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Improving Milk Quality and Animal Health Through Efficient Pasture Management

FINAL REPORT
Low-Input Sustainable Agriculture Project LNE89-17
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PROJECT SUMMARY

Three grazing systems: intensively managed rotational grazing, traditional continuous grazing, and confinement housing, were compared on 17 Vermont dairy farms. The purpose was to determine if grazing systems had an effect on milk quality, animal health and reproductive efficiency.

Effect of grazing treatment on milk quality was determined by collecting bulk tank milk samples from each farm, each month for one year. The samples were analyzed by dairy cooperatives for standard plate count which is a measure of total bacterial contamination in raw milk. Results were retrieved by the University of Vermont Quality Milk Research Laboratory for analysis. Although no significant differences were determined among the grazing systems used, results did indicate trends towards improved milk quality during the summer grazing season in pastured herds compared with confined herds. During the summer grazing season (May through October), average standard plate count among herds using the rotational grazing system was 4,300 colony forming units per milliliter of

raw milk (which will be abbreviated as CFU/ml). Average count for herds using traditional grazing systems was 5,000 CFU/ml, and the average count for herds using confinement housing was 12,700 CFU/ml.

In addition to the samples evaluated by dairy cooperatives, duplicate samples were collected and sent to the University of Vermont Quality Milk Research Laboratory for analysis. These samples were analyzed for both distribution of specific bacteria types and for somatic cell count (which is a measure of the magnitude of udder infection present in the herd).

In order to determine the distribution of bacterial types, samples were incubated on a nutritive agar medium containing calf blood and the sugar esculin. Calf blood is used to determine if an organism present has toxins which cause breakdown of red blood cells and esculin is used to determine if the organism has the ability to metabolize this sugar. Sampling the milk in this manner yielded interesting trends. Non-agalactiae streptococci, which is a term describing a homogenous group of organisms found on hair, skin, and mucous membrane of cattle, as well as in soil, manure and many other locations, were more numerous in milk from farms utilizing either traditional grazing or confinement housing compared with those using rotational grazing. Determination of bulk tank milk somatic cell count indicated similar trends towards lower counts in milk from farms using rotational grazing compared with either traditional grazing or confinement.

In addition to evaluating milk quality, a survey was also conducted to determine if animal health and reproductive efficiency were impacted by the system of grazing management. Animal health and reproductive efficiency were evaluated by analyzing monthly reports by veterinarians incorporating barn records, Dairy Herd Improvement Association test reports, and records from bi-weekly or monthly herd health clinics conducted by veterinarians. As in the survey of milk quality, no significant differences were determined among the grazing systems used for animal health or reproductive efficiency. Mean occurrence of diseases, disease incidence densities, and estimates of risk were similar in all treatments for metabolic disorders, lameness and reproductive disorders. Some trends were however indicated for udder health. Udder diseases, including clinical mastitis, udder edema and teat injuries, were consistently less in herds managed on pasture compared with herds managed in confinement.

These results indicate that intensively managed rotational grazing **may** provide an environment more conducive towards improved milk quality compared with traditional continuous grazing or confinement housing methods. In addition, managing cows on pasture cows may help prevent problems related to udder health. It must be pointed out that during the period in which this study was conducted, several management changes were made on the farms surveyed. Variation of this sort is difficult to account for, and may have effected the results reported here. This study was designed as a survey. Results of this study may be used to determine sources of sampling error so that these might be controlled in future studies in this field.

SUMMARY OF EXTENSION EFFORT

Results of LNE89-17 were presented at 6 National and statewide meetings, they were featured on a segment of The University of Vermont Extension Services television series, "Across The Fence," appeared as abstracts in two proceedings, and have been published in an international journal.

MEETINGS: Meetings that results from this trial were presented are listed in chronological order.

1) November 7-8, 1989. University of Vermont Extension Service - In-Service Training. Burlington, VT. 35 persons attending.

2) July 8-10, 1990. Northeast American Dairy Science Association/ American Society of Animal Science regional meeting. Chazy, NY. 150 persons attending.

