Characteristics and management practices associated with milk production in dairy herds in Ohio enrolled in official Dairy Herd Improvement Association programs

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Objective—To determine herd characteristics and management practices associated with milk production in dairy herds enrolled in official Dairy Herd Improvement Association (DHIA) programs in Ohio.

Sample Population—186 dairy farms in Ohio.

Procedure—All herds in official DHIA programs in 9 counties were invited to participate. Information regarding herd characteristics and management practices was obtained, using a standardized questionnaire. Bulk-tank milk samples were obtained for bacteriologic culture. Official DHIA test-day records were obtained, and associations were identified, using multivariable ANOVA procedures.

Results—Of 479 eligible producers, 186 (39%) participated, and consecutive bulk-tank milk samples were available for culture from 172 (36%). *Streptococcus agalactiae* and *Mycoplasma* spp were not recovered from bulk-tank milk samples, but *Staphylococcus aureus* was recovered from 64 (37%) herds. Mean (± SD) number of lactating cows in participating herds was 97 ± 66, with 123 (66%) herds milking < 100 cows. The RHA was significantly associated with number of cows in milk, estimated percentage of herd detected in estrus, reported annual percentage of heifer calves born alive that died before 8 weeks old, percentage days in milk, use of bovine somatotropin during the preceding 2 years, and sex of the person completing the questionnaire.

Conclusions and Clinical Relevance—In this study, the strongest indicator of milk production was number of cows in milk. However, merely adding cows to a herd should not be considered to guarantee increased milk production, because other management traits could be confounded with increased number of cows in a herd. (*Am J Vet Res* 2001;62:1262–1266)

The national **rolling herd average (RHA)** in the United States for primarily Holstein herds (herds in which Holstein cows accounted for ≥ 50% of the cows) increased from 7,693 kg/cow in 1991 to 7,972 kg/cow in 1996.[1] Nationally, herds with 30 to 49 cows decreased from 17% of all herds in the United States in 1991 to 13% in 1995.[1] The trend in herd size has been for the proportion of herds in the small-herd category to consistently diminish, whereas that of herds with greater numbers of cattle has continued to increase.[2]

Greater productivity per cow is an achievable goal, as illustrated by producers in California, New Mexico, and Washington, where milk production per cow is > 8,182 kg.[1,3] Mean herd size for these 3 states in 1991 and 1995 was 276 and 382, 78 and 173, and 79 and 132 cattle, respectively.[1,3] Production trends in all herds in Ohio increased from 6,566 kg/cow in 1991 to 7,235 kg/cow in 1995.[1,3] During this same period, there was a small increase in mean herd size from 36 cattle in 1991 to 38 cattle in 1995.[1,3] Although production per cow and herd size in Ohio have had an upward trend, the state still lags behind the national average as well as the average of many other dairy states.

The realities of farm-level economics suggest most US dairy producers of the future will have herds that consist of > 300 cows or < 100 cows.[2] Although many of the skills required to successfully manage large and small herds differ considerably, both may be expected to benefit from greater productivity per cow. The study reported here was conducted to determine herd characteristics and management practices that were associated with high milk production in dairy herds in Ohio, which may be typical of herds found elsewhere in the midwestern United States. Of special interest was the possibility of tentatively identifying those management practices that have not previously been reported to result in increased milk production. Such information would assist personnel associated with dairy farms in determining areas meriting further emphasis in educational programs directed toward increasing milk production in dairies in Ohio and in similar dairies throughout the United States.

Materials and Methods

Study population—The study population comprised all dairy farms (n = 479) that were enrolled in official **Dairy Herd Improvement Association (DHIA)** testing programs in 9 of the 10 counties with the largest number of cattle in Ohio. Four counties (Auglaize, Darke, Mercer, and Shelby) were in western Ohio, and 5 (Ashland, Holmes, Stark, Tuscarawas, and Wayne) were in northeastern Ohio. The tenth county (Ashtabula) was not included in the study, because it is located in far northeastern Ohio and is fairly remote from the other 2 regions; thus, it would have been logistically difficult

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to collect milk samples from herds in that county. We included only dairies in official DHIA programs in the study to ensure the validity of DHIA records. Data was collected on dairies enrolled in official DHIA programs by a third party used by the DHIA cooperative.

