Biological Times Volume No. 3 | Issue No. 11 | Pages 46-47

Advancement in milk yield and quality improvement via selective breeding and genetic engineering in dairy cows

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ABSTRACT

Dairy farming has remarkably evolved since the Europeans introduced it in the 15th century due to its transformation from natural grazing systems to technologically advanced operations. In the early stages, dairy cows were grazed on natural pastures and after the 1960s the milk yield was significantly boosted by advancements in management practices, supplementary feeding, and selective breeding. By the 1980s, innovations like improved nutritional standards and roughage quality drove milk production. In the United States between 1993 and 2002, genetic advancements accounted for a 55% increase in milk yield per cow and underscored the critical role of selective breeding in dairy farming. Beyond conventional methods, genetic engineering offers promising avenues to enhance milk composition and yield by addressing consumer demands and profitability for producers. Technologies such as DNA recombination and marker-assisted selection are instrumental in producing transgenic animals with altered milk properties including reduced fat content for health-conscious consumers. These scientific breakthroughs combined with modern genome editing techniques such as CRISPR-Cas9 signify a new era in dairy farming.

Keywords: Selective Breeding, Genetic Engineering, Milk Yield Improvement Techniques, Artificial Insemination and Genetic Merit

To cite this article: Shah MAH, ZA Nomi, M Azam, M Tahir & SA Rajput. Advancement in milk yield and quality improvement via selective breeding and genetic engineering in dairy cows. Biological Times. 2024 November 3(11): 46-47.

Introduction

Europeans introduced the concept of dairy farming in the 15th century. Before their efforts, cows grazed in natural pastures. Since the 1960s dairy systems have gradually incorporated technology, management practices, more cows, and more inputs such as supplementary feeds. It is interesting to point out that, until the second half of the 1980s, the major increase in milk yield resulted from improved management and better organizational controls like the application of nutritional standards and an increase in roughage quality [1]. In the US between 1993 and 2002, the average milk production per cow increased by 1287 kg, and genetic factors were held to be solely responsible for 708 kg of this production, which is about a 55% increase in the total milk production in dairy cows. In the past century, dairy cattle science has evolved vastly in its contribution to improving milk production and quality. This resulted in higher yields to fulfill the consumption demand for nutritious milk for humans [2]. It appears that there are many different strategies for milk engineering to improve both nutrient quality and milk yield. Mother Cow has been bred into a milk-producing specially bred animal that yields more than the requirement of the calf. For dairy producers, it contains high-fat-containing milk for cheese makers. Since defined by genetics as the main spontaneous conception and the effective use of artificial insemination (AI) following the DNA typing of bulls and distribution of semen (Insemination straws) all around the world with high genetic merit for production [3].

Increasing milk yields by selective breeding

Selective breeding is the process of choosing parents who have characteristics and then breeding them to produce offspring with more beneficial or required characteristics. The main objective of dairy cattle selection and breeding, over the last fifty years, was to increase productivity in milk production with the major concentration being on genetic improvement. This goal has been welcomed widely because of its importance in meeting consumer requirements worldwide. Generate more profitability for those practicing farming and decrease the cost to consumers [4]. Bovine milk production can be further increased if current levels of infertility, lameness, and mastitis are reduced. So, selection would be more beneficial for animals if their health issues were kept in mind while selecting higher milk yields. More milk production means an increase in milk secretion and resulting in high demand for energy energy-providing diet. Selection for production increases feed intake but, with a genetic correlation between yield and feed intake rewards better profits [5].

Milk production improvement via genetic engineering

The recombination of DNA is a method used in genetic engineering which is a group of techniques used for direct genetic modification of organisms or populations of organisms. These procedures are used to identify, replicate, modify, and transfer the genetic material of cells, tissues, or complete organisms. The direct manipulation of DNA oriented to the expression of genes is the most common among the techniques used in DNA recombination. The incorporation of DNA markers for selecting (MAS): marker-assisted selection), for increasing the efficiency of the conventional methods of breeding based on phenotypic information is involved in genetic engineering. The manipulation of DNA sequences is the most focused purpose of genetic engineering [6]. This technique involves isolation, cutting, and then transferring of DNA fragments of specific genes. Some unique genes are responsible for milk composition and properties that can be altered to modify milk proteins and their composition. In transgenic animals, human lactoferrin is introduced into the bovine milk which is the application of milk modification while altering the concentrations of antibacterial proteins such as lysozyme or transferrin in the milk helps reduce threats of mastitis and other bacterial inflammations [7].