3)* November 7, 1990. LISA (Low-Input Sustainable Agriculture) Dairy Seminar. Waterbury, VT. 112 persons attending.

4) February 11-13, 1991. National Mastitis Council annual meeting. Reno, NV. 385 persons attending.

5) May 9, 1991. University of Vermont Extension Service - Pasture Walk Series. Randolph Center, VT. 20 persons attending.

6) May 10, 1991. University of Vermont Extension Service - Pasture Walk Series. St. Albans, VT. 15 persons attending.

* The LISA dairy seminar, held in Waterbury, Vermont on November 7, 1990, was designed specifically to discuss with farmers, veterinarians, and dairy industry specialists how intensively managed rotational grazing can be utilized to improve profitability, sustainability, and animal health on dairy farms. As stated above, 112 people were registered to attend the meeting. The proportions of those attending were approximately 40% farmers, 15% veterinarians, 20% students form agriculture colleges, and 25% industry and research personnel. The meeting featured 14 speakers representing farmers, veterinarians, researchers, industry personnel, and extension specialists. Also featured were small discussion groups focussing both on the implications of rotational grazing as a LISA system, as well as the considerations of farmers needs when developing other LISA systems. Feedback from participants seemed promising, and ideas discussed have been implemented in subsequent proposals for LISA projects.

PUBLICATIONS: Results of LNE89-17 have been presented in the following publications.

Refereed Journals:

Goldberg, J.J., E.E. Wildman, D.B. Howard, J.R. Kunkel, B.M. Murphy, and J.W. Pankey. 1991. The Influence of Intensively Managed Rotational Grazing, Traditional Continuous Grazing, and Confinement Housing on Bulk Tank Milk Quality and Udder Health. J. Dairy Sci. IN PRESS.

Thesis/ Dissertation:

Goldberg, J.J. 1991. Improving Milk Quality and Animal Health Through Efficient Pasture Management. M.S. Thesis. University of Vermont. Burlington, VT.

Abstracts:

Goldberg, J.J., J.R. Kunkel, J.W. Pankey, and E.E. Wildman. 1990. Improving Milk Quality and Animal Health Through Efficient Pasture Management. Northeast ASAS/ADSA. July 8-10, Chazy, NY.

Goldberg, J.J., E.E. Wildman, D.B. Howard, J.R. Kunkel, B.M. Murphy, and J.W. Pankey. 1991. The Influence of Rotational Grazing, Continuous Grazing, and Confinement Housing on Bulk Tank Milk Quality. 30th. Ann. Natl. Mastitis Council mtg. Feb. 11-13, Reno, NV.

Presentations:

Brace, P. 1990. Traditional continuous grazing. LISA (Low-Input Sustainable Agriculture) Dairy Seminar. Nov. 7, Waterbury, VT.

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The Influence of Intensively Managed Rotational Grazing, Traditional Continuous Grazing, and Confinement Housing on Bulk Tank Milk Quality and Udder Health

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ABSTRACT

Monthly bulk tank milk samples and veterinary records were analyzed for one year on 15 Vermont dairy farms. Data were evaluated using ANOVA to compare effects of grazing management systems on milk quality and udder health. Systems evaluated were: intensively managed rotational grazing, traditional continuous grazing, and confinement housing. Bulk tank samples were evaluated for standard plate count, bacterial type counts on tryptose blood-esculin agar, and SCC. Veterinary records were evaluated for incidence of clinical mastitis, udder edema, and teat injuries. Within and between treatment group analysis were conducted by season, herd size, and udder sanitation systems. Mean standard plate counts were lower in rotational grazed herds compared with confined herds during the grazing season. Similarly, rotational grazed herds with fewer than 60 cows had lower standard plate counts compared with confined herds of similar size. Mean bulk tank counts of non-agalactiae streptococci during the grazing season differed among treatments. Lowest counts occurred in rotational grazed herds. Among herds using predip products recognized efficacious, fewer non-agalactiae streptococci were isolated from BTM of rotational grazed herds compared with confined herds. Rotational grazed herds using postdips recognized efficacious had lower SCC's compared with those using non-recognized postdips. No udder health differences were observed among grazing treatments.

