Cover Page

BARD Project Number: US-3201-01

Date of Submission of the report: 14 February 2006

Project Title: Environmental manipulation during the dry period of ruminants: strategies to enhance subsequent lactation.

Investigators

Principal Investigator (PI): G.E. Dahl

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Keywords Photoperiod, heat stress, prolactin cows, goats.

Abbreviations commonly used in the report, in alphabetical order:

HT = hyperthermic, **IGF-I** = insulin-like growth factor-I, **LDPP** = long day photoperiod, **NT** = normothermic, **PRL** = prolactin, **PRL-R** = PRL receptor, **SDPP** = short day photoperiod.

Budget: IS: \$175,000

US: \$195,000

Total: \$370,000

Signature
Principal Investigator

Signature
Authorizing Official, Principal Institution

Publication Summary (numbers)

	Joint IS/US authorship	US Authors only	Israeli Authors only	Total
Refereed (published, in press, accepted) BARD support acknowledged		6		6
Submitted, in review, in preparation	1	1	2	4
Invited review papers		2		2
Book chapters				
Books				
Master theses				
Ph.D. theses		1		1
Abstracts	1	10		11
Not refereed (proceedings, reports, etc.)		1		1

Postdoctoral Training: List the names and social security/identity numbers of all postdocs who received more than 50% of their funding by the grant.

Cooperation Summary (numbers)

	From US to Israel	From Israel to US	Together, elsewhere	Total
Short Visits & Meetings		3		3
Longer Visits (Sabbaticals)				

Description Cooperation:

The investigators met at the annual meeting of the American Dairy Science Association in 2002, 2003 and 2005 to discuss the project goals, progress and recommendations for application of the findings in the field. These face-to-face meetings were in addition to a steady communication stream via e-mail regarding the studies as they progressed. In addition, an extension of the original proposal was submitted by the team in 2004, but it was not funded. Drs. Dahl and McFadden are planning to visit Israel in 2006 to discuss further collaborative opportunities.

Patent Summary (numbers)

	Israeli inventor only	US inventor only	Joint IS/US inventors	Total
Submitted				
Issued (allowed)				
Licensed				

Environmental manipulation during the dry period of ruminants: strategies to enhance subsequent lactation (BARD Proj. # US-3201-01).

Final Scientific Report for 2001-2005

Abstract

The project resulted from earlier observations that environmental factors, especially photoperiod and temperature, had profound effects on milk yield in dairy cattle during lactation. More recently we had determined that photoperiod manipulation during the dry period altered milk yield in the next lactation, and this was associated with shifts in circulating concentrations of prolactin; specifically exposure to short days during the dry period decreases prolactin but increases milk yield. Because prolactin is also affected by temperature, with heat stress causing an increase in prolactin similar to that of long day exposure, we focused our efforts on determining prolactin signaling provides a common pathway for generation of environmental effects on mammary growth, development and subsequent function during the dry period of dairy ruminants.

Over the project period we made significant progress toward testing our hypotheses that **(I):** In cows, there is a discrete duration of time during the dry period in which exposure to short days will result in optimal enhancement of mammary development and milk yield in the following lactation, and that this effect is mediated through demonstrable changes in mammary gland development, prolactin signaling, and mammary gene expression; and **(II):** Modulation of photoperiod and temperature during the dry period will affect milk yield in goats in the subsequent lactation via shifts in nutrient and endocrine partitioning, and mammary gene expression, during the dry period and into lactation.

Cows exposed to short days for only the final 21 days of the dry period did not produce more milk than those on long day or natural photoperiod when dry. However, cows on short days for the entire 60 days dry did produce more milk than the other 3 groups. This indicates that there is a duration effect of short day exposure on subsequent milk yield. Results of the second study in cows indicate that mammary growth increases differentially during the dry period under long vs. short days, and that short days drive more extensive growth which is associated with altered prolactin signaling via decreases in an suppressors of cytokine signaling that represent an inhibitory pathway to mammary growth.

Evidence from the studies in Israel confirms that goats respond to short days during the dry period in a similar manner to cows. In addition, heat stress effects on during the dry period can be limited by exposure to short days. Here again, shifts in prolactin signaling, along with changes in IGF-I secretion, are associated with the observed changes in mammary function in goats.

These results have a number of biological and practical implications. For dairy producers, it is clear that we can recommend that cows and goats should be on reduced light exposure during the dry period, and further, cows and goats should be cooled to avoid heat stress during that time. Environmental influences on mammary growth are apparent during the dry period, and those effects have persistent impact in the subsequent lactation. Prolactin signaling is a consistent mechanism whereby extended light exposure and heat stress may depress mammary growth and development during the dry period. Thus, the prolactin signaling system offers an opportunity for further manipulation to improve production efficiency in dairy ruminants.

