ARIZONA AND NEW MEXICO DAIRY NEWSLETTER

COOPERATIVE EXTENSION
The University of Arizona
New Mexico State University

JULY 2006

THIS MONTH'S ARTICLE:

Does Negative Energy Balance (NEBAL) Limit Milk Synthesis in Early Lactation?

Lance H. Baumgard, Laura J. Odens, Jane K. Kay,
Robert P. Rhoads, Matthew J. VanBaale and Robert J. Collier
Department of Animal Sciences
The University of Arizona, Tucson, Arizona

(Reprinted from the 21st Annual Southwest Nutrition & Management Conference Proceedings February 23-24, 2006, Tempe, Arizona)

Does Negative Energy Balance (NEBAL) Limit Milk Synthesis in Early Lactation?

Lance H. Baumgard, Laura J. Odens, Jane K. Kay, Robert P. Rhoads, Matthew J. VanBaale and Robert J. Collier

Department of Animal Sciences
The University of Arizona
Corresponding Author: baumgard@ag.arizona.edu

Summary

- Most cows enter NEBAL after parturition and this is a normal mammalian adaptation to lactation
- Peak milk production may occur when cows are in NEBAL
- The extent of NEBAL in early lactation is independent of genetic potential for milk yield
- Milk production and energy balance slopes are in opposite direction immediately post-calving but parallel each other in later lactation
- The effects of increasing metabolizable energy on production variables probably depends on the animals energy balance status

Introduction

Energy balance (EBAL) is the difference between energy consumed and energy used for both maintenance and production (milk, meat, reproduction, etc.). For a detailed description of the different methods of calculating EBAL see our recent review (Moore et al., 2005). Frequently in a cows life cycle, there are instances when energy availability, or more specifically a lack of available energy, may limit milk or milk component synthesis, reduce reproductive performance and prevent body condition replacement. Examples include the transition period in both TMR and pasture-based systems, periods of poor feed quality and adverse environmental situations such as heat stress and drought. Incidentally this bioenergetic phenomenon is not exclusive to dairy cows; as most female mammals experience a similar nutrient imbalance after parturition and in fact, the severity of this nutrient inequality is quite minor in cows compared to a large number of other species (see our recent review, Collier et al., 2005).

Cows in early lactation typically cannot consume enough calories to meet the energetic requirements of maintenance and copious milk secretion, and consequently enter into a state of negative energy balance (NEBAL). The severity, magnitude and day of NEBAL nadir (~4-9 DIM) are closely associated with metabolic disorders and reproductive failures (Butler, 2000; Drackley, 1999; Buckley et al., 2003; Rhoads et al., 2005). The impact of NEBAL on reproductive parameters is even more critical in strict pasture-based systems as pasture allowance is restricted and calving patterns must coincide with forage availability to maintain farm sustainability (Rhodes et al., 2003). Attempts to improve or alleviate NEBAL traditionally involve increasing dietary energy density via the addition of concentrates or fats (Schingoethe & Casper, 1991; Hayirli & Grummer, 2004). However, the effectiveness of these dietary strategies is frequently inconsistent and is associated with potential drawbacks (i.e. acidosis and reduced DMI; Hayirli & Grummer, 2004). There are a number of reviews concentrating on the benefits and limitations of increasing the dietary content of grains and fats with regards to EBAL and they will not be discussed further in this paper.

Interestingly and contrary to what is often reported (Broom, 1995; Veerkamp, 1998; Veerkamp et al., 2000; Heuer, 2004; Oltenacu & Algers, 2005), genetically superior or higher producing cows have similar calculated NEBAL parameters (severity, magnitude etc.) and blood energetic variables when compared to their lesser producing herd mates (Vicini et al., 2002; Crooker et al., 2006). The increased milk yield associated with genetic progress is accompanied by homeorhetic mechanisms that favor increased feed intake during early lactation (Crooker et al., 2001; Crooker et al., 2006). It is logical to predict that selecting animals for increased milk production simultaneously selects animals capable of coordinating metabolism to sustain evolutionary advantages. Furthermore, the fact that genetic selection for milk yield doesn't intensify NEBAL parameters, jeopardize health or cause cow "burn out" is due to natural coordinated homeorhetic mechanisms as we recently described (Collier et al., 2005).

