Chapter

Technology for Carbon Neutral Animal Breeding

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Abstract

Animal breeding techniques are to genetically select highly productive animals with less GHG emission intensity, thereby reducing the number of animals required to produce the same amount of food. Shotgun metagenomics provides a platform to identify rumen microbial communities and genetic markers associated with CH4 emissions, allowing the selection of cattle with less CH4 emissions. Moreover, breeding is a viable option to make real progress towards carbon neutrality with a very high rate of return on investment and a very modest cost per tonne of CO2 equivalents saved regardless of the accounting method. Other high technologies include the use of cloned livestock animals and the manipulation of traits by controlling target genes with improved productivity.

Keywords: breeding, GHG, animals, cloned, technology, carbon neutral

1. Introduction

A serious, systemic problem that affects us now, not in the future, is climate change [1]. C-neutral farming collaborates with farmers and agri-food companies to develop a technological solution that lessens the impact on the environment. All industries, including agriculture, must significantly reduce their emissions if we are to reach net-zero emissions. Achieving net-zero emissions will have an impact on productivity, the environment, and land use, though the precise effects on the livestock industry are unknown. To achieve carbon neutrality, it is necessary to change dietary habits, increase the value of food and agricultural waste, switch from fossil fuels to renewable energy, develop low-carbon technologies and low-carbon agriculture, build resilient cities and buildings, implement decentralized energy systems, and electrify the transportation industry [2]. To enable SHF to realize its climate-resilient dairy development strategies, interventions at various points along the dairy value chain are required [3]. The importance of raising the carbon peak, pursuing a strategy that is carbon-neutral, and supporting the long-term development of animal husbandry [4].

The idea of modifying an animal to make it more environmentally friendly raises questions about its wider sustainability and ethical implications, even though there are still significant gaps in the evidence proving the effectiveness of the solutions being advanced.

Perhaps the most significant result of relying on climate engineering to provide low-cost and straightforward ways to control our climate is the failure to critically examine, much less address, the constantly increasing demand, production, and food waste. The already shaky political will for other important and radical climate change responses may also be weakened as a result. I illustrate my point by making a comparison between the extensive measures taken to change a cow's regular behaviour and the major efforts made to meaningfully challenge the regular actions, consumption patterns, and dietary choices of the public [5].

The continued increase in global population, the unequal distribution of wealth, and the rising demand for socially and nutritionally sustainable livestock products will shape the future of livestock. Other uses of land and water are predicted to compete fiercely, making more socially acceptable, efficient, and sustainable livestock production necessary. Climate change, environmental mitigation, and animal adaptation are recent issues in the field of animal breeding that have new demands on breeding procedures and research [6]. However, putting a negative economic value on methane would encourage action and help to reach the reduction goal in fewer generations. Therefore, it seems that including methane in the breeding objective will aid dairy cattle in more quickly reducing their methane emissions [7].

2. Efficient and robust animals

Sustainability in animal breeding is defined as the on-going availability of breeding animals and their germinal products for commercial production, which now and in the future meet the needs of a wide range of stakeholders, including breeders, farmers, livestock keepers, producers, consumers, and others while promoting more animal welfare-conscious agriculture. The implementation of international agreements encourages the development of sustainable breeding and production policies for animals. Long-term policy perspectives are necessary for animal breeding and livestock development strategies because poor choices can have negative long-term consequences [8].

The management and breeding of dairy cattle for a reduced impact on the environment are the two most significant applications of CH4 proxies. Single or multiple proxies can be used as indirect criteria for the breeding objective when selecting traits with lower environmental impact, but care must be taken to prevent unfavourable correlated responses.

Finally, even though combinations of proxies seem to offer the most accurate estimates of CH4, their current greatest drawback is the fragility of their general applicability. Therefore, future work should focus on creating proxy combinations that are reliable and usable in a variety of production systems and environments [9].

