SUSTAINABLE LIVESTOCK PRODUCTION: PROSPECTS FOR INNOVATION

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RESEARCH AND DEVELOPMENT OPPORTUNITIES IN SUSTAINABLE LIVESTOCK PRODUCTION

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ABSTRACT

Livestock is an integral component of the agricultural economy around the world. There are diverse livestock production systems such as free-range pastoral systems, high-input intensive farming, and crop-livestock mixed farming. In addition to providing high-quality animal protein in the human diet, livestock also contributes to various ecosystem services such as enhancing grassland biodiversity and soil fertility. However, livestock production also contributes to environmental change, for example, the emission of methane from livestock leads to global warming. The sustainability of the livestock system is defined in two ways, one as resource sufficiency and the other as functional integrity. In resource-sufficient systems, the resources are produced and depleted at a sustainable rate and account for conservation, regeneration and substitution for sparingly available resources. In the functional integrity approach, there is a significant thrust on reproducing crucial elements such as soil fertility and biodiversity. A transformation from the current marginal production system to a more commercial production system is recommended as a sustainable way of livestock production. To achieve this goal, various research development opportunities are also suggested.

INTRODUCTION

Sustainable livestock is essential for both protecting existing ecosystems and developing better farming practices that care for natural resources. Research and development (R&D) are integral elements of this drive to create a sustainable livestock sector. This review will discuss the importance of R&D in creating a sustainable livestock sector in the future (Twine, 2021; Dumont et al., 2019).

One important form of R&D that could shape the development of a sustainable livestock sector is the use of genomics (Eisler et al., 2014). Genomics research is dedicated to understanding how genetics influence the biology and health of animals, allowing the development of new breeds and improved genetic lines. This in turn can result in more efficient livestock production, with animals that can better withstand disease and climate change, as well as consume fewer resources. Additionally, genomics could lead to improved animal welfare, by giving scientists a better understanding of animal responses to stress and other stimuli.

Environmental sustainability is also an important focus for research and development in sustainable livestock, especially as global agricultural systems are linked to climate change (Van Zanten et al., 2018). To this end, researchers have developed techniques to reduce agricultural greenhouse gas emissions and control nutrient pollution caused by animal production. These techniques range from modifications to the animal environment like improved barn designs to alterations in the feed that is provided. Research into such innovations shows promise for the development of a more sustainable livestock sector.

Research and development and the resulting technological advances can help to create a more equitable animal production system that takes into account the rights of farmers, consumers, and local communities (Leinonen, 2019). For example, innovations in gene editing technology and other forms of biotechnology can be used to develop breeds of livestock that are more adapted to local climates and that are more resistant to certain diseases. This could benefit smaller-scale livestock farmers, allowing them to produce better yields while decreasing the environmental burden of large-scale farms. Additionally, research can help to ensure that small-scale farmers have access to the materials and services needed for efficient livestock production as well as access to the benefits of R&D outputs.

RECENT INNOVATIONS IN THE LIVESTOCK SECTOR

Livestock production has been a key component in global food production for centuries, but it has come with unsustainable practices that are causing rapid environmental degradation and reduced sustainability (Liu et al., 2021). As a response to this challenge, researchers and government officials have been exploring recent innovations in sustainable livestock production in order to preserve the environment and maintain an efficient food production system.

One of the most promising practices in sustainable livestock production is the integration of technology (Tilman and Clark, 2014). Advances in cameras, sensors, networking, and farm management software have allowed farmers to manage their animals and make informed decisions. With technology, farmers can monitor water use and the quality of animal products, allowing them to make efficient use of the resources at their disposal. They can also track animal health, providing early warning of potential health problems that can be mitigated before issues arise.

Additionally, sustainable livestock production utilises renewable energy sources to power the farm and reduce reliance on polluting fuel sources such as fossil fuels (Twine, 2021). This reduces the carbon emissions created during livestock production and helps farmers create a sustainable agricultural system. Some farms are now utilizing solar power, wind turbines, and biogas digesters to power their operations. Through these practices, livestock farmers can benefit from renewable energy sources and save on operational costs.

An additional innovation is the increased use of precision agriculture techniques in livestock production. Through this technique, farmers are able to monitor soil fertility and make informed decisions regarding local fertilizer input. This promotes sustainable farming practices and helps maintain soil health, allowing farmers to better manage their animals and produce a more sustainable product.

