**ARIZONA AND NEW MEXICO
DAIRY NEWSLETTER**

**COOPERATIVE EXTENSION
The University of Arizona
New Mexico State University**

APRIL 2007

THIS MONTH'S ARTICLE:

Evaluation of Different Cooling Systems in Lactating Heat Stressed Dairy Cows in a Semi-Arid Environment

R Burgos, LJ Odens, , RJ Collier, LH Baumgard, and MJ VanBaale
The University of Arizona, Tucson, Arizona

Dr. Todd Bilby, Dairy Extension Specialist & Assistant Professor, The University of Arizona

Hello Arizona and New Mexico dairy producers and industry. I am the new Dairy Extension Specialist at the University of Arizona. I joined the University of Arizona Department of Animal Sciences faculty on February 19, 2007. I grew up close to Rosendale, Missouri, on a small cattle ranch in the northwest corner of the state. I began my academic career attending a junior college in Northeastern Oklahoma as a stepping-stone to Oklahoma State University, where I majored in Animal Sciences production and business and minored in agricultural economics for my Bachelor's Degree. My next stop was the University of Arkansas for a Masters of Science degree with an emphasis in reproduction. My studies involved testing the efficiencies of different heat detection technologies, optimizing timing of embryo transfer, and enhancing embryo development in vitro. I also was a teaching assistant for Techniques in Reproduction where we taught students artificial insemination, ultrasonography, palpation and embryo transfer. In addition, I assisted in teaching Cow-Calf Management. It was during my Masters program that my passion for working with the dairy industry escalated. At that time, I was offered the opportunity to obtain my Ph.D. under the advisement of Dr. Bill Thatcher at the University of Florida in the area of reproduction. The focus of my Ph.D. project was examining ways to reduce early embryo loss in the high producing dairy cow. I explored ways in which a pharmaceutical and/or nutraceutical may be used to improve early embryo development subsequently reducing embryo loss. In addition, I worked with optimizing synchronization protocols on large commercial dairies in the Southeast and feeding various fat sources to reduce heat stress effects on the early embryo. As part of my teaching responsibilities, I assisted Dr. Albert DeVries with Dairy Management System Analysis. The major themes of this course included: decision-making process, risk and uncertainty, evaluation of alternative solutions, evaluation of production and financial performance, and identification of factors limiting production and economic performance. After graduating from Florida, I was hired by Monsanto to work in the Central Valley area in California. I managed a sales territory and assisted various producers with improving different facets of management such as reproduction and cow comfort. I am very excited about my new position at the University of Arizona. My appointment is 60% Extension, 30% Research, and 10% Teaching. The focus of my research will be in the field of reproductive physiology investigating ways to improve reproduction during the heat stress months. My primary extension objective will be to provide research-based information that enables dairy clientele to make informed management decisions that will improve farm profitability while being an active and significant contributor to the success of the Department of Animal Sciences. I will also teach an Advanced Dairy Production course to senior and masters level students. Although my expertise is in reproduction, please don't hesitate to use me as a resource for any of your dairy needs. My email address is trbilby@ag.arizona.edu and my cell phone number is 520-609-9393. I look forward to meeting and working with each of you.

Sincerely,

Todd Bilby

Evaluation of Different Cooling Systems in Lactating Heat Stressed Dairy Cows in a Semi-Arid Environment.

R. Burgos, L. J. Odens, R. J. Collier, L. H. Baumgard, and M. J. Vanbaale
The University of Arizona, Department of Animal Sciences, Arizona 85721

Abstract

Two independent trials were conducted from June 3rd to September 30th of 2004 and 2005. In each trial, 400 multiparous and 100 primiparous Holstein cows were randomly assigned to 1 of 2 cooling treatments (Advanced Dairy System fan plus misters – Shade Tracker (ADS-ST) vs. Korral Kool (KK)). In 2004, production did not differ for multiparous cows housed in ADS-ST or KK (41.8 kg/d) pens. However, milk yield for primiparous cows housed under KK conditions tended ($P = 0.10$) to be higher than cows housed under ADS-ST conditions (37.8 vs. 36.7 kg/d). Respiration rates (RR) of multiparous cows cooled with ADS-ST were higher (60.5 vs. 58.3 breaths per min (BPM)); however, RR in primiparous cows did not differ between trts (59.2 BPM). In 2005, milk yield for multiparous (42.2 vs. 38.3 kg/d) and primiparous (35.2 vs. 32.7 kg/d) cows housed in KK were higher ($P < 0.01$) compared to cows housed in ADS-ST pens. In 2005, multiparous (70.9 vs. 59.3 BPM) and primiparous (72.2 vs. 61.3 BPM) cows cooled with ADS-ST had a higher RR. During both trials ADS-ST cooling system used less electricity (526 vs. 723 and 517 vs. 840 kwh/d; 2004 and 2005, respectively) and water (291 vs. 305 and 290 vs. 460 L/d; 2004 and 2005, respectively) than KK coolers. During moderate to severe heat stress conditions, cows housed under KK coolers out performed those housed under ADS-ST fans, but the KK system used more resources than the ADS-ST fans.

Introduction

Hot, semi-arid environments impose thermal stress on dairy cattle when effective environmental temperature exceeds the upper critical temperature of the thermal-neutral zone (Bianca, 1962; Collier et al., 2006). Because the effective temperature is composed of ambient temperature, relative humidity, and solar radiation, a temperature humidity index (THI) or black globe heat index is often used to access the degree of thermal stress for a given environment (Collier and Beede, 1985). The black glove heat index incorporates solar radiation and is most useful when cows do not have shade access, whereas the THI is most commonly used for cows housed under shade. A THI above 72 has adverse effects on production and reproduction in high-producing dairy cows (Bianca, 1962; Sainsbury, 1967; Hahn, 1976). However, the THI has limitations because it reflects the average conditions in the facility and not an individual cows microenvironment. Surface temperature (ST) measured by infrared thermography is a method to assess the actual ambient conditions around the animal as well as metabolic heat production. Total heat accumulation is derived from environmental heat and failure to dissipate the heat increments of metabolism and digestion (Collier and Beede, 1985). Previous ST impact estimates on heat loss indicate that sensible heat loss (conduction, convection, radiation), which require a thermal gradient to operate, are the primary routes of heat loss below 35°C (Berman, 2003). Above 35°C, evaporative cooling becomes the only method for heat dissipation and sweating and panting are the evaporative heat loss mechanisms employed to maintain thermal homeostasis.

Evaporative cooling shade systems provide protection from solar radiation and cool the immediate air surrounding the cow. Evaporative cooling systems have proven beneficial for animal productivity in areas of low humidity and in more humid areas during peak sun hours when humidity is low (Armstrong, 1994; West, 2003). Although these systems require a large investment, they are clearly cost effective in warm semi-arid climates. Two evaporative systems currently available are: spray fans (SF) and Korral Kool (KK) and studies comparing of SF and KK have been conducted previously. Cows housed under both SF or KK systems have greater milk yield than non-cooled cows (Stott et al., 1972; Armstrong et al., 1985, 1986, 1988; Ryan et al., 1992; Correa et al., 1997), but direct SF and KK comparisons indicate variable responses, ranging from no differences between the two, to almost 4 kg/d difference in milk yield (Armstrong et al., 1988, 1993, 1999; Ryan et al., 1992; Correa et al., 1997). In our recent trial, although respiration rates (RR) and surface temperatures (ST) were reduced for cows housed under the KK compared to the SF system, milk yield was similar between the two (Table 1., Collier et al., 2003). However, due to new technologies (Advanced Dairy System fan plus misters-Shade Tracker (ADS-ST) system now follows the shade and continuously adjusts water spray to temperature and humidity changes), a study directly comparing the effects of both cooling systems on milk production, reproductive indices and other heat stress parameters during hot summer months was warranted.