Additionally, genetically modified animals have significant positive effects on human health and the environment because they are more effective at turning feed into animal protein and produce less waste. In vitro methods for studying genes and their regulation, various methods for gene therapy, and the development of novel strains of existing microorganisms for use in medicine or industry all fall under the umbrella of genetic engineering. There are an increasing number of useful applications for genetic engineering in animal production, including the creation of transgenic animals that are disease-resistant, raising animal productivity, treating genetic disorders, and creating vaccines [10]. This entails creating novel heritable genetic material combinations using recombinant nucleic acid (DNA or RNA) techniques and then incorporating that material either directly through micro-injection, macro-injection, or micro-encapsulation techniques or indirectly through a vector system [11].

Animals that are consistently able to increase their output per unit of input because they are less susceptible to diseases and changes in their environment and management are the focus of breeding and reproduction organizations. Farmers can now request that breeding organizations label their products based on their use of resources, susceptibility to disease or stress, and climate adaptability. In Europe, there are voluntary codes of good practice for breeding organizations. The advantages are long-lasting and accumulate over time: genetic advancement currently accounts for 0.5–1% of an increase in animal productivity annually. Targeted breeding programs can help to increase this even more, but the context and farming system will determine the suitability of particular breeds, their ability to mitigate risks, and any trade-offs with other breeding goals. Emerging issues in the field of animal breeding include climate change, environmental mitigation, and animal adaptation, which place new demands on breeding practices and research [6]. Regardless of the accounting method, breeding, despite its slowness, is a realistic option for moving closer to carbon neutrality because it offers a very high rate of return on investment and a very low cost per tonne of CO2 equivalents saved [12]. Agricultural areas produce the most carbon emissions from animal husbandry, followed by agro-pastoral areas (which are on the decline) and pastoral (with a rising trend) [13].

Breeding objectives are set to support sustainability's many facets, including quality, diversity, acceptability, the environment, and economics (Elzbieta [8]) states that the implementation of international agreements aids in the development of policies for sustainable animal breeding and production. Better health, reproduction, feed efficiency, heat stress, and other adaptation traits are likely to be prioritized over higher production in countries where cattle production has already been intensified. This could necessitate the use of cutting-edge phenotyping technologies as well as additional new big data techniques to extract data for breeding [14].

Precision animal breeding will be made possible by incorporating thorough mechanistic models of animal performance in a given environment into genetic evaluation techniques that allow the prediction of genetic merit for underlying biological traits [15]. The idea of telos, which was previously primarily discussed in discussions about traditional genetic engineering, has been applied to genome editing and genomic selection to enhance animal welfare. It contests prevalent understandings of telos and offers a substitute theory that can be applied to recently developed breeding technology applications. This account rejects both removing the desire to pursue characteristic activities and altering animal bodies in ways that compromise their ability to perform such activities, while conditionally allowing increasing robustness against environmental stress [16]. The identification of genes and genetic markers suggests that it is possible to design strategies for breeding cows with the desired microbiota composition associated with phenotypes [17]. Wheat inclusion in the dairy cow diet could be an effective strategy for significantly lowering methane emissions; it also reduced milk fat percentage and milk fat and energy-corrected milk production [18].

3. Improved performance on low-quality feed

A significant portion of the global GHG emissions related to livestock production is caused by the production and feeding of animal feed. Though current research identifies traits for selecting animals that show excellent performance on lower-quality feed, most animals perform better on high-quality feed. Once they have been located, breeding organizations can choose these animals for their breeding and reproduction programs and sell them. Monogastric animals that thrive on subpar feed should be commercially available in five years. This should take 8–10 years for cattle.

This development benefits both extensive systems that depend on lower-quality feed and the intensive livestock industry by allowing adjustments to current feeding regimens. Enhancing efficiency is one of the best ways to lower emissions from the production of beef. “Improved efficiency” can refer to better feed utilization, less need to clear more land, and fewer emissions of greenhouse gases per kilogram of beef produced. Researchers are working on techniques to breed animals for lower emissions after discovering that enteric methane intensity is a genetic trait. These technologies are still being developed, though [19].

