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The Relationship Between Milk Production and Antibody Response to Ovalbumin During the Peripartum Period

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ABSTRACT

Suboptimal innate and immune mechanisms of host resistance during the peripartum period may contribute to increased incidence of mastitis. To evaluate associations between antibody response to ovalbumin and milk production during the peripartum period, 136 Holstein cows and heifers from three herds with known antibody response profiles, were evaluated for projected 305-d milk, protein, and fat yield. Using a previously described index (Wagter et al., 2000), cows were quantitatively classified based on their profile of antibody response to ovalbumin into high, average, or low antibody response groups. The single-effect antibody response group contributed significantly to variation in fat and protein yield, but not milk yield. The interaction between antibody response and parity significantly contributed to the variation in milk, fat, and protein yields; therefore the effects of group were reported on a within-parity basis. Among first-parity cows, low responders had a higher fat and protein yield than high or average antibody responder animals. Among older cows (parity 3 or greater) milk yield was significantly higher for those in the high antibody response group compared with average and low response groups. However, no significant differences in fat or protein yields were observed between high and low antibody response groups. These results suggest the possibility to select cows for enhanced immune response with no adverse effects on yield. That first-parity cows with low antibody response produce more fat and protein may be offset by the fact that mastitis occurrence was highest in this group in two out of three herds investigated. Selection for high immune response may prove beneficial to herd life by maintaining optimal yield, yet minimizing occurrence of disease.
(**Key words:** antibody, milk production, peripartum, selection)

Abbreviation key: OVA = ovalbumin antigen.

INTRODUCTION

Selection of dairy cows with superior milk production traits has resulted in a steady increase in the incidence of clinical mastitis (Emmanuelson et al., 1988; Harmon, 1994; Owen et al., 2000). Clinical mastitis accounts for a large proportion of costs due to antibiotic therapy, milk withdrawal, veterinary costs, and losses due to culling and death. Losses attributed to subclinical disease include an overall reduction in the quantity and the quality of milk. To help prevent continued increases in mastitis, transmitting abilities of SCS (the log-linear transformation of SCC) are incorporated into the total merit index for Canadian sires (Reents et al., 1995). As various host resistance mechanisms are compromised during the peripartum period (Kehrli et al., 1989a; 1989b; Cai et al., 1994; Detilleux et al., 1995; Grohn et al., 1995; Dietz et al., 1997), when mastitis and other diseases are frequent, it may be beneficial to identify sires and cows based on potential health-related markers. Selection for improved host defense could reduce the prevalence of mastitis and other infectious diseases (Detilleux et al., 1995; Owen et al., 2000; Wagter et al., 2000). Previous studies (Mallard et al., 1997) have indicated that not all cows have depressed defense mechanisms, including antibody responses, during the peripartum period, and that sufficient genetic variation exists to accommodate breeding for these traits (Mallard, 1999). However, relationships between the

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amount of immune response and production traits of dairy cows are largely unknown. In pigs selected for both high-antibody and cell-mediated immune responses, favorable associations were observed with production traits such as days to reach market weight and live born piglets (Mallard et al., 1998). The objective of this study was to evaluate the effect of antibody response group on 305-d projected production traits (milk, fat, and protein).

MATERIALS AND METHODS

Animals and Treatments

Phenotypic and genotypic variation in antibody responses of 136 Holstein cows and heifers from two research herds (Herd 1, n = 32, 6 heifers and 26 cows; Herd 2, n = 67, 34 heifers and 33 cows) and one commercial herd (Herd 3, n = 37, 8 heifers and 29 cows) were previously examined from 8-wk relative to calving (wk 0) to 6-wk postpartum (wk 6) (Wagter et al., 2000). Forty-eight were first-parity cows, 47 cows were in their second lactation, and 41 were multiparous cows. As described previously (Mallard et al., 1997), in order to stimulate antibody during the peripartum period, animals received an intramuscular injection of ovalbumin antigen (**OVA**, Type VII, Sigma Chemical Co., St. Louis, MO) dissolved in an *Escherichia coli* J5 endotoxemia preventive vaccine with the manufacturer's adjuvant (Rhône Mérieux, Lenexa, KS), at wk -8 (4 mg) and wk -3 (2 mg). At parturition (wk 0), animals received a single immunization of the OVA dissolved in phosphate-buffered saline (PBS – 0.1 *M*, pH 7.4) (2 mg, i.m.). Using a mathematical index (Wagter et al., 2000), animals were categorized based on their antibody response profiles to OVA and grouped into high (Group 1), average (Group 2), and low (Group 3) antibody response phenotypes.