Current study objectives were to evaluate the effects of ADS-ST compared to KK coolers on milk yield, milk composition, body condition score (BCS), body weight (BW), RR, ST, and typical reproduction and animal health parameters of lactating dairy cows on a large commercial dairy over a two year trial.

Material and methods

Animals. Two studies were conducted during two consecutive summers (cooling season) on a commercial dairy near Buckeye, Arizona (33° 24'N, 112° 35'W; 400 m elevation). All procedures involving animals were approved by the University of Arizona Animal Care and Use Committee. From June 3 to September 30, 2004 and 2005 cows were in mild to moderate heat stress (THI = 72- 82) for an average of 17-18 h/d throughout the studies (Fig. 1 A and B). Maximum daily THI was above 73 for 14 out of the 17 wks of the trial and THI was never below 71 for all weeks (Fig. 2). In both trials, 400 multiparous and 100 primiparous Holstein cows, bST-supplemented at 63 DIM ± 3.5 d (Posilac, Monsanto Inc., St. Louis MO) were housed in a dry lot facility (with shade over the feed manger) and randomly assigned to one of two trts, ADS-ST or KK cooling systems. All cows were housed in open dry-lot pens (161.5 m/cow) with shades (14.6 m/cow) in the center of each pen oriented north-south. Shade dimensions were 121.9 m long by 9.1 m wide by 4.0 m high. All animals had ad libitum access to feed and water and a total mixed ration (TMR) balanced to meet or exceed nutrient requirements (NRC, 2001). Cattle in both treatments were fed a diet that was 53.9% dry matter at 0500, 1200 and 2000 h, respectively. The diet comprised of 32, 26, 15, 13, 5, 4, 3, and 2 % barley, alfalfa hay, alfalfa green chop, corn silage, whole cotton seed, vitamin mineral pre-mix, molasses, and a by pass fat derived from calcium salts and palm oil which provided a calculated nutrient composition of 40.5, 27.3, 17.6, 16.6, and 5.8 % NFC, NDF, ADF, CP, fat and a 1.9 NE_L Mcal/kg (calculated as 0.245 x % TDN - 0.12), respectively. One mixed load of feed from the same wagon was split between the 2 pens. The 2 pens were milked back to back 3 times daily at 0400, 1200 and 2000 h and cows from both trts were cooled identically while in the wash and holding pen prior to milking.

Evaporative Cooling Systems. In both trials, 20 oscillating ADS-ST fans and misters located on the eastern edge of the shade structure 6.1 m apart from each other were used to cool cows in the ADS-ST treatment. The ADS-ST fans were programmed and controlled by a computer system that tracked and cooled shaded areas during the day. Air (5,852 cubic m/min @ 1140 rpm) and water (1.0-5.7 L) flow were continuously adjusted based on ambient temperature and humidity. Each fan was 0.91 m in diameter and powered by 1,471 watt motor and oscillated to 270º. Tracking the shade and oscillations were powered by a 368 watt gear motor and the water pump for the misters was a 7,355 watt variable frequency drive pump (Table 2). Temperature and humidity were the major determinants of how much water was pumped through the misters (1.0 to 5.7 L/min) however the size (5-15 microns @ 250 - 1250 psi) of the droplets was always constant. The aforementioned variables were per manufactured recommendations (Advanced Dairy Systems LLC, Chandler, AZ).

In both trials, 17 KK evaporative cooling systems were placed in the center of the shaded structure 6.1 m apart from one another and each cooler was 1.5 m in diameter and powered by a 2,207 watt motor. The water flow to the coolers was controlled by two 3,768 watt water pump motors. Korral Kool systems cools cows by pulling in fresh outside air down through the coolers (1,204 cubic m/min @ 411 rpm) while simultaneously injecting miniscule sized (30-65 microns @ 300 psi) water droplets into the air stream, thus cooling the environment around the cow and increasing water evaporation on the body's surface. Korral Kool systems are also programmed and operated in order to increase cooling as the ambient temperature increases. Settings on this system can be altered either based on the actual ambient environmental temperature or on a maximum limit to cool the ambient temperature one degree above the actual ambient environmental temperature (Table 2). The aforementioned variables were per manufactured recommendations (Korral Kool Inc, Mesa, AZ).

Ambient Temperature (AT), RR, ST, BCS and BW. Throughout both trials, daily and hourly environmental data (Fig. 1 and 2) were obtained from the Arizona Meteorological Network weather station located 1.6 km from the experimental site. Fig. 2 shows the average THI by wk for the experimental periods (06/03/04 to 09/30/04 and 06/03/05 to 09/30/05) and an average THI of the past 7 summers collected over the same time period. Interestingly, the average THI for the past seven years (1998 to 2004) was higher ($P < 0.05$) compared to the THI over the same time period (06/03 to 09/30 2004 and 2005) during both trials reported in this paper. Thus, on average, both studies were conducted under cooler historical conditions for the area.

During the summer of 2005, ST and RR from 40 multiparous and 20 primiparous (20% of the pen total) cows were obtained randomly from 3 zones within each pen every Thursday at 0330 and 1200 h. Respiration rates were measured by counting flank movements over a 10 sec interval and multiplying by 6 to establish breaths/min at a minimum of 1 to a maximum of 10 times/animal throughout both 17 wk studies. Respiration zones in a pen were divided into 3 even areas across the pen, from which an equal number of animals were sampled. During both trials, all ST measurements were acquired with an infrared temperature gun (Raynger®MX™ model RayMX4PU Raytek C, Santa Cruz, CA). During both trials the ST measurement was acquired from the left side of the cow in the thurl region just cranial of the pin bone and temperatures determined from ~1.2 to 1.8 m from the surface of the cow, and in 2005 udder surface temperature (UST) were similarly measured. Cows were weighed and scored for body condition

(Roche et al., 2005) at the onset of the trial and at 28 ± 3.5 d intervals from ~20 multiparous and ~20 primiparous cows/trt.

Milk Yield, Milk Composition, Dry Matter Intake (DMI), Reproduction and Herd Health. During both trials, daily milk weights were measured electronically by Boumatic computer software (Madison, WI) for each cow throughout the 17 wk study. Monthly milk composition SCC analysis was conducted at Arizona DHIA Tempe, AZ. Pen intake was monitored daily and recorded using PROFEED2000® (Tempe, AZ) feed management software. Milk yield was recorded at each milking and transferred to daily milk yield data and then collapsed into weekly averages for statistical analyses. Reproductive measurements and herd health information typically monitored on the commercial dairy were collected and evaluated. Reproductive measurements were: 1) % pregnant, 2) % cows open within 65 d VWP, 3) cows not yet diagnosed as pregnant, and 4) average DIM at pregnancy. The herd health measurements were classified as cows that went to the hospital pen for: 1) mastitis, 2) digestive disorders, 3) respiratory problems, 4) lame/injury, 5) reproductive issues and 6) other unknown disorders.