Bioenegetics of Production

It is well known that animals primarily eat to meet their energy requirements (Church and Pond, 1988), but this is slightly complicated in ruminants due to the effects of forage quality and gut fill (Van Soest, 1982). Nonetheless, if an animal is in positive EBAL (PEBAL), providing additional metabolizable energy (ME) should not theoretically increase milk yield, but rather decrease feed intake and thus improve efficiency. In contrast, if an animal is in NEBAL, adding additional ME would logically increase milk production without altering feed intake. Both of the above scenarios assumes that calculated net whole animal EBAL is tightly linked with the mammary glands energetic and nutrient requirements to synthesize milk. Adding additional energy (or any nutrient for that matter), if milk synthesis wasn't limited by nutrient availability, can not "push" milk as milk synthesis itself "drives/pulls" nutrient and energy intake (i.e. DMI; Bauman & Currie, 1980; Collier et al., 2005). As demonstrated in Figure 1, predicting the effects (milk yield, DMI and feed efficiency) of enhanced ME probably depends on whether or not the animal is in NEBAL or PEBAL.

During established lactation, decreased energy and nutrient availability (either experimentally induced or due to poor feed quality [drought, heat stress, spoiled feed etc.]) is closely matched by a coinciding decrease in milk yield. As a consequence of the reduction in milk synthesis, actual calculated net EBAL remains near zero. When nutrient supply or the level of nutrition increases, milk yield parallels the enhanced nutrient state. Therefore, clearly in mid to late lactation, nutrient/energy availability can limit or restrict milk synthesis.

During early lactation the connection between nutrient supply and milk production appears uncoupled. This is especially obvious during the first 10 days in milk (DIM) where milk yield is increasing at a steep slope while calculated EBAL is simultaneously decreasing towards its nadir (see theoretical diagram in Figure 1). Milk yield continues to increase until peak (~40-70 DIM) while cows are still in calculated NEBAL (albeit progressing towards PEBAL; Figure 1). Obviously tissue mobilization accounts for the energy deficit in early lactation, but it's interesting that there is a stark contrast between dietary energy/nutrient supply and milk production during early vs. later lactation. Why doesn't tissue mobilization compensate for the decrease in nutrient supply and thus maintain production in later lactation, even temporally?

Although early lactation NEBAL is frequently blamed for a variety of metabolic and reproductive disorders (Drackley, 1999; Butler, 2000), whether or not it limits or prevents maximum milk yield is not clear. Attaining a high milk yield in early lactation and

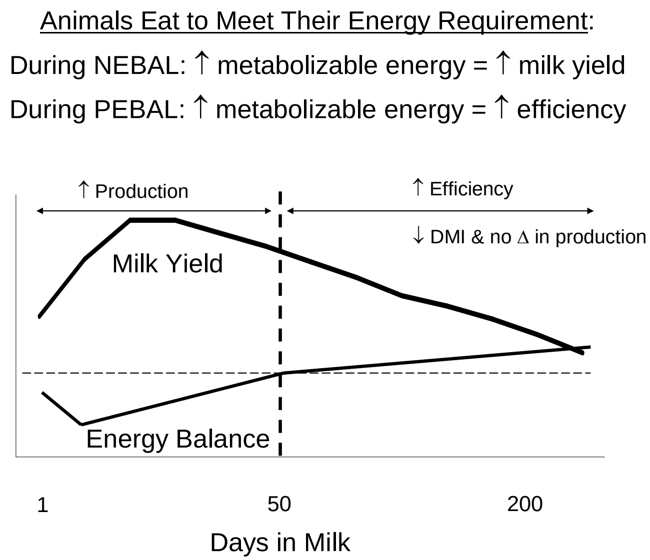

Figure 1. Theoretical lactation and energy balance curves. Bioenergetics would predict that increasing metabolizable energy will have different effects on production parameters depending upon calculated energy balance status.

