Evaluation of On-Farm Milk Progesterone Tests to Determine Nonpregnant Cows and to Prevent Insemination Errors

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ABSTRACT

The effect of using the on-farm milk progesterone test for early detection of nonpregnancy and for prevention of insemination errors was evaluated using modeling and simulation. The test was evaluated assuming low and high accuracies of progesterone measurement. For early detection of nonpregnancy, three testing schemes (one test on d 21 after service; two tests on d 21 and 23; three tests on d 19, 21, and 23) were compared against a control. Using the test extended the calving to first service interval by 3 d, resulted in 4 fewer d open, decreased the replacement rate from 20.4 to 18.4%, and increased the net return per cow per year by $13.00. Neither the accuracy of the test nor the testing scheme significantly affected the results. The use of the test to prevent insemination errors was evaluated for two error rates of estrus detection, 15 and 30%. Using the test resulted in .16 fewer services per conception, 3 additional d open, and $6.00 less in net return per cow per year. An interaction between using the test and the prevailing rate of errors in detection of estrus was found; the effect of the test was greater in herds with high prevalence of detection errors but was still unprofitable under the assumed costs and returns.

INTRODUCTION

Progesterone in either milk or blood provides an effective way of monitoring ovarian activity in cattle. As an indicator of the cow's reproductive status, progesterone can play an important role in reproductive management. The following management uses have been suggested for the test: 1) early pregnancy detection; 2) confirmation of estrus at time of breeding; 3) determination of the resumption of ovarian activity after calving; and 4) design of specific treatments for various cystic and other pathological conditions associated with ovarian activity (4, 7, 8, 17).

Until recently, progesterone was measured using radioimmunoassay methods, which are accurate but relatively expensive and slow, (results are available only after several days). New and faster methods of measuring progesterone, such as enzyme-linked immunosorbent assay (ELISA) and latex agglutination assay, are available. With these methods tests can be performed on the farm and results are available within minutes. The ELISA method provides only a qualitative measure of progesterone in milk, low or high, but this information is adequate for management uses. Descriptions of the ELISA methodology and several progesterone kits available on the market have been published (8, 9, 10). To help farmers and their advisers decide if this technology should be adopted, a sound evaluation of biological and economic consequences of its use in reproduction management is needed.

The objectives of this study were to evaluate the use of on-farm milk progesterone tests for early detection of nonpregnancy and for the prevention of insemination errors. To determine the dependence of the effect of using the test on other reproductive management factors, the evaluation was conducted across a range of herd fertilities and efficiencies of detection of estrus.

MATERIALS AND METHODS

The model developed by Oltenacu et al. (11, 12, 13, 16) was refined, and several new components were added. The reproductive process

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was described as a sequence of events including: parturition, return to cyclicity, estrus, insemination, conception, embryonic loss, abortion, and culling. The effects of the major biological, environmental, and management factors affecting the sequence of events and the time interval between events have been described (11, 12, 13, 16).

For this study, standing behavior, mounting behavior during estrus, and the progesterone profile associated with the estrous cycle were added to the original model. Data published by Bloomfield et al. (2) and Wimpy et al. (18) were used to define the progesterone profile associated with the ovulatory cycle. The cycle was divided in two stages with respect to the progesterone, a low stage (LOWP4) representing the follicular phase, and a high stage (HIGHP4) associated with the luteal phase of the cycle. The phases were assumed to be independent and normally distributed with means and SD of 7 ± 1.5 and 14 ± 3.7 d for LOWP4 and HIGHP4 stages, respectively.

Three events were simulated during LOWP4 using data from Esselmont and Bryant (3), Hurnick et al. (6), and Pennington et al. (14): onset of estrus, duration of standing estrus, and mounting activity, Estrus onset followed a uniform distribution and was restricted to occur during LOWP4. Duration of standing estrus was simulated as a normally distributed random variable with mean and SD of 8± 1.3 h, truncated at 0. The number of mounting activities was approximated by a normal distribution with mean and SD of 16± 8 activities, truncated at 0 and adjusted for the number of cows simultaneously in estrus. Mounting activity was not uniform during a 24-h period but was more frequent during late evening and early morning hours. The distribution of mounting activities during standing estrus was generated assuming probabilities of .20, .12, .12, .16, .18, and .22, for mounting during the intervals 0 to 4 h, 4 to 8 h, 8 to 16 h, 16 to 20 h, 20 to 22 h, and 22 to 24 h, respectively.