Decreasing fat percentage in milk by Genetic engineering

All over the world, many people cannot digest the fats present in bovine milk. Their guts even cannot tolerate, which leads to diarrhea or many more gastrointestinal issues even though some people have cardiac health issues like heart stroke or lipids deposition in veins and arteries. The overall fat content of US dairy cow's milk is 3.8%. About half of that fat is synthesized in the mammary gland. If those stem cells in the mammary gland could be targeted and disrupted then it led to the reduction of fat percentage, we might get milk having 2.0% fat (about a reduction of 40%). To reduce fat synthesis stem cell knockout or ribozyme technology targets expression of the acetyl-coenzyme A (CoA) carboxylase gene. In the future possibility of this concept, a recent study proves that there are preadipocyte cells with genes encoding ribozyme targeting AcetylCoA carboxylase RNA [8]. Acetyl-CoA carboxylase RNA was reduced from non-ribozyme-expressing cells. A reduced expression of acetyl-CoA carboxylase mRNA was observed by a significant decrease in the activity of the enzyme and resulted in a decrease of fatty acid synthesis of 30-70% that was seen in controls [11].

Modern dairy cows are profitable if milk income exceeds feed, labor, housing, breeding, veterinary, or different expenditures over the cow's lifetime. In the beginning, cows produced milk only for their calves. After the domestication of these cattle, specialized breeds were improved for dairy production. Selecting animals focusing on hair color, different breed features, udder size, milk yield or milk quality, and other phenotypic production measures. Selective breeding and feeding highly nutritious diets containing cereal grains and quality forages play a crucial role in dairy production advancement [9]. Genetic engineering techniques create transgenic animals that produce milk containing human proteins or enzymes, which can be used for medical purposes. Traditional techniques including selecting animals phenotypically like milk yield, udder formation, and teat alignment are focusing on these now used in modern dairy science, genome editing advanced tools like CRISPR-Cas9 to modify the genetic code of dairy cows leading to the improvement traits affecting milk yield and composition [10].

Conclusion

In conclusion, the evolution of dairy farming, from its introduction by Europeans in the 15th century to the advanced genetic engineering techniques, reflects the remarkable progress in enhancing milk production and quality. Early dairy systems relied on natural grazing but with the passage of time selective breeding improved management practices and technological innovations have transformed dairy cows into specialized milk producers. However, genetic engineering promises to tailor milk composition and enhance dairy cow health by opening new avenues for human nutrition and medical applications. As we move forward, the challenge will balance the need for higher milk production with the health and well-being of dairy cows.

References

[1] McGuffey RK. A 100-Year Review: Metabolic modifiers in dairy cattle nutrition. Journal of Dairy Science. 2017 Dec 1;100(12):10113-42.

[2] Wells JC, Pomeroy E, Stock JT. Evolution of lactase persistence: turbo-charging adaptation in growth under the selective pressure of maternal mortality?. Frontiers in Physiology. 2021 Aug 23; 12:696516.

[3] Garg M. Biotechnological tools to enhance sustainable livestock production. InEmerging Issues in Climate Smart Livestock Production 2022 Jan 1 (pp. 19-45). Academic Press.

[4] TESEMA B. Cattle Genetic Improvement Strategies for Sustainable Development in Tropics. Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Animal Science & Biotechnologies. 2023 Nov 1;80(2).

[5] Garvey M. Lameness in dairy cow herds: disease aetiology, prevention and management. Dairy. 2022 Mar 18;3(1):199-210.

[6] De Vries A, Marcondes MI. Overview of factors affecting productive lifespan of dairy cows. Animal. 2020 Mar;14(S1): s155-64.

[7] Qureshi MA, Fatima Z, Muqadas SM, Najaf DE, Husnain M, Moeed HA, Ijaz U. Zoonotic diseases caused by mastitic milk. Zoonosis, Unique Scientific Publishers, Faisalabad, Pakistan. 2023; 4:557-72. https://doi.org/10.47278/book.zoon/2023.179

[8] Wall RJ, Kerr DE, Bondioli KR. Transgenic dairy cattle: genetic engineering on a large scale. Journal of Dairy Science. 1997 Sep 1;80(9):2213-24.

[9] Sandri M. Relation of rumen microbiome and blood transcriptome with the genetic merit in Italian Simmental and Italian Holstein cows.

[10] Van Eenennaam AL, De Figueiredo Silva F, Trott JF, Zilberman D. Genetic engineering of livestock: the opportunity cost of regulatory delay. Annual Review of Animal Biosciences. 2021 Feb 15;9(1):453-78.

[11] Mu T, Hu H, Ma Y, Feng X, Zhang J, Gu Y. Regulation of key genes for milk fat synthesis in ruminants. Frontiers in Nutrition. 2021 Nov 25; 8:765147.