Statistical Analysis. In both trials, data were analyzed using PROC MIXED procedures of SAS (SAS, 1999). Previous 305 d mature equivalent milk yields were included as a covariate in the analysis for multiparous cows. Dependent variables tested were milk yield, ST, UST, RR, CBT, BCS, BW, BW change, milk fat, milk protein, milk SCC and equipment water and electrical usage. The independent variables included trt, parity, time and the respective interactions. Time (wk of study) was fit as a repeated measure using a first-order autoregressive covariance structure. The level of significance was set at $P < 0.05$ for all main effects and interactions and the LSMEANS test was conducted when significance was detected.

Results and Discussion

2004 Trial. Overall milk production did not differ ($P = 0.15$) for multiparous cows housed in ADS-ST or KK (41.4 vs. 42.2 ± 0.6 kg/d; Table 3; Fig. 3 A) pens. However, average milk yield for primiparous cows housed in the KK pen tended ($P = 0.10$) to be higher than the ADS-ST pen (37.8 vs. 36.7 ± 0.7 kg/d; Fig. 3a). Weekly DMI were similar between the two pens (~25 kg/d; P > 0.10) and there was no difference in BW change between multiparous cows (2.1 ± 9.5 kg) in the ADS-ST or KK pens (Table 3). However, primiparous cows housed in ADS-ST pens gained less BW (8.6 vs. 39.8 kg ± 11; $P < 0.01$) than those housed in KK pens (Table 3). Multiparous cows housed in ADS-ST pens had higher RR (60.5 vs. 58.3 ± 0.5 BPM; $P < 0.01$) compared to multiparous cows in KK cooled pens, however RR did not differ in primiparous cows housed in ADS-ST or KK pens. There was no difference in ST for multiparous (32.2 ± 0.1˚C) or primiparous (32.3 ± 0.2˚C) cows housed in ADS-ST vs. KK pens, respectively (Table 3). Milk fat percentage, SCC and BCS did not differ between trts ($P > 0.05$), regardless of parity. However, milk protein content was increased ($P < 0.05$) for cows housed under the ADS-ST compared to the KK coolers (2.84 vs. 2.77 ± 0.03; Table 3).

The percentage of cows pregnant (58.5%) and average DIM at pregnant (194) were not different ($X^2 = 0.93$) between cows housed under either cooling conditions. One hundred seventeen cows (47%) from the ADS-ST and 113 (45%) from the KK trt visited the hospital pen during the 17 wk study. Mastitis was the primary reason for going to the hospital pen for both ADS-ST (88/117) and KK (72/113) housed cows. Of the remaining ADS-ST cows that went to the hospital pen, 15, 6, 5, 2 and 1 went for lame/injury, digestive disorders, respiratory problems, unknown reasons or reproductive disorders, respectively. Of the remaining KK cows that went to the hospital pen, 15, 14 and 12 went for digestive problems, respiratory disorders and lame/injury complications, respectively. Fourteen animals housed in the ADS-ST pen and 12 housed under KK conditions left the herd during the 17 wk study.

2005 Trial. Milk production was higher ($P < 0.01$) for primiparous (35.2 vs. 32.7 ± 0.6 kg/d; Fig. 4A, Table 4) and multiparous (42.2 vs. 38.3 ± 0.4 kg/d; Fig. 4B) cows housed under KK trts compared to ADS-ST housed cows. There was no difference in DMI (~23 kg/d; P > 0.10) or in BW change for multiparous (6.4 ± 11.5 kg; P=0.38) and primiparous (40.2 ± 29.8 kg; P = 0.19; Table 3b) cows housed in ADS-ST or KK pens, respectively. Primiparous cows housed under ADS-ST had higher RR than primiparous cows housed under KK (72.2 vs. 61.3 ± 0.5 BPM; $P < 0.01$; Table 4). Multiparous cows RR were also higher for cows housed under ADS-ST compared to KK (70.9 vs. 59.3 ± 0.7 BPM; $P < 0.01$). Surface temperatures were higher for primiparous (33.6 vs. 31.3 ± <0.1°C; $P < 0.01$) and multiparous (33.5 vs. 31.1 ± <0.1°C; $P < 0.01$; Table 4) cows housed under ADS-ST. Udder ST were also higher for primiparous (35.0 vs. 33.0 ± <0.1°C; $P < 0.01$) and multiparous (34.8 vs. 33.0 ± <0.1°C; $P < 0.01$) cows housed in the ADS-ST compared to KK cooled cows. There was no differences in milk fat content in either primiparous or multiparous cows (Table 4), however primiparous cows (but not multiparous cows) housed under ADS-ST had higher percentages of milk protein than KK animals (2.80 vs. 2.76 ± 0.02; $P < 0.05$; Table 4). Body condition score was not different in primiparous cows, however it was higher in multiparous cows housed under KK compared to cows housed under ADS-ST (3.16 vs. 3.09 ± 0.02; $P < 0.01$). There were no differences in milk SCC, or change in BCS for primiparous or multiparous cows housed under either cooling system.

The percentage of cows pregnant was lower (28 vs. 49) and average times bred was higher (2.7 vs. 2.3) for cows housed under ADS-ST compared to KK coolers. One hundred and twenty cows (48 %) from the ADS-ST and 126 (50.4%) from the KK trt visited the hospital pen during the 17 wk study. Mastitis was the primary reason for going to the hospital pen for both ADS-ST (95/120) and KK (106/126) cows. Of the remaining ADS-ST cows that went to the hospital, 1, 9, 4, and 11 went for digestive problems, respiratory complications, lame/injury, and reproductive issues, respectively. Of the remaining KK cows that went to the hospital pen, 7, 2, and 11 went for respiratory issues, lame/injury, reproductive disorders, and other unidentified problems. Seven cows housed in the ADS-ST pen left the herd and the KK trt had no cows culled during the 17 wk study.

On Arizona dairies the most widely used evaporative cooling systems are KK and SF coolers. Korral Kool coolers are positioned in the center of the shade structure, thus cooling the immediate air around the cow (Ryan et al., 1992; Armstrong, 1994; VanBaale et al., 2004), and uses curtains attached to the east and west (depending upon the time of day) sides of the shade structure (oriented north to south) to decrease the amount of solar radiation exposure. With the KK system, the curtain keeps the shade and the cooled air focused under the shade roof. While the microenvironment is cooled effectively with the KK system, corral maintenance requirements may be increased because of the need to remove moist bedding.

Advanced Dairy Systems-Shade Tracker is installed into the eastern edge of the shade's structure and the fan itself has a range of motion of up to 270º, thus cooling areas around and under the shade structure depending on the suns position. An advantage of the ADS-ST system is that the system cools shaded areas throughout the day, thus distributing moisture from the coolers and animals across a larger area. As the shade and cooling leaves an area, it is typically followed by sunlight which helps dry the corral/bedding and reduces the corral maintenance intensity under ADS-ST system.