specifically peak milk yield, is thought to "prime" the gland for the entire lactation, and retrospective statistical analysis indicates that for every one unit (kg or lb etc.) increase at peak lactation equates to a 127 unit increase in total lactation yield (Dr. Bob Everett, Cornell University; Personal Communication). A variety of different approaches have attempted to alter or improve EBAL and they include 1) supplemental fats, 2) additional concentrates, 3) reduced milking frequency (i.e. 1x/d), 4) propylene glycol, 5) monensin and 6) conjugated linoleic acid induced milk fat depression (CLA-MFD). The first four approaches have limitations (i.e. palatability, acidosis, mammary function etc.) that create difficulties when evaluating their effect on EBAL.

A unique approach to improve transition period EBAL is to decrease the milk energy content, thus manipulating the energy expenditure side of the EBAL equation, rather than the energy intake portion. Fat is the most energetically expensive milk component to synthesize (50% of total milk energy; Tyrell & Reid, 1965) and the milk parameter most easily manipulated by management (Bauman & Davis, 1974; Bauman et al., 2001). Therefore, governing milk fat via controlled MFD offers a novel technique/opportunity to improve EBAL through the transition period.

Conjugated Linoleic Acid Transition Trials

We've conducted three CLA-MFD trials during the transition period (Moore et al., 2004; Kay et al., 2004; Odens et al., 2006), with the two later trials designed to evaluate the effects of CLA-MFD on EBAL parameters and production variables. As we predicted (Baumgard et al., 2002), both trials indicate that when EBAL is improved due to CLA-MFD, milk yield is enhanced (Figures 2 and 3). As would bioenergetically be predicted by Figure 1, CLA-MFD does not increase milk yield during established lactation when cows are in PEBAL (Geisy et al., 2002; Perfield et al., 2002). Our studies demonstrate that a dietary supplement of CLA reduces milk fat synthesis immediately postpartum and may be useful as a management tool to alleviate NEBAL and improve milk production in TMR and pasture-fed dairy cows.

Monensin Transition Trials:

Another approach to improve transition EBAL that has recently become available to USA producers is monensin (Rumensin, FDA approved 2004, Elanco Animal Health, Greenfield, IN). Feeding ionophores, specifically monensin, alters rumen metabolism/physiology to favor a more energetic fermentation pathway (see reviews by Schelling, 1983; Ipharraguerre & Clark, 2003). A number of papers demonstrate an improved energy status (NEFA, ketones, glucose etc.) with monensin (Ipharraguerre & Clark 2003) and this is especially apparent in early lactation (Green et al., 1999; Duffield et al., 2003; Melendez et al., 2004; Gallardo et al., 2005). As would bioenergtically be predicted by Figure 1, monensin feeding typically increases milk to a larger extent in early lactation (Hays et al., 1996; Beckett et al., 1998; Gallardo et al., 2005) compared to later lactation, where feed efficiency is improved by monensin (see reviews by Ipharraguerre & Clark, 2003; McGuffey et al., 2003).

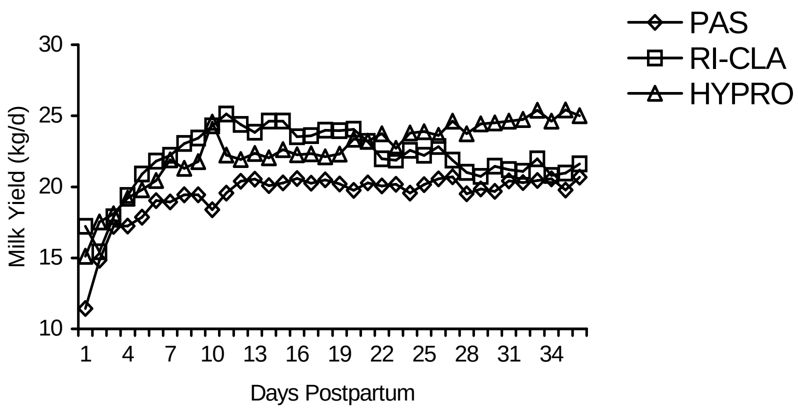

Figure 2. Effects of pasture fed cows (PAS) supplemented with rumen inert palm oil (HYPRO) or CLA on milk yield in transitioning lactating dairy cows. Adapted from Kay et al. 2004.

