temperatures. The HS conditions decreased protein synthesis and secretion of interferon-tau by 71 % in embryos; however, endometrial secretion of prostaglandin $F_{2\alpha}$ and embryo secretion of prostaglandin E_2 increased in response to HS by 72 %. Wolfenson et al. (1993) observed that secretion of prostaglandin $F_{2\alpha}$ was increased *in vivo* when heifers were exposed to high ambient temperatures. Collectively these studies demonstrate that both the embryo and the uterine environment can be disrupted due to HS inhibiting the embryo's ability to secrete interferon-tau (signal to block CL regression) and maintain pregnancy and (or) manipulating production of important proteins from the uterine lining.

A reduction in the amount of growth factors due to an increased level of milk production and (or) decline in nutritional status due to HS, may reduce the amount of necessary embryotrophic growth factors. Secretion of embryotrophic growth factors into the uterine lumen may be controlled by nutritional status of the cow since embryo transfer pregnancy rates were reduced in recipients with low BCS (Mapletoft et al., 1986). Plasma concentrations of insulin, insulin-like growth factor-1, and glucose are decreased in summer compared to winter months; most likely due to low DMI and increased negative energy balance. This reduction in important growth factors and nutrients for reproduction hampers the embryo's ability for normal growth and production of interferon-tau. Bilby et al. (2006) reported that supplementing lactating dairy cows with recombinant growth hormone at the time of AI and 11 d later increased growth factors, conceptus lengths, interferon-tau production, and pregnancy rates in lactating dairy cows compared to cows without bST supplementation. Possibly increasing availability of important growth factors during HS may improve embryo growth and survival.

Uterine Environment

The reproductive organ can be compromised during HS providing a suboptimal uterine environment for fertilization, embryo growth, and implantation. Heat stress causes redistribution of blood flow from the visceral organs to the periphery resulting in decreased availability of nutrients and hormones, ultimately compromising uterine function. The increase in uterine blood flow caused by injection of estradiol-17β was reduced in cows not exposed to shade in summer compared with those receiving shade (Thatcher and Collier, 1986). Also, as mentioned earlier, prostaglandin production is increased and embryo growth and interferon-tau produced by the embryo are reduced due to heat shock exposure.

Immune Function

The effect HS has on immune function has not been evaluated in detail, especially in agriculturally important species. However, the incidence of some health problems certainly appears to increase during the summer months as increased rates of mastitis, retained placenta, metritis, and ketosis have been reported (Collier et al., 1982a). Several epidemiological studies reveal a reduction in fertility for cows affected by disorders of the reproductive tract, mammary gland, feet, and metabolic diseases such as ketosis, milk fever, and left-displaced abomasums. Retained placenta, metritis, and ovarian cysts are risk factors for conception. Cows had lower conception rates of 14 % with retained placenta, 15 % with metritis and 21 % for those with ovarian cysts (Grohn and Rajala-Schultz, 2000). Mastitis also significantly reduces fertility in lactating dairy cattle (Hansen et al., 2004). In addition, general *stress* enhances glucocorticoid levels, which reduces neutrophil function. Therefore, HS induced increases in cortisol levels may partially explain the negative effects HS has on health.

An additional cause of compromised immune function may be negative energy balance (**NEBAL**). NEBAL in early lactation is associated with a variety of health and reproductive issues (Drackley, 1999). The HS cow also enters NEBAL and thus (probably not surprising) experiences many of the same health problems and reduced reproductive parameters as *transitioning* cows. The calculated NEBAL during HS (approx. -5 Mcal/d) is not as severe as in early lactation (i.e. approx. d 7:approx. -15 Mcal/d), but it almost certainly is not a coincidence that both situations have increased rates of similar disorders.

CURRENT SOLUTIONS FOR REDUCING NEGATIVE EFFECTS OF POSTPARTUM HEAT STRESS

Current and past research has resulted in dramatic improvements in dairy cow management in hot environments. Two primary strategies are to minimize heat gain by reducing solar heat load and maximize heat loss by reducing air temperature around the animal or increasing evaporative heat loss directly from animals. Below are several strategies to potentially help reduce the negative impacts of HS on reproduction in lactating dairy cows.