Finally, researchers have developed genetically modified crops that provide more nutritious fodder for livestock. These crops are modified to increase proteins and amino acids in the feed and optimize the animal's growth and health. These crops also provide environmental benefits, such as improved soil fertility and increased water retention, helping farmers maintain their farms sustainably.

In conclusion, recent innovations in sustainable livestock production are enabling farmers to more effectively and sustainably produce food. These advances in technology, renewable energy, precision agriculture, and livestock feed are helping farmers create a farming system that is not only efficient but maintains optimal animal health and preserves the environment.

HOW THE FUTURE LIVESTOCK FARM WILL LOOK LIKE?

The future of livestock farming is one that involves new and revolutionary technologies in the care and rearing of cows, pigs, and chickens, as well as any other forms of livestock (Seshadri et al., 2018). These technologies are designed to reduce the impact of current farming practices on the environment, while still making them more productive and efficient (Obersteiner et al., 2016).

First and foremost, the use of renewable resources such as solar and wind energy will reduce the environmental impact of livestock farming considerably. For instance, solar-powered barns and litter, which are designed to provide sufficient light and heat for animals, will allow farms to reduce emissions and save on their electricity bill. Furthermore, certain renewable energy sources can also be used to provide hot water for bathing, which can improve animal welfare.

In addition, the use of precision farming methods is expected to be increasingly adopted in future livestock farms. This technology enables farmers to create nutrient-rich diets for their animals and make more informed decisions regarding when and what to harvest. It has been suggested that this technologically-driven approach can reduce feed wastage by up to 40 per cent, which can help reduce the cost of production.

The use of artificial intelligence (AI) technology is also predicted to be a major factor in the future of livestock farming. With AI-based software and robotic platforms, farmers can monitor a herd's health and behaviour remotely. This will allow them to detect even the slightest health concerns, prompting the farm to take swift action. AI can even be used to identify economical methods of providing food to livestock, such as the use of automated feeders.

Robotics is also expected to revolutionize the way livestock farms are managed. For example, autonomous grazing machines can be used to move animals from one area to another with ease. Furthermore, robots can be employed to clean and maintain barns, as well as for sorting and package meat for distribution. The development of these technologies is expected to not only improve livestock welfare but also reduce labour costs significantly.

Finally, the use of sophisticated tracking systems is also set to transform livestock farming. These systems can be used to maintain detailed records regarding animal moods and sleeping patterns. Additionally, they can also be used to monitor the animal's growth rate and its response to certain diets and other environmental factors.

The future of livestock farming is indeed an exciting one, bringing with it several exciting technological advances. These advances are expected to not only improve the quality of the animals produced but also reduce the environmental impact associated with livestock farming, leading to a much more sustainable industry.

Overall, research and development are necessary in creating a sustainable livestock sector and achieving long-term goals of environmental and economic stability. From genetic innovation to the improvement of environmental practices to the strengthening of equity and access, R&D is a crucial component of this journey. As our societies strive towards providing a healthier and more sustainable future, research and development will be key in ensuring the success of this endeavour.

CONCLUSION

The increasing human population and rising demand for animal products push the livestock production systems more towards high-input intensive production. The sustainability of the livestock system is defined both in terms of resource availability and increasing the fragility of the production. In both these scenarios, research and development have been considered more pressing now to meet the rising demands of the future.

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MOLECULAR APPROACHES TOWARDS SUSTAINABLE LIVESTOCK

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INTRODUCTION

The role of livestock is diversified in most developing countries like India. The various contributions of livestock in such countries include:

- Provision of livelihoods for rural poor
- Food security (meat, milk, eggs)
- Nutritional security (animal source - quality protein and micronutrients)
- Savings and insurance
- Livelihood diversification through integrated/mixed crop farming allows risk reduction
- Inputs to crop production (draft power, manure, fertilizer)
- Transportation
- Uses of hides and skin are varied and sometimes even for housing!
- Fulfilling social obligations during special ceremonies or when gifted as dowry
- Employment and income to other value chains input providers, traders, processors, retailers etc in the animal husbandry sector.
- Benefits to households from the use of common property resources like communal grazing areas

In this context, increasing the productivity of livestock becomes the key goal of any developing economy. Due to increased urbanization, population rise and income growth, the demand for animal-source proteins is also high. Hence, there is a need to attain sustainability by way of increasing productivity in terms of more output per unit of input in animal production.