Bacteriologic culture of milk samples—Samples were obtained for bacteriologic culture of major bacteriologic pathogens associated with contagious mastitis. Milk haulers obtained 3 successive bulk-tank samples from the participating herds during January and February 1997. Milk haulers obtained the milk samples at the same time they were collecting the bulk-tank sample that would be used for regulatory purposes. Milk samples were frozen by the producers and subsequently delivered by DHIA personnel to the offices of the Ohio DHIA[a] (mean time from collection to delivery did not exceed 1 week). Milk samples then were transported to a laboratory in the Department of Veterinary Preventive Medicine at The Ohio State University. On arrival at the laboratory, samples were placed in a freezer (–20 C) until thawed for bacteriologic culture. Maximum interval from sample collection to bacteriologic culture was 35 days. Methods used for bacteriologic culture have been reported elsewhere.[4]

Producer survey—A questionnaire to assess herd characteristics and management practices of the dairy herds was administered to the producers by DHIA supervisors in December 1996 and January 1997. Data were obtained on general farm and herd characteristics, milking facility and milking procedures, udder health, microbiologic characteristics of milk, nutrition, and general management practices. The questionnaire consisted of 42 questions and required approximately 15 minutes to complete. Completed questionnaires were sent to the authors between December 1996 and March 1997. Because they were familiar with the participating farms, DHIA supervisors visited each farm and helped to verify producers' responses. To encourage participation, producers were promised results of bacteriologic culture of bulk-tank milk samples and a summary of results for the data collected. An honorarium ($5/questionnaire and $1/milk sample) was paid to the DHIA supervisors as incentive for their participation. Investigators (MLK, KHH) also trained DHIA supervisors in the area of questionnaire administration to minimize interviewer bias. Supplementary data on dairy herd characteristics pertaining to all 479 eligible farms in the study area for the months of January and February 1997 were obtained from DHIA records and used in the analysis.

Statistical analysis—Data were analyzed, using multivariable ANOVA procedures. All independent variables (herd characteristics and management practices) were screened initially for a simple association with the dependent variable (milk production as measured by RHA), using the F statistic. Variables that met a critical value of $P \leq 0.25$ on initial screening were considered in additional multivariable modeling. A value of $P \leq 0.25$ was used in the initial screening to permit a broad subset of variables to be included in the model-building process. At the same time, this value would eliminate obviously nonassociated variables from this process. Multivariable model building used a forward-selection stepwise procedure with a criteria of $P = 0.05$ to remain in the model, similar to that described previously.[5,6] Pairwise comparison of least-squares means for the various levels of categoric variables was completed by use of the Tukey-Kramer statistic. Goodness of fit of the final model was tested by plotting the residuals against the predicted values.

Results

Of 479 eligible producers, 186 (39%) participated. Characteristics and management traits of herds that participated have been described elsewhere.[4] Briefly, 3 bulk-tank milk samples were obtained from 172 (36%) eligible dairies. All bulk-tank milk samples from 172 herds were negative for *Mycoplasma* spp and *Streptococcus agalactiae*. Of the 172 herds, 64 (37%) had positive results on at least 1 sample for *Staphylococcus aureus*. Predominant breed for respondents was Holstein (158/186; 85%), and RHA milk production for these herds ranged from 5,331 to 11,952 kg/cow (mean ± SD herd production, 8,737 ± 1,246 kg/cow). A limited comparison of characteristics of herds that participated in the study and those that did not could be made by use of DHIA records. The only obvious difference found among eligible Holstein herds was that those that participated in our study had a mean of 50 more cows in milk than those that did not participate **(Table 1)**. The association of somatic cell count with herd performance and milk production for these herds has been reported elsewhere.[4]

When data were investigated for their association with RHA milk production, 64 of 136 variables survived the initial screening procedure. Many of these variables were the same ones that survived the initial screening procedure in a parallel study that related management practices to bulk-tank somatic cell counts.[4] Variables from the study reported here that were retained in the final multivariable model ($P < 0.05$) included number of cows in milk, estimated percentage of herd detected in estrus, estimated annual percentage of calves born alive but that died before they were 8 weeks old, percentage of days in milk, use of **recombinant bovine somatotropin (rBST)** during the preceding 2 years, and sex of the person completing the questionnaire (**Table 2**).