Physiological responses to heat stress in dairy cattle such as decreased DMI, increased maintenance requirements and decreased milk production start to occur at a THI of 72 (Armstrong, 1994). During the summers of 2004 and 2005 (17 wk study) the environment outside the shade structures equated to mild (THI = 72-79) or moderate (THI = 80-89) heat stress for an average of 18 h/d throughout the experimental periods (Fig. 1a and 1b). The maximum daily THI on the farm exceeded 80 for 16 of the 17 wk experiment (Fig. 2). The minimum average weekly THI was never below values associated with thermal stress (72 THI) in dairy cattle during the entire experiment (Fig. 2). However, in the 2004 trial, cow RR under the shade (regardless of cooling) averaged only 59 BPM and the surface skin averaged 33.2°C. In addition, milk yield for both multiparious and primiparous cows was markedly higher (>7 and > 5 kg/d, respectively) during 2004 than 2005. These parameters indicate cows may not have been severely heat stressed during 2004 and as a consequence, the cooling systems were both able to minimize the impact of heat on production and physiological parameters measured.

During the 2004 trial there were no differences in milk yield between multiparous cows on the two trts, however primiparous cows housed under KK coolers tended to produce more (1.1 kg/d) milk than cows housed under the ADS-ST system (Table 3); however during the 2005 trial milk yield was increased for multiparous (~4 kg/d) and primiparous (~ 3 kg/d) cows housed under KK compared to ADS-ST conditions (Table 4). Our 2004 findings agree with our 2001 data indicating milk production of primiparous cows was less affected by cooling as compared to multiparous cows (Table 1; Collier et al., 2003). Furthermore, Ryan et al. (1992) compared a **SF** system to KK evaporative coolers and did not detect an interaction between cooling system and parity on milk yield. However, the SF system discussed in Ryan's paper was not equipped with the technological advances (continuous cooling adjustment and shade tracking) of the ADS-ST system used in the current study.

As mentioned previously, elevated RR and ST are associated with increased thermal stress. Minimizing or preventing an increase in RR and ST would be expected to enhance cow comfort and likely improve feed intake and overall lactation performance. Normal RR has been reported as 26 BPM (Monty and Wolff, 1974) in early to mid lactation cows and 35 BPM (Huhnke and Monty, 1976) in early lactation cows. More recently, multiparous cows housed in the Animal Research Complex (ARC; Tucson, AZ) environmental facility under thermal neutral conditions (18.6˚C ± 0.4; 63.5 THI ± 0.7) for 48 h followed by heat stress (36.6 ± 0.9˚C; 79.6 THI ± 1.0; no cooling) for 16 out of 24 h/d for 3 d had RR ~45 BPM during thermal neutral and 71 BPM during heat stress conditions, respectively (Baumgard et al., unpublished). Therefore, it appears that increased RR is one mechanism by which genetically superior animals utilize to dissipate extra heat and attain extra oxygen associated with enhanced milk synthesis. In the current 2004 study, RR was statistically higher for cows and heifers (60.5 and 59.7 BPM) housed under ADS-ST conditions compared to cows and heifers (59.6 and 58.3 BPM) cooled with the KK system, however, both systems were able to maintain RR below 61 as environmental conditions were not as severe. In the 2005 trial, primiparous (72.2 vs. 61.4 BPM) and multiparous (70.9 vs. 59.3 BPM) cows housed under the ADS-ST system also had higher RR, and the large differences clearly indicate that ADS-ST was not as capable as the KK system at cooling cows under more extreme heat stress conditions. This agrees with Correa-Calderon et al. (2004) who reported increased RR for cows cooled with a SF system (64 BPM) compared to cows cooled with KK coolers (50 BPM).

When ST reaches 35°C the flow/direction of heat/energy radiating from the body core to the surface is essentially zero (Berman, 2003). Both cooling systems have shown modest (although significant) reductions in ST in primiparous cows (Ryan et al., 1992) or in both primiparous and multiparous cows (Correa-Calderon et al., 2004). During thermal neutral conditions, normal ST has previously been reported as ~27.4°C (Huhnke and Monty, 1976) for early lactation cows. During the 2004 study, ST (32.3°C) was not different for cows or heifers housed under ADS-ST or KK conditions, however during the 2005 study primiparous (35.0 and 33.6 ºC) and multiparous (33.0 and 31.3 ºC) cows had higher UT and ST when housed under ADS-ST compared to KK, respectively. These findings agree with our previous results (Table 1; Collier et al. 2003) indicating both ADS-ST and KK systems kept ST below 35°C.

Recently we reported that multiparous cows lost 18 kg of BW during a ~ 2 mo heat stress trial (Moore et al., 2005). During the 2004 trial, monthly BCS were not different between trts regardless of parity, and in 2005 primiparous cows BCS were not different, however, multiparous cows had a statically higher BCS in the KK trt (3.09 vs. 3.16) although this small difference is not likely to be biologically meaningful. In the 2004 study there was no difference in BW change between multiparous cows (-3 vs. + 12 kg) in the ADS-ST or KK pens, respectively, however, primiparous cows housed in ADS-ST pens gained less BW (8.6 vs. 39.8 kg) than those housed in KK pens (Table 2a).

Minimizing chronic thermal stress probably improves reproductive performance as a number of reproductive indices were improved when cows were housed in an evaporative cooling system (compared to non-cooled cows; Armstrong et al., 1985; Ryan et al., 1992). We did not detect differences in reproductive performance, evaluated as the percent pregnant (58.5), percent open (41.5), average times bred (2.79) and DIM at pregnancy (194) during the 2004 trial, however in 2005 only 28% of the cows housed under ADS-ST conditions were impregnated compared to 49% under the KK system. This agrees with Ryan et al. (1992) who reported an increase in the percent of cows pregnant and a decrease in days open for cows cooled with a KK compared to SF coolers.

The ADS-ST and KK cooling systems installed in dairies located in hot semi-arid climates like AZ can contribute up to 20% of the total construction cost. During the 2004 and 2005 trials, the initial investment for the ADS-ST system used in these studies was $58,500 ($234/cow) compared to $118,067 ($472/cow; [which included $90/cow for curtains]) for the KK system. During both trials ADS-ST cooling system used less electricity (526 vs. 723, 2004 and 517 vs. 840, 2005 kwh/d) and water (291 vs. 305 and 290 vs. 460 L/d) than the KK coolers. The daily costs for the ADS-ST and KK system was $27.30 and the KK system was $36.36/d in 2004 and 25.95 vs. $42.06 during the 2005 trial. In the 2004 study the cost/cow for the ADS-ST and KK systems was 0.11 and $0.15 and per 45.4 kg of milk and 0.10 and $0.14 for ADS-ST and KK coolers (Table 3), respectively. In the 2005 study, the cost/cow for the ADS-ST and KK systems was 0.10 and $0.17 and per 45.4 kg of milk and 0.12 and $0.19 for ADS-ST and KK. Lifespan, depreciation or amortization factors were not measured in this experiment.

