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Application of liquid semen technology under the seasonal dairy production system in New Zealand

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ABSTRACT

Systems for preserving semen in liquid form for artificial insemination were developed before cryopreserved semen became widely available in the 1960s. Advantages of liquid semen include reduced number of sperm per dose, reduced storage and transportation costs, increased insemination speed and safety in the field. A liquid semen dose requires one tenth the sperm number in a frozen semen dose to achieve equivalent fertility (24 day non-return rate: 67.6% for liquid versus 67.8% for frozen). The main disadvantage of liquid semen is its relatively short shelf life, thus limiting its application mainly to countries, like New Zealand and Ireland, with predominantly seasonal dairy production systems. Nevertheless, successful application of liquid semen technology can improve the rate of genetic gain by increasing the utilization of elite sires. This brief review covers the principles of liquid semen preservation and describes why and how this technology is implemented by Livestock Improvement Corporation in New Zealand.

1. Introduction

Genetic improvement is one of the main factors responsible for the large increase in milk yield of modern dairy cows (Hansen, 2000). This success is mainly attributable to the efficient application of artificial insemination (AI) with semen from proven sires selected using traditional progeny testing programs and more recently using genomic selection. AI allows an elite sire to produce far more progeny than would otherwise be possible through natural mating, resulting in rapid dissemination of favorable alleles. The success of AI arises from advances made during decades of research in semen processing, preservation and insemination technologies. Systems for preserving semen in liquid form for use in AI were developed before cryopreserved semen became widely available in the 1960s. However, cryopreserved semen has since been predominantly used in most developed dairy industries except New Zealand and to a lesser degree Ireland, where the seasonal dairy production systems facilitate the use of liquid semen. The developmental history of AI technologies has been reviewed previously (Foote, 1978; Vishwanath and Shannon, 2000; Foote, 2002; Vishwanath, 2003). This brief review mainly focuses on liquid semen preservation and its application under the seasonal dairy production systems in New Zealand. Unpublished information presented in this review is from Livestock Improvement Corporation (LIC), the largest dairy cattle breeding and service company in New Zealand with a market share for semen sales around 75%.

2. Opportunities for liquid semen under seasonal dairy production systems

The unique seasonal dairy production system in New Zealand is the main reason why liquid semen is the predominant semen product for dairy cattle breeding. The New Zealand dairy industry heavily depends on efficient utilization of pasture grown on each

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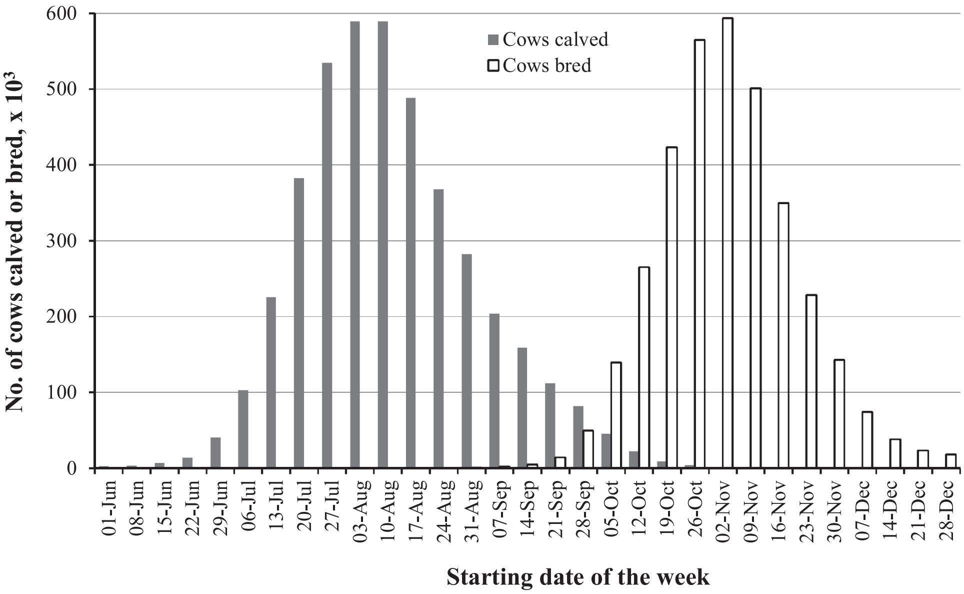

