Response to Modified Live and Killed Multivalent Viral Vaccine in Regularly Vaccinated, Fresh Dairy Cows*

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ABSTRACT

Vaccination programs for viral pathogens in the dairy industry span the full spectrum of possibilities even though few of these have been evaluated in field situations. One such program is the vaccination of fresh cows 30 to 60 days postpartum with modified live viral (MLV) vaccines. The purpose of this study was to evaluate the antibody response to booster vaccinations during this period. The impact of vaccinations on milk production and reproductive performance was also examined. The response of cattle boosted with MLV bovine viral diarrhea virus (BVDV) was greatly enhanced compared with the saline controls and the killed vaccine test group. Similar increases were not seen with the MLV infectious bovine rhinotracheitis virus (IBR) and bovine respiratory syncytial virus (BRSV) vaccines. Changes in milk production were not detected. There was a positive effect on the rate of conception with the MLV group even though there was no evidence of the presence of the three viruses in the herd at the time of study. Although this was a single field trial, and thus limited in scope and repeatability, the results indicate that the vaccines used had a positive effect.

INTRODUCTION

Most cattle vaccine programs include multivalent bovine viral diarrhea virus (BVDV), infectious bovine rhinotracheitis virus (IBR), and bovine respiratory syncytial virus (BRSV) vaccines. The viral components in many of these vaccines are killed, modified live viral (MLV), or a combination of both killed and MLV. Veterinarians and producers use one or more of these vaccines in a variety of programs, often without real knowledge of the disease protection that their use achieves.

Killed BVDV and IBR vaccines are often used because they can be administered to the
entire herd at one time without the risk of
causing abortion.1 A disadvantage of killed
BVDV and IBR vaccines is that their duration
of fetal protective immunity is limited; thus re-
vaccination is usually recommended in 4 to 6
months.1–3 A temporary drop in milk produc-
tion is also sometimes reported following the
use of killed multivalent vaccines.4

Modified live vaccines have gained wide-
spread use because they provide longer—
and often a greater degree of—protective immu-
ni ty than killed vaccines.5,6 In addition, a single
dose of vaccine can immunize whereas two
doses of killed vaccine are needed.1 A negative
aspect of MLV vaccines is that they may cause
abortion, which limits their use to only non-
pregnant animals.1 To take advantage of the
greater protection afforded by MLV vaccines,
many cattle vaccine programs now include a
dose of MLV vaccine at about 35 days in milk
(DIM). Quite often this is in addition to a pre-
viously administered annual or semiannual
vaccination with killed components.

To evaluate the efficacy of this protocol, a
study was designed to measure the immune re-
sponse to both killed and MLV multivalent vac-
cines administered at 35 DIM to cows vaccinat-
ed semiannually. Other objectives of the study
were to estimate the short-term effects of these
vaccine treatments on milk production in early
lactation and to study the effects on fertility.

**MATERIALS AND METHODS**

**Serum Neutralization Assays**

Serum (virus) neutralization (SN) assays fol-
lowed standard microplate formats with serial
twofold dilutions done in duplicate wells. All
sera were titrated to endpoints for the three
viruses in the study: BVDV, IBR, and BR
SV. The virus content for all three agents was ap-
proximately 100 to 300 tissue culture infectious
dose50 per well. The strain of viruses used in the
assays were: BVDV-Singer, IBR-Cooper, and
BR
SV-A4. The cells used in the assays were low
pass bovine testicular cells for BVDV and BR
SV
SN tests, and RK-13 cells for IBR SN tests.

**Subjects**

The study group consisted of 163 Holstein
cows in a herd housed at the Cornell Dairy
Teaching and Research Center in Dryden, NY.
The cows were calved between December 1997
and May 1998 and were followed be-
tween 35 and 71 DIM after calving. Primipar-
ous cows and multiparous cows were ran-
domized separately into three treatment
groups: saline (control group), killed multiva-
lent vaccine (BVDV, IBR, BR
SV, bovine
parainfluenza type 3 virus [PI3]; Triangle 4,
Fort Dodge), and MLV multivalent vaccine
(BVDV, IBR, BR
SV, PI3; Pyramid MLV4, Fort
Dodge). Cows were vaccinated by intramuscu-
lar injection according to label instructions on
day 35 of lactation. Controls were adminis-
tered saline in the same manner. A prevaccina-
tion serum sample was collected on day 35,
and postvaccination serum samples were col-
lected on days 49 and 70 of lactation. In addi-
tion, all cows in this study received a scheduled
semi-annual herd vaccination with a multiva-
lent vaccine (mixed live and killed; IBR,
BVDV, BR
SV, PI3, and Leptospira spp.; Cattle-
master, Pfizer) on November 16, 1997. The
earliest study vaccination would have occurred
approximately 31 days from the last semi-an-
ual herd vaccination.