Three programs to detect estrus based on visual observation were considered: 1) low detection efficiency (DT1), with two 20-min observation periods per day at 0600 and 1700 h; 2) average detection efficiency (DT2), with two 30-min observation periods/d at 0600 and 1700 h; and 3) high detection efficiency (DT3), with three 30-min observation periods/d at 0600, 1200, and 1700 h. a cow in estrus was detected if one or more mounting activities occurred within these observation periods. Errors in detection of estrus were generated for all open cows in the herd and probability was 15% of being reported in estrus and inseminated during the luteal phase of the cycle. When the use of the test to prevent insemination errors was evaluated, a higher rate of detection errors, with probability of 30%, was also simulated. A first breeding policy based on a 50-d waiting period was implemented. Three fertility classes were simulated, resulting in average conception rates of .45 (FERT1), .55 (FERT2), and .65 (FERT3) for low, medium, and high fertility, respectively. A cow was culled for failure to conceive if she was open after five services or for more than 220 d. A herd health program consisting of monthly veterinary visits was assumed.

The accuracy of the on-farm test is a function of the underlying progesterone concentration and of the user's expertise. The test is more accurate when progesterone is either high or low than during the transition periods. Bloomfield (2) reported that progesterone in milk drops faster (12 h) than it rises (18 h). Two accuracies of the test were simulated: 1) a low accuracy, with 80% probability of correct measurement within the first 18 h of high progesterone stage and the first 12 h of low progesterone stage (transition periods) and 90% for other times of the cycle, and 2) a high accuracy with 90% and 95% probability of correct measurement for the transition period and for other times, respectively.

For each set of management factors and for the control, five herds (replicates) of 60 cows each were simulated. Each herd was simulated for 10 yr and the last 5 yr were used in the evaluation. The following measures of reproductive performance were considered: days to first service (SRV1), services per conception (SRV/C), days open (DOPN), and replacement rate (RPRT). Net return per cow per year (NRCY) was used to measure the economic performance, and it was calculated considering the incomes from milk over feed costs, sale of calves, and sale of culled cows, minus the costs associated with test kits, services, veterinary visits, and replacements. Prices used in net return calculations are in Table 1.

To evaluate the effect of using on-farm milk progesterone tests for early detection of non-

TABLE 1. Costs and returns used in the calculation of net return.

Item	Amount
Cost	
Progesterone test kit	$4.50/sample
Services	$5.25/service
Semen	$10.00/dose
Veterinary visits	$2.00/cow
Replacements	$850.00/pregnant heifer
$PGF_{2\alpha}$ treatment	$5.00/dose
Income	
Milk over feed costs	$8.40/cwt
Sale of calves	$70.00/head
Sale of culled cows	$350.00/cow

pregnancy, three testing schemes were simulated: a) one test on d 21 after service with a low accuracy test (LOW-1) or with a high accuracy test (HIGH-1); b) two tests on d 21 and 23 after service with either a low (LOW-2) or a high (HIGH-2) accuracy test; and c) three tests on d 19, 21, and 23 after service with either a low (LOW-3) or a high (HIGH-3) accuracy test. The outcome of the test determined the subsequent management interventions. If the test(s) indicated high progesterone, the cow was considered pregnant and left alone. If the test indicated low progesterone, no more tests were performed and the cow was observed for 10 d and bred if detected in estrus. If not seen in estrus, the cow was tested again and treated with prostaglandin ($PGF_{2\alpha}$) or examined by the veterinarian, depending upon whether the second test indicated high or low progesterone. The consequences of treating a pregnant cow with $PGF_{2\alpha}$ due to errors of the test were also included. The control, against which these testing schemes were compared, consisted of herds using pregnancy diagnosis by rectal palpation on the first veterinary visit after d 45 postservice.

The experiment was simulated as a complete 7 × 3 × 3 factorial design representing the six testing schemes plus the control, three herd fertilities, and three programs for detection of estrus. Two orthogonal contrasts were evaluated: first, comparing the control and the progesterone tested groups, and second, comparing progesterone tested groups with different test accuracies.

The use of the on-farm progesterone test to prevent insemination errors was also evaluated using both low and high accuracies for the test. The protocol was to test before service one-third of the cows detected in estrus 19 to 23 d or 40 to 44 d after a previously detected estrus, and all cows detected in estrus outside these ranges. If the test indicated low progesterone the cow was bred; otherwise she was not. The proportion of cows tested was based on the report that two-thirds of the cows in estrus show clear estrous behavior while one-third have weak signs of estrus (15).

This experiment was simulated as a 3 × 2 × 3 × 3 complete factorial design, representing control plus testing with two test accuracies, two frequencies of detection errors, three herd fertilities, and three programs for detection of estrus.