(**Key words:** grazing, bulk tank milk quality, udder health)

Abbreviation key: BTM = bulk tank milk, **CH** = confinement housing, **IMI** = intramammary infection, **IMRG** = intensively managed rotational grazing, **SPC** = standard plate count, **TBA** = tryptose blood-esculin agar, **TCG** = traditional continuous grazing.

Introduction

In recent years, more attention has been given to increasing sustainability of farming systems by reducing input costs and reliance on antibiotics and pesticides (21). This became known as Low-Input Sustainable Agriculture.

On the dairy farm, intensively managed rotational grazing (IMRG) has the potential of reducing feed and labor costs by increasing efficiency of pasture utilization compared to traditional continuous grazing (TCG). Cattle managed under TCG selectively grazed more palatable plant species when pasture productivity was high, leaving less palatable species (30). As a result of selective grazing, less palatable or unpalatable plant species were given a competitive growth advantage resulting in lower livestock productivity across the grazing season (30).

Modern dairies in the United States rely mainly on confined housing (CH) and use of stored forage and commercial concentrates to maintain milk production levels. Shift towards increased confinement has been associated with increased incidence of intramammary infection (IMI) and other udder health problems including edema and stepped on teats (1, 2). Several investigators observed that confined herds had highest incidence of clinical mastitis in summer and the majority of cases were caused by environmental pathogens (4, 13, 28). In a study evaluating teat end microflora, populations of environmental pathogens on teat ends were lower on pastured cattle compared with confined cattle (5). Bulk tank milk (BTM) bacteria counts have also been shown to be lower when cows are pastured compared to confined (16). Mastitis control depends on lowering rate of new IMI and elimination of existing IMI through effective management including hygiene and therapy (4, 23, 24, 25). Use of iodophor teat dips, have resulted in increased human dietary intake of iodine from increased residues in milk (9, 10). Grazing systems that minimize teat bacterial contamination and reduce need for teat sanitizers may indirectly decrease residues in milk. Utilization of IMRG may lower teat end exposure to bacteria, decrease incidence of new IMI, decrease need for therapeutic antibiotics, and enhance BTM quality (1, 2, 3, 13, 29). Common microflora can be differentiated by culturing BTM on tryptose blood-esculin agar (TBA) (20).

The objective of this study was to survey farms using IMRG and determine if pasture management had an effect on BTM quality and udder health. A further objective was to compare milk quality and udder health among three grazing treatments: IMRG, TCG, and CH.

MATERIALS AND METHODS

Grazing Treatments

Data were collected on 15 Vermont farms from May 1, 1989 through April 30, 1990. Five farms used IMRG, five used TCG, and five used CH. The grazing treatments evaluated were initially defined by the following parameters: IMRG herds divided available pasture land into small areas (paddocks). Forage was rationed according to animal needs while protecting the plants from overgrazing (18). Period of time that cattle remained on each paddock depended on forage availability within the paddock, number of paddocks within the system, number of animals within the grazing group, number of groups, and amount of time necessary for grazed plants to recover and accumulate 15 to 20 cm of top growth.

Farms using TCG pastured cattle continuously on all or part of the available pasture land throughout most of the grazing season.

Farms using CH (zero grazing) denied cattle access to pasture and relied primarily on stored and commercial feeds to meet nutritional requirements.

The length of grazing season and grazing management varied among individual farms. All farms confined cattle during the winter months.

Criteria for Cooperator Herds

Farms were nominated by three Vermont veterinary practices that cooperated in this study. Veterinarians chose farms based on breed, rolling herd average, herd size, current mastitis management systems as measures of managerial ability, enrollment in DHIA, and willingness to cooperate. Each veterinary practice was required to nominate sets of three herds having similar breed, production, size, and managerial abilities. Each set had one farm for each of the three grazing treatments.