Number of cows in milk was the first variable associated with milk production ($F = 341.88$, $P < 0.001$) in the initial screening process. Analysis of results for the final model indicated that for the 186 herds participating in our study, for each 1-cow increase in herd size, there was a corresponding increase of 91 kg in RHA milk production. For each increase of 1% in estimated detection of estrus, there was a corresponding increase of 24 kg in RHA milk production. For each estimated increase of 1% in annual death rate of heifer calves, there was a corresponding decrease of 51 kg in RHA milk production. For each increase of 1% in percentage days in milk, there was a corresponding increase of 71 kg in RHA milk production. Use of rBST significantly ($P < 0.05$) affected milk

Table 1—Descriptive statistics of dairy herds in Ohio that participated in the study and those of herds that did not participate in the study

Characteristics	Participating herds (n = 186)	Nonparticipating herds (n = 293)
No. of cows in milk*	97 ± 66	49 ± 12
Bulk-tank SCC	319,000 ± 159,000	325,000 ± 169,000
Low linear score† for SCC (%)	77 ± 8	77 ± 11
RHA milk production (kg)	8,737 ± 1,246	8,071 ± 1,686

Values reported are mean ± SD.
*Values differ significantly ($P < 0.05$) between groups. †Linear SCC of 0 to 4.
SCC = Somatic cell count. RHA = Rolling herd average.

Table 2—Summary of results for the final model for estimating milk production among dairy herds, using a multivariable ANOVA

Variable	df	F	β*	SE of β	LS means
No. of cows in milk	1	164.55†	91.04	7.08	NA
Amount of herd detected in estrus (%)	1	25.44†	24.42	10.65	NA
Estimated annual death rate of heifer calves (%)‡	1	11.56†	–50.66	32.77	NA
Days in milk (%)	1	11.27†	–71.28	46.72	NA
Use of rBST during the preceding 2 years	1	6.55§	NA	NA	NA
No	NA	NA	NA	NA	8,570
Yes	NA	NA	NA	NA	8,858
Sex of person answering questionnaire	1	6.48§	NA	NA	NA
Male	NA	NA	NA	NA	8,943
Female	NA	NA	NA	NA	8,484

*Regression coefficients for continuous variables. †Value differs significantly ($P = 0.01$) among herds. ‡Percentage of heifer calves born alive but that died before they were 8 weeks old. §Value differs significantly ($P < 0.05$) among herds that used recombinant bovine somatotropin (rBST) and those that did not use rBST.

LS means = Least-squares means. df = Degrees of freedom. NA = Not applicable.

production. Herds that had used rBST during the preceding 2 years had RHA milk production 289 kg higher than those herds that had not used rBST. Mean milk production for dairies where male producers answered the questionnaire (8,943 kg) was significantly ($P < 0.05$) higher, compared with dairies where females answered the questionnaire (8,484 kg). Dairies where women answered the questionnaire also had significantly ($P < 0.05$) fewer cows in milk than those where men answered the questionnaire. Included among herd characteristics and management practices previously reported to be related to milk production, but which we did not find to be so in our study, were feeding home-grown grains, use of a total-mixed ration feeding system, use of artificial insemination for heifers, therapy for nonlactating cows, frequency of milkings per day, and detection of *Staphylococcus aureus* in bulk-tank milk samples.

Discussion

Producers that participated in the study reported here had larger herds than those that refused to participate. There was considerable variation in herd size in the study population. Coupled with a potential low power because of a response rate of only 39%, this may have resulted in a failure to detect other differences between herds that participated in the study and those that did not participate.

Our sample population may not have been representative of all herds in Ohio or even all herds enrolled in the various DHIA testing programs in the state. Expense associated with official DHIA testing is greater than for other DHIA programs, because a third party must personally supervise testing and collection of milk samples from all cows each month. A reasonable assumption is that producers enrolled in official programs, compared with producers enrolled in nonofficial owner-supervised DHIA programs, may be enrolled because official records are perceived to be of value in marketing breeding stock. If this assumption is true, then findings from our study may not be directly applicable to all commercial dairy producers. Nevertheless, herds enrolled in official DHIA testing programs in Ohio and other dairy states constitute an important subset of the dairy industry and merit research and educational efforts. Even for this population of herds, we found that as herd size increased, milk production per cow increased. This is in contrast to another report[b] that involved herds of similar size to those in our study. In that report, smaller herds had higher milk production. The dairy industry has experienced rapid changes during the past decade. To ensure competitiveness in the future, those management practices associated with increases in herd size need to be considered for adaptation and implementation, even in the often-prevalent smaller herds in the midwestern United States.