RESULTS AND DISCUSSION

Both herd fertility and efficiency of detection had a of estrus significant effect on reproductive performance and profit per cow (Table 2). For fertility, FERT2 and FERT3 increased NRCY by $18.00 and $29.00 relative to FERT1, and DT2 and DT3 increased NRCY by $40.00 and $61.00 relative to DT1. These results are in agreement with those previously published (12, 13, 16).

Use of On-Farm Milk Progesterone Tests for Early Detection of Nonpregnant Cows

Confirmation of pregnancy or its complement, identification of open cows, is an important component of reproductive management. The on-farm progesterone test provides the opportunity to accomplish these management tasks earlier after breeding than present strategies (nonreturn to estrus or pregnancy diagnosis by rectal palpation). Reproductive and economic performance measures for the control and for each testing scheme by accuracy combination are presented in Table 3.

Days to first service were increased by 3 d ($P<.01$) when the test was used, independent of the testing scheme or accuracy. This increase is the consequence of an older herd resulting from a lower replacement rate and from the fact that older cows resume cyclicity later after parturi-

TABLE 2. Effect of herd fertility and program for detection of estrus on reproductive and economic performance measures.

Factor[1]	SRV1	SRV/C	DOPN	RPRT	NRCY
	(d)	(n)	(d)	(%)	($)
Fertility					
FERT1	86	2.02[a]	123[a]	22.3[a]	499[a]
FERT2	86	1.86[b]	118[b]	20.1[b]	517[b]
FERT3	87	1.72[c]	114[c]	19.3[c]	528[c]
Detection program[3]					
DT1	91[a]	1.77[a]	122[a]	27.1[a]	481[a]
DT2	86[b]	1.89[b]	119[b]	19.3[b]	521[b]
DT3	83[c]	1.95[c]	114[c]	15.3[c]	542[c]

[a,b,c]Means within a column with different superscripts differ ($P<.05$).

[1]SRV1 = Days to first service; SRV/C = services per conception; DOPN = days open, RPRT = replacement rate; NRCY = net return per cow per year.

[2]FERT1, FERT2, and FERT3 represent low, average, and high fertilities with associated average conception rates of 45, 55, and 65%.

[3]DT1, DT2, DT3 represent programs for detection of estrus of 20 min twice daily, 30 min twice daily, and 30 min three times daily with associated average detection efficiencies of 45, 55, and 65%.

tion and have a higher frequency of silent estrus. It is therefore observable only after the effect of using the test reaches equilibrium and not immediately after implementation of the test.

Days open were reduced on the average by 4 d. The accuracy of the test did not affect the results, but the testing scheme did. Testing two or three times during the 19 to 23 d postinsemination interval (LOW-2, LOW-3, HIGH-2, HIGH-3) reduced ($P<.05$) days open more than testing only once (LOW-1, HIGH-1). Because SRV1 was increased by 3 d, the service period (days from first service to conception) was

TABLE 3. Effect of using on-farm milk progesterone tests for early detection of cows not pregnant on reproductive and economic performance measures.

Factor[1]	SRV1	SRV/C	DOPN	RPRT	NRCY
	(d)	(n)	(d)	(%)	($)
Testing scheme[2]					
Control	84[a]	1.92	116[a]	20.4[a]	517[a]
LOW-1	86[b]	1.94	114[b]	18.3[b]	527[ab]
LOW-2	87[b]	1.93	111[c]	18.5[b]	529[b]
LOW-3	86[b]	1.94	111[c]	18.3[b]	535[b]
HIGH-1	87[b]	1.96	114[b]	18.4[b]	530[b]
HIGH-2	87[b]	1.94	113[c]	18.5[b]	530[b]
HIGH-3	86[b]	1.95	111[c]	18.3[b]	531[b]
Contrast 1					
Control	84[a]	1.92	116[a]	20.4[a]	517[a]
Tested	87[b]	1.95	112[b]	18.4[b]	530[b]
Contrast 2					
Low accuracy	86	1.94	112	18.4	530
High accuracy	87	1.95	112	18.4	530

[a,b,c]Means within a column with different superscripts differ ($P<.05$).

[1]SRV1 = Days to first service; SRV/C = services per conception; DOPN = days open, RPRT = replacement rate; NRCY = net return per cow per year.

[2]Low and high represent test error rates and 1, 2, and 3 represent one test on d 21 after service, two tests on d 21, and 23 after service and three tests on d 19, 21, and 23 after service, respectively.

reduced by 7 d to achieve the observed reduction of 4 d in DOPN. Our results agree with the 6-d reduction in calving interval previously reported when a similar testing scheme was used (1).