Management differences between farms were considered before data analysis to determine parameters consistent among all herds, and independent variables that needed to be considered for data analysis. Parameters considered included: use of lactating and dry cow therapy, milking machine system and maintenance schedule, season, herd size, and premilking and postmilking udder sanitation.

All farms utilized dry cow treatment on all quarters of all cows at dry off. Likewise, lactating cow antibiotics were promptly administered to quarters with clinical mastitis. Antibiotic usage was not considered as an independent management variable for statistical analysis.

Milking systems were evaluated on each farm (28). Most farms had some milking equipment problems, but were deemed insignificant (17). Remaining variables: season, herd size, premilking and postmilking udder sanitation, were not consistent among farms. These independent management variables were considered for statistical analysis by sorting herds by each variable prior to ANOVA.

Microbiological Sampling

Duplicate BTM samples were collected monthly by dairy cooperative personnel. Samples were collected from each herd using standard methods (27). Samples were placed in 50ml sterile disposable Polyvial culture tubes (VWR Scientific; San Francisco, CA). One sample was evaluated for SPC by milk cooperatives using standard methods (26). The second sample was transported on ice to the Quality Milk Research Laboratory, University of Vermont, for bacteriological evaluation on TBA and for SCC (19, 20). The fat layer, where bacteria often concentrate in raw milk, was distributed throughout the sample by manually shaking the sample vial over a 30 cm arc 25 times. A .01 ml aliquot of milk was then smear plated with a sterile calibrated inoculating loop (Difco Laboratories; Detroit, MI) across the entire diameter of a TBA plate containing tryptose soy agar, 5% washed bovine blood, and .1% esculin (Micro Diagnostics; Addison Ill.) (12). All samples were streaked in duplicate. After 48h incubation at 37°C, TBA plates were evaluated to determine total count of specific bacterial types and species. Presumptive identification of microbial groups were conducted based on colony morphology, pigmentation, hemolytic reaction and esculin reaction (12, 20).

After streaking TBA plates, the milk sample was fixed with one drop of Preservo Liquid containing 2-Bromo-2-nitropropane-1,3-diol (D & F Control Systems Inc.; San Francisco, CA). Samples were stored at 5°C for a minimum of 24h. Within 7d of fixation, .5 ml was processed using a Fossomatic-90 Milk Cell Counter (A/S N.Foss Electric; Denmark) to measure SCC.

Udder Health Data Collection

Veterinarians that cooperated utilized a computer based herd health monitor program to aid in conducting bi-weekly or monthly herd health clinics (6, 7, 8). The monitor spreadsheet contained data provided by each farm including production, feed program, dry matter intake, body condition, animal inventory, cull program, reproduction, mastitis and disease, and calf and heifer health. Veterinarians used this information to generate monthly reports used for on farm consultations. Veterinarians then supplied copies of reports each month to the University of Vermont Quality Milk Research Laboratory through interchange of magnetic media. Reports were evaluated for incidence of clinical mastitis, udder edema, and teat injuries. Production, reproductive efficiency, and incidence of metabolic diseases were evaluated as part of a separate study (11).

Milk Quality Data Analysis

Arithmetic mean counts of milk quality parameters were transformed to $\log_{10}$ in order to attain homogeneity of variance. Log transformed data were compared using ANOVA on Type III sums of squares (29). A maximum α level of .15 was used to determine if significant differences existed which were of practical importance to producers. For each variable measured, data were ordered by grazing treatment, independent management variable, and the combination of grazing treatment and independent management variable.

Season. The study year was divided into two categories: GRAZING SEASON which included data collected from May through October, and WINTER CONFINEMENT SEASON which included data from November through April. Comparisons were conducted within and between grazing treatments to determine the effects of season. Calculations were also made based on the interaction between season and grazing treatment.

Herd Size. Farms were separated based on herd sizes. Small herds were those with less than 60 lactating cows and large herds included those with 60 or more lactating cows. Comparisons were conducted within and between grazing treatments to determine the effects of size. Calculations were also made based on the interaction between season and grazing treatment.