Achievements

Objective 1 was developed to “Determine the critical duration for photoperiodic treatment during the dry period to cause milk yield increases in the next lactation.” We treated 96 cows with one of 4 treatments during the dry period: 1) short day photoperiod (8L:16D; SDPP) for 60 d, 2) long day photoperiod (16L:8D; LDPP) for 60 d, 3) simulated natural photoperiod (NDPP) for 60 d, and 4) SDPP for the final 21 d of the dry period after NDPP during the early dry period (SD21). Cows exposed to SDPP produced significantly more milk than those on any other treatment through 110 DIM when data collection ended. There were no overall differences in milk yield among LDPP, NDPP and SD21 groups, which suggests that the impact of short days requires more than 21 days to develop.

In Objective 2 we “Determine(d) developmental differences, particularly with regard to mammary cell turnover and function, that accompany SDPP treatment during the dry period”. Using sequential mammary biopsies, we determined temporal changes in mammary cell proliferation and in expression of genes of the IGF and PRL signaling pathways during the dry period and transition into lactation. For both SDPP and LDPP, cell proliferation rate increased significantly as the dry period advanced, then decreased significantly in early lactation. However, timing of the proliferative response differed between treatments, increasing earlier in SDPP cows than in LDPP cows during the dry period. Overall, expression of IGF-II was significantly greater, whereas that of IGFBP-5 was lower, in SDPP versus LDPP cows. IGFBP-5 mRNA increased significantly during lactation in both groups. Expression of IGF-I did not differ over time or between treatments however, the lower IGFBP-5 expression in SDPP cows coupled with increased IGF-II expression may enhance mammary cell growth and survival. Key among the potential modulators of PRL signaling is the suppressors of cytokine signaling (SOCS) family, the best characterized of which are SOCS-1, -2, -3, and cytokine-inducible SH2-containing protein (CIS). Mammary expression of SOCS-1, -2, -3, and CIS were low during the dry period, but increased in lactation. During the dry period, SOCS expression of cows on SDPP was generally reduced, which may enhance PRL induced proliferation and subsequent milk production.

In Objective 3, we “Determine(d) the effect of photoperiod, temperature, and the interaction during the dry period on subsequent milk production, udder development and plasma hormonal profile in goats.” Previous results were novel, in that they observed an effect of prepartum photoperiod on subsequent lactational performance in goats similar to effect noted in cows. But those results were obtained under normothermic conditions. As a follow-up, an experiment was completed that examined the effect of LDPP and SDPP under hyperthermic conditions (35 ± 1 °C, 70% relative humidity; HT) during late gestation on

subsequent milk yield. Milk yields were higher in SD compared to LD starting from week 3 in lactation, and overall milk yield for the 12-week period was 40% higher in the HS-SD than the HS-LD (2172 vs. 1552 g/ d). Similar trends were observed in milk component yields. These data support the concept that reduced photoperiod ameliorates a portion on the detrimental effects of hyperthermia.

Objective 4, which was to “Determine changes in net blood flow to the mammary gland, nutrient and PRL net influx to the gland, and turnover, function and gene expression of the mammary cells during the dry period as affected by environmental factors”, was a comparison of does exposed to SD under NT or HT conditions. Milk yield was reduced in SDHT does versus SDNT, yet PRL concentrations were not different. However, mammary expression of PRL-R mRNA did change during the dry period and was numerically lower in the heat stressed does 10 days before kidding. Circulating IGF-I was also reduced in the heat stressed does relative to normothermic does. These observations suggest an interplay of PRL and the IGF system in mediation of photoperiodic and temperature effects on mammary growth, which is consistent with the observations in cows.

Combined with other studies examining the influence of photoperiod and temperature on cow and doe health, results of this project allows for management recommendations to producers that will improve productivity, animal health and well-being. Specifically, dairy managers should provide short day photoperiod and heat abatement to cows and goats during the dry period to reduce the negative impact of elevated prolactin on subsequent mammary function.

Cooperation

With regard to cooperation between the Israeli and US based laboratories, we have continued to discuss the projects among investigators via e-mail throughout the funding period. Drs. Shamay, Mabeesh, McFadden and Dahl also met extensively at the annual ADSA/ASAS meetings, where project progress and implications were discussed. Additionally, one combined abstract was presented at that meeting that was based on results generated in this project. And, an additional proposal to follow-up on the results of this project was submitted in 2004, although it was not funded.

List of Publications

Wall E. H., T. L. Auchtung-Montgomery, **G. E. Dahl**, and **T. B. McFadden**. 2005. Short communication: Short-day photoperiod during the dry period decreases expression of suppressors of cytokine signaling in mammary gland of dairy cows. *J. Dairy Sci.* 88:3145-3148.