Production Variables

Projected 305-d milk, fat, and protein yields were obtained from the Ontario Dairy Herd Improvement Corporation (Ontario DHI). Projected 305-d milk, fat, and protein yields were calculated based on the last test day before the end of lactation and were based on at least 100 DIM.

Statistical Methods

Type III least squares analysis of variance (ANOVA) and corrected means (least square means) were generated using the general linear model procedure of SAS (Helwig and Council, 1982) to evaluate the effects of herd, season-year, antibody response group, parity, and their interactions on projected 305-d milk, fat, and protein yield (Table 1). The general linear model is as follows:

$$y_{ijkl} = \mu + herd_i + season\text{-}year_j + group_k + parity_l + (group \times parity)_{kl} + e_{ijkl}$$

where,

μ = the population mean,
$herd_i$ = fixed effect of herd (i = 1,2,3),
$season\text{-}year_j$ = fixed season-year effect (j = Spring 1994, Summer 1994, Fall 1994, Winter 1994/1995, Spring 1995, Summer 1995, Fall 1995, Winter 1995/96),
$group_k$ = fixed effect of group based on antibody to OVA (k = 1,2,3),
$parity_l$ = fixed effect of parity (l = 1, 2, or >3),
$(group \times parity)_{kl}$ = fixed effect of group × parity interaction,
e_{ijkl} = residual error term.

The animal term for cow nested within parity and antibody response group [cow (group× parity)] was removed from the model, as it did not significantly affect the variation in 305-d milk, fat, or protein yields. Exclusion of this term provided the necessary degrees of freedom to run the ANOVA and calculate least-squares means. Results were considered to be statistically significant if P was ≤ 0.05, and trends were reported at $P \leq 0.10$.

RESULTS

Effects of Antibody Response Group on Milk Production Variables

Milk yield. Season-year, parity, antibody response group, and the interaction between antibody response group and parity contributed significantly ($P \leq 0.0001$) to variation in projected 305-d milk yield (Table 1). Least-squares means of 305-d projected milk yield for first-parity cows was significantly higher for animals with low antibody to OVA ($P \leq 0.0001$) (9308.2 ± 236.7 kg) compared with those in average (7784.9 ± 103.6 kg) and high antibody response groups (6915.0 ± 213.0 kg). Milk yield for cows in their second parity was not significantly different between animals with high (8381.4 ± 234.4 kg) and average antibody response (8565.5 ± 106.0 kg), but was higher than those in the low response group (8174.5 ± 153.6 kg). Milk yield for cows in their third or greater parity was greatest for those in the high antibody response group (9500.8 ± 182.5 kg) compared with both average (8619.8 ± 107.8 kg) and low antibody response groups (8828.1 ± 181.2 kg). (Figure 1A).

Table 1. Analysis of variance (ANOVA) of projected 305-d milk, protein, and fat yield.

Dependent variable	R^{2a} (%)	CV[b] (%)	Herd	Season-year[c]	Group[d]	Parity	Group × parity
				$P <=$			
Milk yield	28.67	14.20	. . .[e]	0.0001	0.0004	0.0001	0.0001
Protein yield	24.89	12.98	. . .	0.0001	0.0001	0.0001	0.0001
Fat yield	16.66	14.72	. . .	0.05	0.0001	0.0001	0.0001

[a]R^2 = coefficient of determination.

[b]CV= coefficient of variation.

[c]Season-Year = season and year of calving.

[d]Group = variation due to antibody group of animals classified with high, average, or low antibody to OVA.

[e]. . . = not relevant to that dependent variable and therefore removed from the model.