Pre-milking Udder Hygiene. Farms were grouped for statistical analysis based on whether the teat dip product used for predipping had been evaluated for efficacy using controlled studies. Farms utilizing a proven or unproven predip product (4, 22) were compared within and between grazing treatments to determine the effect of predip product utilized. Calculations were also made based on the interaction between season and grazing treatment.

Post-milking Udder Sanitation. Farms were grouped for statistical analysis based on whether the teat dip product used for postdipping had been evaluated for efficacy using controlled studies. Farms utilizing a proven or unproven postdip product (4, 22) were compared within and between grazing treatments to determine the effect of postdip product utilized. Calculations were also made based on the interaction between season and grazing treatment.

Udder Health Data Analysis

Udder health was evaluated based on incidence of clinical mastitis, udder edema, and teat injuries (11). Comparisons were conducted among grazing treatments using methods of the National Animal Health Monitor System (14, 15). Data were stratified by season and herd size in order to obtain more homogeneous groups to evaluate udder health by grazing treatment (11). Analysis of variance was used to compare calculations of udder health parameters including mean occurrence, incidence density, and risk estimate among treatment groups.

RESULTS AND DISCUSSION

Analysis of Bulk Tank Milk Quality

Analysis of BTM microflora indicated that all 15 cooperating herds evaluated were free of *Streptococcus agalactiae*.

Analysis of Seasonal Effects on Milk Quality. Standard plate count is influenced by milking machine sanitation and udder hygiene practices (16, 22). In-line sampling techniques demonstrated significant increases in bacterial populations as milk passed through a pipeline milking system (16). Evaluation of arithmetic means indicated treatment differences within the grazing season. During the grazing season, SPC was lower in IMRG compared with CH herds (4.05×10^3 and 12.67×10^3 cfu/ml) ($P < .10$) (Table 1). No differences were observed among treatment groups for SPC during winter confinement.

Incidence of clinical mastitis is highest in the summer with the majority of cases caused by environmental pathogens including non-agalactiae streptococci (4, 13, 28). Bacteria counts on TBA of non-agalactiae streptococci differed among treatment groups during the grazing and winter confinement season (Table 2). During the grazing season, counts were highest in TCG herds (2242 cfu/ml) ($P < .05$). Further comparison indicated that IMRG herds had lower counts compared with CH herds (933 and 1420 cfu/ml) ($P < .15$). Observations indicate that more traditional methods of pasture management may result in a higher degree of udder contamination during the interval between milking. Managing dairy cattle in confinement may have a similar effect. The lower counts in CH compared with TCG may be the result of closer scrutiny and more intensive management among managers of confinement herds. During winter when all herds were confined, counts of non-agalactiae streptococci were higher in herds utilizing TCG compared with IMRG or CH (4,470, 1,030 and 1,800 cfu/ml) ($P < .05$) (Table 2).

Analysis of Herd Size Effects on Milk Quality. Among herds with fewer than 60 lactating cows, SPC's were higher in CH herds compared with IMRG herds ($P < .15$) (Table 1). Bacteria counts of non-agalactiae streptococci were lower in small and large herds using IMRG compared with those herds using TCG ($P < .10$) (Table 2). When the presence of *Staphylococcus aureus* in BTM was evaluated (Table 3), herds with more than 60 cows using IMRG had lower counts compared with those using TCG, (70 and 723 cfu/ml) (*P* < .15). Comparison between herd sizes demonstrated higher coliform counts in IMRG herds with 60 or more lactating cows than those with less than 60 (*P* < .10) (Table 4). The standard deviation of means demonstrated that management variation had a significant impact on data analysis.

Analysis of Predips on Milk Quality. Predipping with an effective product resulted in a 51% reduction in IMI from environmental pathogens (22). Untested products may not effect bacterial numbers in BTM or incidence of IMI. Herds using predips recognized as efficacious demonstrated lower TBA count of non-agalactiae streptococci in IMRG herds than CH herds (433 and 1774 cfu/ml) (*P* < .05) (Table 2). No TCG herds used predips that had been tested for efficacy. Analysis of data from herds using untested predips demonstrated no noticeable trends towards improved milk quality resulting from grazing management. This observation offers further testimony that the effects of improved management practices may be suppressed by insufficient hygiene prior to milking. No differences were observed between herds using tested and untested predips.