**Effect of Vaccines on Antibody Titers**

The titer values for BVDV serum neutraliza-
tion were analyzed with a log-transformation,
which normalized the data. Parities (1, and 2
and higher) were analyzed separately. General
linear models procedure (PROC GLM) in sta-
tistical analysis system (SAS)7 was used to esti-
mate the effect of vaccine treatments on the
titer values at each of the three times (analyzed

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50
Effect of Vaccines on Milk Production

The data consisted of the same cows described above. Milk measurements were recorded daily, from days 28 to 71 after calving. As stated above, cows were vaccinated on day 35 of lactation.

Because the study consisted of repeated measurements (daily milk weights) taken within a cow, similar statistical procedures were used as in the serological analysis. Data on primiparous and multiparous cows were analyzed separately. The SAS procedure PROC GLM\(^7\) was used to estimate the effect of vaccine treatments on milk production, on each of the 10 days following vaccination (day 35). In addition, the SAS procedure PROC MIXED\(^8\) with an autoregressive covariance structure, was used to account for the fact that the milk measurements were not independent from one another within the same cow. As for the serological analysis, the results from both procedures were similar; only those from PROC GLM are reported here.

Effect of Vaccines on Reproductive Parameters

Data were available on 150 of the 163 cows described previously; information on the reproductive parameters of the remaining 13 cows was unavailable due to premature culling. Days to first service, number of times bred, days open, and whether the cow conceived or remained open were recorded. PROC GLM was used to analyze the effect of vaccines on days to first service and on number of times bred. Survival analysis, using the Cox Proportional Hazards Model in SAS proportional hazards regression model procedure (PROC PHREG)\(^8\) was used to analyze the effect of vaccines on days open.

Output from PROC PH REG is in the form of hazard rate ratios. These can be used to compare the rate at which an event (in this study, conception) occurs in different groups.
of subjects. In this study, for any particular factor, a hazard rate ratio less than 1.0 implies that cows with that factor conceived at a lower rate than cows in the reference group, while a hazard rate ratio greater than 1.0 indicates that cows with the factor conceived at a higher rate than cows in the reference group. Of the 150 cows in the fertility analysis, there were 47 cows in the saline treatment group, 50 cows in the killed vaccine treatment group, and 53 cows in the MLV treatment group. Sixty-five of the cows were primiparous and 85 cows were multiparous.

### ANALYSIS

**BVDV**

Within the saline group BVDV SN titer values did not change significantly over time (Table 1). For primiparous cows receiving either the killed or MLV vaccine, the BVDV SN titer increased significantly between 35 and 49 DIM, as well as between 35 and 70 DIM. Although this response to both vaccines was significant, the response to the MLV vaccine was considerably greater than the response to the killed vaccine. This occurred even though the MLV vaccine group started at a higher

<table>
<thead>
<tr>
<th>TABLE 1. BVDV SN Titer Values</th>
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<tbody>
<tr>
<td>Titer 1 (35 d)</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>PRIMIPAROUS COWS</td>
</tr>
<tr>
<td>Saline</td>
</tr>
<tr>
<td>Killed</td>
</tr>
<tr>
<td>MLVf</td>
</tr>
<tr>
<td>MULTIPAROUS COWS</td>
</tr>
<tr>
<td>Saline</td>
</tr>
<tr>
<td>Killed</td>
</tr>
<tr>
<td>MLVf</td>
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<tr>
<td>MLVf</td>
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<td>MLVf</td>
</tr>
</tbody>
</table>

*Log and actual by parity at days 35, 49, and 70 of lactation in 163 dairy cows. Cows were vaccinated on day 35 with either saline, killed, or modified live vaccine (BVDV, IBR, BRSV, PI3) vaccine. Values are log-transformed mean titers at the original titers. Values with different superscripts are significantly different (α = 0.05) across time (*f,g). Standard errors of means are in parentheses. Modified live.
titer level than the killed vaccine group. The reason for this difference in starting titer is unknown. Among multiparous cows, the BVDV SN titer increased significantly between 35 and 49 DIM, and between 35 and 70 DIM, only for those receiving the MLV vaccine. Time since the whole herd vaccination did not have a meaningful impact on BVDV titer levels, except in two of the subgroups. Among primiparous cows receiving saline, time since vaccination had a negative effect on titer values. Among multiparous cows receiving the killed vaccine, time since vaccination had a positive effect on titer values.