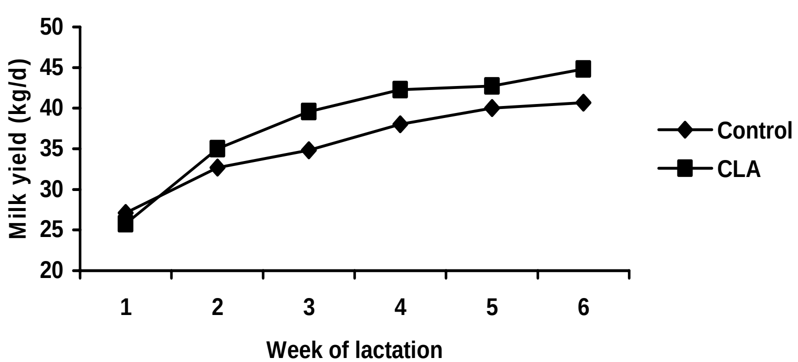

Figure 3. Effects of rumen inert CLA on milk yield compared to cows fed a rumen inert palm oil. Adapted from Odens et al., 2006

Summary

Based on evidence from transition period CLA-MFD and monensin trials, it appears that milk yield in early lactation is limited by a lack of energy intake. Obviously anything that increases ME during this stage of lactation would potentially benefit milk production, whereas increasing ME during mid to late lactation, a period when cows would presumably be in PEBAL, wouldn't logically increase milk yield but probably increase feed efficiency.

References

Bauman, D.E. and W.B. Currie. 1980. Partitioning of nutrients during pregnancy and lactation: A review of mechanisms involving homeostasis and homeorhesis. J. Dairy Sci. 63:1514-1529.

Bauman, D.E. and C.L. Davis. 1974. Biosynthesis of Milk Fat. In: B. L. Larson and V. R. Smith (ed.) Lactation: A Comprehensive Treatise, Vol. 2. pp 31-75. Academic Press, New York.

Bauman, D.E., B.A. Corl, L.H. Baumgard, and J.M. Griinari. 2001. Conjugated linoleic acid (CLA) and the dairy cow. In: *Recent Advances in Animal Nutrition*, P.C. Garnsworthy and J. Wiseman (ed). Nottingham University Press, Nottingham, UK. pp 221-250.

Baumgard, L.H., C.E. Moore, and D.E. Bauman. 2002. Potential application of conjugated linoleic acids in nutrient partitioning. Proc. Southwest Nutr. Conf. 127-141.

Beckett, S., I. Lean, R. Dyson, W. Tranter and L. Wade. 1998. Effects of monensin on the reproduction, health, and milk production of dairy cows. J. Dairy Sci. 81:1563-1573.

Broom, D.M. 1995 Measuring the effects of management methods, systems, high production efficiency and biotechnology on farm animal welfare. In *Issues in Agricultural Bioethics*, pp 319-334. Edited by T.B. Mepham, G.A. Tucker and J. Wiseman. Nottingham University Press, Nottingham, UK.

Buckley F., K. O'Sullivan, J.F. Mee, R.D. Evans and P. Dillon. 2003 Relationships among milk yield, body condition, cow weight, and reproduction in spring-calved Holstein-Friesians. J. Dairy Sci. 86:2308-2319.

Butler, W.R. 2000. Nutritional interactions with reproductive performance in dairy cattle. Anim. Reprod. Sci. 60:449-457.

Church, D.C. and W.G. Pond. 1988 Basic Animal Nutrition and Feeding, Third Edition. John Wiley & Sons, Inc.