When nitrates and vegetable oils were added to the diet, they both reduced enteric CH4 yield by 6-20%. Under smallholder conditions, cattle can be fed condensed tannins, saponin, and starch found in the leaves, pods, and seeds of tropical trees and shrubs, along with nitrates and vegetable oils. Strategies for enteric CH4 mitigation in cattle grazing poor-quality tropical forages can successfully boost productivity while lowering enteric CH4 emissions overall and per unit of product (such as meat or milk), thereby lowering the contribution of ruminants to GHG emissions and consequently to climate change [20]. In high-yielding dairy cows fed a partial mixed ration based on maize silage without access to pasture, the longer rumination time is associated with lower methane emissions as well as lower methane production per milk unit [21].

4. Selecting for low-methane producing ruminants

In milk production systems, enteric methane is a significant source of greenhouse gas emissions [22]. An additional cost-effective, long-lasting, and cumulative mitigation strategy involves breeding animals that take advantage of the natural variation in CH4 emissions. Selective breeding can reduce CH4 intensity by 24% in 2050 if the Dutch breeding goal is expanded to include CH4 production. This demonstrates that breeding is a valuable addition to the full range of mitigation tactics that could be used to meet the objectives for 2050 set by the EU. If it is determined that using animal breeding techniques will reduce enteric CH4 production while also having the desired effect on breeding [23]. Another effective, long-lasting, and cumulative mitigation strategy is animal breeding, which takes advantage of natural variations in CH4 emissions [23].

When the cost of feed in the breeding objective is high, multiple-trait selection can reduce overall GHG emissions while improving the economic performance of beef cattle at a low carbon price. Both the overall and per-unit GHG emissions of the product were decreased. Any plan to lower beef cattle's GHG emissions must include selection. When the cost of feed is low, selecting beef cattle without considering the cost of emissions will significantly increase GHG emissions [24]. Breeding makes a significant contribution to the overall arsenal of mitigation tactics that could be used to meet the EU's goals for 2050. If animal breeding techniques are chosen to reduce enteric CH4 production and have the desired effect on breeding [23]. A potential strategy to lessen the contribution of the dairy industry is the genetic selection of low-CH4-emitting cows [25].

Genetics can also influence the parameters that determine herd structure, such as cow replacement rates or calf death rates. The herd structure or the relative proportions of each animal type within the herd, influences the overall amount of emissions and meat or milk produced [26]. Recent research suggests that genetically improving cattle can significantly reduce emissions at a negative cost, i.e., while providing net financial benefits. The use of concentrates may have to be increased as a result of improved genetics, which would reduce the use of fiber. As a result, it is clear that traits related to the feed efficiency of the bird are the key determinants of changes in EI and how they can be influenced by animal breeding. Broiler birds' daily feed intake has increased as a result of breeding, in order to support their faster growth. The ability to increase growth rate and daily feed intake influences the future potential of breeding to reduce GHG emissions associated with broiler production. By switching to slower-growing birds, feed efficiency will inevitably decrease, increasing GHG emissions and nutrient excretion. Over the years, breeding has significantly increased potential productivity (the number of eggs per hen per year), improved feed efficiency, and lowered the intensity of GHG emissions. Further emissions reductions through breeding, however, are probably going to be less than 10% below the current level as productivity is getting close to its biological limits [26].

To increase our understanding of the taxonomic and functional profiles of microbes connected to this rare and endangered pig breed, we studied the faecal microbiome of a local pig breed [27]. The industry's importance is evidenced by the rise in investment in genomic technologies in Canada, which aim to increase feed efficiency and cut greenhouse gas emissions [28]. The most optimistic predictions for advancements in genomic technologies have been exceeded, allowing for the industrial application of genomic selection. There are already a wide variety of analytical tools available, and many more will be created thanks to advancements in sensor technology and artificial intelligence. Possibly the biggest revolution will be the explicit inclusion of high-dimensional phenomics in animal breeding methods. Phenomics data will undoubtedly improve our understanding of the biological principles underlying phenotypes in the interim [29].