For both the killed and MLV vaccines, there were significant differences in mean titer values between parities at days 35, 49, and 70. The titer values for the multiparous cows were consistently higher than those for the primiparous cows. The only exception was at day 49 for cows receiving the killed vaccine; there was no difference in mean titer values between the parity groups.

To determine whether pre-vaccination BVDV SN titer values at 35 DIM affected titer values at 49 and 70 DIM, linear regression models using PROC GLM were run with the prevaccination titer value as an explanatory variable and the titer value at 49 and 70 DIM as the outcomes (in separate runs). Among primiparous cows in the killed vaccine group, for every unit increase in the prevaccination log titer at 35 DIM, the value at 49 DIM increased by 1.6 units (314.3 units; \( P = 0.0001 \)). At 70 DIM, this increase was 2.7 units (2499.5 units; \( P = 0.0001 \)). For multiparous cows in the MLV vaccine group, a unit increase in the prevaccination log titer at 35 DIM led to a 3.9 unit increase (6274.9 units; \( P = 0.0001 \)) at 49 DIM. At 70 DIM, this increase was 3.4 units (2931.3 units; \( P = 0.0001 \)). As can be seen at both times (49 and 70 DIM), the multiparous cows, who had a higher mean prevaccination titer, had a lower immune response than did the primiparous cows.

**BRSV**

For BRSV SN titer values there were no significant increases across time associated with treatment in either parity group (Table 2). Time since the whole herd vaccination had a negative effect on SN titer values in primiparous cows in the saline and MLV groups.

Similar to BVDV, it was determined whether prevaccination BRSV SN titer values at 35 DIM affected titer values at 49 and 70 DIM. Among primiparous cows, for every unit increase in the prevaccination log titer value at 35 DIM, those in the killed vaccine group showed a 1.1 unit increase (26.6 units; \( P = 0.0001 \)) at 49 DIM. For every unit increase in the prevaccination log titer value at 35 DIM, primiparous cows in the MLV vaccine group showed a 1.3 unit increase (103.5 units; \( P = 0.0007 \)) at 49 DIM. For every unit increase in the prevaccination log titer value at 35 DIM, primiparous cows in the MLV vaccine group showed a 1.3 unit increase (103.5 units; \( P = 0.0007 \)) at 49 DIM. There was no significant increase at 70 DIM in either vaccine group.

Among multiparous cows, for every unit increase in the prevaccination log titer value at 35 DIM, those in the MLV vaccine group showed a 1.2 unit increase (130.4 units; \( P = 0.001 \)) at 49 DIM. No other differences were significant. As with BVDV, primiparous cows showed a consistently higher immune response than did multiparous cows.
IBR SN titer values increased significantly following vaccination in both the killed and MLV groups (Table 3). Among primiparous cows, the most marked increase occurred in cows in the killed vaccine treatment group. Time since whole herd vaccination had a negative effect in primiparous cows in the saline group, but not for any others. Similar to BVDV and BRSV, we determined whether prediagnosis IBR SN titer values at 35 DIM affected titer values in the vaccine group. For every unit increase in the prediagnosis log titer at 35 DIM, there was an increase of 1.7 units (72.8 units; \( P = 0.0001 \)) at 49 DIM. There was an increase of 1.4 units (54.6 units; \( P = 0.0001 \)) at 70 DIM. Among primiparous cows receiving the MLV vaccine, for every unit increase in the prediagnosis log titer at 35 DIM, there was an increase of 1.4 units (54.6 units; \( P = 0.0001 \)) at 49 DIM. There was an increase of 1.7 units (72.8 units; \( P = 0.0001 \)) at 70 DIM. Among multiparous cows receiving the MLV vaccine, for every unit increase in the prediagnosis log titer at 35 DIM, there was an increase of 1.4 units (54.6 units; \( P = 0.0001 \)) at 49 DIM. There was an increase of 1.7 units (72.8 units; \( P = 0.0001 \)) at 70 DIM. Analysis of prediagnosis IBR SN titer values at 35 DIM affected titer values at 49 and 70 DIM. Analysis of prediagnosis BVDV and BRSV titer values at 35 and 49 DIM affected titer values at 49 and 70 DIM. Among multiparous cows receiving the MLV vaccine, for every unit increase in the prediagnosis log titer at 35 DIM, there was an increase of 1.4 units (54.6 units; \( P = 0.0001 \)) at 49 DIM. There was an increase of 1.7 units (72.8 units; \( P = 0.0001 \)) at 70 DIM. Analysis of prediagnosis BVDV and BRSV titer values at 35 and 49 DIM affected titer values at 49 and 70 DIM. Among multiparous cows receiving the MLV vaccine, for every unit increase in the prediagnosis log titer at 35 DIM, there was an increase of 1.4 units (54.6 units; \( P = 0.0001 \)) at 49 DIM. There was an increase of 1.7 units (72.8 units; \( P = 0.0001 \)) at 70 DIM. Analysis of prediagnosis BVDV and BRSV titer values at 35 and 49 DIM affected titer values at 49 and 70 DIM.