Several thrust areas have been identified to work towards increasing the productivity of livestock. The most prominent areas are animal health, animal feeding and animal genetic improvement. Several practical interventions have also been undertaken in these directions to move towards the goal of enhanced animal productivity. These include capacity-building of livestock keepers as well as the livestock value chain actors, new technologies or customization of existing technologies and many supportive policies from governmental and non-governmental agencies.

The conventional approaches in animal genetics have to some extent become successful in bringing about genetic improvement in livestock. Breed substitution programmes using elite exotic cattle breeds (Holstein Friesian, Jersey) and Indian breeds of buffaloes (Murrah), several crossbreeding programmes between highly adapted low producers and lowly adapted high producers and many other within-breed improvement strategies (selective breeding) for indigenous breeds were adopted. The use of reproductive technologies like Artificial Insemination, sexed semen, cryopreservation, embryo sexing, and MOET (Multiple Ovulation and Embryo Transfer) have also contributed immensely to the goal of genetic improvement and enhanced productivity of livestock in our country.

However, many shortfalls have been identified with such conventional approaches adopted in animal genetics and breeding for enhanced livestock productivity. Three major areas of lacunae identified are:

- Insufficient parentage/pedigree / ancestral data on the animals
- Lack of effective recording of *in situ/field* performance data of animals
- Prevalence of unstructured crossbreeding in livestock populations

These factors ultimately lead to a lack of information on the individual animals of a population concerning the following aspects:

- Breed composition/breed type of individual animals
- Purity of the breed
- Breed proportion (level of admixture)
- Relationship among animals within a herd
- Milk quantity as well as milk quality
- The herd size and management level
- The household profit
- Green House Gas (GHG) emission intensity

In a nutshell, under the conventional approaches adopted for genetic improvement and livestock productivity, a realistic picture of the smallholder production environment concerning individual productivity will be lacking. The details on the individual productivity of livestock will be largely insufficient.

MOLECULAR TECHNOLOGIES FOR SUSTAINABLE PRODUCTIVITY: THE OMICS

Molecular technologies in animal genetics have provided viable and workable solutions to overcome the constraints in conventional breeding approaches. These technologies find application in issues ranging from the determination of breed composition of animals in the absence of pedigree data to their direct application in breed improvement programmes. The basic omic technologies are genomics, transcriptomics, proteomics and metabolomics. The high throughput technologies involved in OMICS study the entirety of bio-molecules and their interactions on various levels of biological organization. They go from the level of DNA (genomics) to its accessibility for transcription (epigenomics) to the abundance of gene transcripts (transcriptomics) to the abundance of proteins (proteomics) to the abundance of metabolites (metabolomics) and to characterizing populations eg: microbial communities in the gut (metagenomics).

GENOMICS

Genomics deals with the identification of entire genes or SNPs which are associated with traits of interest *via* genotyping methods or by sequencing the entire genome in Genome-Wide Association Studies (GWAS). Genomics helps the analysis of genetic diversity, genetic evaluation, the discovery of selection signatures and gene discovery through immediate tools like genome sequencing assemblies, associated annotations and the commercially available SNP genotyping assays.

Genomic information can be used to:

- Identify the most appropriate breed or crossbreed type (breed composition) for different livestock production systems
- Enable or enhance breeding programmes
- Create new breed types
- Discover genetic variants of economic or ecological significance

The lack of pedigree information and unstructured crossbreeding prevalent in the Indian livestock systems make it difficult to assign breed types to individual animals. High Density (HD) SNP assays can be used to genotype animals and generate an estimate of the ancestral breed composition of each animal. Thus SNP data can be used to assign parentage wherever pedigree data is not available. Knowledge of the breed composition of bulls and cows is also obtained which can be utilized further to determine what optimum breed composition of parents is required to produce progeny of a desired breed type. I*n-situ* performance data collected on production, reproduction and disease resistance traits over two years when combined with the genomic data (High-Density SNP) on breed composition can also be used to determine what breed composition works best for different smallholder environments.