Cow Comfort and Cooling

Identify where HS is occurring on the dairy facility by identifying *hot spots* is key to implementing the proper cooling or management strategy to eliminate these hot spots. Temperature devices have been used to monitor core body temperatures in cows by attaching a temperature monitor to a blank continuous intravaginal drug release (**CIDR®,** Pfizer Animal Health, New York, NY) device for practical on-farm use. The device is inserted into the cow's vagina measuring core body temperature every minute for up to 6 d. This allows monitoring of the cow's body temperature and identification of where the cow is experiencing HS.

Providing enough shade and cow cooling is vital for proper cow comfort. There should be at least 38 to 45 sq ft of shade/mature dairy cow to reduce solar radiation. Spray and fan systems should be used in the holding pen, over feeding areas, over the feeding areas in some freestall barns, and under shades on drylot dairies in arid climates. Exit lane cooling is an inexpensive way to cool cows as they leave the parlor. Providing enough access to water during HS is critical. Water needs increase 1.2 to 2 times during HS conditions. Lactating cattle require 35 to 45 gal of water/d. Access to clean water troughs when cows leave the parlor, at two locations in drylot housing, and at every crossover between feeding and resting areas in freestall housing is recommended. Keep in mind milk is approximately 90 % water; therefore water intake is vital for milk production and to maintain thermal homeostasis.

The holding pen is often an area of elevated HS conditions. Cows are crowded into a confined area for several minutes to hours. Cows should not spend more than 60 to 90 min in the holding area. In addition, provide shade, fans and sprinklers in the holding pen. An Arizona study showed a 3.5 ºF drop in body temperature and a 1.76 lb increase in milk/cow/day) when cows where cooled in the holding pen with fans and sprinklers (Wiersma and Armstrong, 1983). Cattle handling such as sorting, adding cattle to the herd, vet checks, and lock-up times should be completed in the early morning. The cow's warmest body temperature occurs between 6 p.m. and midnight. Reducing lock-up times can also reduce HS, especially in facilities with little or no cooling above head locks.

Nutritional Modifications

The nutritional impacts on reproduction are well documented. Reducing metabolic diseases will further enhance our ability to improve reproduction during the summer months. Some simple feeding and nutritional strategies can be implemented to reduce the negative effects of summer HS on reproduction.

Feed Times and Push-up

The maintenance requirement of lactating dairy cows increases substantially as environmental temperature increases. When possible, increase the number of feedings and (or) push-up times in order to increase DMI. In addition, feed during cooler parts of the day and increase moisture content in the ration from an average of 35 to 40 % to an average of 45 to 50 %.

Rumen Health

The HS cow is prone to rumen acidosis and many of the lasting effects of warm weather (laminitis, low milk fats, etc.) can probably be traced back to a low rumen pH during the summer months. As a consequence, care should be taken when feeding *hot* rations during the summer. Obviously fiber quality is important all the time, but it is paramount during the summer as it has some buffering capacity and stimulates saliva production. Furthermore, dietary HCO_3^- may be a valuable tool to maintain a healthy rumen pH.

Fat

Feeding dietary fat (rumen inert/rumen bypass) remains an effective strategy of providing extra energy during a time of negative energy balance. Compared to starch and fiber, fat has a much lower heat increment in the rumen; thus provides energy without a negative thermal side effect.

Glucose

We have previously demonstrated that maximizing rumen production of glucose precursors (i.e. propionate) may be an effective strategy to maintain production during HS (Wheelock et al., 2006). However, due to the rumen health issue, increasing grains should be conducted with care. A safe and effective method of maximizing rumen propionate production is with monensin (approved for lactating dairy cattle in 2004). In addition, monensin may assist in stabilizing rumen pH during stress situations. Proplyene glycol is fed typically in early lactation but may also be an effective method of increasing propionate production during HS. With the increasing demand for biofuels and subsequent supply of glycerol, it will be of interest to evaluate glycerol's efficacy and safety in ruminant diets during the summer months.

DCAD

Having a negative dietary cation-anion difference (**DCAD**) during the dry period and a positive DCAD during lactation is a good strategy to maintain health and maximize production. It appears that keeping the DCAD at a healthy lactating level (approx.+20 to +30 meq/100 g DM) remains a good strategy during the warm summer months (Wildman et al., 2007).

Minerals

Unlike humans, cattle utilize potassium (K^+) as their primary osmotic regulator of water secretion from their sweat glands. As a consequence, K+ requirements are increased (1.4 to 1.6 % of DM) during the summer and this should be adjusted for in the diet. In addition, dietary levels of sodium (Na^+) and magnesium (Mg^+) should be increased, as they compete with K^+ for intestinal absorption.