### TABLE 2. BRSV SN Titer Values

<table>
<thead>
<tr>
<th></th>
<th>Titer 1 (35 d)</th>
<th>Titer 2 (49 d)</th>
<th>Titer 3 (70 d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Log Mean (Mean)</td>
<td>SE</td>
<td>Log Mean (Mean)</td>
</tr>
<tr>
<td><strong>PRIMIPAROUS COWS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saline</td>
<td>4.3 (85.0)</td>
<td>0.1 (12.9)</td>
<td>4.2 (83.8)</td>
</tr>
<tr>
<td>Killed</td>
<td>4.4 (135.3)</td>
<td>0.2 (24.5)</td>
<td>4.4 (119.5)</td>
</tr>
<tr>
<td>MLV</td>
<td>4.6 (250.2)</td>
<td>0.2 (50.9)</td>
<td>4.8 (199.3)</td>
</tr>
<tr>
<td><strong>MULTIPAROUS COWS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saline</td>
<td>5.2 (222.1)</td>
<td>0.1 (36.8)</td>
<td>5.2 (240.5)</td>
</tr>
<tr>
<td>Killed</td>
<td>5.1 (259.8)</td>
<td>0.2 (41.5)</td>
<td>5.2 (280.3)</td>
</tr>
<tr>
<td>MLV</td>
<td>5.3 (362.7)</td>
<td>0.1 (58.9)</td>
<td>5.5 (338.4)</td>
</tr>
</tbody>
</table>

\( ^a \) Log and actual by parity at days 35, 49, and 70 of lactation in 163 dairy cows. Cows were vaccinated on day 35 with either saline, killed, or modified live multivalent (BVDV, IBR, BRSV, PI3) vaccine. Values are logarithms of the original titers; actual mean titers are in parentheses. Both sets of values are presented because the statistical analysis was done on the logarithmic scale to account for the non-normality of the original data.

\( ^b \) Titer 1 was measured immediately before vaccination.

\( ^c \) Standard errors of log means; standard errors of actual means are in parentheses.

\( ^d \) Modified live.
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There was an increase of 1.5 units (89.3 units; P = 0.0001) at 49 DIM. There was an increase of 1.1 units (33.4 units; P = 0.0003) at 70 DIM. Among multiparous cows receiving the MLV vaccine, for every unit increase in the pre-vaccination log titer at 35 DIM, there was an increase of 1.2 units (41.1 units; P = 0.0001) at 49 DIM. There was no significant increase at 70 DIM for the MLV vaccine group.

Milk Yield

Within each parity group there were no significant differences in milk yield from day to day for either the killed or MLV vaccine group. Among primiparous cows, there were no significant differences in milk yield from day to day for either the killed or MLV vaccine group. Among multiparous cows, there were no significant differences in milk yield from day to day for either the killed or MLV vaccine group.

