EFFECT OF IN VITRO EMBRYO PRODUCTION AND SEXED SEMEN IN DAIRY MOET NUCLEUS SYSTEMS

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SUMMARY

Deterministic modeling of dairy cattle nucleus herds using multiple ovulation, embryo transfer (MOET), in vitro embryo production (IVEP) and sexed semen was used to compare 15-year selection responses with an efficient progeny testing system (PT). Selection response adjusted for inbreeding depression (RFy) in adult and juvenile nucleus herds using MOET-IVEP, was optimised for several population structures and sizes. High responses are possible in juvenile or adult MOET-IVEP nucleus of 1000 or more first-lactation cows, with 64 or 128 progeny per donor female. These responses are competitive with an efficient PT scheme for RFy. Adult nucleus herds of 655 to 2300 first-lactation cows could have rates of RFy similar to PT. Juvenile nucleus herds had lower responses than adult nucleus herds with population sizes of 1000 or less and slightly greater responses compared to adult with population sizes of 4000 or more, and inbreeding rates were higher. Sexed semen had minor effects on responses (0.4 to 1.4%), but allowed a reduction in the total number of embryo transfers per year for the same rate of genetic gain. It is concluded that use of IVEP techniques to obtain more progeny per donor female, could increase the rates of genetic response in MOET nucleus herds of dairy cattle, but inbreeding rates need to be limited. Optimum MOET-IVEP schemes will be competitive with PT for RFy, but inbreeding rates and variability of response will be higher. Effect of semen sexing on RFy will be comparatively small.

Keywords: Dairy cattle, selection response, MOET, in vitro embryo production, semen sexing.

INTRODUCTION

Development of in vitro embryo production (IVEP) techniques and semen sexing may have an important influence in the future organisation of efficient breeding programs in dairy cattle (e.g., Van Vleck 1981; Woolliams and Wilmuth 1989; Lohuis 1995; Nicholas 1996). Sexing semen by flow cytometry, is currently possible (Johnson et al., 1994). This technique is not feasible from the timing and cost point of view for commercial production, but can be integrated with MOET and IVEP technologies in nucleus breeding systems. These techniques may increase the selection response in MOET nucleus systems of dairy cattle (Leitch et al. 1994, 1995)

The objectives of the present study were 1) to evaluate the genetic responses using MOET-IVEP nucleus herds with optimum values for female to male ratio, number of progeny per donor female in populations of differing size, 2) to study the effect of sexing of semen and 3) to compare the responses with those of an efficient progeny testing scheme (PT) in a large recorded population. Deterministic modeling was adopted in order to study several combinations of population sizes and structure. Responses from MOET-IVEP nucleus herds optimised for mating ratios, numbers of

progeny per donor and sex ratios were compared, the effect of realistic high levels of inbreeding were used, and the effects of inbreeding depression on fertility and reproduction were included in the model.

MATERIALS AND METHODS

Expected genetic responses adjusted for inbreeding depression (RFy) for juvenile and adult closed nucleus systems with hierarchical MOET-IVEP herd designs were obtained with deterministic methods (Nicholas and Smith 1983; Dekkers 1992; Van Vleck, 1993) accounting for gametic phase disequilibrium on variance, for reduced selection intensities due to small numbers selected and for correlations among indices of related individuals. Effects of inbreeding depression on genetic variance and on reproduction and survival also were included in the model (Goddard and Smith, 1990). Inbreeding levels were assumed to be five times higher with BLUP selection on correlated indices than in a random mating population (Leitch et al. 1994; Wray et al. 1994; Meuwissen and Wooliams, unpublished results). Expected response for a large PT system was obtained for a population of 1,200,000 recorded cows with continuous genetic evaluation and use of embryo transfer in the dam-sire path. The population structure of Lohuis (1993) was adapted to the parameters used in this study to obtain the expected genetic response for PT.

Heritability of 0.25, repeatability of 0.50, phenotypic standard deviation of 1, and a planning horizon of 15 years were assumed for a production trait in dairy cattle (e.g. milk or a composite trait such as milk-fat-protein value).

In juvenile nucleus systems, selection was at 15 months of age on basis of pedigree information with an index based on one lactation record of dam, full and half-sib information of dam, as well the pedigree index of the sire (Bondoc and Smith 1993). Transfer of Y= 8, 16, 32, 64 or 128 embryos per female was assumed as possible within the time framework with the use of IVEP techniques, giving a generation interval of 2 years. Adult nucleus herds have a generation interval of 3.8 years and selection on basis of sib, pedigree, and individual information on females

Herd sizes (first-lactation recorded cows) were 1000, 4000 and 8000. Sires used per year were 2, 4, 6, 10, 20 and 40. Sex ratios (proportion of males) were 0.1, 0.2, 0.3, ... , 0.9. Values of female to male ratio, number of progeny per donor female and proportion of males to maximising RFy for each population size were found using response surface with the RSREG procedure of SAS (SAS, 1981). Then the minimum sizes of adult and juvenile nucleus herds having the same RFy as PT were found assuming an achievable progeny number per donor of 64, under average and low reproduction rates, with and without semen sexing .

