Breeding Strategies for Dairy Herds Improvement

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Abstract

For dairy herds to be more productive, healthy, and sustainable, breeding strategies are essential. With an emphasis on the integration of genetic and genomic tools, reproductive technology, and sustainable practices, this study examines the most recent developments and methodologies in dairy herd breeding. Crossbreeding programs to improve hybrid vigor, the use of sophisticated reproductive techniques including artificial insemination and embryo transfer, and the selection of high-performing sires and dams based on genomic studies are important tactics. To increase herd longevity and lessen environmental effects, a focus is made on striking a balance between production qualities and reproductive and health features. Genetic improvements in conventional milk production qualities and low-heritability traits like fertility and health have been made possible by the use of such strategies in routine breeding operations. These methods have emerged in the fields of genetic modification, epigenetics, genotyping and sequencing, and reproduction. While many of these strategies provide promising prospects that the benefits and drawbacks of genetically enhancing dairy herd populations must be balanced against their effects on society, genetic variety, and the economy.

Keywords: Breeding strategies, Artificial insemination, Embryo transfer, Crossbreeding, Genetic improvement

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Introduction

A herd is a collection of animals belonging to the same species that live or travel together. Meat herds consist of animals such as pigs, Dorper sheep, and Hereford and Angus cattle that are raised for their flesh. These herds are raised to provide high-quality meat, quick weight gain, and muscular growth. Their care centers on keeping them healthy till slaughter and optimizing growth with a balanced diet. Dairy herds include goats, buffaloes, and cattle like Holsteins and Jerseys are raised to produce milk. Because they were chosen for their high milk production, these animals need to be milked frequently and fed a diet that emphasizes lactation through the use of high-energy feeds and supplements (Norman et al., 2004).

The expanding middle classes in emerging economies and the overall rise in the world's population are predicted to cause a sharp rise in the demand for dairy products in the near future. The cattle industry will need to boost production efficiency in order to fulfill rising demand and stay competitive. This will necessitate maintaining or even raising product quality while expanding overall output without raising prices. Numerous state-of-the-art genornic technologies, procedures, and phenotypic collection techniques for novel features have surfaced in recent years. The dairy industry, in particular, has incorporated these technologies into regular breeding programs with speed, enabling the introduction of new functional features and further improvements in breeding value accuracy (Anderson, 1998).

A thorough examination, assessment, and understanding of the implications are necessary before using these cutting-edge genomic technologies, methodology, and phenotype collection approaches on a large scale (Aliloo et al., 2016).

Enhancing a dairy herd's desirable qualities through breeding is essential to raising overall productivity and profitability. Even while genetic advancements have a slow effect, they can eventually significantly influence how well a dairy farm performs (Chagunda et al., 2004).

Importance of Dairy Herds Improvement

Herd improvement is a dynamic process in which farmers strive to improve their herd's genetic makeup. The Breeding Worth (BW) index is used by dairy farmers in New Zealand to gauge the genetic progress of their cattle from one generation to the next. In order to give farmers an unbiased evaluation of an animal or herd's genetic merit, BW integrates a variety of data gathered on the farm. Using Breeding Values (BV), which are an estimate of a cow or bull's genetic merit for a trait, farmers can also easily choose for particular traits like temperament or conformation. Farmers directly benefit economically from genetic enhancement. Every year, the national herd's rate of gain increases, and the value of those gains builds up over time. Genetically superior heifers join the milking herd every year. Their personal performance is the first way they add value, followed by the genes they pass on to their daughters. For this reason, genetic increase gradually affects agricultural profitability. It is projected that the annual profit difference between a herd in the top 10% and the median herd's genetic quality is $12,600 (Chawala et al., 2019).

Making breeding decisions can be difficult, and they have a long-lasting and compounding impact on a dairy herd.The basis for their potential profit will be established by the herd's genetic value. Farmers and their advisors can also take into account the potential effects of genetic choices on animal welfare when developing a herd improvement plan (Haskell et al., 2014).