Reproductive Parameters

The vaccines had no effect on days to first service or on number of times bred. However, cows receiving the killed vaccine had a lower conception rate at 15 DIM (89.3 units; P = 0.0001) compared to the MLV vaccine group. There was an increase of 1.1 units (33.4 units; P = 0.0003) at 70 DIM. Among multiparous cows receiving the MLV vaccine, for every unit increase in the pre-vaccination log titer at 35 DIM, there was an increase of 1.2 units (41.1 units; P = 0.0001) at 49 DIM. There was no significant increase at 70 DIM for the MLV vaccine group.
Receiving the MLV vaccine were nearly twice as likely to conceive as cows receiving saline (Table 5). This unexpected finding may be explained by the fact that no information was available on postpartum disease monitoring; disorders such as dystocia, retained placenta, and metritis could have accounted for this difference. There was no significant difference in the rate of conception between cows receiving the killed vaccine and cows receiving saline. Other factors influencing time to conception (days open) were days to first service and number of times bred. The parity group (1, ≥2) had no effect on time to conception.

| TABLE 4. Least Squares Means and Standard Errors (SE; kg) of Daily Milk Yield |
|---------------------------------|-----------------|-----------------|-----------------|
|                                 | Saline          | Killed          | MLV a           |
|                                 | Mean  SE        | Mean  SE        | Mean  SE        |
| PRIMIPAROUS COWS                |                 |                 |                 |
| Day -1 b                        | 31.7 1.0        | 34.8 0.9        | 36.2 1.0        |
| Day 0b                          | 33.5c 1.0       | 34.0 1.0        | 33.8 1.0        |
| Day 1                           | 35.0 1.0        | 34.8 0.9        | 33.8 1.0        |
| Day 2                           | 35.7 1.1        | 34.3 1.0        | 33.5 1.1        |
| Day 3                           | 35.2 1.0        | 36.3 1.0        | 33.6 1.0        |
| Day 4                           | 36.1 1.1        | 34.9 1.0        | 34.0 1.1        |
| Day 5                           | 36.8 1.2        | 34.9 1.2        | 35.0 1.1        |
| Day 6                           | 36.0 1.0        | 34.6 1.1        | 34.1 1.1        |
| Day 7                           | 35.6 1.0        | 34.9 1.0        | 34.3 1.0        |
| Day 8                           | 36.0 1.0        | 35.5 0.9        | 34.4 0.9        |
| Day 9                           | 36.1 1.0        | 35.7 1.0        | 35.0 1.0        |
| Day 10                          | 37.5 1.0        | 37.2 1.0        | 35.3 1.0        |
| MULTIPAROUS COWS                |                 |                 |                 |
| Day -1                          | 47.3 1.0        | 48.6 1.0        | 44.9 1.0        |
| Day 0                           | 46.5 1.0        | 45.2 1.0        | 48.0 1.0        |
| Day 1                           | 46.6 1.0        | 47.9 1.0        | 47.4 1.0        |
| Day 2                           | 46.6 1.0        | 44.7 1.1        | 45.0 1.1        |
| Day 3                           | 46.8 0.9        | 46.8 1.0        | 46.5 1.0        |
| Day 4                           | 47.1 0.8        | 46.7 0.9        | 48.2 0.9        |
| Day 5                           | 47.9 1.1        | 48.0 1.1        | 48.7 1.1        |
| Day 6                           | 49.1 1.2        | 46.7 1.3        | 49.4 1.2        |
| Day 7                           | 47.4 1.1        | 47.3 1.0        | 48.4 1.1        |
| Day 8                           | 47.0 1.4        | 47.1 1.4        | 48.4 1.3        |
| Day 9                           | 46.6 1.0        | 47.7 1.0        | 48.7 1.0        |
| Day 10                          | 48.5 1.2        | 47.0 1.2        | 48.9 1.2        |

a Modified live.
bIndicates mean milk yield on day before vaccination.
cIndicates number of days after vaccination (Day 0 = day of vaccination); values for Days 0–10 are adjusted by vaccine and parity.
DISCUSSION

Because SN titer values in the saline control group remained constant, it is unlikely that any of the treatment animals were exposed to a field strain of BVDV, IBR, or BRSV during the course of the experiment. Therefore, the SN titer changes noted in the vaccinated groups are a true response to the treatment vaccines.

