Reproductive technologies and generation interval

Reproductive technologies *Multiple ovulation together with embryo transfer (MOET)*	• Yearly compared with OPU regarding profitability • Number of flushed donors • Genetic level at flushings (females and bulls) • Age and results at flushings • Born calves per donor • Number of embryos - Frozen and fresh • Time between flushing and transfer • Number of sires used • Action plan for ethical aspects • Checklist to motivate and update farmers regarding MOET
Reproductive technologies *Ovum pick-up (OPU)*	• Yearly compared with MOET regarding profitability • Number of OPU donors • Genetic level at OPU (females and bulls) • Born calves per donor • Time between session and transfer • Number of sires used • Age and results at session • Action plan for ethical aspects • Checklist to motivate and update farmers regarding OPU

Generation interval	• Bull and female generation interval - Reproductive technology program - High index mating program • Reproductive start for females and bulls • Semen quality and egg quality at certain ages (months) • Management checklist for animals in the AI-station – yearly evaluated

Reproductive technologies *Multiple ovulation together with embryo transfer (MOET)*	
Yearly compared with OPU regarding profitability	Yearly compared with OPU regarding profitability.
Number of flushed donors	Track how many donors in total that are flushed in the MOET breeding program per year.
Genetic level at flushing (females and bulls)	Genetic level at flushings for flushed donors and used bulls in the MOET breeding program.
Age and result at flushing	Track age and results at flushings.
Born calves per donor	Number of born calves per donor in the MOET breeding program.
Number of embryos –frozen and fresh	Number of embryos in the MOET breeding program: Total and per donor.
Time between flushing and transfer	Time between flushing and transfer. Variation in time between flushing and transfer?
Number of sires used	Number of sires used in the MOET breeding program.
Action plan for ethical aspects	Yearly updated action plan for ethical aspects. Positions and opinions for decisions.
Checklist to motivate and update farmers regarding MOET	Plan to update and motivate farmers so that animals with a high genetic valued are flushed.

Generation interval	
Bull and female generation interval - Reproductive technology program and high index mating program	Bull and female generation interval. In the reproductive technology program and in the high index mating program.
Reproductive start for females and bulls	Track reproductive start for females and bulls.
Semen quality and egg quality at certain ages (months)	Track semen quality and egg quality at certain ages (months).
Management checklist for animals in the AI-station	Management checklist for best reproductive capacity.. For example feed plans, diseases, animals that fall off until reproductive start.

Breeding scheme *Evaluation*	
Genetic trends for total merit	Track trends for total merit.
Check genetic trends for all breeding goal traits - Within and across countries	Track trends for all breeding goal traits. Are there differences between countries?
Phenotypic trends in main breeding goal traits	Phenotypic trends in main breeding goal traits over time to check breeding scheme.
Cost per dose of semen - Sold and produced	Could in cases be a good KPI to evaluate efficiency of the breeding scheme. Check both sold and produced.
Yearly track law changes - Impact on breeding scheme	Check law changes that could have impact on the breeding scheme. For example: You have to register a certain phenotype correct which could affect quality.
Action plan for ethical aspects	Plan for ethical aspects to be able to argue for decisions. Some examples: gen editing, cloning.

Breeding scheme *Evaluation*	• Genetic trends for total merit - Check genetic trends in main breeding goal traits - Within and across countries • Phenotypic trends in main breeding goal traits - Within and across countries - Females and bulls • Cost per dose of semen - Sold and produced • Yearly track law changes - Impact on breeding scheme • Action plan for ethical aspects - For example: gen editing, cloning

Comments:

Reproductive technologies – Literature review

MOET and OPU

Nicholas & Smith (1983) present that multiple ovulation together with embryo transfer (MOET) could increase genetic improvement by 30% in a dairy cattle breeding scheme. MOET reduces the number of required bulls dams which consequently increases the selection intensity and the genetic gain (Pedersen et al., 2011). Further, ovum pick-up (OPU) combined with in vitro fertilization is another reproductive technology used in dairy cattle (Rick et al., 1996). OPU was first used on problem cows that did not respond to superovulation, but later on it has also been applied on pregnant cows and heifers, including prepubertal heifers (Galli et al., 2014)

There are several studies suggesting that the highest selection intensity in the female pathway is achieved through nucleus breeding schemes. (Pedersen et al., 2009; Pryce et al., 2010). Thomasen et al. (2016) studied how genomic selection interacts with the use of reproductive technologies. The reproductive technologies used were MOET and OPU and their effect on AMGG was monitored. Three factors were taking in consideration: 1) 0 or 2000 genotyped heifers per year, 2) 0 or 50 donors selected at 14 months of age which produced 10 offspring and 3) 2 reliabilities of genomic prediction. In addition, Thomasen et al., (2016) investigated how well different reproductive technologies interacts with the reliability of genomic predictions. A stochastic simulation was used and the number of donor was 25, 50, 100, or 200 and the number of born calves per donor was 10 or 20. Further, the age of donors was 2 or 14 months and the number of sires was 25, 50, 100 and 200. The cost of a born calf was €500 Euro, €1000 euro or €1500. The results showed that reproductive technologies combined with genomic selection have the potential to improve AMGG in dairy cattle breeding. Higher reliabilities of genomic predictions resulted in less inbreeding. A more widespread donor program with more born calves per donor resulted in higher inbreeding. Although, when more sires were used the inbreeding was reduced without markedly lower AMGG. Younger donors resulted in higher AMGG because there was no major loss in selection accuracy when genomic information was available and the generation interval was shorter when donors were 2 months compared to 14 months (Thomasen et al., 2016).

