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Genetic parameters for oocyte number and embryo production within a bovine ovum pick-up–in vitro production embryo-production program

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Abstract

Genetic factors influencing the outcome of bovine ovum pick-up–in vitro production (OPU-IVP) and its relation to female fertility were investigated. For the first time, genetic parameters were estimated for the number of cumulus-oocyte complexes (Ncoc), quality of cumulus-oocyte complexes (Qcoc), number and proportion of cleaved embryos at Day 4 ($Ncleav_{D4}$, $Pcleav_{D4}$), and number and proportion of total and transferable embryos at Day 7 of culture ($Nemb_{D7}$, $Pemb_{D7}$ and $NTemb_{D7}$, $PTemb_{D7}$, respectively). Data were recorded by CRV (formally Holland Genetics) from the OPU-IVP program from January 1995 to March 2006. Data were collected from 1508 Holstein female donors, both cows and pregnant virgin heifers, with a total of 18,702 OPU sessions. Data were analyzed with repeated-measure sire models with permanent environment effect using ASREML (Holstein Friesian). Estimates of heritability were 0.25 for Ncoc, 0.09 for Qcoc, 0.19 for $Ncleav_{D4}$, 0.21 for $Nemb_{D7}$, 0.16 for $NTemb_{D7}$, 0.07 for $Pcleav_{D4}$, 0.12 for $Pemb_{D7}$, and 0.10 for $PTemb_{D7}$. Genetic correlation between Ncoc and Qcoc was close to zero, whereas genetic correlations between Ncoc and the number of embryos were positive and moderate to high for $Nemb_{D7}$ (0.47), $NTemb_{D7}$ (0.52), and $Ncleav_{D4}$ (0.85). Genetic correlations between Ncoc and percentages of embryos ($Pcleav_{D4}$, $Pemb_{D7}$, and $PTemb_{D7}$) were all close to zero. Phenotypic correlations were in line with genetic correlations. Genetic and phenotypic correlations between Qcoc and all other traits were not significant except for the phenotypic correlations between Qcoc and number of embryos, which were negative and low to moderate for $Nemb_{D7}$ (–0.20), $NTemb_{D7}$ (–0.24), and $Ncleav_{D4}$ (–0.43). Results suggest that cumulus-oocyte complex (COC) quality, based on cumulus investment, is independent from the total number of COCs collected via OPU and that in general, a higher number of COCs will lead to a higher number of embryos produced. The correlation between the estimated breeding values for Ncoc and $PTemb_{D7}$ of sires in this study and the sires breeding index for female-fertility based on the Dutch cattle population was close to zero. This study revealed OPU-IVP traits ($Nemb_{D7}$, $NTemb_{D7}$, and Ncoc) that could be of potential value for selection. Introduction of such traits in breeding programs would enhance the number of offspring from superior donors as well as improve the cost efficiency of OPU-IVP programs.

Keywords: Bovine; Genetic parameters; Oocyte; OPU-IVP

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1. Introduction

Since the late 1980 s, bovine ovum pick-up followed by in vitro production (OPU-IVP) has become an embryo production technique well known and established in both research and commercial production programs. International Embryo Transfer Society (IETS) statistics [1] indicate that besides approximately 578,000 in vivo–derived embryos, obtained primarily from superovulated cows, approximately 245,000 in vitro–produced embryos were transferred worldwide in 2007. The success and efficiency of such a program highly depends on both the quantity and the quality of the retrieved cumulus-oocyte complexes (COCs). Oocyte quality can be expressed both morphologically and intrinsically, in which the latter often is described as developmental competence or the competence of an oocyte to develop into an embryo after fertilization. Oocyte quantity and quality are both influenced by a large number of nongenetic factors; for example, OPU technician, OPU assistant, OPU interval, hormonal treatment, and parity [2]. Furthermore, embryo production efficiency, as a parameter for oocyte quality, is considered to be determined mainly during the collection and maturation phase, whereas embryo quality is thought to be determined during the in vitro culture phase [2,3].

Since the introduction of OPU-IVP, many efforts have been undertaken to improve embryo production efficiency. These were all focused on nongenetic factors. Besides some results from multiple ovulation and embryo transfer programs (MOETs), reports focusing on genetic factors in OPU-IVP programs are very limited. This approach, however, may also lead to a significant improvement of the efficiency of an OPU-IVP program by selecting donors with high in vitro production results. Machado et al. [4] studied the variability of OPU results and in vitro embryo production from monozygotic twin cows. They found substantially less variation within twin-pairs than among nonrelated cattle, suggesting the presence of a genetic component and heritability of these traits. This is in agreement with our own unpublished findings showing less variability of OPU results and in vitro embryo production within full-sib heifers than that among nonrelated animals.

To explore the potential of an additional way to enhance the efficiency of an OPU-IVP program, this study aimed to investigate the genetic factors influencing the outcome of OPU-IVP. For the first time, heritabilities and genetic correlations are reported for COC quality and quantity, the number and proportion of cleaved embryos at Day 4, and total and transferable embryos at Day 7. In addition, the estimated breeding values for number of COCs and proportion of transferable embryos were compared with the sires' breeding index for female-fertility to gain insight in the relationship between those OPU-IVP traits and female fertility.

2. Materials and methods

2.1. Oocyte donor and pedigree data

The OPU-IVP data used in this study were established by CRV (formally Holland Genetics) from the open nucleus breeding program from January 1995 to March 2006. Data were collected from 1508 Holstein female donors, both cows and pregnant virgin heifers, with a total of 18,702 OPU sessions. The pedigree data used to determine the family relations among the 1508 donor animals included multiple generations (between two and five generations) (Holstein Friesian). There were between 1 and 9 known mates per sire and between 1 and 33 offspring per dam.

2.2. OPU and classification and maturation of oocytes

Immature COCs were recovered twice weekly, on Monday and Thursday, by ultrasound-guided transvaginal OPU at two nucleus herds in The Netherlands. The OPU sessions were performed by teams of two persons, with the technician responsible for the manipulation of the ultrasound probe and ovary and the assistant responsible for the punctures of the follicles. Per donor per OPU session, all retrieved COCs were treated as one batch throughout the whole IVP system. Transport and in vitro maturation (IVM) of the COCs took place in 2 mL maturation medium in transport vials (2-mL cryovials; Greiner, Frickenhausen, Germany). Maturation was performed for 23 to 27 h in TCM199, supplemented with 10% (vol/vol) fetal calf serum (FCS), 6 μg luteinizing hormone (LH), and 4 μg follicle-stimulating hormone (FSH)/mL (Sioux Biochemicals Inc., Sioux Center, Iowa, USA) and 0.1 mM cysteamine (Sigma, St. Louis, Missouri, USA; since January 2004) at 38.5 °C under an atmosphere of 5% CO_2 in air with maximum humidity. Cumulus-oocyte complexes were classified into four different classes designated 1 to 4, based on the cumulus investment as described before [2].

2.3. In vitro fertilization and embryo culture

After maturation (Day 0), the batches of COCs were fertilized in vitro with frozen-thawed gradient-separated semen. Cumulus-oocyte complexes and spermatozoa