Breeding Strategies for Dairy Herds Improvement

In dairy cattle breeding programs, the primary goal has typically been to increase production per unit input. Animals with high genetic merit have been developed through selective breeding for commercially key traits, which have more recently relied on genomic selection after previously being based on phenotypic records. Concurrently, reproductive technologies have been refined to spread high-merit genotypes (Flint & Woolliams, 2008). A global issue of considerable concern is the decline in dairy cattle fertility. Therefore, reproductive technologies that increase reproductive efficiency have been given top priority and will be essential to addressing the growing food supply concerns (Murphy, 2012). Dairy cow fertility has decreased over the last 50 years while the amount of milk produced per cow has gone up. For high-performing cows that produce milk, improving reproduction remains a difficulty des pite advancements in research (Pryce et al., 2004; Walsh et al., 2011).

The most recent genetic selection strategies have been combined with modern reproductive technology to enhance economically significant features, such as fecundity (Veerkamp & Beerda, 2007; Berendt et al., 2009). Genetic selection aims to increase fertility on a long-term genetic foundation, whereas reproductive technologies are made to assist with common farm-level management issues. Generally, breeding values for fertility are not very accurate because a variety of factors influence fertility features, and the phenotypes now gathered are very different from the animals' true biology (such to the non-return rate and the time between calving and the first service). Reproductive traits are significantly impacted by environmental factors, such as diet, stress, temperature, and the presence of infections, which also reduce the accuracy of documenting them. However, fertility-related traits have been effectively studied using genome-wide association studies (GWASs), and numerous QTLs, or quantitative trait loci, have been found (Veerkamp & Beerda, 2007; Sahana et al., 2010; Khatib, 2014). Furthermore, attributes like conceptus-maternal interactions and early embryo development, which are crucial for both embryo quality (Jaton et al., 2017) and a successful pregnancy have been investigated using functional genomic approaches (Mondou et al., 2012; Walsh et al., 2012).

Fertility features have recently been examined using gene expression and epigenetics investigations (Inbar-Feigenberg et al., 2013; Kohda & Ishino, 2013). The basic idea was that biological systems are able to adjust to their environment, and that early stress during development can have long-term effects, as demonstrated by the reproductive system in particular. Research is being focused on better understanding how early experiences affect performance later on. According to Walsh et al. (2011), metabolic stress brought on by a negative energy balance during the early stages of lactation is the cause of the decline in fertility in dairy cattle. The resulting heifers from these dairy cows would be less fertile due to their decreased ovarian reserves. There has also been interest in the uterine environment's long-term effects, which may help choose better candidates for the transfer of embryos. The growing conditions of heifers and young bulls are important and may affect the impacts of the epigenome, as numerous studies have shown.

A number of features of both new and existing reproductive technologies intended to quicken the pace of genetic advancement in dairy cattle are described below:

Artificial Insemination

This section reviews the use of artificial insemination (AI) and how it has advanced dairy herd breeding and production initiatives. Al has been the primary focus of reproductive technology due of its accessibility and males' high gamete production rates. This may be AI's biggest benefit since it maximizes the usage of superior bulls. Since its inception, the Al industry has experienced significant growth. Over two centuries ago, in 1784, a dog underwent the first successful insemination. It was also used to research horses, dogs, and bunnies in the last century. Ivanow was the first to use AI to farm animals as a practical approach in the early 1900s (Foote, 2010). In 1968, the use of Al allowed one dairy sire to provide semen for more than 60,000 services, and in 1970, the US Department of Agriculture reported that 7344420 dairy females, or 46% of the total number of female dairy cows, were artificially bred. The export markets, especially for Holstein semen in the 1980s, led to significant improvements in the AI system (Funk, 2006; Foote, 2010).