Although breeding is an effective strategy for reducing methane yield, traits like wool, live weight, and fat deposition may be impacted over time and should be watched closely [30]. Genetic selection for residual feed intake is an indirect method for reducing enteric methane (CH4) emissions in beef and dairy cattle (RFI). If enteric CH4 production is measured directly, it should be expressed as residual CH4 production or as CH4 production (g/animal per day) after accounting for body size, growth, body composition, and dry matter intake (DMI). Additionally, RFIfat cattle may benefit from a 1% to 2% increase in dry matter and CP digestibility compared to +RFIfat cattle due to lower DMI, shorter feeding intervals, improved rumen fermentation, and a different rumen bacterial profile. The rate of genetic change using this method is expected to boost feed efficiency and reduce enteric CH4 emissions from cattle by 0.75–1.0% per year with equal levels of body size, growth, and excess weight when compared to cattle not selected for RFIfat [31]. To lessen the impact of dairy cattle products on the environment, phenotypes must be chosen for emitting animals. This includes a direct selection for breath measurements, in addition to indirect selection using traits such as feed intake, milk spectral data, and rumen microbial communities. Even with a few registrations, it is still possible to include methane emission as a breeding goal trait with genomic selection. Many of these characteristics are either expensive or difficult to record. If methane emission reduction became a reality, there would be little disagreement about which phenotype to choose: methane in grams or liters per day, methane in liters per kilogram of energy-corrected milk or dry matter intake, or a residual methane phenotype, where methane production is adjusted for milk production and cow weight [32]. Rumen microbial biomarkers have been linked to methane production in dairy cows; if heritable, these biomarkers could be used for targeted methane-reduction selection programs in the dairy cattle industry [33]. It is also discussed how the systems biology approach can be used to integrate and assess various levels of biological data, which can help with understanding the genetic underpinnings and biology of traits that cause ruminants to produce CH4 and reduce agriculture's overall environmental impact [34]. In particular, the order Veillonellales and the phylum Proteobacteria were found to be enriched in low emitters, while the order Desulfovibrionales and the order Proteobacteria were found to be enriched in high emitters [35]. Consequently, it is possible to target the rumen microbiome and cow genome separately by breeding low-methane-emitting cows and concurrently by looking into potential methods that target changes in the rumen microbiome to reduce CH4 emissions in the cattle industry [36].

As predicted for Australian macro pods, lower emissions were accompanied by increased Succinovibrionaceae abundance, changes in acetate and hydrogen production, and decreased methanogens. Numerous predicted protein sequences were different between cattle that emit more and less methane [35]. Propionate pathway enhancement in high-quality forage diets serves as a hydrogen sink for methanogens. In the propionate pathway, which is enhanced by high-quality forage-based diets, betaproteobacteria genes were found to be present, suggesting a syntrophic relationship may be at play to lower methane emissions in beef cattle [37]. The distinct group of rumen methanogens whose transcriptional profiles along the ethnogenesis pathway correlate with methane yields and offer fresh options for reducing CH4 at the levels of microbiota composition and transcriptional control [38]. Metagenomics has recently been the main technology used to describe the GI microbiome and its connection to host nutrition and health [39]. As predicted for Australian macropods, lower emissions were accompanied by increased Succinovibrionaceae abundance, changes in acetate and hydrogen production, and decreased methanogenesis. Between high and low methane-emitting cattle, there were differences in a significant number of predicted protein sequences. Ninety-nine percent were unidentified, indicating a promising future resource [35].

A thorough and high-quality protein sequence database that enables accurate protein identification and quantification, representative samples, precise protein extraction, and fractionation are all essential for conducting meaningful and accurate metaproteomic analyses [40]. These findings demonstrate that using conventional PETs improved animal performance while reducing the environmental impact of the feedlot cattle industry. As a result, eliminating them would result in an increase in the environmental impact of beef produced for both domestic and foreign markets [41].