Genomic data can also be best used in multi-objective studies involving assessment of breed composition, performance, GHG emission intensity, household profit, management level, herd size etc. rather than tackling isolated genetic issues.

Genomics also helps admixture analysis by estimating breed proportion or the level of admixture in the absence of pedigree recording using Ancestry Informative Markers (AIM) selected from SNP 50K chips.

Genomic data can also enhance genetic improvement programmes by:

- Estimating genetic parameters
- Increasing the accuracy of estimates of relationships among animals
- Characterizing genetic diversity, population structure and evolutionary relationships
- Constructing a genetic relationship matrix among animals for quick generation of estimated breeding value (EBV)
- Estimating genomic breeding values (gEBV) for traits in the population by way of the G-matrix obtained from SNP genotyping data
- Increasing the accuracy of estimated breeding value (EBV)
- Increasing the accuracy of genetic evaluations and breed effects
- Ensuring the purity of breed in pure-bred populations
- Revealing functional variants in the population that can be selected directly
- Allowing rapid expansion of recording to include animals with no previous information, once phenotype and pedigree recording are in place

Genomics and its associated technologies like transgenesis, cloning, and gene/genome editing offer opportunities for creating desirable breed types. The most appropriate breed type is one thought of as both productive as well as adaptive/resilient to stress or diseases. An example of this is trypanosome-resistant cattle like the N'Dama cattle of Africa which possess inherent resistance to trypanosomiasis. The genetic approaches that can be followed for the creation of such new breed types are:

Mapping of QTL (Quantitative Trait Loci) influencing response to Trypanosome challenge

- Identification of TLFs (Trypanosome Lytic Factors) resistant to Trypanosomes as in primates

- Linkage mapping
- Expression analysis
- Candidate gene sequencing
- Population studies
- *In vitro* studies

Another application of genomic data is the discovery of useful genetic variants of economic and ecological significance in the population. These are also known as *improved* animals concerning traits like:

- Prolificacy (sheep and goat)
- Trypano - tolerance (cattle)
- Resistance/tolerance to gastro-nematodes (sheep and goat)
- Thermal stress tolerance (zebu cattle)
- Robust milk yield in harsh conditions
- Heat tolerance/thermoregulation

Genomics also helps to detect the signatures of selection like *slick hair phenotype* for heat tolerance and tropical adaptation in cattle and other traits related to feeding/drinking behaviour, tick resistance, immune response, meat quality, reproductive performance etc. Identification of such genetic variants or QTL or candidate genes for desired traits will be followed by their validation as functional mutations. These can be fed into genetic improvement programmes *via*:

- Breeding programmes using genomic data
- Through the creation of new breeds by way of introgression or genome modification approaches

Genome-Wide Association Studies (GWAS) is an advanced approach in genomics that helps to gain insight into phenotypes wherein the analysis is done for *selection sweeps* that indicate the genomic signatures in the form of loss of polymorphism around selected loci, left by positive selection for certain genes. GWAS helps to identify the genes or genetic regions controlling production, reproduction and adaptability traits in large populations. The genetic regions or QTLs that control massive genetic differences between breeds or genetic groups concerning such traits can be identified through GWAS. Phenotype and genotype recording of a sufficient number of animals is essential for GWAS studies.

Genomics also plays part in characterizing genetic diversity, population structure and relationships including those of evolutionary significance.

The wide range of genomic tools for analysis of genetic diversity, genetic evaluation signatures of selection, GWAS and gene discovery generally rely on the tools of genome sequencing assemblies, associated annotations and commercially available SNP (single nucleotide polymorphism) genotyping assays.

TRANSCRIPTOMICS

The transcriptome is the complete set of coding (mRNAs) and non-coding (small RNAs) encoded by the genome in an individual cell or a population of cells. Transcriptomics is a quantitative science.

Transcriptomic technologies are hybridization-based (DNA microarray) and sequencing-based (RNA Seq) approaches that infer and quantify transcriptome changes. These techniques capture transcription occurring in a sample at a specific time point although the content of transcriptome can change during cell differentiation. In these techniques, a list of “Reads” is assigned to transcripts in the genome. The density of the reads corresponding to each transcript is counted to calculate the expression strength.

Transcriptome studies in farm animals have disclosed potential candidate genes associated with many economic traits like muscle growth, meat quality, lactation reproduction efficiency and response to diseases.