Implications

During both studies in 2004 and 2005, cows were in moderate heat stress for 16 of the 17 wks of the trial. Although in 2004 multiparous or primiparous cows had no difference in daily milk yield, primiparous cows housed under KK systems tended to produce more milk compared to cows housed under ADS-ST systems. However, the heat stress conditions in 2004 appear to be less than the heat stress conditions in the 2005 trial and less than historically observed. The differences in production and heat stress indices/parameters between the two years support this. Specifically, in 2005 both primiparous and multiparous cows housed under KK coolers produced more milk (2.5 and 3.9 kg/d) and had lower RR (10.9 and 11.6 BPM) compared to cows housed under ADS-ST. Surface temperatures were not affected in mulitparous or primiparous cows housed under ADS-ST or KK system in 2004, however in 2005 primiparous and multiparous cows had higher UT and ST when housed under ADS-ST compared to KK. Overall, the variable costs to operate ADS-ST system is less expensive because it was utilizing less water and electricity, however under moderate to extreme conditions heat stress, it does not cool cows as efficiently as KK systems.

Acknowledgements

The authors would like to thank the United Dairymen of Arizona (Tempe, AZ), Advanced Dairy Systems, LLC and Korral Kool Inc. for funding these trials. We appreciate Tom Thompson and the employees of Stotz dairy for their help, Dave Henderson for statistical support, and Arnaldo Burgos of Dairy Nutrition Services, Inc. (Chandler, AZ) for diet formulations and analysis.

References

Armstrong, D.V., Wiersma, F., Fuhrman, D.J., Tappan, J.M., Cramer, S.M., 1985. Effect of evaporative cooling under a corral shade on reproduction and milk production in a hot-arid climate. J. Dairy Sci. 68 (suppl. 1):167 (Abstr.)

Armstrong, D.V., Wiersma, F., Wise, M.E., Huber, J.T., Marcus, K.M., Ammon, D.S., 1986. Effect of refrigerated air conditioning and evaporative cooling on milk production. J. Dairy Sci. 69 (suppl. 1):161 (Abstr.)

Armstrong, D.V., Wise, M.E., Torabi, M.T., Wiersma, F., Hunter, R., Kopel, E., 1988. Effect of evaporative cooling under a corral shade on reproduction and milk production in a hot-arid climate. J. Dairy Sci. 71 (suppl. 1):212 (Abstr.)

Armstrong, D.V., Welchert, W.T., Wiersma, F., 1993. Environmental modification for dairy cattle housing in arid climates. *In Proc.*: 4th Int. Livestock Environmental Symp., Warwick, Coventry, England. Am. Soc. Agric. Eng., St. Joseph, MI.

Armstrong, D.V., 1994. Heat stress interaction with shade and cooling. J. Dairy Sci. 77, 2044-2050.

Armstrong, D.V., Molina, D.J., Correa-Calderon, A., Gonzalez-Garcia, H., Faber, S., 1999. Effect of a three stage spray and fan cooling system on milk yield and reproduction of Holstein cows in early lactation. J. Dairy Sci 82:(suppl. 1): 48 (Abstr.)

Berman, A., 2003. Effects of body surface area estimates on predicted energy requirements and heat stress. J. Dairy Sci. 86, 3605-3610.

Bianca, W., 1962. Relative importance of dry and wet-bulb temperatures in causing heat stress in cattle. Nauchni Tr Vissh Med Inst Sofiia. 195, 251-252.

Collier, R.J., Annen, E.L., Armstrong, D.E, Wolfgram, A.L., 2003. Evaluation of two evaporative cooling systems for dairy cattle under semi-arid conditions. J. Dairy Sci. 86 (suppl. 1). 18 (Abstr.)

Collier, R.J., Dahl, G.E., VanBaale, M.J., 2006. Major advances associated with environmental effects on dairy cattle. J. Dairy Sci. 89, 1244-1253.

Multiparous Cows

Collier, R.J., Beede, D.K., 1985. Thermal stress as a factor associated with nutrient requirements and interrelationships. In: Nutrition of grazing ruminants in warm climates. In: Nutrition of Grazing Ruminants in Warm Climates, Ed. L.R. McDowell Academic Press, Inc, Orlando, Fl pp. 59-71.

Correa, A., Armstrong, D.V., DeNise, S.C., Howison, C.W., Ray. D.R., 1997. Milk production and reproduction response of Holstein and Brown Swiss dairy cattle to two different evaporative cooling systems in a semi-arid climate. J. Dairy Sci. 80 (suppl. 1):230 (Abstr.).

Correa-Calderon, A., Armstrong, D.E., Ray, D.R., DeNise, C., Enns, M., Howison, C., 2004. Thermoregulatory responses of Holstein and Brown Swiss heat-stressed dairy cows to two different cooling systems. Int. J. Biometeorol. 48, 142-148.

Hahn, G.L. 1976. Rational environmental planning for efficient livestock production. Int. J. Biometeorol. 6, 106-114.

Huhnke, M.R., Monty, D.E., 1976. Physiologic responses of preparturient and postparturient Holstein-Friesian cows to summer heat stress in Arizona. Am. J. Vet. Res. 37, 1301-1304.

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Monty, D.E., Wolff, L.K., 1974. Summer heat stress and reduced fertility in Holstein-Friesian cows in Arizona. Am. J. Vet. Res. 35, 1495-1500.

Moore, C.E., Kay, J.K., VanBaale, M.J., Collier, R.J., Baumgard, L.H., 2005. Effect of conjugated linoleic acid on heat stressed Brown Swiss and Holstein cattle. J. Dairy Sci. 88, 1732-1740.

Roche, J.R., Dillon, P.G., Stockdale, C.R., Baumgard L.H., VanBaale, M.J., 2004 Technical Note: Relationship between international body condition scoring systems. J. Dairy Sci. 87, 3076-3079.

Ryan, D.P., Boland, M.P., Kopel, E., Armstrong, D., Munyakazi, L., Godke, R.A., Ingraham, R.A., 1992. Evaluating two different evaporative cooling management systems for dairy cows in a hot, dry climate. J. Dairy Sci. 75, 1052-1059.

Sainsbury, D.W.B. 1967. Animal health and housing. The Williams and Wilkins Co., Baltimore. pp. 25-27.

SAS User's Guide: Statistics, Version 8.0 Edition. 1999. SAS Inst., Inc., Cary, NC.

Stott, G.H., Wiersma, F., Lough,O., 1972. Consider cooling possibilities: the practical aspects of cooling dairy cattle. Arizona Ext. Serv. Rep. P-25, Univ. Ariz. Tucson.

West. J.W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86, 2131-2144.