Services per conception were not affected by the use of the test, but replacement rate was reduced from 20.4 to 18.4% ($P<.05$), regardless of the testing scheme or the accuracy of the test. A significant interaction of progesterone testing with program of estrus detection (Figure 1) and with herd fertility (Figure 2) was also observed. The reduction in RPRT due to the use of the test was larger when detection efficiency or herd fertility were low than when they were high.

Net return per cow per year increased $13.00 ($P<.05$) when the test was used, regardless of testing scheme or the accuracy of the test. Interaction between the test and herd fertility was found (Figure 3) with the effect of using the test being greater when herd fertility was low than when it was average or high. To determine the price range for which testing was economically feasible the break even cost for the test was calculated and found to be $6.20 per kit for low fertility herds and $5.00 per kit for average or high fertility herds.

The use of the test for early detection of nonpregnancy both improves the reproductive performance of the herd and is economically profitable.

Use of On-Farm Milk Progesterone Tests to Prevent Insemination Errors

In dairy herds, 5 to 50% of open cows are erroneously concluded to be in estrus (5, 15). Failure to interpret correctly the signs of estrus is an important cause of reproductive inefficiency in some problem herds. The effect of using milk progesterone tests to prevent insemination errors on various reproductive and economic performance measures are shown in Table 4.

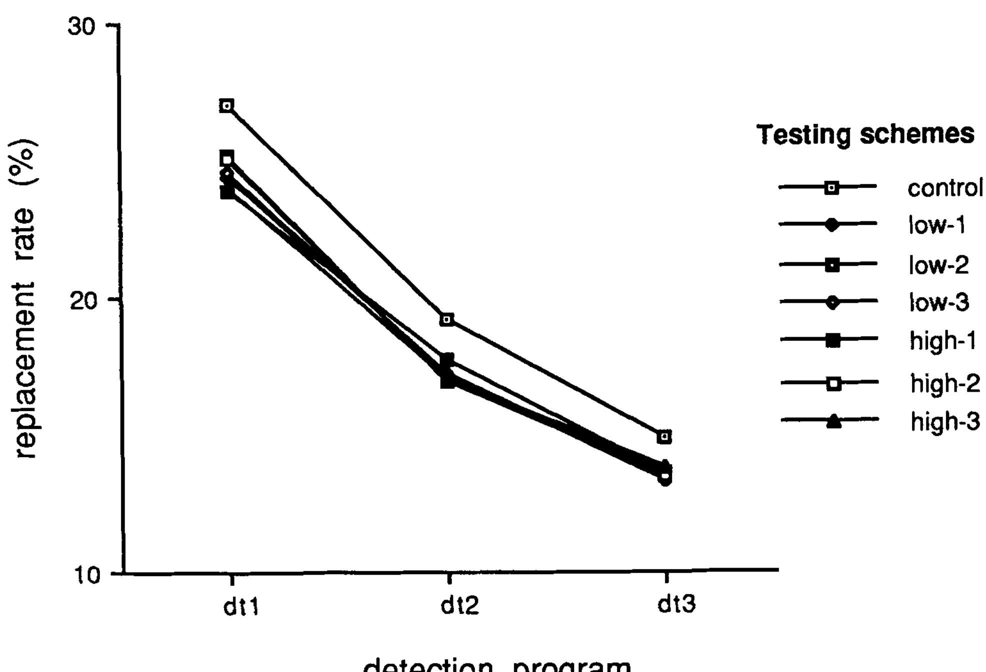

Figure 1. Early detection of cows not pregnant after insemination. Effect of progesterone testing and program for detection of estrus on replacement rate. Low and high represent test error rates and 1, 2, and 3 represent one test on d 21 after service, two tests on d 21 and 23 after service, or three tests on d 19, 21, and 23 after service, respectively. The dt1, dt2, and dt3 represent detection programs of 20 min twice daily, 30 min twice daily, and 30 min three times daily with associated detection efficiencies of 45, 55, and 65%, respectively.