A sophisticated technique called transgenesis allows for targeted gene modification and has the potential to boost genetic diversity by producing animals with improved productivity, reduced environmental impact, and disease resistance. The ability to alter a single gene is becoming more feasible as more data from genomic sequencing projects becomes available. A tool to address new issues and global challenges facing production agriculture could be the use of transgenic technologies in the production of farm animals. However, proponents of biotechnology tools like cloning and transgenesis will probably encounter resistance from the public at large, which does not understand or accept these reproductive methods for producing animals [42]. Although cloning is a potent tool for creating genetically identical copies of desired donor animals, its effectiveness is still debatable. For a variety of reasons, many scientists and regular people are against cloning. Due to the high failure rate of cloned animal growth from fetus to adulthood, it has been deemed an ineffective technique up until this point [43]. In this instance, selective breeding was successful in reducing methane production by 20% over the course of ten years, but at the cost of increasing the ad hoc weight of methane in the selection index to 33% and slowing the genetic gain for production traits from 6 to 18%. This demonstrates the feasibility of incorporating environmental characteristics into the selection indices while maintaining populations that are profitable for producers [44].

In contrast to selection based on measured CH4 using respiration chambers (13%), which was used in our population, selection based on the abundances of the 30 most informative microbial genes offered a mitigation potential of 17% of mean CH4 emissions per generation. This shows the great potential of microbiome-driven breeding to reduce CH4 emissions over time and slow down climate change. Marker-assisted and genomic selection could be used to improve phenotypes like PME that are challenging and expensive to measure. Additionally, the ability of VFA indicators to predict methane emissions may help to increase the size of the reference population needed for genomic selection and genome-wide association studies [45].

If they are heritable, the rumen microbial biomarkers linked to dairy cows' methane production could be used for targeted methane-reduction selection programs in the dairy cattle industry [33]. Wide phenotypic variation and a lack of accurate methane measurements at the individual level are the main obstacles to the implementation of reduced methane emission traits in breeding programs. CH4 production trait heritability is generally moderate, and breeding programs can use it to target changes in microbial composition to decrease CH4 emission in the dairy industry for long-term environmental benefits at the expense of a minimal genetic gain reduction in production traits [46]. The current meta-analysis demonstrated that dairy cow's exhibit additive genetic variation for methane emission traits that could be used in genetic selection strategies [47]. The intensity of CH4 would be drastically reduced to about 0.2 kg CH4/kg LW gain, as observed in some intensive feeding systems, by optimizing the LW gain of grazing sheep and cattle to thresholds of 0.14 and 0.7 kg/day, respectively. This might indicate a 55% mitigation potential for livestock products in pasture-based systems. Our findings add fresh information to the discussion about reducing the negative environmental effects of pastoral ecosystems [48].

Nitrates, essential oils, and tannins are rumen environment modifiers that influence methanogens and reduce the availability of fermentation products required for CH4 formation. Breeding interventions may also be used to directly or indirectly select low-CH4-emitting animals, and genome-wide association studies are predicted to help with this process. Overall, dietary changes and the addition of feed additives have short-term, reversible effects, whereas selective breeding results in long-term, cumulative reductions in CH4 emissions [49]. The rumen microbiome of cows likely has no genetic influence on the variation in CH4 emission. As a result, breeding low-methane emitting cows while simultaneously researching potential strategies that target changes in the rumen microbiome to reduce CH4 emissions in the cattle industry allows for separate targeting of the rumen microbiome and cow genome [36].

Wide phenotypic variation and a lack of accurate methane measurements at the individual level are the main obstacles to the implementation of reduced methane emission traits in breeding programs. CH4 production trait heritability is generally moderate, and breeding programs can use it to target changes in microbial composition to decrease CH4 emission in the dairy industry for long-term environmental benefits at the expense of a minimal genetic gain reduction in production traits [46]. Since residual methane and feed intake have a moderate correlation and a positive correlation response, including residual feed intake in the breeding goal could further reduce methane. A significant reduction in methane emissions could be achieved while maintaining an increase in milk production by adding a negative economic value for methane [50].

Future breeding goals should take into account how both traits differ along with (and across) lactation(s) and how they correlate with various production, maintenance, and intake traits [51]. Dairy cows that were given concentrates while grazing produced more milk overall and produced less CH4 per unit of milk [52]. In this instance, selective breeding was successful in reducing methane production by 20% over the course of ten years, but at the cost of increasing the ad hoc weight of methane in the selection index to 33% and slowing the genetic gain for production traits from 6% to 18%. This study demonstrates the feasibility of incorporating environmental characteristics into selection indices while maintaining populations that are profitable for producers [44]. The current meta-analysis demonstrated that dairy cattle exhibit additive genetic variation for methane production traits that could be used in genetic selection strategies [47].