Bouquet et al. (2015) simulated an open MOET nucleus in a juvenile scheme. The study evaluated the number of used bulls, flushed heifers and flushings per heifers. In addition the genotyping capacity allocated to young females was analyzed. The results showed that a MOET program increased genetic gain without increased inbreeding if the nucleus was large enough and the number of used bulls was large enough. The results also showed that increasing the nucleus size could not compensate the loss in genetic gain from closing the nucleus. Increasing the number of flushings per heifer resulted in higher genetic gain and inbreeding than if the number of flushed heifers was higher. Thus, more flushings per heifer was economically superior to more flushed heifers if inbreeding was kept on a healthy level. Regarding the genotyping capacity, the number of genotyped females was increased from 800 to 1800 and 3600 to quantify its impact on genetic gain. Increasing the number of genotyped animals above 800 females had little impact on genetic gain (Bouquet et al., 2015).

Sexed semen

Pedersen et al. (2011) studied sexed semen and MOET and their effect on selection intensity on cow dams. The population consisted of 20,000 cows and each year 2,000 females were selected for genotyping. The bull dams consisting of the 2,000 females were divided into two groups; top bull dams and remaining bull dams. The number of bull dams in the different groups varied depending on the amount of sexed semen usage. The largest genetic benefit from using sexed semen was achieved when X-semen was used in both a nucleus population and production population. However, when MOET was used there was no effect of using sexed semen on genetic gain. The optimal use of MOET depended on the accepted rate of inbreeding. With an accepted inbreeding of 1% the maximum genetic gain was achieved with 100% MOET combined with conventional semen on the top bull dams. The top bull dams group in the maximum genetic gain case consisted of 400 females (Pedersen et al., 2011).

Reproductive technologies –Optimal breeding scheme

Genomic information with the possibility for more accurate breeding values for young animals has enhanced reproductive technologies. The uses of reproductive technologies in form of OPU and MOET have been showed to be an effective way to increase AMGG. What limits the usage of OPU and MOET in a long-term genetic gain perspective is the control of inbreeding. In smaller dairy cattle populations, the profitability of implementing RT as a part of the breeding scheme relies on the possibilities of obtaining a high reliability of genomic prediction and of producing progeny from reproductive technologies at a lower level of cost. If the reliabilities of genomic selection were higher the inbreeding level was lower (Thomasen et al., 2016). More sires could also be used to reduce inbreeding without markedly lower AMGG (Thomasen et al., 2016; Pedersen et al., 2011). The younger donors the higher AMGG, due to the availability of genomic selection no major increase in inbreeding was observed (Thomasen et al., 2016).

In theory there are no known limits for OPU and MOET in terms of AMGG as long as inbreeding is controlled. However, there might be practical, logistic or ethical aspects that the theory does not cover. Practical and logistic factors might be easier to control if the breeding structure is more nucleuses based. There are also several studies suggesting that the highest selection intensity in the female pathway is achieved through nucleus breeding schemes. (Pedersen et al., 2009; Pryce et al., 2010). Further, Bouquet et al. (2015) showed that MOET increased genetic gain without increasing inbreeding if the nucleus and the number of bulls used were large enough. More flushings per heifer was economically superior to more flushed heifers if inbreeding was kept on a healthy level (Bouquet et al., 2015). The biggest challenges with reproductive technologies for the three Nordic breeds are probably also practical or logistic. Animals are spread over several countries and in a relatively large area with a quite open breeding structure. There might also be restriction in how you are allowed to move animals across countries. To make sure the right semen is used on the best females at the right time this will therefore require a lot of planning and logistics.

When using reproductive technologies it is important to be aware of the ethical aspects. For example using MOET, multiple ovulations is brought about by hormone injection. The usage of hormones in food production has been a debated and questioned the last decades. With today’s social media, information can spread rapidly and it is important to be able to argue for your decisions. Therefore, in an optimal breeding scheme it should be preferable with action plans for those kinds of situations.

Logistics and optimization (Generation interval) – Optimal breeding scheme

With genomic information and the possibility for more accurate breeding values for young animals there are potentials for better decision making from a very young age or animals that are not even born. This makes it possible for optimizations before an animal is used for breeding. For example, feed optimization could help a bull to start producing semen earlier or a heifer could be mature for MOET earlier. It is also possible to make sure that the right animals are at the right place at the right time. Those factors could for example help to reduce the generation interval and thereby increase genetic gain. However, those factors are rarely captured by the literature but could have considerable effect on an optimal breeding scheme.

There might be need for closer collaborations between breeding companies and farmers. With the need of more accurate phenotypes and genotyping collaboration, the partnerships between farmers and breeding organizations have to be strengthened. This situation is new and will require increased knowledge in the whole community about genomic selection and its effect on the breeding schemes. Further, the breeding scheme should also be regularly evaluated and adjusted when phenotypic trends gets available. It does not matter how theoretical optimal the breeding scheme if the breeding scheme does not add extra value for the farmers.