According to Foote (2010), artificial insemination (AI) is one of the biotechnologies that has gained international acceptance and is frequently applied to enhance farm animal genetics and reproduction. The author went on to say that all other related methods, including synchronization, timing of insemination, sexing, and freezing semen, were developed following the widespread success of artificial intelligence. In particular, it was discovered that these methods improved AI's efficiency. For example, an approach called timed AI (TAI) commonly combines Al with oestrus synchronization. Successful AI requires high-quality oestrus detection, which can be difficult for certain herds. AI is not very effective if oestrus is not correctly detected (Sales et al., 2011). Oestrus synchronization, on the other hand, increases AI efficiency and eliminates the need for oestrus detection. Abnormal epigenetic regulation has been linked to a number of artificial reproduction procedures, however research on this topic is still in its infancy (Kremenskoy et al., 2006). However, breeding dairy cattle with an emphasis on non-production qualities to increase fertility, lifespan, and profitability is currently the trend in the AI industry. To combat in-breeding depression, crossbreeding initiatives and purebreed line breeding have also been explored (Funk, 2006).

Sexed Semen

Dairy Herd breeders have long coveted sexed semen, which has revolutionized the dairy sector. It may be regarded as the most recent revolutionary development in animal reproduction, and the commercialization process has accelerated lately.

The actual application of this approach is well advanced, especially in the dairy business. By creating replacement heifers from genetically superior animals. It may be possible to increase production efficiency by using sexing semen to create offspring of the desired sex (SEiDEl Jr , 2012; Boro et al., 2016). Although sex predetermination has a positive impact on profitability, it often has little effect on the rate of genetic progress. It is not anticipated that the percentage of one sex will rise relative to the other. To enhance animals' genetic quality, even though the total number of selection candidates is expanded. Furthermore, it can be argued that the technique is hampered by issues like reduced conception rates and expensive prices, which prevent its broad commercial use in dairy herd (Garrick & Ruvinsky, 2014).

Embryo Transfer

Embryo transfer is another way to increase the number of offspring from genetically superior females. Since its commercialization in the early 1970s, embryo transfer has been a standard procedure in dairy herd breeding (Mikkola et al., 2015; Mikkola & Taponen, 2017). Although this procedure has been used commercially for nearly 50 years, the quantity of transferred embryos from a single donor in a single embryo harvest has remained unchanged. The pace of improvement in this area has been slow (Mikkola & Taponen, 2017). Numerous factors, including those related to animals as well as management and the environment, might be blamed for the worse outcomes of embryo transfer. Heat stress and poor oestrus detection are the main management problems with dairy cows. Oestrus identification is a major problem since high-producing cows have shorter oestrus periods and fewer obvious behavioral indications of oestrus (Macmillan, 2010; Walsh et al., 2011). An alternative technique that has been proposed to make embryo transfer independent of oestrus detection is fixed-time embryo transfer (FIET) (Rodrigues et al., 2010). One benefit of this process is that it increases the number of recipient cattle that are well-synchronized, which leads to increased pregnancy rates (Rodrigues et al., 2010; Baruselli et al., 2011). Similar to the TAI discussed above, the FTET enables timed breeding without requiring oestrus detection. Enhancing this approach and boosting its effectiveness is the current direction of study in this field (Baruselli et al., 2011; Bó et al., 2011).

Synchronization

Ovarian follicular growth and development cause dairy calves to have distinct follicular wave dynamics during the lactation period. This process has a significant impact on cows' reproductive physiology and gets more dramatic as milk production rises. Dairy cows with reproductive inefficiencies are currently being treated using synchronization (Wiltbank et al., 2011). Oestrus and/or ovulation synchronization has also been utilized to reduce the time between conception and calving in dairy cows. For dairy herd, a number of synchronization protocols have been created and adjusted; some are more successful than others (Figure 1) (Macmillan, 2010).