RESULTS AND DISCUSSION

RFy for PT was 0.114 phenotypic standard deviations (PSD), inbreeding change per year was .12%, and the standard deviation of the response 0.004 PSD.

From optimisation results, progeny per donor, proportion of males, number of sires and female to male ratio and RFy that gave maximum RFy in juvenile schemes were 75, 0.38, 11, 1.2 and 0.113 for 1000 cow herds; 121, 0.39, 16, 2.1 and 0.149 for 4000 cow herds; and 136, 0.39, 18, 3.3 and

0.163 for 8000 cow herds. With no sexing of semen, responses were reduced by 0.4 to 0.5%. Progeny per donor, proportion of males, number of sires and female to male ratio and RFy that gave maximum RFy in adult schemes were 113, 0.36, 5, 1.8 and 0.130 for 1000 cow herds; 132, 0.35, 8, 3.8 and 0.153 for 4000 cow herds; and 128, 0.34, 10, 6.3 and 0.160 for 8000 cow herds. With no sexing of semen, responses were reduced by 1.2 to 1.4%.

Table 1. Sizes of first lactation juvenile and adult nucleus herds to achieve RFy of a progeny test program

Nucleus type	Herd size	Transfers per year	Number of sires	Donors	X	Y	Pm	Prop	Surv	FTy	RFy	SRFy
Juvenile	1150	1735	8	13	2	64	0.5	0.70	0.8	2.54	0.114	0.017
	1100	1661	8	12	2	64	0.4	0.70	0.8	2.57	0.114	0.017
	3000	6240	10	24	2	64	0.5	0.50	0.7	1.89	0.115	0.015
	2800	5829	10	22	2	64	0.4	0.50	0.7	1.93	0.114	0.015
Adult	655	970	3	7	2	64	0.5	0.70	0.8	1.76	0.114	0.025
	583	865	3	6	2	64	0.3	0.70	0.8	1.82	0.114	0.025
	2300	4693	5	18	4	64	0.5	0.50	0.7	1.02	0.114	0.020
	1900	3881	5	16	3	64	0.3	0.50	0.7	1.06	0.114	0.020

X=Female to male ratio, Y=embryos per donor female,
Pm=Proportion of males,
Prop=proportion of cows having transferable embryos, Surv=survival rate of progeny,
FTy=inbreeding change per year (%),
RFy=selection response per year corrected for inbreeding depression in phenotypic standard deviations, SRFy=standard deviation of RFy.

Table 1 lists minimum sizes of juvenile and adult nucleus herds to be competitive with a large, efficient PT program for RFy, using or not using semen sexing, and under average or low reproductive rates. In terms of embryo transfers, with average reproductive rates, a juvenile nucleus herd of 1150 first lactation cows was required without semen sexing and of 1100 cows with semen sexing. For adult nucleus herds, 655 first lactation cows are required without sexing of semen, and 583, with sexing of semen. If a low reproductive scenario is assumed, these numbers increase to 3000 first lactation cows for juvenile nucleus herds without semen sexing, and 2800 cows with semen sexing. For adult nucleus herds, the required number of transfers per year was 2300 without semen sexing and 1900 with sexing of semen. With low reproduction rates, numbers of transfers per year were up to 6240 in juvenile nucleus herds and 4693 in adult nucleus herds (Table 1).

The main technical limitations associated with these schemes are the increase in levels of inbreeding and variability of response compared with a PT scheme. The levels of inbreeding are high and may be partially the result of lack of any restriction on matings among related individuals implicit in the closed population model used in this present study. In practice, these levels of inbreeding could be reduced by several methods such as optimising mating on the basis of the coancestry among individuals (Meuwissen 1996), increasing the genetic variance in mixed-model equations to reduce

emphasis on family information in selecting individuals (Luo et al. 1995), and using factorial schemes which involve the use of several sires to mate each dam on repeated ova collection, making sib families smaller (Kinghorn et al. 1991; Leitch et al. 1995). Use of distantly related reproductive animals, possible in a situation with several operating MOET-IVEP nucleus herds, or in open nucleus systems combining MOET-IVEP and PT under BLUP evaluation (Meuwissen 1991; Luo et al. 1995) could also delay the build up of inbreeding for the horizon considered. Inbreeding reduction may have also a positive effect on the genetic responses (Caballero et al. 1996). Thus, optimisation of selection response with restriction on inbreeding could make MOET-IVEP technology more competitive with PT compared with the results of this present study.

It is concluded that use of IVEP techniques to obtain more progeny per donor female, could increase the rates of genetic response in MOET nucleus herds of dairy cattle, but inbreeding rates need to be limited. Optimum MOET-IVEP schemes will be competitive with PT for RFy, but inbreeding rates and variability of response will be higher. Effect of semen sexing on RFy will be comparatively small.

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