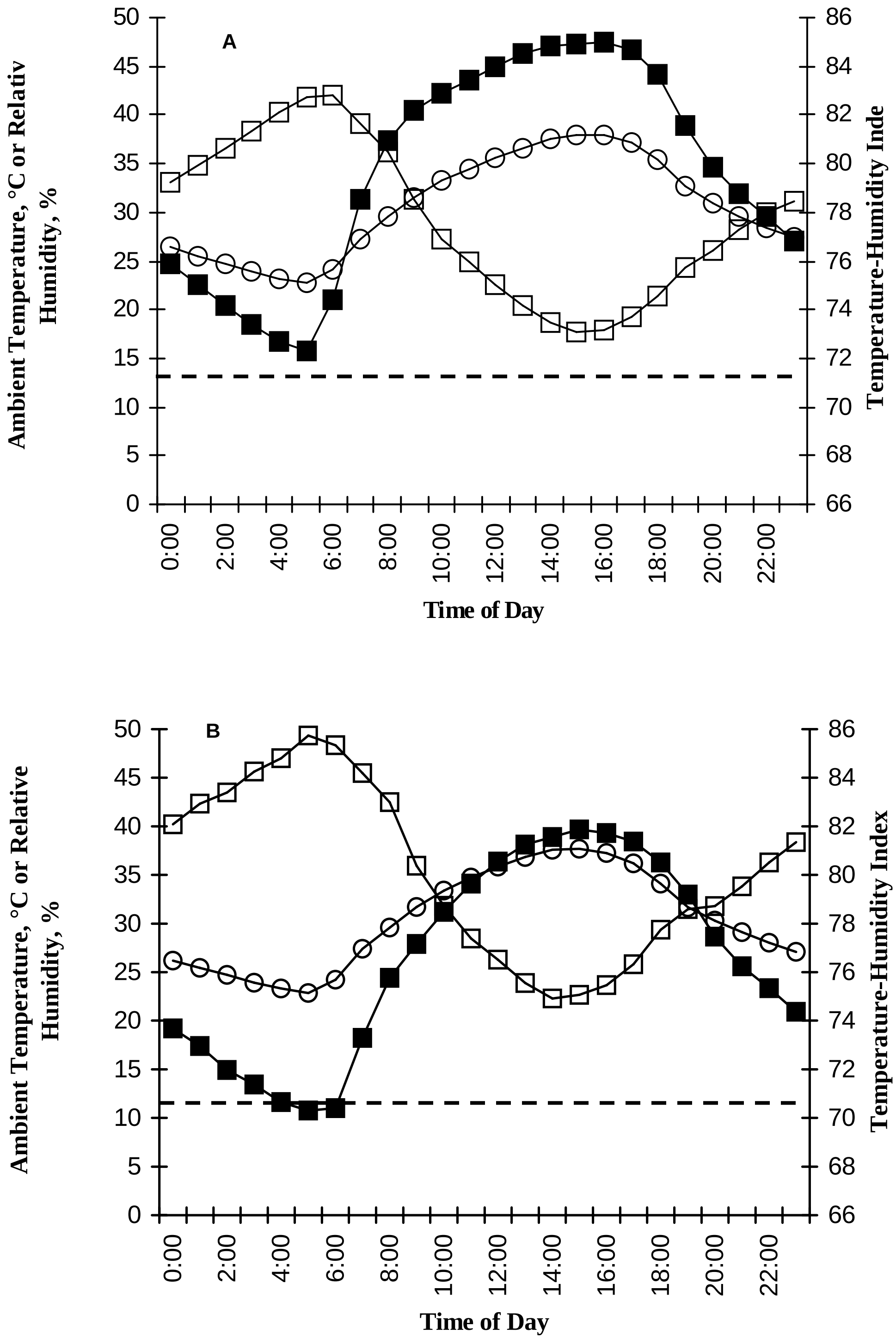

Figure 1. Average diurnal patterns for ambient temperature (O), relative humidity (□), and temperature-humidity index (■) during the experimental period of June 3, 2004 to September 30, 2004 (A) and June 3, 2005 to September 30, 2005 (B). Temperature and humidity data used to calculate the temperature-humidity indexes were obtained from the Arizona Meteorological Network weather station 1.61 km from the experimental site. ---------- represents 72 THI.

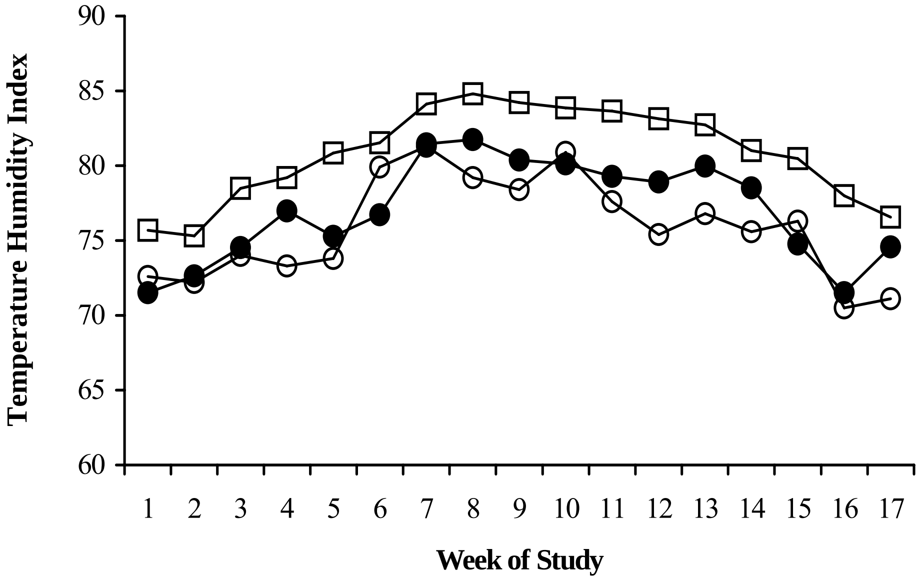

Figure 2. Average diurnal patterns temperature-humidity index during the experimental periods (06/03 to 09/30 2004 [○] and 2005 [●]) and the average temperature for the same time period from 1998 to 2003 (□). Temperature and humidity data used to calculate the temperature-humidity indexes were obtained from the Arizona Meteorological Network weather station 1.61 km from the experimental site.

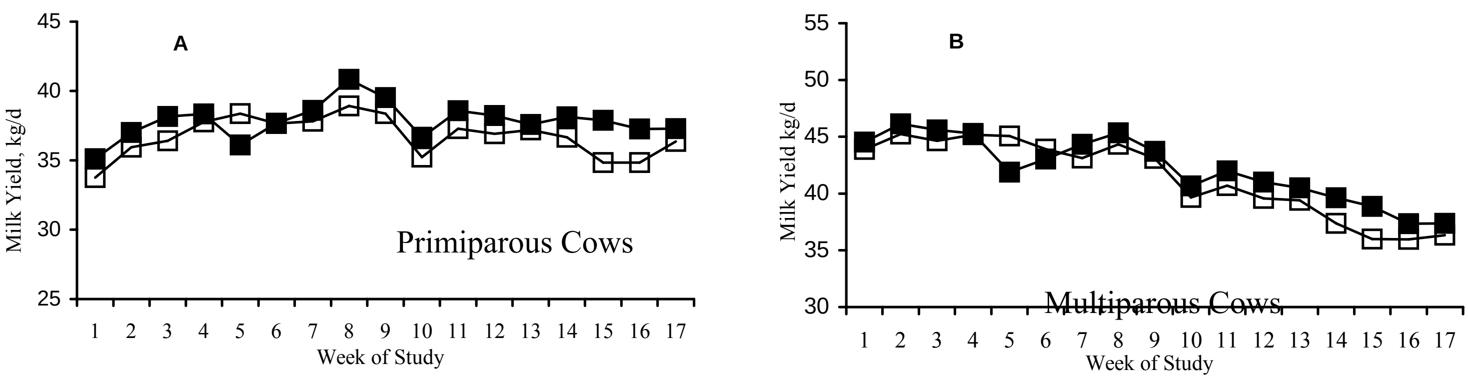

Figure 3. Temporal pattern of milk yield in primiparous (A) and multiparous (B) cows cooled with ADS-ST (□) or KK (■) from 06/03/2004 to 09/30/2004.