Transcriptomics uncovers the transcriptional and post-transcriptional regulatory mechanisms controlling the expression of genes. Transcriptomics catalogue all species of RNA transcripts and this helps to determine the translational structure of genes in terms of their start sites, 5’ and 3’ ends. It also quantifies the changing expression levels of each transcript during development and under different conditions.

Transcriptome data helps to gain insight into processes like cellular differentiation and biomarker discovery. Transcriptomic data is complementary to proteomic and metabolomic data and hence can be used to predict molecular species like metabolomes.

The applications of transcriptomics are seen in studies related to:

- Genetic changes in carcinogenesis

- Stem cell research
- Embryo selection in IVF
- Cryopreservation of oocytes
- Transcriptome conservation in evolution
- Phylogeny
- Forensic medicine
- eQTL mapping
- Identification of SNPs related to diseases
- Identification of genes and pathways that respond to various stress
- Genome-wide disease-association studies

Limitations of transcriptomics are however many. Roughly 5% of genes are generally transcribed in a particular cell type and it can vary with the stage of cell differentiation and external environmental conditions. Moreover, levels of mRNA are not always directly proportional to the expression level of proteins they code for. The number of protein molecules synthesised using a given mRNA molecule as a template is highly dependent on the translation-initiation features of the mRNA sequence. Also, relatively small changes in mRNA expression can produce large changes in the total amount of the corresponding protein present in the cell.

PROTEOMICS

Proteomics examines the entire set of proteins formed after mRNA translation and subsequent post-translational modifications. It is well suited to screen bio-fluids (blood, urine, saliva etc.) for specific proteins associated with a specific condition or state and to assess stress in farm animals.

METABOLOMICS

Metabolomics is the study of metabolites - lipids, water-soluble and volatile molecules –that are necessary for a protein or enzymatic activity to occur or that are formed because of these reactions. It is informative about the functional state of an organism and therefore close to functional endpoints and phenotypes. Metabolomes are not often species-specific or breed-specific and this suggests their high potential in translational studies.

Proteomics and Metabolomics are future tools as they present a snapshot of proteins and metabolites indicating the physiological and functional state of an individual.

CHOICE OF OMICS TECHNOLOGIES

Each omics technique provides various types of complementary information and has the potential to identify different potential candidate bio-marker molecules. Choice of which omics technique to use depends on the physiological level to be evaluated as well as the purpose of the research. Omics data will consist of gene polymorphisms and quantification of gene transcripts, proteins, metabolites and hormones. A multi-omics integration is many times better to arrive at solutions.

The Discovery and development of heritable biomarkers through genomics can enable an efficient sire or dam selection programme. Genomic markers are regarded as the ultimate biomarkers for prediction or pre-disposition or potential to express a specific trait. SNPs are genetic variants of choice due to their high abundance (several million; one SNP per Kbp segregating in a population), stability of DNA matrix, mutational stability or consistency of DNA and their categorical nature (most SNPs are bi-allelic in nature). These features make SNPs perfectly suitable for high throughput interrogation required for a Genome-Wide analysis. Genomic biomarkers are also best suited for the early prediction of stress or susceptibility to adaptation stress or behavioural disorders.

When the objective is to assess the current or *recent* exposure to stress, a preferable approach would be to search for associated biomarkers through proteomics and metabolomics.

CONCLUSION

The idea of sustainability in livestock production aims at increasing the robustness, resilience and efficiency of the livestock for more meat, milk and eggs simultaneously taking care of the economic and environmental sustainability of the production systems. Both phenotypic and genotypic data are required in such livestock improvement programmes. The cost of genotyping is declining day by day, and phenotypic information is becoming more expensive and difficult to obtain than genotypic data. Therefore, cheaper reliable easy-to-use phenotyping tools are much essential in animal improvement programmes. Wearable devices for remote recording of livestock health, movement and reproductive status are needed for this purpose.

SNP assays using high-density DNA chips (HD) are currently widely accepted for genotyping of livestock. However, they are too expensive and hence the development of low-density SNP panels or *reduced* SNP panels consisting of 200-400 SNPs each may be developed. One set of panels for parentage determination and another set for accurate determination of breed composition may be designed for the Indian livestock populations. These essays also need to be tested in the field to determine the feasibility of delivery to the farmers at an affordable cost.