Protein yield. Season-year, parity, antibody response group, and the interaction between antibody response group and parity contributed significantly ($P \leq 0.0001$) to variation in protein yield (Table 1). Least-squares means of 305-d projected protein yield for first-parity cows was highest for those in the low antibody response group (304.1 ± 7.0 kg; $P \leq 0.02$) compared with high (234.2 ± 6.3 kg) and average antibody response groups (250.0 ± 3.1 kg). Yield for second parity cows was not significantly different between antibody response groups. Third or greater parity cows had a unique protein yield profile in that protein yields for the high (290.1 ± 5.4 kg) and low antibody response groups (288.8 ± 5.3 kg) were not significantly different from each other, but were significantly higher than those in the average group (270.1 ± 3.2 kg).

Fat yield. Season-year, parity, antibody response group, and the interaction between antibody response group and parity contributed significantly ($P \leq 0.05$) to variation in 305-d fat yield (Table 1). Fat yield for first-parity cows was significantly different between all antibody response groups ($P \leq 0.006$). Low antibody responders had the highest fat yield (348.8 ± 9.6 kg), followed by those in the average (294.5 ± 4.2 kg) and high antibody response groups (269.8 ± 8.6 kg). Within second parity cows, fat yield was not significantly different between antibody response groups. Fat yield for third or greater parity cows was not significantly different between high (354.4 ± 7.4 kg) and low antibody response groups (354.9 ± 7.3 kg), but was significantly higher than those with average antibody response (315.1 ± 4.2) (Figure 1C).

DISCUSSION

Antibody response group significantly contributed to the variation in milk, protein, and fat yields. Production measures were affected significantly by parity, therefore the effects of antibody response group are reported on a within-parity basis. Within first-parity cows, those in the low antibody response group had the highest milk, protein, and fat production. Within second parity cows, milk, protein and fat yields were not significantly different between low and high antibody response groups. Within third or greater parity cows, milk yield was significantly higher for the high antibody response group compared with the low antibody response group; however, it is worth noting that protein and fat yields for older cows were not significantly different between high and low antibody response groups. As parity increases, so too does production yield and occurrence of disease (Dunklee et al., 1994; Owen et al., 2000). In this study, cows in their third or greater parity, and which were identified as high antibody responders, had the highest milk yield overall. These cows produced as much fat and protein as their counterparts with low antibody response to OVA. In a previous study, it was shown that cows classified as high antibody responders to OVA also had the highest antibody response to an *E. coli* J5 vaccine and had no occurrence of mastitis in two of the three herds investigated (Wagter et al., 2000). Selection of these animals may prove beneficial to herd life by maintaining optimal yield, yet minimizing the occurrence of common peripartum diseases, including mastitis. As the high antibody response group within first-parity cows had the lowest production, a within-parity classification of antibody response may be necessary when considering the economic impact of the interaction between antibody response and parity on milk production variables.

Given the positive genetic correlation between selection for increased milk production and the increased rate of clinical mastitis (Emmanuelson et al., 1988; Owen et al., 2000), one might hypothesize that superior production is associated with unfavorable changes in host defense mechanisms that could result in an increased occurrence of mastitis. However, if animals are concurrently selected that have both superior immune response and production characteristics, it may be possible to reduce the adverse positive correlation between