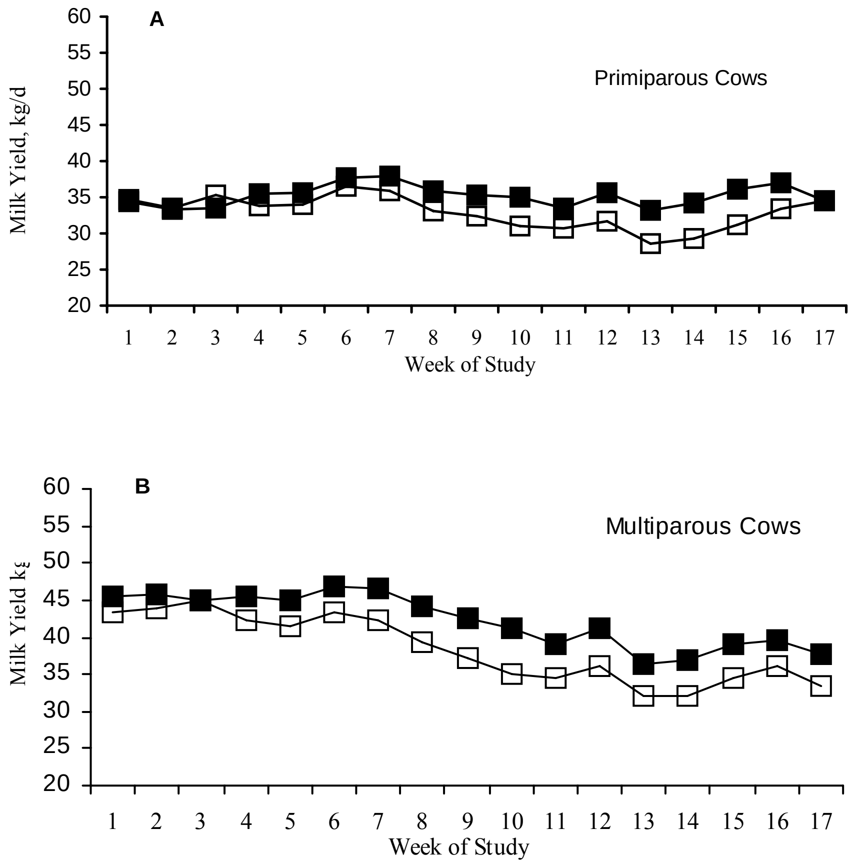

Figure 4. Temporal pattern of milk yield in primiparous (A) and multiparous (B) cows cooled with ADS-ST (□) or KK (■) from 06/03/2005 to 09/30/2005.

Table 1. Production data and heat stress parameters in primiparous and multiparous cows cooled with ADS-ST or KK evaporative cooling systems.

	Primiparous		Multiparous		
Variable	ADS-ST	KK	ADS-ST	KK	SEM
Milk yield, kg/d	36.5	35.2	36.4	38.8	1.7
ST, ºC	34.4[a]	29.7[b]	34.2[a]	29.6[b]	0.3
RR, breaths/min	70.4[a]	56.9[b]	63.2[a]	56.6[b]	1.3
Body Condition Score	2.74[a]	2.74[a]	2.88[a]	2.53[b]	0.06

[a,b] Means within a row with different superscripts differ.
ADS-ST = Advanced Dairy Systems Shade Tracker Cooling System,
KK = Korral Kool Cooling System
Adapted from Collier et al., 2003

Table 2. System parameters for each of the evaporative cooling systems used during both studies.

	Cooling System	
Variable	ADS-ST	KK
Size of fan (m)	0.914	1.524
Fan Motor (W)	1492[a]	2238
Water Pump Motor (W)	7355 [b]	3730[c]
Gear Motor[a] (W)	3686	N/A
Mean On/Off Temperature (°C)	26.6/26.6	27.8/26.6
Mean Cooler Settings	Adjusts[d]	Adjusts[e]

ADS-ST = Advanced Dairy Systems Shade Tracker Cooling System
KK = Korral Kool Cooling System
[a]programmed to run at 70% capacity
[b]variable frequency drive pump ranges from 1119 to 5595 W
[c]the control module contains two 3730 W motors that pump water to the coolers
[d]oscillations and the shade tracker function were powered by a 368 W gear motor, depending on the temperature and humidity, 1.0 to 4.7 liters of water per min were pumped through the misters, and droplet size (5-15 microns @ 17.6 to 87.9 kg/cm^2) and airflow (5,852 cubic m/min@ 1140 rpm) was not altered.
[e] the depending on the temperature and humidity, 1.0 to 7.2 liters of water per min were pumped through the cooler, and droplet size (30-65 microns @ 21.1 kg/cm^2) and air flow (1,204 cubic m/min @ 411 rpm) was not altered.

Table 3. Production variables and heat stress parameters in primiparous and multiparous cows cooled with ADS-ST or KK evaporative cooling systems from 06/03/2004 to 09/30/2004.

	Primiparous				Multiparous			
Variable	ADS-ST	KK	SEM	*P*	ADS-ST	KK	SEM	*P*
Milk yield, kg/d	36.7	37.8	0.7	0.10	41.4	42.2	0.6	0.15
Milk fat, %	3.59	3.71	0.09	0.19	3.64	3.65	0.05	0.84
Milk protein, %	2.84	2.77	0.03	0.02	2.86	2.86	0.02	0.99
Somatic Cells X 1,000	211	215	80	0.95	570	448	80	0.13
ST, ºC	32.3	32.3	0.2	0.81	32.2	32.2	0.1	0.35
RR breaths/min	59.7	58.6	0.8	0.15	60.5	58.3	0.5	<0.01
Body condition score	3.53	3.51	0.02	0.38	3.61	3.65	0.56	0.48
BW change, kg	8.6	39.8	11.0	<0.01	-1.4	5.7	9.5	0.45

ADS-ST = Advanced Dairy Systems Shade Tracker Cooling System,
KK = Korral Kool Cooling System.

Table 4. Production variables and heat stress parameters in primiparous and multiparous cows cooled with ADS-ST or KK evaporative cooling systems from 06/03/2005 to 09/30/2005.

	Primiparous				Multiparous			
Variable	ADS-ST	KK	SEM	*P*	ADS-ST	KK	SEM	*P*
Milk yield, kg/d	32.7	35.2	0.60	<0.01	38.3	42.2	0.40	<0.01
Milk fat, %	3.63	3.61	0.08	0.83	3.56	3.55	0.04	0.94
Milk protein, %	2.80	2.76	0.02	<0.05	2.80	2.77	0.01	0.01
Somatic Cells X 1,000	276	354	87	0.38	368	438	55	0.21
Udder ST, ºC	35.0	33.0	0.04	<0.01	34.8	33.0	0.03	<0.01
ST, ºC	33.6	31.3	0.06	<0.01	33.5	31.1	0.09	<0.01
RR, breaths/min	72.2	61.3	0.47	<0.01	70.9	59.3	0.67	<0.01
Body condition score	3.10	3.14	0.01	0.19	3.09	3.16	0.02	<0.01
BW change, kg	19.9	60.5	29.8	0.19	13.3	-0.49	11.5	0.38

ADS-ST = Advanced Dairy Systems Shade Tracker Cooling System
KK = Korral Kool Cooling System.