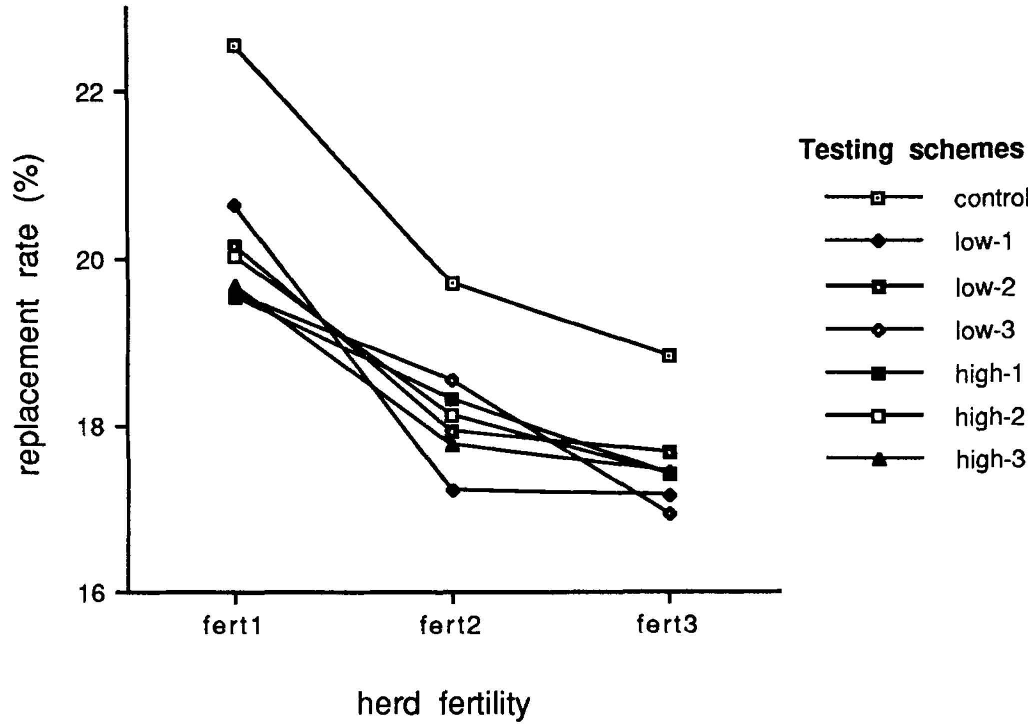

Figure 2. Early detection of cows not pregnant after insemination. Effect of progesterone testing and herd fertility on replacement rate. Low and high represent test error rates and 1, 2, and 3 represent one test on d 21 after service, two tests on d 21 and 23 after service, or three tests on d 19, 21 and 23 after service, respectively. The fert1, fert2, and fert3 represent low, average, and high fertility herds with associated average conception rates of 45, 55, and 65%, respectively.

TABLE 4. Effect of using on-farm milk progesterone tests to prevent insemination errors on reproductive and economic performance measures.

Factor[1]	SRV1	SRV/C	DOPN	RPRT	NRCY
	(d)	(n)	(d)	(%)	($)
Testing schemes					
Control	84[a]	1.98[a]	116[a]	20.6	519[a]
Low accuracy test	89[b]	1.81[b]	120[b]	20.7	512[b]
High accuracy test	87[c]	1.82[b]	118[c]	20.4	513[b]
Detection error rate					
LOW (15%)	87	1.81[a]	118	20.7	515
HIGH (30%)	87	1.84[b]	118	20.4	514
Contrast					
Control	84[a]	1.98[a]	116[a]	20.6	519[a]
Tested	88[b]	1.82[b]	119[b]	20.6	513[b]

[a,b,c]Means within a column with different superscripts differ ($P<.05$).

[1]SRV1 = Days to first service; SRV/C = services per conception; DOPN = days open, RPRT = replacement rate; NRCY = net return per cow per year.