Feed is an important factor in breeding goals because it makes up a significant portion of the variable costs linked to dairy systems. As a result, traits that indicate feed efficiency are increasingly in demand for genetic analysis. Many countries already have an idea of how much energy is required for milk production, maintenance, and so on, their breeding goals are to take feed efficiency into account. Currently, it is not possible to take actual feed intake variation into account when determining traits like residual feed intake (RFI), which is the difference between actual and predicted feed (or energy) intake. Given the high cost of accurately measuring feed intake in numerous cows, phenotypes derived from it are obvious candidates for genomic selection, provided that the trait is heritable and the accuracy of genomic predictions is acceptable to those using the breeding values. If breeding values are estimated for heifers rather than cows, the traits of the heifer and cow must be correlated. According to research on beef and dairy cattle, genomic predictions of dry matter intake (DMI) and RFI have an accuracy of about 0.4. There are ways to improve prediction accuracy; for instance, it has been demonstrated that combining data from three research herds (in Australia and Europe) can raise DMI genomic prediction accuracy from 0.33 within the country to 0.35 using a three-country reference population. Genetic correlations with other traits must first be estimated before RFI is included as a selection objective. Because of the mathematical relationship between RFI and energy balance calculation, failure to properly account for the mobilization of body reserves may result in the selection of a trait that is similar to the selection for a reduced energy balance.

Therefore, if RFI is to become a selection objective, it should be incorporated into a multi-trait selection index with net profit as the breeding objective, as this would allow genetic correlations with other traits to be properly taken into account. RFI is an obvious breeding goal if genetic parameters are accurately predicted. In the event that these are uncertain, DMI may be preferred [53].

Reduced CH4 emissions from ruminants may be achieved through the adoption of genetic selection and, in the future, genomic selection. Short-term (a few minutes to several hours) and long-term (days) feed intake is closely related to CH4 emissions. Even though there is less genetic variation than there is for CH4 emissions, CH4 yield (MY, g CH4 per kg dry matter intake) is a heritable and repeatable trait when measured over the medium term. Individual animal CH4 emissions are only moderately repeatable across diets and feeding levels when measured in respiration chambers. Short-term measurements have lower repeatability, possibly as a result of changes in the amount of feed consumed before the measurement and variations in time.

Even though repeated measurements are beneficial, it is best if they are taken at least three to fourteen days apart. But in order for short-term measurements to be helpful for genetic evaluation, we believe that a number (between 3 and 20) of measurements taken over a long period of time will be necessary (weeks to months). There are opportunities to use short-term measurements to measure CH4 in standardized feeding situations, such as breath "sniffer" devices attached to milking parlors or total mixed ration feeding bins [54].

The potential to reduce national livestock emissions by implementing these dietary interventions could be estimated using the confidence intervals derived for the mitigation efficacy [55]. The potential to reduce national livestock emissions by implementing these dietary interventions could be estimated using the confidence intervals derived for the mitigation efficacious [56].

When nitrates and vegetable oils were added to the diet, they both reduced enteric CH4 yield by 6–20%. Condensed tannins, saponins, and starch found in the leaves, pods, and seeds of tropical trees and shrubs can be fed to cattle under smallholder conditions, along with nitrates and vegetable oils. Strategies for enteric CH4 mitigation in cattle grazing low-quality tropical forages can successfully increase productivity while reducing enteric CH4 emissions overall and per unit of product (such as meat or milk), thereby lowering the contribution of ruminants to GHG emissions and subsequently to climate change [20].

Consuming milk products from cows fed nitrate may be safe in terms of residual nitrate and nitrite levels and the linseed plus nitrate combination may have a long-term CH4-mitigating effect on dairy cows. To prevent decreased cow performance, more work needs to be done to optimize the linseed and nitrate doses [57]. Diets had little effect on protozoa concentration or rumen fermentation parameters. Tea saponin is ineffective in this experiment's conditions at lowering dairy cows' methane emissions [58].