Analysis of Postdips on Milk Quality. Milk quality data from herds using untested postdips indicated trends towards lower TBA counts of *Staphylococcus aureus* in herds using IMRG compared with TCG (100 and 721 cfu/ml) (*P* < .15) (Table 3). Analysis of data using postdip product as an independent management variable demonstrated a SCC reduction in IMRG herds using tested postdips compared with those IMRG herds using untested postdips ($P < .15$) (Table 5).

Management Variations on Commercial Dairy Farms. Management variations within and between herds increased sample variance and decreased power (1 - ß) of the model to detect significant differences at $\alpha < .05$. In an example, an IMRG herd initially grazed cattle at all times other than milking. In order to maximize milk production, milking frequency was changed from 2X to 3X. To accommodate 3X milking, time on pasture was systematically reduced so that in barn feeding programs could be initiated. The result was a modified version of the IMRG system initially intended to be evaluated on this farm.

Small sample size contributed to low power in the model. When data were partitioned to account for independent management variables, number of farms evaluated in each analysis decreased, and resulted in increased standard deviation and decreased power.

Analysis of Udder Health

Trends were observed indicating differences in reported incidence of udder health problems among grazing treatments (Table 6). Traditional continuous grazed herds reported fewer cases of udder health problems per month compared with CH herds (1.5 cases/mo compared with 5.2 cases/mo.). Reported incidence of clinical mastitis was subjective among herdsman. Reported incidence may not be representative of the true incidence of clinical infections in each herd. Reports of udder edema and teat injuries may have suffered from the same inconsistencies. Calculation of mean occurrence indicated that high incidence of udder health problems in CH herds resulted from high reported incidence of clinical mastitis in one herd with fewer than 60 lactating cows utilizing CH (11).

CONCLUSIONS

Trends appeared to demonstrate differences in milk quality among grazing treatments. Standard plate count was higher in herds using confinement housing compared with rotational grazing. Counts of bacterial types including non-agalactiae streptococci and *Staphylococcus aureus*, indicated higher contamination of BTM on farms using TCG compared with those using IMRG or CH. Coliform counts in BTM were lower in IMRG herds with less than 60 cows compared with those with 60 or more cows. Bulk tank SCC was lower in IMRG herds using tested postdips compared with those using untested postdips.

Effects of improved management practices may be suppressed by insufficient hygiene prior to milking. Although low sample sizes may have limited power to detect differences among treatment groups, managing cows on pasture may help reduce exposure to environmental pathogens. Adoption of rotational grazing may be a practical and profitable alternative to enhance milk quality and mastitis control. Based on trends observed, further controlled studies that minimize management variation among commercial dairy herds are justified. Specific areas to be evaluated include: a) Relation of bacterial populations in bedding to environmental factors, b) Relation of bacterial populations in bedding with teat end contamination, c) Relation of environmental bacterial populations with BTM quality.

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TABLES

Table 1. Least squares means and significance of effects of independent management variables: season, herd size, predip and postdip, on Standard Plate Count (X 10^3/ml) among grazing treatments.

Independent management variable	Rotational Grazing			Continuous Grazing			Confinement Housing			Type III SS[1] P > F for independent management variables (Column[2])
	(n)	Mean	SD	(n)	Mean	SD	(n)	Mean	SD	Column
Season										NS
Summer grazing	30	4.1[a]	1.1	30	5.0[ab]	1.3	30	12.7[b]	3.9	
Winter confinement	30	3.0	.6	30	4.6	.9	30	4.5	1.0	
Herd Size										NS
< 60 lactating cows	36	4.1[c]	.9	36	5.3[cd]	1.2	12	5.9[d]	3.1	
≥ 60 lactating cows	24	2.2	.6	24	3.8	.8	48	8.0	2.9	
Predip										NS
efficacious	24	2.4	.8	--	---	--	24	5.9	1.6	
non-efficacious	36	4.0	.8	60	4.7	.8	36	8.7	3.8	
Postdip										NS
efficacious	24	3.2	.8	36	3.4	.6	12	5.9	3.1	
non-efficacious	36	3.5	.9	24	6.7	1.6	48	8.0	2.9	

[a,b] Means within row not sharing same superscripts differ (*P* < .10).
[c,d] Means within row not sharing same superscripts differ (*P* < .15).
[1] SS= Sums of Squares
[2] Column comparisons evaluate each of the four independent management variables within each grazing treatment.

