Should I Consider Using Genomics And IVF?

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Introduction

Dairy producers have a wealth of options at their disposal for creating and managing the next generation of replacement heifers. The days of needing to rear every heifer calf just to maintain the milking herd have passed, for a variety of reasons. First and foremost is improved reproductive management, most notably the availability of highly effective timed artificial insemination (TAI) programs that can yield conception rates >50% and pregnancy rates >30% in lactating cows on well-managed farms. Second is the reduction in involuntary (forced) culling due to illness, injury, or infertility. Forced culling due to reproductive failure has decreased for reasons mentioned previously, while at the same time forced culling due to mastitis has been reduced by improvements in milking routines and hygiene, and forced culling due to lameness and injuries has been reduced (to some extent) by improved housing facilities. The third reason, which is often incorrectly quoted as most important, is the availability of gender-enhanced (sexed) semen. Sexed semen is a powerful tool for increasing the number of heifer calves born on a given farm, but in reality the large increases in pregnancy rates achieved over the past fifteen years would have provided surplus heifer calves regardless of the availability of sexed semen.

Extra heifer calves can only lead to improvements in production efficiency and net farm income if one can identify superior animals early and accurately, and that's where selection based on genomic predicted transmitting abilities (GPTAs) comes into play. More than 3 million dairy cattle have been genomic tested in North America over the past decade, and due to genotype imputation and the availability of inexpensive low- and medium density chips, dairy farmers now test approximately 50,000 calves per month. Genomic test results flow through the Council on Dairy Cattle Breeding (CDCB) genetic evaluation process seamlessly, and farmers can make selection, culling, and (future) breeding decisions before young calves are weaned. As a result, genetics is no longer just a tool for pedigree breeders who wish to market breeding stock – it is a tool that is used for routine day-to-day management decisions on commercial dairy farms.

Genomics and Early Culling of Inferior Heifer Calves

The first and most obvious application of genomic testing is in the culling of genetically inferior calves that are unlikely to contribute positively to herd profitability in the future, using an index such as Lifetime Net Merit (LNM$). This strategy is well-established and supported strongly by research studies (e.g., Weigel et al., 2012; Calus et al., 2015), as well as countless real-life success stories on commercial farms. Risk-averse managers often choose to maintain a "cushion", for example by keeping 80% of heifer calves when only 75% are projected as necessary to maintain the milking herd. Managers with greater risk tolerance may take the opposite approach and keep 5 or 10% fewer heifer calves than needed, in part to reduce rearing costs, but also to ensure that they are not forced to cull too many healthy, pregnant cows that are producing at a mature level in the future. Early culling is a strategy that should be used by any herd that invests in routine genomic testing, preferably in combination with individual health histories for respiratory disease and other disorders that affect future performance.

Genomics and Sexed Semen

The availability of sexed semen, and more recently the competition between sexed semen providers, is a tremendously important if one wishes to implement a proactive herd improvement strategy (e.g., Sorensen et al., 2011; Kaniyamattam et al., 2016). Sexed semen is targeted for superior females, either by using it preferentially in yearling heifers and first parity cows that have higher average merit due to genetic trend, or by ranking cows and heifers individually using an index such as LNM$. Selection of superior dams leads to significant gains in average genetic merit of the next generation of replacement heifers and, because sexed semen is not much more expensive than conventional semen, the vast majority of gains in genetic merit are translated directly into gains in herd profitability. In the early years, the pool of bulls with sexed semen available tended to have slightly lower genetic merit than those with conventional semen only, because artificial insemination (AI) studs tended not to sort the semen of their most highly marketable bulls. In recent years, however, farmers have access to a remarkable lineup of genetically elite bulls with sexed semen available – at very modest prices. Sexed semen should be in the toolbox of every dairy manager, but it will be far more effective when coupled with genomic testing, because GPTAs are much more accurate than parent averages (PAs) from pedigree data only.