Several studies have reported better detection of estrus in high-yielding herds, compared with herds with lower milk yield.[7-10,c] This appeared to be the case in herds in our study. Unlike RHA, percentage of herd detected in estrus was an estimate calculated by the DHIA program, and the estimated annual percentage of heifer calves born alive but that died before they were 8 weeks old was provided by each producer and not obtained from DHIA records. Therefore, errors in producer reporting to the DHIA supervisor as well as recall bias must be considered possibilities. However, the fact that reported percentage of heifer calves born alive but that died before 8 weeks old was associated with milk yield also may be reflective of general management and, more specifically, management practices for calves on these farms. Larger dairies that have higher milk production reportedly have better management practices for calves.[1] For example, in a survey conducted in the United States in 1996, producers for large herds (≥ 200 cows) were more likely to separate calves from their dam at birth before suckling, to feed colostrum by means of a bucket or esophageal feeder, and to feed ≥ 4 liters of colostrum, compared with producers for smaller herds (< 100 cows).[1]

Not surprisingly, use of rBST in the previous 2 years in our study was strongly associated with increased milk production. This finding is supported by a report that identified use of rBST as 1 management practice associated with high milk production.[1] That study identified management practices used on high-producing US dairy herds in 20 states that represented 83.1% of US milk cows.

Most herds that participated in our survey were traditional family-owned farms in which both spouses were involved as owners. Nevertheless, a difference in

RHA milk production and herd size was observed in herds depending on whether a male or female producer answered the questionnaire. One could speculate that the smaller herd size and lower milk production observed in herds in which women were the decision makers may have been related, at least in part, to perceived relative importance of the dairy enterprise to the overall family income on these farms. On such farms, the male owner may have been more involved in other farm activities or in off-farm employment. Regardless of reason, the resulting lower production could represent a missed opportunity. This observation certainly merits additional investigation, especially in regions of the United States with relatively large numbers of small traditional family dairy farms. Thus, assuming the findings reported here are indeed real, educational efforts by extension personnel should be targeted toward those producers in an effort to encourage and improve production and, consequently, profitability. Such efforts could prove useful in ensuring survivability of small dairy farms and improving rural communities.

Surprisingly, variables such as attendance at extension meetings, sources of information for producers, and reference to magazines regarding dairy farming failed to make it into the final model. These also could be areas on which to focus future research and educational programs. Also, several herd characteristics and management practices that have reportedly been associated with milk production were not found to be significantly associated with milk production in our study. These included variables such as use of antibiotic therapy in nonlactating cows, frequency of milkings per day, and infection status of herd with regard to *S aureus*. Among possible reasons for not finding these variables to be significantly associated were potential confounders that were not identified and, therefore, not accounted for in the analysis. For instance, it was not surprising that a significant effect was not detected between frequency of milkings per day and milk production given that only 5 of 186 herds were milking cows 3 times/d. Similarly, it was not possible to ascertain the relationship between milk production and use of antibiotic therapy in nonlactating cows, because there was little variability in the use of this procedure among herds. Failure to detect a reported association of milk production with infection status of herds in regard to *S aureus* could have been the result of the low sensitivity of the culture methods used for bulk-tank samples to diagnose herds that were infected. Sensitivity and specificity for bacteriologic culture of a single bulk-tank milk sample, compared with bacteriologic culture of composite samples obtained from each cow, is estimated to be 20.5 and 94%, respectively, for *S aureus*.[11] High specificity but low sensitivity indicates that few herds would wrongly be classified as infected but that many infected herds would not be detected. The response rate for the study reported here (39%) could be another factor. Our sample size of 186 herds was smaller than that used in several other studies. A small sample size reduces the power of the test to detect associations that may exist.

We identified 6 herd characteristics and management practices that were the major sources of variation in milk production among the dairy herds in Ohio included in our study. There were many variables tested in our study that were significant only in the univariate analysis and that did not make it into our final multivariate model. The possibility that implementation of those management practices could result in increased milk production does exist. Some of these practices have been tested in controlled studies and have been documented to result in increased milk production; therefore, they also could be included in educational programs. Others have not been tested in controlled studies but could be a basis for future studies.

[a]Ohio Dairy Herd Improvement Cooperative, Powell, Ohio.
[b]Cassel BG, Nebel RL, Stalling CC, et al. Management practices of 39 average and high producing Virginia dairy herds (abstr). *J Dairy Sci* 1992;75(suppl 1):190.
[c]Wiggans GR, Ernst CA. Effect of genetic merit of sire for milk yield and herd yield level on reproductive traits (abstr). *J Dairy Sci* 1987;70(suppl 1):232.

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