Reproduction Protocol Changes

Estrous detection

Improve estrous detection during summer by increasing the time and number of visual observations for estrus. Tail head paint is the most popular estrous detection aid and should be applied in adequate amounts with easily observable colors. This should be coupled with visual estrous detection. There are several technologies available to improve identification of estrus. The HeatWatch® (CowChips, LLC, Denver, CO) system records the number and times mounted during estrus through the use of a radiotelemetric pressure transducer placed on the tail head to transmit information to a computer. Pedometers can also be used to measure the increased amount of activity associated with estrus.

Bull Breeding

Heat stress significantly impairs bull fertility in the summer. Semen quality decreases when bulls are continually exposed to ambient temperatures of 86 ºF for 5 wk or 100 ºF for 2 wk despite no apparent effect on libido. Heat stress decreases sperm concentration, lowers sperm motility, and increases percentage of morphologically abnormal sperm in an ejaculate. After a period of HS, semen quality does not return to normal for approximately 2 mo because of the length of the spermatic cycle, adding to the carry-over effect of HS on reproduction. It may prove beneficial to periodically check semen quality. In addition, many dairy producers use A.I. for a set number of breedings (i.e. 3 A.I. breedings) and then move the cow to the bull pen; however it may be advantageous to continue to A.I. for several more breedings to by-pass the deleterious effects described above during and immediately after periods of HS.

Timed AI programs

The use of fixed timed AI (**TAI**) to avoid the deleterious effects of reduced estrous detection has been well documented. Utilizing some type of TAI (i.e. Ovsynch, Cosynch72, or Ovsynch56), either coupled with or without estrous detection, can improve fertility during the summer. A study conducted in Florida during the summer months observed an increase in pregnancy rate at 120 d postpartum (27 % vs. 16.5 %, respectively), and a decrease in days open, interval from calving to first breeding, and services per conception in cows TAI versus inseminated at estrus (De la Sota et al., 1998).

GnRH Injection at Estrus

Another possible way to improve fertility in the summer is through an injection of GnRH at estrus. Ullah et al. (1996) injected GnRH into lactating dairy cows at detected estrus during late summer in Mississippi and increased conception rate from 18 % to 29 %. In agreement with this study, lactating dairy cows were injected with GnRH at the first signs of standing estrus during the summer and autumn months in Israel, and conception rates increased compared to untreated controls (41 % to 56 %, respectively; Kaim et al., 2003).

POSSIBLE FUTURE SOLUTIONS FOR IMPROVING REPRODUCTION DURING HEAT STRESS

Embryo Transfer

Embryo transfer can significantly improve pregnancy rates during the summer months (Drost et al., 1999). Embryo transfers can by-pass the period (i.e. before d 7) in which the embryo is more susceptible to HS.

Nevertheless, embryo transfer is not a widely adopted technique. Improvements need to be made in the *in vitro* embryo production techniques, embryo freezing, timed embryo transfer, and lowering cost of commercially available embryos before this becomes a feasible solution.

Genetic Manipulation

Selecting particular genes that control traits related to thermotolerance make it possible to select for thermal resistance without inadvertently selecting against milk yield (Hansen and Arechiga, 1999). Traits that could possibly be selected for include coat color, genes controlling hair length, and genes controlling heat shock resistance in cells (see review by Hansen and Arechiga, 1999). In addition, genetic modification or altering biochemical properties of the embryo before embryo transfer may be possible to improve thermal resistance and increase summer fertility.

Nutraceuticals

There may be feed additives, which can partially alleviate HS through increased heat dissipation; thereby lowering internal body temperature. In several studies, fungal cultures in the diet decreased body temperatures and respiration rates in hot, but not cool, weather (Huber et al., 1994). A recent experiment in Arizona showed an increase in sweating rates and lower core body temperatures when encapsulated niacin was fed to lactating cows compared to thermal neutral controls (Zimbelman et al., 2007). Feeding unsaturated fatty acids to ewes has been shown to alter lipid composition of oocytes, improving thermotolerance (Zeron et al., 2002). The use of encapsulation techniques to by-pass the rumen, feed additives to improve heat loss, and (or) manipulating cellular biochemical composition may improve reproductive function during the summer months; however, more studies are warranted.