HIGH COW REPORT
MARCH 2007

MILK

Arizona Owner	Barn#	Age	Milk	New Mexico Owner	Barn #	Age	Milk
* Shamrock Farms	8142	04-10	34,570	* Providence Dairy	5139	05-09	39,930
* Withrow Dairy	8167	04-08	33,680	* Providence Dairy	5374	05-05	39,220
* Ambian Dairy	21827	03-03	33,080	* Providence Dairy	5948	04-05	38,890
* Shamrock Farms	1294	07-01	32,690	* S.A.S. Dairy	7211	04-11	38,175
* Danzeisen Dairy, LLC.	3918	07-04	32,470	* S.A.S. Dairy	5541	05-10	37,047
* Rio Blanco Dairy	5649	06-05	32,440	* Providence Dairy	4828	06-05	36,250
* Stotz Dairy	18691	04-06	32,420	* Providence Dairy	6356	04-01	36,110
* Cliffs Dairy	306	05-03	32,400	* Providence Dairy	9563	06-02	35,930
* Cliffs Dairy	529	03-01	32,330	* Milagro Dairy	1931	05-06	35,880
* Stotz Dairy	20582	03-08	32,120	* Providence Dairy	9054	06-04	35,820

FAT

* Rio Blanco Dairy	6351	04-08	1,443	Tee Vee Dairy	8433	07-06	1,499
* Stotz Dairy East	22564	02-01	1,336	Tee Vee Dairy	1393	05-06	1,476
Parker Dairy	2843	04-07	1,310	* Providence Dairy	6409	03-10	1,440
* Shamrock Farms	C963	03-06	1,290	* S.A.S. Dairy	8085	04-00	1,401
* Dutch View Dairy	2979	02-01	1,284	* S.A.S. Dairy	5541	06-10	1,359
* Rio Blanco Dairy	5644	06-08	1,283	Tee Vee Dairy	423	06-06	1,356
* Danzeisen Dairy, LLC.	3918	07-04	1,237	* Cross Country Dairy	274	04-03	1,343
* D & I Holstein	226	02-10	1,217	* Providence Dairy	180	05-11	1,342
* Withrow Dairy	8167	04-08	1,188	* Providence Dairy	9801	06-02	1,339
* Stotz Dairy East	22325	02-03	1,179	* Butterfield Dairy	6124	04-03	1,328

PROTEIN

* Cliffs Dairy	344	04-11	974	* S.A.S. Dairy	5541	05-10	1,153
* Cliffs Dairy	306	05-03	956	* S.A.S. Dairy	7211	04-11	1,152
* Stotz Dairy	21175	03-03	951	* Providence Dairy	5374	05-05	1,126
* Cliffs Dairy	529	03-01	947	* S.A.S. Dairy	7121	05-00	1,086
Parker Dairy	2843	04-07	941	* Milagro Dairy	1931	05-06	1,082
* Cliffs Dairy	218	06-02	939	* Providence Dairy	5139	05-09	1,081
* Cliffs Dairy	251	05-11	939	Tee Vee Dairy	423	06-06	1,075
* Rio Blanco Dairy	6589	04-01	937	* S.A.S. Dairy	7812	04-04	1,075
* Withrow Dairy	8167	04-08	935	* Providence Dairy	4828	06-05	1,072
* Cliffs Dairy	623	02-01	925	* McCatharn Dairy	1998	04-06	1,065

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

ARIZONA - TOP 50% FOR F.C.M.[b]
MARCH 2007

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	CI
* Stotz Dairy West	2,247	26,159	965	26,954	15.3
* Danzeisen Dairy, Inc.	1,556	24,047	890	24,825	14.5
* Stotz Dairy East	1,173	23,954	879	24,606	14.3
* Red River Dairy	8,903	26,489	784	24,162	13.9
* Goldman Dairy	2,260	24,046	840	24,014	14.3
* Zimmerman Dairy	1,213	23,650	843	23,891	14.5
* Mike Pylman	6,429	23,527	825	23,546	14.7
Parker Dairy	4,235	22,387	843	23,345	14.6
* Shamrock Farm	8,719	23,702	803	23,265	13.6
* Withrow Dairy	4,961	23,148	817	23,253	13.0
* Arizona Dairy Company	5,342	22,598	814	22,966	14.7
* Butler Dairy	606	22,577	797	22,682	14.9
Paul Rovey Dairy	310	21,203	802	22,169	13.7
Lunts Dairy	604	21,319	793	22,073	12.8
* Saddle Mountain	2,980	21,620	778	21,960	13.8
* DC Dairy, LLC	1,113	21,605	766	21,759	13.2
* Yettem	3,591	17,990	815	20,990	13.1

NEW MEXICO - TOP 50% FOR F.C.M.[b]
MARCH 2007

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	DO
* Vaz Dairy 2	2,049	26,047	965	26,911	153
* Hide Away	2,843	25,288	899	25,513	116
* SAS	1,899	25,652	881	25,378	125
* Do-Rene	2,316	24,055	874	24,574	143
* Vaz	1,456	23,894	872	24,472	152
* McCatharn	1,023	24,366	850	24,319	139
* Milagro	3,491	23,589	866	24,243	143
* Butterfield	2,115	23,920	836	23,900	130
* Caballo Dairy	3,646	23,443	843	23,807	151
* Pareo	3,192	22,817	830	23,325	148
* Tee Vee Dairy	1,003	22,396	830	23,143	148
* Stark Everett	2,614	22,295	818	22,905	140
* Goff	5,478	21,554	813	22,504	137
* Tres Hermanos Dairy	498	22,113	778	22,178	131

* 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 MARCH 2007

		ARIZONA	NEW MEXICO
1.	Number of Herds	34	27
2.	Total Cows in Herd	79,271	49,155
3.	Average Herd Size	2,332	1,821
4.	Percent in Milk	94	89
5.	Average Days in Milk	209	186
6.	Average Milk – All Cows Per Day	71.6	64.1
7.	Average Percent Fat – All Cows	3.5	3.7
8.	Total Cows in Milk	73,382	43,026
9.	Average Daily Milk for Milking Cows	76.7	71.7
10.	Average Days in Milk 1st Breeding	83	77
11.	Average Days Open	166	137
12.	Average Calving Interval	14.3	13.7
13.	Percent Somatic Cell – Low	84	78
14.	Percent Somatic Cell – Medium	11	15
15.	Percent Somatic Cell – High	5	8
16.	Average Previous Days Dry	60	64
17.	Percent Cows Leaving Herd	35	32
		STATE AVERAGES	
	Milk	22,786	22,824
	Percent butterfat	3.51	3.60
	Percent protein	2.95	2.97
	Pounds butterfat	796	872
	Pounds protein	650	699

THE UNIVERSITY OF
ARIZONA®
COOPERATIVE EXTENSION
Department of Animal Sciences
PO Box 210038
Tucson, AZ 85721-0038

Phone: 520-626-9382
Fax: 520-621-9435
Email: ljr22@ag.arizona.edu