Table 2. Least squares means and significance of effects of independent management variables: season, herd size, predip and postdip, on counts of non-agalactiae streptococci (X 10^2/ml) among grazing treatments.

Independent management variable	Rotational Grazing			Continuous Grazing			Confinement Housing			Type III SS[1] P > F for independent management variables (Column[2])
	(n)	Mean	SD	(n)	Mean	SD	(n)	Mean	SD	Column
Season										NS
Summer grazing	30	9.3^{ac}	2.3	29	22.4^{bcd}	4.8	27	14.2^{ad}	3.2	
Winter confinement	30	10.3^{a}	2.1	30	44.7^{b}	9.6	30	18.0^{a}	3.9	
Herd Size										NS
< 60 lactating cows	36	9.3^{e}	2.3	35	27.6^{f}	4.3	11	10.2^{ef}	2.6	
≥ 60 lactating cows	24	8.6^{e}	2.0	24	41.5^{f}	11.5	46	18.5^{ef}	2.8	
Predip										NS
efficacious	24	4.3^{a}	1.0	--	----	---	23	17.7^{b}	4.4	
non-efficacious	36	12.2	2.4	59	33.3	5.3	34	16.3	2.7	
Postdip										NS
efficacious	24	9.5	2.3	35	24.3	4.4	11	10.2	2.6	
non-efficacious	36	8.3	1.9	24	46.4	11.1	46	18.5	2.8	

[a,b] Means within row not sharing same superscripts differ (*P* < .05).
[c,d] Means within row not sharing same superscripts differ (*P* < .15).
[e,f] Means within row not sharing same superscripts differ (*P* < .10).
[1] SS= Sums of Squares
[2] Column comparisons evaluate each of the four independent management variables within each grazing treatment.

Table 3. Least squares means and significance of effects of independent management variables: season, herd size, predip and postdip, on counts of *Staphylococcus aureus* ($X\ 10^2$/ml) among grazing treatments.

Independent management variable	Rotational Grazing			Continuous Grazing			Confinement Housing			Type III SS[1] P > F for independent management variables (Column[2])
	(n)	Mean	SD	(n)	Mean	SD	(n)	Mean	SD	Column
Season										NS
Summer grazing	30	.5	.2	29	.3	.2	27	.5	.3	
Winter confinement	30	.7	.2	30	5.6	4.7	30	3.5	2.7	
Herd Size										NS
< 60 lactating cows	36	.5	.1	35	.3	.1	11	2.1	.7	
≥ 60 lactating cows	24	$.7^{a}$	.3	24	7.2^{b}	5.3	46	2.0^{ab}	1.6	
Predip										NS
efficacious	24	.3	.1	--	---	---	23	1.2	.4	
non-efficacious	36	.9	.2	59	3.1	2.2	34	2.6	2.1	
Postdip										NS
efficacious	24	.4	.1	35	.3	.1	11	2.1	.7	
non-efficacious	36	1.0^{a}	.3	24	7.2^{b}	5.3	46	2.0^{ab}	1.6	

[a,b] Means within row not sharing same superscripts differ ($P < .15$).

[1] SS= Sums of Squares

[2] Column comparisons evaluate each of the four independent management variables within each grazing treatment.

Table 4. Least squares means and significance of effects of independent management variables: season, herd size, predip and postdip, on counts of coliforms (X 10^2/ml) among grazing treatments.