Ruminant feeding of whole-plant oat forage may reduce CH4 emissions, but lower biodegradability may also hurt animal performance. In contrast, feeding barley forage may reduce emissions without hurting animal performance [59]. Rumen fermentation profiles and enteric CH4 emissions per unit of ECM, GEI, and ADG demonstrate excellent potential for enteric CH4 emissions estimation [60]. By decreasing methane emissions by 40% + and 90%, respectively, the supplements 3-nitrooxypropanol and the seaweed Asparagopsis increased animal productivity with negligible effects on animal health or product quality. Methane emissions were reduced by 10% or less using biochar, nitrate, grape marc, vaccination, genetic selection, or vaccination. Cattle browsing legumes, such as Desmanthus or Leucaena species, and best management practices increase animal productivity and mitigate methane to a small extent. Large daily doses of ground wheat fed to dairy cows reduced methane emissions by about 35%, but the reduction was not long-lasting [61].

The gas emitted by ruminants that has the biggest negative impact on the environment is methane from enteric fermentation. It may be possible to reduce rumen methane emissions by adding lovastatin (Lv) to feedstocks, which would reduce the number of methanogenic archaea (MA). However, in vivo tests showed that there was a decline in VFA production. During in vitro and in vivo tests, Lv had no detrimental effects on the digestibility of dry matter; in fact, there is evidence that it may even increase digestibility [62].

Although their long-term impact has not been well established, some feed supplements have had the potential to lower ruminant CH4 emissions, even though some of them are toxic or may not be practical from an economic standpoint [63]. A potential feed ingredient for reducing goats' enteric methane emissions is red yeast rice. However, it needs to be used carefully because it might stop some nutrients from being digested [64].

A potential feed ingredient for reducing goats' enteric methane emissions is red yeast rice. However, it must be used with caution as it may prevent some nutrients from being digested [65]. With low feed inclusion, Asparagopsis retains its significant methane-mitigating potential in a commercial feedlot setting [66]. Tea saponin alone, when added to pelleted concentrates, had no effect on reducing enteric methane emissions in non-lactating dairy cows under experimental conditions [67].

5. Finding new traits for GHG emissions

The potential for breeding and selection programs to choose for lower-emitting animals increases with any variation in emissions among individual animals; these are already being studied. The makeup of the microbial ecosystems in the animal's stomach and the structure of the stomach serves as the foundation for additional factors affecting the animal's emissions. For instance, early-life feeding practices may have a lasting impact on the rumen microbial composition and, consequently, methane emissions throughout an animal's productive life. Currently, research is being done on the possibility of altering the rumen microbial composition in lambs and calves after weaning to reduce methane production in adulthood. Genome editing will help us achieve these goals only if global regulatory and policy frameworks allow their use in agricultural breeding programs and deployment to farms. The regulatory environment for genome editing products is rapidly changing on a global scale, with an increasing number of nations putting more emphasis on product qualities and whether they could be achieved through conventional breeding than on the technologies involved in their creation [68].

One of the tasks assigned to the committee was to produce a report evaluating methods for identifying potential unintended compositional changes in the range of messenger ribonucleic acid (mRNA), proteins, metabolites, and nutrients that may occur in food derived from cloned animals that have not had their genes altered through the use of genetic engineering techniques. The committee was also tasked with researching ways to spot the unintended negative health effects of foods made from cloned animals [69].

The direct selection of a residual methane production trait would favorably influence all other methane traits. The large standard errors emphasize the need to increase data sets by assessing the methane emissions and DMI of more animals or by investigating proxy traits and combining data through international cooperation [70].

According to this meta-analysis, sheep have low to moderate genetic control over their gas emission traits. When accurate phenotypic records or genetic parameter estimates for traits related to gas emissions are unavailable, the average genetic parameter estimates that were obtained could be taken into account in genetic selection programs for sheep [47].

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