The marked SN titer response to the BVDV fraction of the modified live vaccine strongly supports the efficacy of vaccinating cows with a modified live BVDV vaccine prior to breeding. This response does not support the hypothesis that cows previously vaccinated on a semiannual basis with a killed BVDV vaccine are likely to neutralize a modified live BVDV vaccine before it can replicate sufficiently to stimulate an immune response. This is further verified by the finding that the magnitude of the SN response was not correlated with the length of time following the semiannual herd vaccination. It is not known whether the adjuvant in the MLV vaccine had an impact on the enhanced response to the BVDV fraction of the vaccine.

These data also support the idea that some killed vaccines may not induce a complete humoral immune response. The challenge of the animals with a live virus permitted an enhanced response with antibody titers stabilizing at significantly higher values. A vaccination strategy of priming with killed vaccine followed by an MLV booster may achieve titer levels not found with either vaccine type alone. Further studies to assess vaccine strategies will be forthcoming.

The SN response to the BVDV fraction of the killed vaccine administered postpartum was much less than the response observed with the modified live vaccine. A possible explanation for this might be that one dose of the killed vaccine was insufficient to stimulate a strong response because the vaccine previously used in

TABLE 5. Effect of Vaccines on Days Open (Hazard Rate Ratio)a,b

<table>
<thead>
<tr>
<th>Factor</th>
<th>Hazard Rate Ratio</th>
<th>95% Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saline (control group)</td>
<td>1.0</td>
<td>—</td>
</tr>
<tr>
<td>Killed</td>
<td>1.59</td>
<td>0.90, 2.83</td>
</tr>
<tr>
<td>MLV c</td>
<td>1.91d</td>
<td>1.10, 3.31</td>
</tr>
<tr>
<td>Days to 1st service</td>
<td>0.96d</td>
<td>0.94, 0.98</td>
</tr>
<tr>
<td>Times bred</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>0.17d</td>
<td>0.09, 0.30</td>
</tr>
<tr>
<td>3</td>
<td>0.07d</td>
<td>0.03, 0.13</td>
</tr>
<tr>
<td>4</td>
<td>0.03d</td>
<td>0.01, 0.07</td>
</tr>
<tr>
<td>≥5</td>
<td>0.01d</td>
<td>0.00, 0.03</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>—</td>
</tr>
<tr>
<td>≥2</td>
<td>0.85</td>
<td>0.55, 1.32</td>
</tr>
</tbody>
</table>

aHazard rate ratio: a value less than 1.0 implies that cows with that factor conceived at a lower rate than cows in the reference group, while a value greater than 1.0 indicates that cows with the factor conceived at a higher rate than cows in the reference group. The baseline group always has a hazard rate ratio of 1.0 to which all other groups (i.e., levels) for that variable are to be compared.

bAdjusted for days to first service, number of times bred, and parity for 150 cows calving in New York State between December 1997 and May 1998.

cModified live.

dP ≤ 0.05.
the semiannual herd vaccination contained a different adjuvant and strain of BVDV. A more likely explanation is that there was a threshold value of antibody stimulated by killed vaccines, and repeated vaccination with a similar product has minimal effect. Multiparous cows had a lower response than did primiparous cows; this may be due in part to the fact that older cows started out at a higher titer, even before vaccination, than did the younger cows.

The apparent lack of a response to the IBR and BRSV fractions of the modified live vaccine administered postpartum may be due to the fact that the semiannual vaccine used in the herd also contained modified live fractions of IBR and BRSV. These fractions may have already stimulated the immunity to these viruses to a maximum threshold above which the additional postpartum booster had no effect. As with BVDV, older cows tended to show less of a response than did younger cows. In all of these discussions regarding vaccine responses, one must keep in mind that no assessments were made of cell-mediated immunity.

Many veterinarians report a temporary decrease in milk production following administration of multivalent killed vaccines. In this experiment this was not noted, nor was there a positive response for the lactation in milk production or reproductive performance. For a positive vaccine response in these parameters, a disease problem theoretically would have to exist in a herd at the time of vaccination. In this study, because no field viruses were evident in the herd during the experiment, there was no opportunity for the additional vaccine to improve on these parameters.

No challenge was administered to the live study subjects because this was a field situation and introducing a disease into the population was not an option.

**CONCLUSION**

Although the results from this field study on one dairy herd in New York State cannot necessarily be generalized to other settings, they do indicate a beneficial immune response in dairy cattle to the products used.

**ACKNOWLEDGMENT**

The authors thank Fort Dodge Animal Health for its generous financial support of this study.

**REFERENCES**