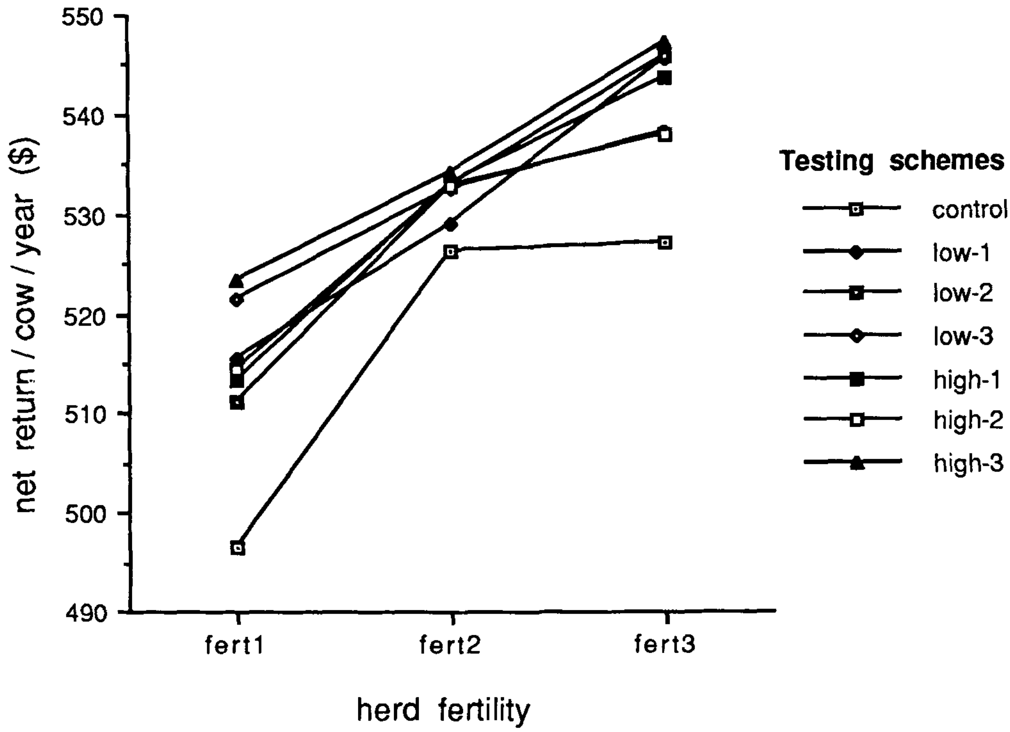

Figure 3. Early detection of cows not pregnant after insemination. Effect of progesterone testing and herd fertility on net return per cow per year. Low and high represent test error rates and 1, 2, and 3 represent one test on d 21 after service, two tests on d 21 and 23 after service, or three tests on d 19, 21 and 23 after service, respectively. The fert1, fert2, and fert3 represent low, average, and high fertility herds with associated average conception rates of 45, 55, and 65%, respectively.

Days to first service increased ($P<.01$) by 5 and 3 d when the test with low or high accuracy was used, respectively. These increases were a direct consequence of preventing some erroneous first services. An interaction between the use of the test and the incidence of errors in detection of estrus in the herd was found (Figure 4) with a greater increase in SRV1 in herds with high incidence of detection errors.

Days open increased ($P<.01$) by 4 and 2 d when using the test with low or high accuracy, respectively. These increases were the result of the errors associated with the test. With less than 100% accuracy of the test there were cases when, following the test, a cow was not bred when she was in estrus and would have conceived if bred. An interaction ($P<.05$) between the use of the test and programs for detection of estrus was also found (Figure 5). Use of the test resulted in a greater increase in DOPN when detection efficiency was high than when it was low. This result was probably due to the fact that high efficiency in detection of estrus resulted in more cows being tested and in more cows actually in estrus not being bred because of errors associated with the test.

Services per conception decreased by .16 ($P<.01$) when the test was used. A significant interaction between the test and incidence rate of detection errors in the herd was found (Figure 6). Testing reduced the SRV/C by .20 in herds where detection errors were common. In contrast, a reduction of only .12 SRV/C was observed in herds with a low frequency of errors in detecting estrus. Replacement rate was not significantly affected by the use of progesterone tests.

Net return per cow per year was reduced ($P<.01$) by \$6.00 as a result of using the tests. An interaction between the use of the test and