Reevaluation of the Temperature-Humidity Index

The temperature-humidity index (**THI**) is calculated using both ambient temperature and relative humidity. To date, researchers suggest that cows experience HS beginning at a THI of 72. The THI values were categorized into mild, moderate and severe stress levels for cattle by the Livestock Conservation Institute (Armstrong, 1994). Berman (2005) pointed out that the supporting data for these designations are not clear. For example, the index is based on a retrospective analysis of studies carried out at The University of Missouri in the 1950's and early 1960's on a total of 56 cows averaging 34.1 lb of milk/d with a range of 5.9 to 69.9 lb/d. In contrast, average production per cow in the United States is presently over 60 lb/d with many cows producing over 100 lb/d at peak lactation. Current studies are underway at the University of Arizona to re-evaluate the THI index utilizing modern-day high producing dairy cows. Most likely, the new THI interpretations may encourage use of cooling techniques at lower temperatures than currently recommended. The resulting management changes could reduce the negative effects of HS on reproduction.

CONCLUSION

Improved cooling is still the most profitable and effective way to improve both milk production and reproduction during the summer months. Even generally milder climates experience HS or heat waves that dramatically reduce fertility. Dry cows are also susceptible to HS and should be provided some type of cooling to improve subsequent fertility after calving. Postpartum HS can significantly decrease pregnancy rates with impacts lingering well into the fall months. Designing strategies to reduce negative effects of HS on fertility; such as enhanced cooling, ration adjustments, and reproductive protocol changes, will improve dairy farm profitability.

References Upon Request

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HIGH COW REPORT
OCTOBER 2007

MILK

Arizona Owner	Barn#	Age	Milk	New Mexico Owner	Barn #	Age	Milk
* Stotz Dairy	20546	04-04	42,250	* Providence Dairy	111	06-06	39,420
* Stotz Dairy	20063	04-10	37,620	S.A.S. Dairy	7957	04-08	37,611
* Stotz Dairy	21787	03-03	37,600	S.A.S. Dairy	8590	03-10	37,531
* Stotz Dairy	18658	05-01	37,390	* Providence Dairy	860	05-08	36,140
* Stotz Dairy	21963	03-02	37,360	* Providence Dairy	6178	04-09	35,640
* Danzeisen Dairy, LLC	605	04-11	36,760	S.A.S. Dairy	8688	03-08	35,357
* Stotz Dairy	20781	04-02	36,660	* Butterfield Dairy	1610	06-06	35,180
* Stotz Dairy	21781	03-04	36,260	McCatharn Dairy	1396	04-02	35,113
* Stotz Dairy	21712	03-04	36,110	* Providence Dairy	9492	06-09	34,940
* Mike Pylman	20252	03-06	36,110	* Wayne Palla Dairy	30215	03-02	34,940

FAT

* Stotz Dairy	20546	04-04	2,008	* Providence Dairy	111	06-06	1,465
* Mike Pylman	765	04-07	1,523	* Providence Dairy	5991	04-10	1,331
* Stotz Dairy	18619	05-01	1,503	Cross Country Dairy	4546	05-06	1,309
* Stotz Dairy	20701	04-03	1,491	* Providence Dairy	6178	04-09	1,303
* Stotz Dairy	20251	04-08	1,464	Tee Vee Dairy	1535	05-06	1,295
* Stotz Dairy	19904	05-03	1,463	* Vaz Dairy	2745	05-08	1,274
* Mike Pylman	945	04-07	1,414	Flecha Dairy	9689	05-06	1,266
* Mike Pylman	635	04-08	1,412	* Providence Dairy	6998	03-10	1,261
* Stotz Dairy	18182	05-05	1,410	Tee Vee Dairy	374	07-06	1,261
* Mike Pylman	3771	04-09	1,401	* Wayne Palla Dairy	30215	03-02	1,253