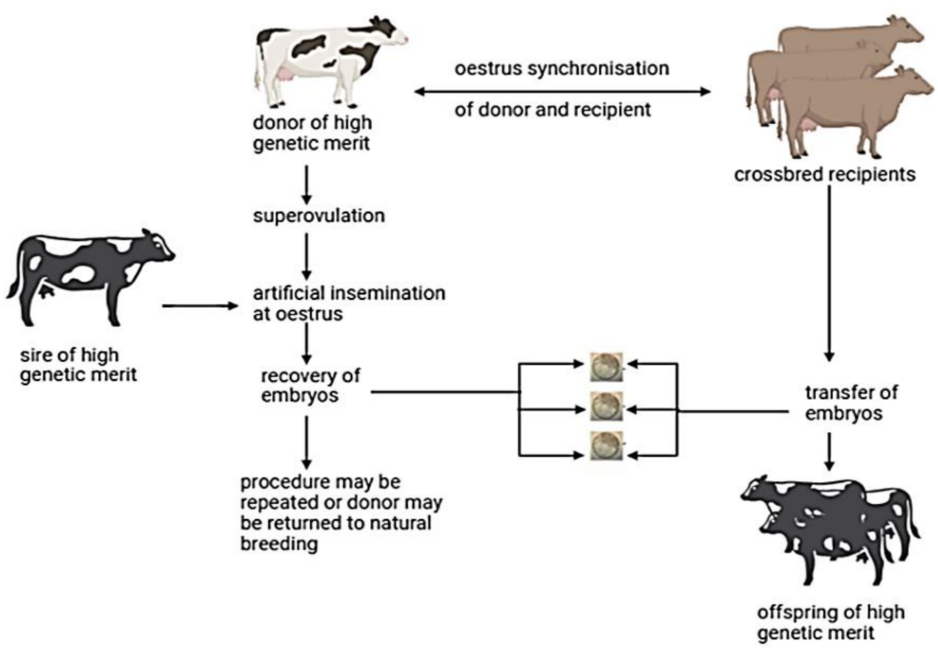

Fig. 1: Synchronization and Embryo Transfer (Prepared by using Biorender)

Rabiee et al. (2005) shown that while synchronizing oestrus also synchronizes the period of ovulation, this method might not be enough to achieve high TAI success rates. However, when oestrus synchronization is done, particularly high-producing cows may have a shorter oestrus period and less overt behavioral signs of oestrus (Walsh et al., 2011; Wiltbank et al., 2011). Ovulation synchronization has become popular as a solution to this issue, as it eliminates the necessity for oestrus identification in scheduled breeding methods. Ovulation synchronization might be considered the main component of contemporary Al and embryo transfer (ET) methods, such as fixed-time artificial insemination (FTAI) or fixed-time embryo transfer (FTET) (Mapletoft & Bó, 2011; Walsh et al., 2011).

Genomic Selection

The breeding of dairy cattle has undergone a revolution thanks to genomic selection, which has had a significant impact on dairy herd management. The rate of genetic advancement for fertility, health, and production qualities has significantly increased, particularly in Holstein and jersey breeds. Young bulls and heifers that undergo genomic testing have the potential to increase innovative features like fetal loss while also increasing the accuracy of selection decisions using standard reproductive traits like daughter pregnancy rate (Aliloo et al., 2016).

The use of reproductive technology is increasingly including genetic enhancement. In the pastor, improving Al and semen cryopreservation was the primary goal. More focus is being placed on the sire, even if the primary goal of studies on reproductive technologies has been the matemal contribution (Kropp et al., 2017). Lately, a set of single nucleotide polymorphisms (SNPs) linked to bull fertility was identified by Khatib (2014). Improving every factor that contributes to fewer open days and more offspring per cow is the ultimate objective. By combining the most cutting-edge reproductive technologies with the most recent genomic selection tools, breeding businesses are now investigating ways to increase the merit of next-generation animals (Figure 2).