Genomics and Beef Semen

As heifer calves have arrived in surplus on most commercial dairy farms, the market price of dairy heifer calves with average or inferior genetic merit has plummeted. Furthermore, the price of crossbred dairy x beef calves exceeds that of dairy bull calves and, in most cases, dairy heifer calves. For these reasons, the practice of mating "surplus dams" (dairy cows and heifers with below-average genetic merit) with beef semen has become tremendously popular in a very short period of time. Research studies are relatively few in number (e.g., Hjorto et al., 2015), but in both research and practice the optimal strategy seems relatively clear, particularly when beef semen and sexed semen are combined in a proactive breeding plan. That is, the top 60 to 75% of yearling heifers based LNM$ (or similar index) should be mated with sexed dairy semen to produce replacement females for the next generation, as should the top 25 to 40% of lactating cows. At the same time, the bottom 25 to 40% of yearling heifers and the bottom 60 to 75% of lactating cows should be mated with beef semen to produce crossbred calves for the beef market. In herds that do not use genomic testing or those that require a simpler management strategy, females can be allocated to sexed semen and beef semen by lactation number instead, thereby taking advantage of differences in average genetic merit and fertility between animals of different ages. For example, the first two inseminations of yearling heifers and the first insemination of first and second parity cows could be with sexed semen, while remaining inseminations for yearling heifers and young cows and all inseminations for older cows could be with beef semen. Obviously these ratios must be customized based on the pregnancy rates and culling rates of individual herds, to ensure that enough replacement heifers are created.

Genomics and IVF Programs

The most interesting and most powerful synergy between genomic testing and reproductive technologies involves in vitro fertilization (IVF), but it is also by far the most expensive. With routine genomic testing, it is possible to identify genetically superior females with high accuracy before weaning, and these exceptional heifers can be used as IVF donors at a young age (long before puberty, if desired). At the same time, small quantities of "pre-release" semen are available from young bulls with extraordinarily high genetic merit, albeit at a significant price and/or with buy-back (first right of refusal) stipulations for exceptional male offspring. As a result, farmers who are willing to establish on-farm IVF laboratories or work closely with resident donor facilities can achieve rates of genetic progress that one would have thought impossible just a decade ago. This is precision cattle breeding at its finest, but it comes at a significant cost. Studies such as Thomasen et al. (2016) suggest that optimal IVF programs using elite young males and females with superior GPTAs can be profitable, and there is no question that such programs can achieve remarkable genetic gains. However, studies such as Kaniyamattam et al. (2017) have shown that the large genetic gains achieved with intensive IVF programs may lead to only marginal gains (and often losses) in net profit.

The main challenge with on-farm IVF programs, as well as strategies based on routine purchase of IVF embryos generated by others, is cost. However, many technical factors contribute to the profitability of herd improvement program based on creating or purchasing IVF embryos. Some of these factors are beyond the control of the farmer or IVF laboratory, such as reliability of the GPTAs of donor females, cost of genomic testing, or the interest rate used in net present value calculations. Other factors, such as veterinary costs, number of viable embryos per collection, conception rate, and (especially) rate of embryonic loss, are key factors that must be optimized to achieve a profitable and sustainable program. The biggest challenge, however, is not actually the high cost or modest technical efficiency of an IVF program. Rather, it is the extremely low cost and very high efficiency of its primary competitor: (sexed) AI semen of elite dairy bulls. When a farmer can purchase large quantities of sexed semen from exceptional dairy sires very cheaply, for example sexed semen of a bull with >1000 LNM$ for less than $25 per unit, it is very hard for even the most efficient IVF programs to produce large quantities of replacement females that can compete on a net profit basis with those produced by using the best available AI sires generation after generation.

Summary

Genomic testing provides an accurate assessment of the genetic superiority or inferiority of heifer calves, and this information can guide culling decisions and inform the use of advanced reproductive technologies. Sexed semen, beef semen, and IVF embryos (purchased or created) can provide great synergies with genomic testing, when used properly. Sexed semen and beef semen are used widely already, and in a cost-effective manner. Meanwhile, IVF programs can provide extraordinary genetic progress, but they are very costly, and it is difficult for such programs to compete with routine use of the highest genetic merit AI bulls on a net profit basis.

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