PROTEIN

* Stotz Dairy	20546	04-04	1,219	* Goff Dairy	6308	8-06	1,158
* Danzeisen Dairy, LLC.	4465	06-09	1,097	* Goff Dairy	6129	4-03	1,094
* Mike Pylman	20252	03-06	1,089	* Providence Dairy	111	6-06	1,090
* Danzeisen Dairy, LLC.	605	04-11	1,084	Pareo Dairy	5461	4-08	1,043
* Stotz Dairy	18708	05-00	1,074	Tee Vee Dairy	1535	5-06	1,038
* Mike Pylman	3989	04-01	1,074	* Providence Dairy	6998	3-10	1,038
* Stotz Dairy	18658	05-01	1,068	Tee Vee Dairy	1287	5-06	1,035
* Mike Pylman	8967	04-04	1,067	S.A.S. Dairy	6561	6-03	1,030
* Mike Pylman	945	04-07	1,059	S.A.S. Dairy	6670	6-01	1,027
* Stotz Dairy	21787	03-03	1,056	S.A.S. Dairy	8688	3-08	1,027
* Mike Pylman	13449	03-00	1,056				

*all or part of lactation is 3X or 4X milking

ARIZONA - TOP 50% FOR F.C.M.b
OCTOBER 2007

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	RR
* Stotz Dairy West	2,230	27,789	1,019	28,534	36
* Red River Dairy	9,734	26,789	897	26,124	29
* Danzeisen Dairy, Inc.	1,689	25,053	920	25,746	36
* Goldman Dairy	2,364	24,409	853	24,382	36
* Zimmerman Dairy	1,299	24,040	855	24,254	36
* Mike Pylman	7,066	23,853	858	24,222	35
* Stotz Dairy East	1,287	23,787	858	24,194	36
* Arizona Dairy Company	5,576	23,422	844	23,809	29
* Butler Dairy	622	23,733	833	23,765	27
Parker Dairy	4,526	22,399	850	23,464	37
* Shamrock Farms	8,194	23,660	809	23,344	36
Paul Rovey Dairy	287	22,700	834	23,335	36
* Withrow Dairy	5,151	22,862	801	22,870	36
Lunts Dairy	666	21,593	804	22,370	37
* Saddle Mountain	3,059	20,969	768	21,516	36
* DC Dairy, LLC	1,128	21,396	754	21,474	37
* Yettem	3,805	17,753	821	20,985	26
* Cliffs Dairy	309	20,434	740	20,831	36

NEW MEXICO - TOP 50% FOR F.C.M.b
OCTOBER 2007

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	CI
* Desperado	2356	15902	649	17400	13.01
Rocky Top Jersey	1515	15178	675	17509	13.44
* Goff 2	1362	16584	722	18879	13.60
Dutch Valley Farms	3356	16072	746	19047	13.38
Flecha	2426	20224	711	20274	13.84
Breedyk	2794	21884	708	20944	14.14
* Red Roof	1570	21380	740	21245	13.70
Tres Hermanos	392	21218	751	21353	12.80
* Tallmon	589	20810	762	21355	13.00
*Mid Frisian	1541	21468	759	21591	13.91
Cross Country	3742	21624	765	21755	13.26
*Goff	5627	21652	765	21768	13.77
Tee Vee	1022	21272	799	22155	14.29
Stark Everett	3154	21506	794	22175	14.10

* all or part of lactation is 3X or 4X milking
[b] average milk and fat figure may be different from monthly herd summary; figures used are last day/month

ARIZONA AND NEW MEXICO HERD IMPROVEMENT SUMMARY FOR OFFICIAL HERDS TESTED OCTOBER 2007

		ARIZONA	NEW MEXICO
1.	Number of Herds	35	27
2.	Total Cows in Herd	72,885	53,941
3.	Average Herd Size	2,082	1,997
4.	Percent in Milk	86	86
5.	Average Days in Milk	209	199
6.	Average Milk – All Cows Per Day	55.5	61.1
7.	Average Percent Fat – All Cows	3.7	3.6
8.	Total Cows in Milk	62,287	18,239
9.	Average Daily Milk for Milking Cows	65.0	71.0
10.	Average Days in Milk 1st Breeding	85	75
11.	Average Days Open	170	145
12.	Average Calving Interval	14.4	14.0
13.	Percent Somatic Cell – Low	84	88
14.	Percent Somatic Cell – Medium	11	8
15.	Percent Somatic Cell – High	6	4
16.	Average Previous Days Dry	62	62
17.	Percent Cows Leaving Herd	31	34
		STATE AVERAGES	
	Milk	21,959	22,231
	Percent butterfat	3.69	3.63
	Percent protein	2.96	3.09
	Pounds butterfat	813	853
	Pounds protein	656	668

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Dairy Calf & Heifer Association

Profit Seminar

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