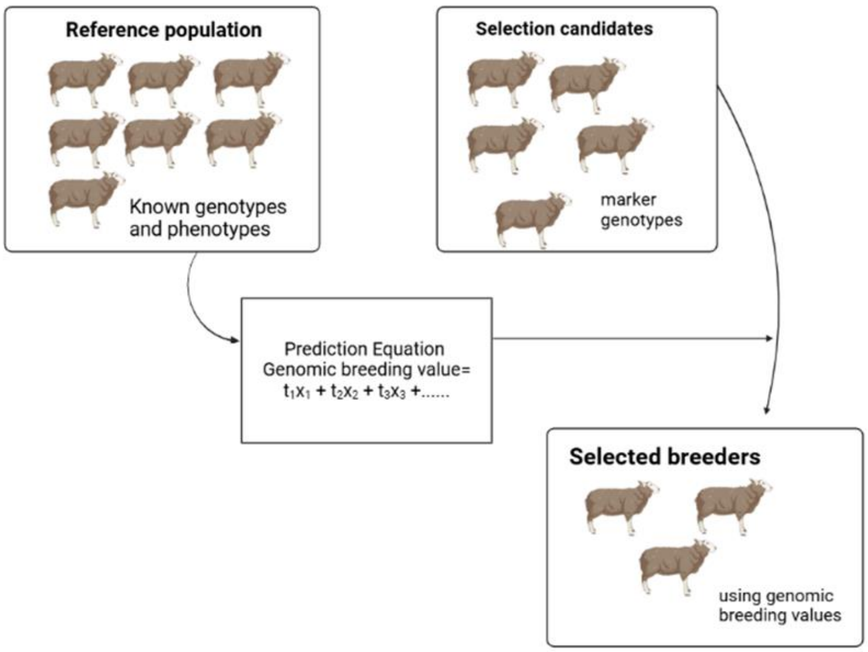

Fig. 2: Genomic Selection (Prepared by using Biorender)

Genomic selection is a formidable method that may make it easier to anticipate a bull's genetic quality at birth or even sooner with embryonic biopsy. This could effectively result in children from prepubertal parents, particularly when paired with optimizing *in-vitro* embryo creation and enhancing gonad functioning. Furthermore, as they have a significant impact on an animal's long-term and future fertility, the conditions before and during conception, gestation, and puberty should all be carefully taken into account. These elements' effects throughout the animal's life have sparked a new area of inquiry and research that should greatly increase cattle fertility (Khatib, 2014)

An animal reference population is genotyped and scored for significant production traits using a commercial or custom single nucleotide polymorphism array. The genotypes are represented by the variable x, which has values 0, 1, and 2 (homozygous, heterozygous, or alternative homozygous). Each animal's genomic estimated breeding value is calculated by incorporating all of the marker genotypes and their effects into a prediction equation. The best animals can be chosen for breeding by applying this prediction equation on a group of unphenotyped animals in order to determine breeding values (Aliloo et al., 2016).

Cloning

Artificial cloning is the process of creating one or more duplicates of an individual by nuclear transfer or embryo splitting. At low concentrations, it can happen spontaneously (Hansen, 2014). It has long been used in plant breeding and is a severe kind of reproductive boosting. Through cloning, a set of genes that function well for one person can be duplicated in another with the same pattern of combination. This kind of beneficial relationship between a set of genes that an individual possesses may be broken down by normal breeding cycles. Because of this, cloning might be considered a means of producing better animals. However, it doesn't alter the genetic variation needed to select future high-achieving individuals. The ability to create genetically identical replicas of the upcoming top bulls is one of the primary benefits of cloning (Moore & Thatcher, 2006). Deavage-stage blastomere separation is the most widely used method for cloning dairy herd. It produces many monozygotic calves, such as twins, triplets, or quadruplets. In order to create essentially identical twins, using post-compacted embryos, embryo bisection is the alternative technique (Rho et al., 1998; Tagawa et al., 2008). Both techniques have shown higher levels of effectiveness in creating monozygotic twins after laparoscopic transfer to recipient cows. Furthermore, 60% or more of cow embryos were split efficiently (Garrick & Ruvinsky, 2014). Rodriguez-Martinez (2012) demonstrated that cloning genetic copies of animals with superior genetic makeup might also be used for somatic cells to create transgenic animals.

Crossbreeding

The mating of individuals from various lineages, breeds, or populations is known as crossbreeding. There are two primary justifications for using crossbreeding in animals. Utilizing the various additive genetic levels among breeds to produce offspring with improved economic potential due to novel combinations of additive genetic components is the first strategy. "Special combining abilities" refers to the use of the various additive genetic levels among breeds. Second, heterosis is expressed via crosses between pure lines or breeds. Compared to their parent breeds, crossbred animals are more resilient and cost-effective (Christensen & Pedersen, 1988).