Fig. 1. Weekly number of cows calved or bred in seasonal herds in New Zealand between 1 June and 31 December 2016. The breeding data were for cows inseminated by AI technicians employed by Livestock Improvement Corporation.

farm to maintain its competitive advantage in the world dairy export market. Because of the seasonal variation in pasture growth rate and quality (Verkerk, 2003), about 95% of cows in New Zealand calve over a short period in late winter and early spring (Fig. 1), which is to ensure that feed requirement for peak milk production coincides with the high pasture growth rate in spring and early summer. In order to achieve a seasonally concentrated calving pattern and maintain a 365 day inter-calving interval, breeding for all cows in a seasonal herd starts on a fixed calendar date in spring, regardless of the calving dates for individual cows. Cows detected in estrus are bred by AI for the first 4–8 weeks, then by natural mating for a few more weeks.

The weekly numbers of AI performed by technicians from LIC in 2016 are shown in Fig. 1. During the peak period between late October and early November, more than half a million inseminations were performed per week (more than 70,000 per day). On the one hand, this daily requirement for a large number of inseminations over a short breeding period can be an operational challenge at providing an efficient AI service. On the other hand, this becomes an opportunity for implementing liquid semen in a cost-effective manner by overcoming some of the inherent limitations associated with liquid semen. Over the peak breeding period, more than 85% of inseminations were carried out with liquid semen.

3. Advantages and disadvantages of liquid semen

Liquid and frozen semen each has its unique features that would make them more suitable to different dairy production and breeding conditions. The first key difference is in the number of sperm in a semen dose (dose rate) required to achieve optimal reproductive performance. In New Zealand, the dose rate for liquid semen is between 1.25×10^6 and 2×10^6 total sperm, depending on the target day of usage post collection, while that for frozen semen is typically 15×10^6. The difference in dose rate between liquid and frozen semen implies that an ejaculate can produce about 10 times as many liquid semen doses as frozen semen doses. This greatly increases the breeding capacity of the few available elite bulls, resulting in increased genetic gain in the national dairy cow population. This has been the main driver behind the widespread use of liquid semen in New Zealand. Theoretically, a bull that produces 40 billion sperm per week would be able to produce over 300,000 liquid semen doses at a dose rate of 1.5×10^6 over a 12 week breeding period and another 100,000 frozen semen doses at a dose rate of 15×10^6 during the remainder of the year. This compares with about 133,000 doses if only frozen semen were produced throughout the year. From a genetic gain perspective, the number of LIC bulls required to meet semen demand would need to be more than doubled if only frozen semen were used, thus reducing the average genetic merit of semen available for breeding the next crop of replacement heifers.

The cost to process each liquid semen dose is much less than a frozen semen dose, mainly due to the lack of a freezing step and the increased efficiency gained as a result of the greater number of liquid semen doses from each ejaculate. The cost comparison for storage and distribution between liquid and frozen semen is not as straightforward as for processing. This is because the costs not only depend on the number of semen straws per shipment, but also a potential need for temperature control during storage and shipment. In New Zealand, distribution of liquid semen is much cheaper than frozen semen because its mild temperature allows liquid semen to be distributed under ambient conditions and a large number of liquid semen straws are distributed to each site.

Another benefit of liquid semen is the ease of use in the field. Time required to inseminate a liquid semen straw is less than a frozen semen straw mainly due to no requirement for a thawing step. Unlike frozen-thawed semen, which requires insemination soon after thawing, there is no added pressure for AI technicians to complete insemination of liquid semen within a specific timeframe.