Collier, R.J., L.H. Baumgard, A.L. Lock and D.E. Bauman. 2005. Physiological Limitations: nutrient partitioning. Chapter 16. In: Yields of farmed Species: constraints and opportunities in the 21st Century. Proceedings: 61st Easter School. Nottingham, England. J. Wiseman and R. Bradley, eds. Nottingham University Press, Nottingham, U.K. (351-377).

Crooker, B.A., M. Carriquiry and W.J. Weber. 2006. Reproductive success in diary cows: The linkage of milk yield, nutrition, and reproduction. Proc. Inter. Mt. Nutr. Conf. 213-224.

Crooker, B.A., W.J. Weber, L.S. Ma and M.C. Lucy. 2001. Effect of energy balance and selection for milk yield on the somatotropic axis of the lactating Holstein cow: Endocrine profiles and hepatic gene expression. In: Energy Metabolism of Animals (15th Symposium). EAAP Energy Symposium, Snekkersten, Denmark. EAAP Publ. No. 103 pp 345-348.

Drackley, J.K. 1999. Biology of dairy cows during the transition period: the final frontier? J. Dairy Sci. 82:2259-2273.

Duffield, T.F., S. LeBlanc, R. Bagg, K. Leslie, J. Ten Hag and P. Dick. 2003. Effect of a monensin controlled release capsule on metabolic parameters in transition dairy cows. J. Dairy Sc. 86:1171-1176.

Gallardo, M.R., A.R. Castillo, F. Bargo, A.A. Abdala, M.G. Maciel, H. Perez-Monti, H.C. Castro and M.E. Castelli. 2005. Monensin for lactating dairy cows grazing mixed-alfalfa pasture and supplemented with partial mixed ration. J. Dairy Sci. 88:644-652.

Giesy, J.G., M.A. McGuire, B. Shafii, and T.W. Hanson. 2002. Effect of dose of calcium salts of conjugated linoleic acid (CLA) on percentage and fatty acid content of milk fat in midlactation Holstein cows. J. Dairy Sci. 85:2023-2029.

Green, B.L., B.W. McBride, D. Sandals, K.E. Leslie, R. Bagg and P. Dick. 1999. The impact of a monensin controlled-release capsule on subclinical ketosis in the transition dairy cow. J. Dairy Sci. 82:333-342.

Hayes, D.P., D.U. Pfeiffer and N.B. Williamson. 1996. Effect of intraruminal monensin capsules on reproductive performance and milk production of dairy cows fed pasture. J. Dairy Sci. 79:1000-1008.

Hayirli, A., and R. R. Grummer. 2004. Factors affecting dry matter intake prepartum in relationship to etiology of peripartum lipid-related metabolic disorders: A review. Can. J. Anim. Sci. 84:337-347.

Heuer C. 2004. The use of test day information to predict energy intake of dairy cows in early lactation. J. Dairy Sci. 87:593-601

Ipharraguerre, I. and J.H. Clark. 2003. Usefulness of ionophores for lactating dairy cows: a review. Anim. Feed Sci. Tech. 106:39-57.

Kay, J.K., J.R. Roche and L.H. Baumgard. 2004. Effects of dietary CLA on production parameters in pasture-fed transition dairy cows. J. Dairy Sci. Supplement (1) 87: 95

McGuffey, R.K., L.F. Richardson and J.I.D. Wilkinson. 2003. Ionophores for dairy cattle: Current status and future outlook. J. Dairy Sci. (E. Suppl.): E194-E203.

Melendez, P., J.P. Goff, C.A. Risco, L.F. Archbald, R. Litell and G.A. Donovan. 2004. Effect of a monensin controlled-release capsule on rumen and blood metabolites in Florida Holstein transition cows. J. Dairy Sci. 87:4182-4189.

Moore, C.E., H.C. Hafliger, III, O.B. Mendivil, S.R. Sanders, D.E. Bauman and L.H. Baumgard. 2004. Increasing amounts of conjugated linoleic acid (CLA) progressively reduces milk fat synthesis immediately postpartum. J. Dairy Sci. 87:1886-1895.