Many herd producers find crossbreeding desirable, and Hansen (2000) and Kalm (2002) have both advocated it. Over the past few decades, crossbreeding has been widely and successfully employed in systems for producing beef cattle, pigs, and poultry. On the other hand, aside from New Zealand, crossbreeding has not been extensively employed in developed nations for the breeding of dairy cow. The low rate of reproduction in dairy cattle is one of the main causes of the restricted use. Strong animals that can mostly care for themselves are needed as herd sizes grow (in Denmark, the herd size has doubled to 120 cows in the last ten years; Danish Cattle Federation, 2008) and less time is spent on each animal. As a result, crossbreeding in dairy production is becoming more popular in Denmark and other affluent nations (Figure 3) (Heins, 2007).

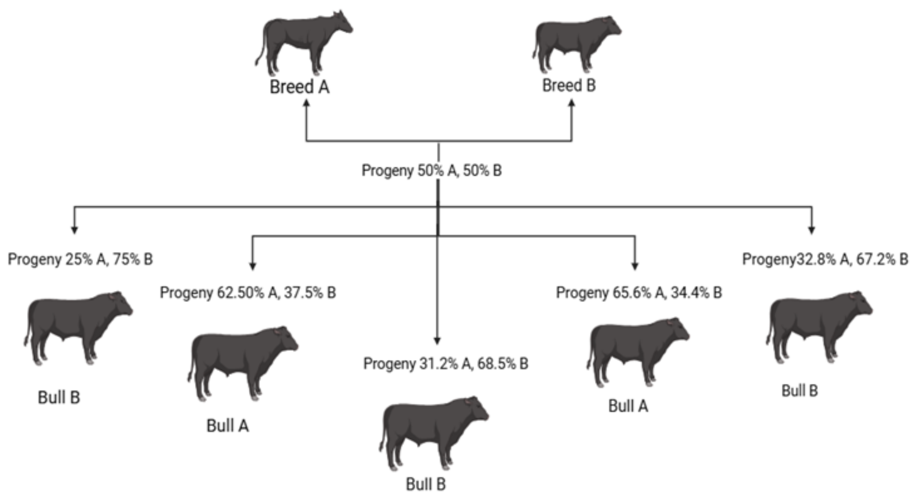

Fig. 3: Crossbreeding (Prepared by using Biorender)

If breeds with roughly the same genetic level for overall merit are employed, crossbreeding can increase profit for the majority of dairy farmers. In addition to the genetic gain that can be produced through pure breeding, crossbreeding produces heterosis. The quantity and variety of breeds participating in the breeding program determine how much the incentive will be. The majority of research indicates that F1 crossings between "unrelated" breeds result in at least a 10% improvement in overall economic gain per cow (Christensen & Pedersen, 1988; Touchberry, 1992; McAllister et al., 1994).

Factors to Take into Account While Implementing New Technologies

As was previously said, new technologies that have the potential to completely transform genetic improvement of the dairy herd population have been and are being developed. But even if the technology did result in better animals or the spread of elite genetics, there are still other things to take into account. AI is one example of a technology that has quickly gained industry acceptance and adoption and had a significant influence. Not every technology has received the same warm reception. The adoption of technology may be hampered by a number of variables that should be considered (Van Eenennaam, 2017). Here, we discuss factors pertaining to economics, social acceptance, and genetic variety.

Variability in Genetics

In dairy herd breeding, the degree of genetic variability in the population today and the consequences of its decline are important subjects. Strong selection has resulted in significant genetic advancements in the dairy herd in several areas, including milk production. This breakthrough was made possible by numerous developments in computing, reproductive, and genotyping technologies as well as breeding practices. However, one notable consequence of the genetic benefits has been an increase in inbreeding trends. Inbreeding has been associated with decreased performance for a number of variables, particularly fitness factors. This reported inbreeding depression has been linked to decreased dairy cow output and reproductive performance (Pryce et al., 2014).