Independent management variable	Rotational Grazing			Continuous Grazing			Confinement Housing			Type III SS[1] P > F for independent management variables (Column[2])
	(n)	Mean	SD	(n)	Mean	SD	(n)	Mean	SD	Column
Season										NS
Summer grazing	30	9.3	3.7	29	5.7	2.7	27	3.4	2.0	
Winter confinement	30	8.0	3.8	30	5.4	3.3	30	3.6	1.1	
Herd Size										S
< 60 lactating cows	36	3.8[a]	1.4	35	3.0	1.7	11	3.7	2.4	
≥ 60 lactating cows	24	11.1[b]	4.7	24	8.4	3.9	46	4.5	1.4	
Predip										NS
efficacious	24	6.1	.5	--	---	--	23	7.7	.6	
non-efficacious	36	7.2	.6	59	5.2	.4	34	7.1	.3	
Postdip										NS
efficacious	24	6.6	2.9	35	4.2	2.9	11	3.7	2.4	
non-efficacious	36	7.0	3.1	24	6.5	2.5	46	4.5	1.4	

[a,b] Means within column not sharing same superscripts differ (P < .10).
[1] SS= Sums of Squares
[2] Column comparisons evaluate each of the four independent management variables within each grazing treatment.

Table 5. Least squares means and significance of effects of independent management variables: season, herd size, predip and postdip, on Somatic cell counts (X 10^5/ml) among grazing treatments.

Independent management variable	Rotational Grazing			Continuous Grazing			Confinement Housing			Type III SS[1] P > F for independent management variables (Column[2])
	(n)	Mean	SD	(n)	Mean	SD	(n)	Mean	SD	Column
Season										NS
Summer grazing	30	1.6	.1	29	2.2	.2	27	2.1	.2	
Winter confinement	30	1.6	.2	30	1.8	.2	30	1.8	.2	
Herd Size										NS
< 60 lactating cows	36	1.5	.1	35	1.8	.2	11	1.5	.2	
≥ 60 lactating cows	24	1.9	.2	24	2.3	.2	46	2.2	.1	
Predip										NS
efficacious	24	1.8	.1	--	---	--	23	2.3	.2	
non-efficacious	36	1.5	.1	59	2.0	.1	34	1.9	.1	
Postdip										S
efficacious	24	1.3[a]	.1	35	2.0	.1	11	1.5	.2	
non-efficacious	36	2.1[b]	.1	24	2.0	.3	46	2.2	.1	

[a,b] Means within column not sharing same superscripts differ ($P < .15$).
[1] SS= Sums of Squares
[2] Column comparisons evaluate each of the four independent management variables within each grazing treatment.

Table 6. Mean occurrence (MO), incidence density (ID), risk estimate (RE) and significance of effects of independent management variables: season and herd size on udder health among grazing treatments.

Independent management variable	Rotational Grazing (n)	MO	ID	RE	Continuous Grazing (n)	MO	ID	RE	Confinement Grazing (n)	MO	ID	RE	Type III SS[1] P > F management systems. Column[2]
Season													NS
Summer grazing	40	3.1[ab]	.1	.1	28	1.5[a]	.1	.1	28	5.2[b]	.1	.1	
	(SD)	.6	.01	.01		.3	.01	.01		.7	.02	.01	
Winter confinement	40	3.5	.1	.1	30	1.7	.1	.1	27	4.3	.1	.1	
	(SD)	.6	.01	.01		.4	.01	.01		.5	.01	.01	
Herd Size													NS
< 60 lactating cows	34	2.8	.1	.1	36	1.1	.1	.1	12	7.5	.2	.2	
	(SD)	.6	.02	.01		.2	.01	.01		1.1	.03	.02	
≥ 60 lactating cows	46	3.7	.1	.1	22	2.5	.1	.1	43	3.8	.1	.1	
	(SD)	.6	.01	.01		.4	.01	.01		.4	.01	.01	

[a,b] Means within row not sharing same superscripts differ ($P < .15$).
[1] SS= Sums of Squares
[2] Column comparisons evaluate each of the four independent management variables within each grazing treatment.