Moore, C.E., J.K. Kay, M.J. VanBaale and L.H. Baumgard. 2005. Calculating and improving energy balance during times of nutrient limitation. Proc. Southwest Nutr. Conf: 173-185.

Odens L.J., R. Burgos, M.J. Innocenti, B.C. Pollard, S.H. Baker, S.R. Sanders, J.K. Kay, M.L. Rhoads, C.E. Moore, M.J. VanBaale and L.H. Baumgard. 2006. Effects of varying CLA doses on production and bioenergetic variables during the transition period. J. Dairy Sci. 89:(Suppl. 1; in press)

Perfield, II, J.W., G. Bernal-Santos, T.R. Overton and D.E. Bauman. 2002. Effects of dietary supplementation of rumen-inert conjugated linoleic acid in dairy cows during established lactation. J. Dairy Sci. 85:2609-2617.

Rhoads, R.P., M.L. Rhoads and Y.R. Boisclair. 2005. Implications of a dysfunctional somatotropic axis during the transition period in dairy cattle. Proc. Southwest Nutr. Conf. 197-208.

Rhodes F.M., S. McDougall, C.R. Burke, G.A. Verkerk and K.L. Macmillan. 2003 Invited review: Treatment of cows with an extended postpartum anestrous interval. J. Dairy Sci. 86:1876-1894.

Schelling, G.T. 1983. Monensin mode of action in the rumen. J. Anim. Sci. 58:1518-1527.

Schingoethe, D.J. and D.P. Casper. 1991. Total lactational response to added fat during early lactation. J. Dairy Sci. 74:2617-2622.

Tyrrell, H.F. and J.T. Reid. 1965. Prediction of the energy value of cow's milk. J. Dairy Sc. 48:1215-1223

Van Soest, P.J. 1982. Nutritional Ecology of the Ruminant. O & B books, Inc. Corvallis, Oregon.

Veerkamp, R.F. 1998. Selection for economic efficiency of dairy cattle using information on live weight and feed intake: a review. J. Dairy Sci. 81:1109-1119.

Veerkamp, R.F., J.K Oldenbroek, H.J. Van Der Gaast and J.H.J Van Der Werf. 2000. Genetic correlation between days until start of luteal activity and milk yield, energy balance and live weights. J. Dairy Sci. 83:577-583.

Vicini, J.L., B.A. Crooker and M.A. McGuire. 2002. Energy balance in early lactation dairy cows. CA. Anim. Nutr. Conf. 1-8.

HIGH COW REPORT
JUNE 2006

MILK

Arizona Owner	Barn#	Age	Milk
* Mike Pylman	845	03-03	36,690
* Mike Pylman	733	03-03	36,390
Parker Dairy	452	06-10	35,500
* Mike Pylman	653	03-04	35,400
* Withrow Dairy	9189	03-00	35,350
* Stotz Dairy	17761	04-05	35,110
* D & I Holstein	480	04-00	35,070
* Mike Pylman	391	04-03	34,760
* Withrow Dairy	5885	05-01	34,630
* Withrow Dairy	1727	06-01	34,360

New Mexico Owner	Barn #	Age	Milk

Information unavailable at press time.

FAT

* Mike Pylman	21989	04-08	1,387
* Mike Pylman	21003	05-04	1,350
* Stotz Dairy	16752	05-02	1,327
* Stotz Dairy	18483	03-10	1,325
* Stotz Dairy	17361	04-09	1,298
* Stotz Dairy	17761	04-05	1,295
* Shamrock Farms	5464	05-00	1,291
Parker Dairy	8998	05-08	1,253
* Shamrock Farms	3688	05-08	1,245
* Mike Pylman	626	03-03	1,232
* Dutch View Dairy	408	03-00	1,232