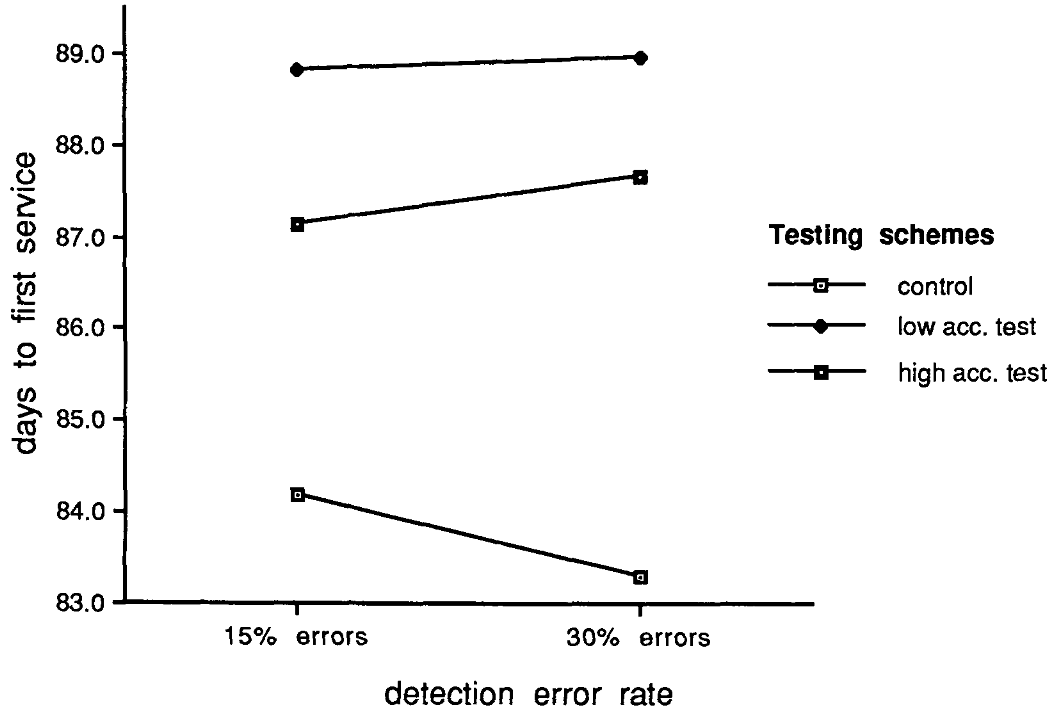

Figure 4. Prevention of insemination errors. Effect of progesterone testing and error rate of detection of estrus on days to first service. The low acc. test and high acc. test refer to low and high accuracy of the tests, respectively.

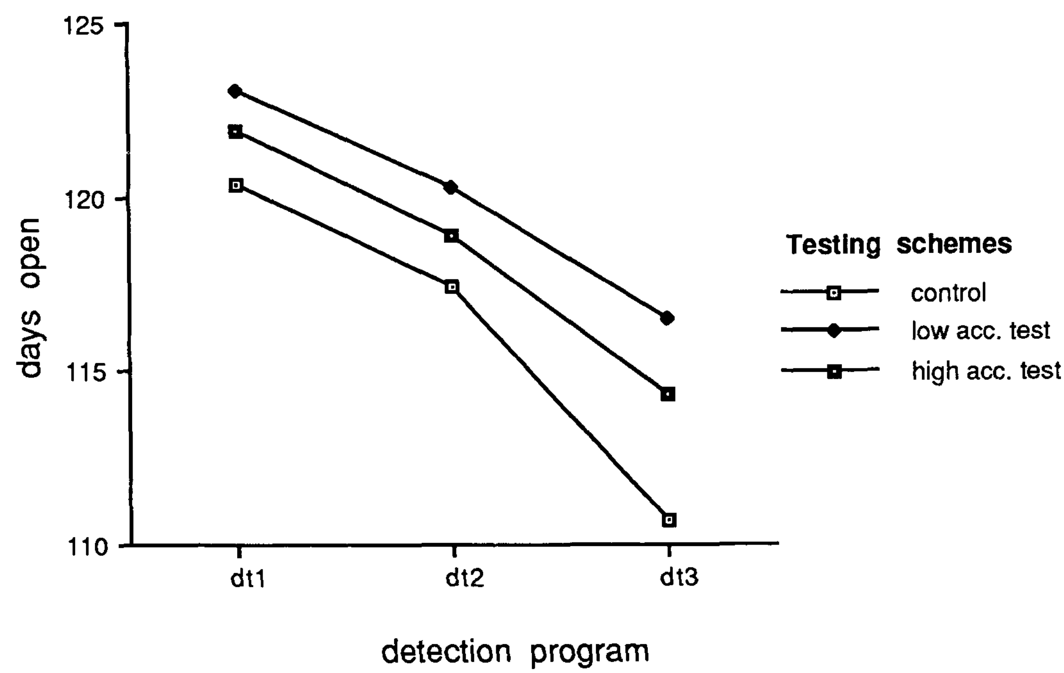

Figure 5. Prevention of insemination errors. Effect on days open of progesterone testing and program for detection of estrus. The low acc. test and high acc. test refer to low accuracy and high accuracy tests, respectively. The dt1, dt2, and dt3 represent detection programs of 20 min twice daily, 30 min twice daily, and 30 min three times daily with associated detection efficiencies of 45, 55, and 65%, respectively.