It is crucial to take into account how new technologies may affect genetic diversity as they become available and present new chances for dairy herds genetic development. Genetic diversity has historically been impacted by the advent of new tools for animal breeders, which have changed both the breeding population's composition and the candidates being chosen. Elite genetics have spread more widely and at faster rates over the world thanks to reproductive technologies. The number of offspring produced by top dairy sires was greatly increased by artificial insemination technology, while the effective male population size was decreased. Since outstanding AI sires were able to generate thousands of daughters in addition to males that were also sampled by AI units, few individuals made meaningful contributions to the generations that followed. According to a different perspective, AI allowed producers to employ more than one sire in their herds, reducing the overall effect of AI on inbreeding in the population as a whole (Young, 1984).

If the cloning technique were to become widely used in the industry, there might also be a loss of genetic variety. The technique of producing a genetically identical replica of a person is known as cloning. Through this process and in subsequent animal reproduction, this would result in a far stronger influence of these genotypes within the population. The entire impact of breeding programs can be determined by the overall strategy for integrating these technologies (Daetwyler et al., 2007).

Economics

Economic value is a prerequisite for the commercialization of innovative animal breeding technology. In general, the cost of techniques like genotyping has decreased to affordable levels due to technological breakthroughs and growing acceptance, making their use viable for producers. The advantages of using modern genomic technologies to improve the genetics of many economically significant traits are enticing, especially as the costs of doing so decline. In addition to delivering major cost savings in bull progeny testing, genomic selection and dairy cattle genotyping offer substantial economic benefits in terms of enhancing genetic and hence financial gain (Schaeffer, 2006).

Whole-genome sequencing has only found use in research since its high costs at its current price point cannot currently be offset by further genetic benefits. This could change if protocols change and this work yields useful outcomes. New uses of NGS technology, like GBS, have also surfaced as a cost-effective way to generate genotypes for a large number of variations. Other criteria, such as efficiency and returns, may be more prohibitive for certain technologies than the actual cost. McCullock et al. (2013) discovered that management factors like conception rate and the market climate had a greater impact on profitability with sexed semen than the additional costs of sexed semen.

Acceptance in Society

The ethical ramifications of using new breeding techniques and technologies, as well as how society will react to them, are crucial topics of discussion. Although scientists view developed technologies as essential and revolutionary, the public may be concerned about their potential applications, which could benefit the dairy business. These issues need to be recognized and resolved, or else such innovative advancements would never be implemented. AI and embryo transfer are two examples of the many reproductive technologies that are now widely used in the dairy sector. Society is aware of the significance of animal welfare, and the use of biotechnology in food production has been widely covered by the media. One of the biggest barriers to the use of technologies like genome editing, genetic engineering, and cloning is the public's perception and fear of them. Research on public concerns has focused on perceptions of risk, utility, ethical or value-related issues including "unnaturalness," trust in information and its sources, and acceptance of its numerous applications (Frewer et al., 2013).

Depending on the intended usage, the public's perception of genetically modified animals may change. Compared to food production, pharmaceutical manufacture has received better acceptance (Laible et al., 2015). Customers may find applications that improve human or animal health or other known benefits more enticing than those that increase output. Furthermore, geographic location affects acceptance because European consumers are often more opposed to genetic engineering applications than are those in North America and Asia (Frewer et al., 2013).

Conclusions

For dairy herds to improve sustainably, effective breeding techniques are crucial. Productivity, health, and longevity can be improved while lowering environmental consequences through the integration of genomic tools, cutting-edge reproductive technologies, and data-driven methodologies. Long-term herd viability and economic efficiency are ensured by giving priority to a balanced selection of characteristics, which includes productivity, fertility, and disease resistance. The consequences of introducing new methods and technologies in livestock breeding populations, as well as the expansion of the use of genomic and reproductive technologies, should be carefully considered. Using creative, sustainable breeding techniques will be essential to boosting resilience and supplying future demands as dairy farming deals with issues like climate change and the world's growing food need.

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