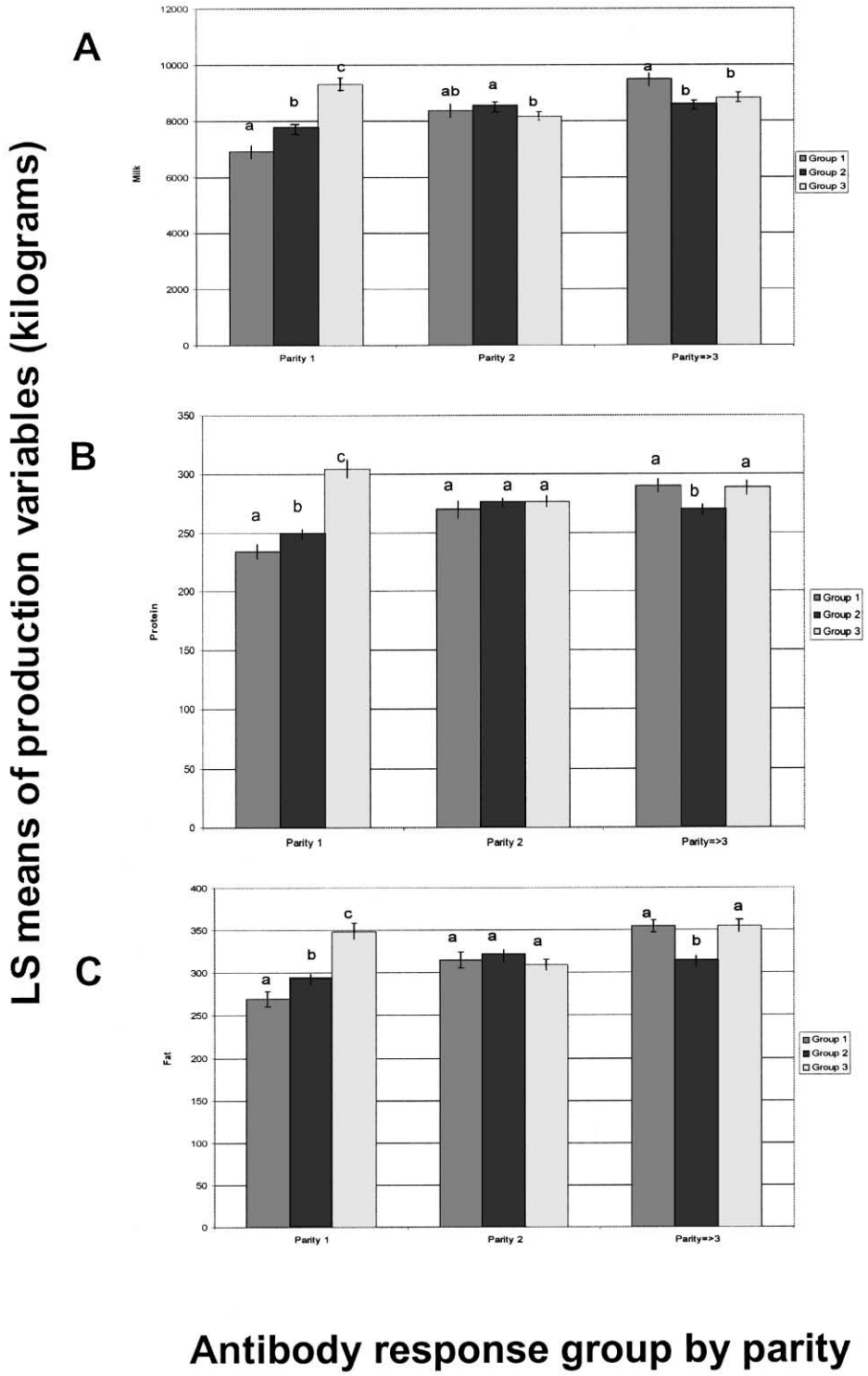

Figure 1. Least squares means of projected 305-d yield for A) milk, B) protein, and C) fat. Group 1 = high antibody response, Group 2 = average antibody response, and Group 3 = low antibody response based on the described index (Wagter et al., 2000). Significant differences between groups are indicated with lower case letters ($P \leq 0.05$).

production and disease. Producers are paid for their milk based on milk solids, so it may not seem beneficial in the short term to select based on antibody response in first-parity heifers. However, among cows of second or greater parity that produce more milk, fat, and protein than younger animals, the high and low antibody responders actually produce similar fat and protein yields, suggesting that selection based on high antibody response would be economically beneficial via reduced health costs, though maximum gains might not be fully realized until a cow's third parity. A previous study (Dunklee et al., 1994) determined that health costs associated with mastitis were positively associated with higher production, but these costs did not outweigh profit potential. Mastitis-related costs have been estimated at approximately $140–300 per cow per lactation in Ontario (Reents et al., 1995). For the higher antibody producing cow, optimum profit potential may not be realized in the short term, but will nonetheless be reflected when looking at the entire lifetime profit potential of that animal.

Regardless of whether health costs do or do not have an impact on the production profit potential of dairy animals, reduced occurrence of mastitis and other infectious diseases via genetic selection for improved immune response should be mutually beneficial to dairy producers, processors and consumers. Milk producers would benefit through a reduction in economic loss incurred by disease, processors would benefit from enhancement of milk quality, and consumers concerned about animal welfare and food safety would appreciate that antibiotic usage to treat disease has been reduced as a result of enhanced immune responsiveness.

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