PROTEIN

* Mike Pylman	845	03-03	1,120
* Stotz Dairy	16752	05-02	1,042
* Shamrock Farms	A290	03-08	1,041
* Shamrock Farms	5177	05-01	1,036
* Stotz Dairy	18202	04-01	1,030
* Stotz Dairy	18483	03-10	1,029
* Shamrock Farms	3688	05-08	1,027
* Shamrock Farms	9745	03-10	1,025
* Mike Pylman	3693	03-06	1,010
* Cliffs Dairy	1714	03-10	1,007

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

ARIZONA - TOP 50% FOR F.C.M.[b]
JUNE 2006

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	CI
* Stotz Dairy West	2,227	27,935	1,003	28,338	14.8
* Stotz Dairy East	1,006	25,256	914	25,737	15.2
* Mike Pylman	7,816	25,571	886	25,419	14.3
* Del Rio Dairy, Inc.	1,375	24,657	855	24,521	12.9
* Zimmerman Dairy	1,195	24,063	858	24,313	14.8
Parker Dairy	4,118	23,237	843	23,713	14.7
* Danzeisen Dairy, Inc.	1,462	23,598	830	23,658	14.6
* Red River Dairy	8,417	25,138	788	23,643	13.9
* Withrow Dairy	5,337	24,374	808	23,637	13.2
* Arizona Dairy Company	5,503	23,924	813	23,523	14.4
* Dairyland Milk Co.	2,978	23,377	818	23,368	13.6
Paul Rovey Dairy	349	23,123	821	23,307	13.5
* Goldman Dairy	2,147	22,965	797	22,849	13.8
* Shamrock Farm	8,342	23,695	763	22,614	13.7
* RG Dairy, LLC	1,226	22,267	785	22,353	13.9
Lunts Dairy	598	21,646	795	22,247	13.1

NEW MEXICO - TOP 50% ACTUAL MILK
JUNE 2006

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	CI
* Do-Rene	2,468	26,379	928	26,455	13.9
* Pareo	1,285	25,499	904	25,685	13.7
* Milagro	3,417	24,088	892	24,880	14.2
* Butterfield	2,061	25,151	851	24,675	14.0
* Cross County	3,765	24,265	870	24,600	13.6
* Macatharn	888	24,702	855	24,546	13.6
* SAS	1,644	24,423	846	24,279	13.4
* Flecha	2,359	23,454	870	24,249	13.4
* Stark Everett	2,974	23,074	820	23,274	13.7
* Tallmon	517	22,516	790	22,547	14.2
* Breedyk	2,774	22,645	731	21,646	14.2
* Goff	1,134	18,308	835	21,457	13.8
* Caballo	3,510	20,870	740	21,024	13.3
* Rocky Top Jersey	1,505	15,582	704	18,154	13.2

* 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 JUNE 2006

		ARIZONA	NEW MEXICO
1.	Number of Herds	31	27
2.	Total Cows in Herd	61,359	49,904
3.	Average Herd Size	1,979	1,848
4.	Percent in Milk	89	87
5.	Average Days in Milk	215	194
6.	Average Milk – All Cows Per Day	61.9	65.9
7.	Average Percent Fat – All Cows	3.6	3.5
8.	Total Cows in Milk	54,802	38,441
9.	Average Daily Milk for Milking Cows	69.2	74.9
10.	Average Days in Milk 1st Breeding	84	70
11.	Average Days Open	167	138
12.	Average Calving Interval	14.2	13.9
13.	Percent Somatic Cell – Low	86	76
14.	Percent Somatic Cell – Medium	8	11
15.	Percent Somatic Cell – High	6	10
16.	Average Previous Days Dry	60	65
17.	Percent Cows Leaving Herd	28	32
		STATE AVERAGES	
	Milk	22,618	23,590
	Percent butterfat	3.54	3.53
	Percent protein	2.97	3.04
	Pounds butterfat	799	823
	Pounds protein	680	691

UPCOMING EVENT:

ARIZONA DAIRY PRODUCTION CONFERENCE
OCTOBER 10, 2006
SHERATON PHOENIX AIRPORT HOTEL
TEMPE, AZ

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