- Wall E. H., T. L. Auchtung-Montgomery, **G. E. Dahl**, S.E. Ellis, and **T. B. McFadden**. 2005. Exposure to short day photoperiod during the dry period enhances mammary growth in dairy cows. *J. Dairy Sci.* 88:1994-2003.
- Zhao, F.-Q., Y-C. Zheng, E.H. Wall, and **T.B. McFadden**. 2005. Cloning and expression of bovine sodium/glucose cotransporters. *J. Dairy Sci.* 88:182-194.
- Auchtung, T.L., A.G. Rius, **T.B. McFadden**, and **G.E. Dahl**. 2005. Effects of photoperiod during the dry period on prolactin, prolactin receptor, and milk production of dairy cows. *J. Dairy Sci.* 88:121-127.
- Dahl, G.E.**, T.L. Auchtung and E.R. Reid. 2004. Manipulating milk production in early lactation through photoperiod changes and milking frequency. *Vet. Clin. No. Amer.* 20:675-685. Review.
- Zhao, F-Q., P.J. Miller, E.H. Wall, Y-C. Zheng, B. Dong, M.C. Neville, and **T.B. McFadden**. 2004. Bovine glucose transporter GLUT8: Cloning, expression, and developmental regulation in mammary gland. **Bioch. Biophys. Acta** 1680:103-113.
- Auchtung, T.L., P.E. Kendall, J.L. Salak-Johnson, **T.B. McFadden**, and **G.E. Dahl**. 2003. Photoperiod and bromocriptine treatment effects on expression of prolactin receptor mRNA in bovine liver, mammary gland, and peripheral blood lymphocytes. *J. Endocrinol.* 179:347-356.
- Dahl, G.E.** and D. Petitclerc. 2003. Management of photoperiod in the dairy herd for improved production and health. *J. Anim. Sci.* 81(Suppl. 3):11-17. Review.
- Dahl, G.E.**, T.L. Auchtung, J.L. Salak-Johnson and D.E. Morin. 2003. Photoperiod and immune function in dairy cows. Published as pp. 20-25 in the *Proceedings of the 5th International Dairy Housing Conference*, American Society of Agricultural Engineers, K.A. Janni ed. and as pp. 175-181 in the *Proceedings of the 42nd Annual Meeting of the National Mastitis Council*.

Appendix Items

Copies of reprints from project studies.

Additional publication citations.

Abstracts:

- E. H. Wall, T. L. Auchtung, **G. E. Dahl and T. B. McFadden**. 2004. Exposure to short day photoperiod enhances mammary growth during the dry period of dairy cows. *J. Dairy Sci.* 87(Suppl. 1): 94. (**3rd place in National ADSA Graduate Student Paper Contest**).
- E. H. Wall, T. L. Auchtung, **G. E. Dahl and T. B. McFadden**. 2004. Exposure to long day photoperiod during the dry period increases mammary gland expression of suppressors of cytokine signaling in dairy cows. *J. Dairy Sci.* 87(Suppl. 1):423-424.
- D.G. Martinez, **G.E. Dahl and T.B. McFadden**. 2004. Mechanisms of transport of vitamins into colostrum: A potential role of megalin and low-density lipoprotein receptor. *J. Dairy Sci.* 87(Suppl. 1): 128. (**2nd place in NE ADSA/ASAS Graduate Student Paper Contest**).
- F. Zhao, P. Miller, E. H. Wall, Y. Zheng, B. Dong and **T. B. McFadden**. 2004. Cloning and expression of bovine glucose transporter GLUT8. *J. Dairy Sci.* 87(Suppl. 1):133.
- E.D. Reid, T.L. Auchtung, D.E. Morin, **T.B. McFadden, and G.E. Dahl**. 2004. Effects of 21-day short day photoperiod (SDPP) during the dry period on prolactin (PRL) concentrations, lymphocyte PRL receptor (PRL-R) mRNA, and general health of dairy cows. *J. Dairy Sci.* 87(Suppl. 1):423.
- E.D. Reid, R.L. Wallace, **T.B. McFadden, and G.E. Dahl**. 2004. The effects of a 21-day short day photoperiod treatment during the dry period on dry matter intake and subsequent milk production in cows. *J. Dairy Sci.* 87(Suppl. 1):424.
- Auchtung, T.L., D.E. Morin, C. Mallard, J.L. Salak-Johnson and **G.E. Dahl**. 2003. Short day photoperiod during the dry period improves immune function of dairy cattle. *J. Anim. Sci.* 81(Suppl. 1):244.
- McFadden, T.B.** 2003. Effects of bioactive components of colostrum and milk on neonatal health, growth and intestinal development. *J. Dairy Sci.* 86(Suppl. 1):135.
- Auchtung, T.L., D.E. Morin, C. Mallard and **G.E. Dahl**. 2003. Photoperiod manipulation during the dry period: effects on general health and mastitis occurrence. *Proc. Natl. Mast. Council 42nd Meeting*, 278-279.
- Rius, A.G., T.L. Auchtung, P.E. Kendall, **T.B. McFadden and G.E. Dahl**. 2003. Evidence for shifts in prolactin sensitivity in cows exposed to long or short day photoperiod during the dry period. *J. Dairy Sci.* 86(Suppl. 1):244.

Mabjeesh, S.J., A. Shamay, G.E. Dahl and T.B. McFadden. 2003. Exposure to short days during the dry period increases milk production in subsequent lactation in dairy goats. *J. Dairy Sci.* 86(Suppl. 1):283.