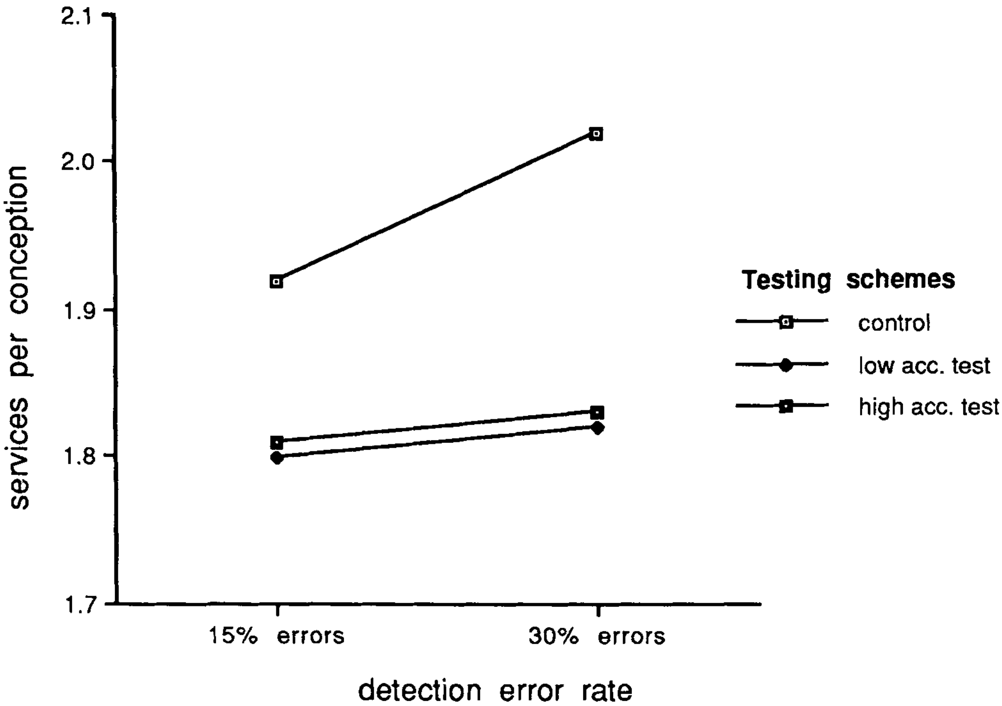

Figure 6. Prevention of insemination errors. Effect of progesterone testing and error rate for detection of estrus on services per conception. The low acc. test and high acc. test refer to low and high accuracy tests, respectively.

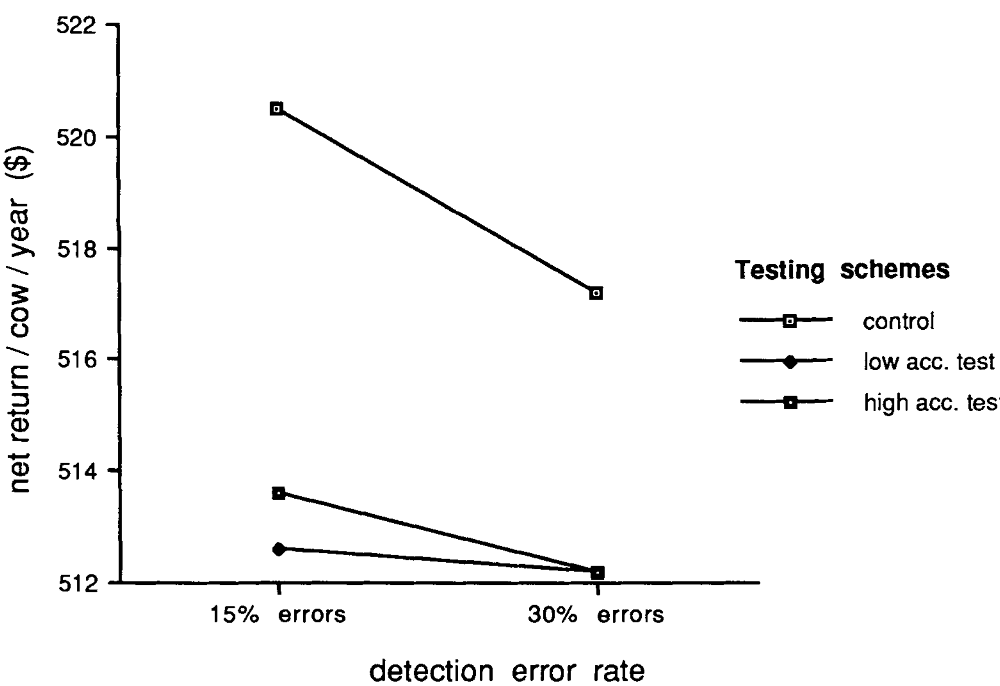

Figure 7. Prevention of insemination errors. Effect of progesterone testing and error rate of detection of estrus on net return per cow per year. The low acc. test and high acc. test refer to low and high accuracy tests, respectively.

incidence rate of errors in detection of estrus ($P<.05$) was also observed (Figure 7). Testing reduced NRCY by $8.00 when the frequency of detection errors was low and by $5.00 when the frequency was high.

The use of on-farm milk progesterone tests to prevent insemination errors significantly reduced the number of services per conception but also increased the number of days open and costs associated with the test were not balanced by the benefits. To make the use of the test economically profitable either higher incidence rate of errors in detection of estrus or higher semen costs than those considered in this study are needed.

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