Thus, targeting the best genotypes to different suitable production environments for the formation of synthetic breeds using various omics and phenotypic data will help to practice long-term genetic improvement programmes for sustainable livestock.

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SELECTION FOR TOLERANCE TO HAEMO PROTOZOAN DISEASES IN RUMINANTS

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INTRODUCTION

Selection is the choice of the individual to be bred as a parent to produce the next generation. Genetic effects of this selection are without creating any new genes its changes the genetic structure of the population by changing the frequency of genes and genotypes, thus the frequency of desired gene is increased in the population, therefore with the increase or change in the frequency of desirable genes, the phenotypic mean of the character of the progeny generation is also increased /changed.

One of the main challenges faced by the researchers is breeding to create a herd that is resistant/ tolerant to haemoprotozoan diseases. E.g. N'dama cattle have a tolerance to trypanosomosis in Africa, hence they are less susceptible to trypanosomosis and they are able to survive better and maintain high productivity in trypanosomosis-endemic areas (Kim *et al*., 2017).

It is an emerging topic because disease-resistant traits have not been studied much in developing nations like India where the production traits are of major concern E.g., selection for milk production and beef cattle production. Genetic variation has been observed in host resistance that is exhibited differently for different disease conditions, so identifying such resistance gene is useful in selecting the haemoprotozoan disease resistant/ tolerant animal e.g., *FAF1* gene responsible for tolerance to *Theileria parva* infection in Boran cattle of Africa (Wrag *et al*., 2022).

So, the optimal solution for potentially conflicting responses must be sought out by integrating breeding programmes for resistance with genetic improvement of production traits in farm animals. If antibiotics and other drugs have become ineffective (Antimicrobial resistance, AMR), selection for disease resistance/ tolerance is the key option. E.g., Buparvaquone drug resistance against *Theileria* spp. infection by developing several point mutations in the cytochrome B locus (*T. annulata*) (Ali *et al*., 2022). It may also be economically significant to select the animals in case of the increased cost of medicines e.g., the cost of buparvaquone against *Theileriosis.* Machado *et al*., 20100.

HAEMOPROTOZOAN DISEASE AND ITS IMPACT

It is mainly caused by parasitic protozoans (Phylum - Apicomplexa), whose life cycle alternates between development in the gut and tissues of diverse blood-feeding vertebrate vectors and the tissues and blood of a variety of vertebrate hosts (O'Donoghue, 2017), thus haemoprotozoan diseases mainly transmitted by vectors (ticks), thus tick-borne diseases decrease cattle production performance in tropical and subtropical regions causes economic losses of 30 billion US dollar per year (Junior *et al.*, 2022) and significant economic losses due to tropical Theileriosis, Babesiosis and Trypanosomosis is Rs. 8426 crore, Rs. 4000 crore and 4474 crore, respectively. Bock *et al.*, 2004, Kumar *et al.*, 2017, Narladkar, 20180.

MAJOR VECTOR-BORNE DISEASES AFFECTING RUMINANTS

Table 1 Major vector-borne diseases affecting ruminants and their causative parasites and transmitting vectors

DISEASE	PARASITE	VECTOR	REFERENCES
Trypanosomosis	*Trypanosoma vivax*, *T. congolense*, *T. brucei*	Biting vectors tsetse flies	Tariq *et al.*, 2022
Babesiosis	*Babesia bigemina*, *B. bovis*	ticks-species *Rhipicephalus (Boophilus) microplus*	Jacob *et al.*, 2022
Anaplasmosis - the obligate intracellular (erythrocytic) rickettsia	*Anaplasma marginale*, *A. ovis*	*Rhipicephalus (Boophilus) microplus*	Bhanot *et.al.*, 2022
Theileriosis (Bovine tropical theileriosis), *T. parva* (East Coast fever), *T. orientalis* (Oriental theileriosis)	*T. annulata* *T. parva* *T. orientalis*	Ixodes ticks of the genera *Hyalomma* and *Rhipicephalus* species	Krishnamoorthy *et. al.*, 2021

The best-known species which is infesting the cattle is *Rhipicephalus* spp. That is majorly involved in tick-borne diseases (Ali *et al.*, 2019), so the majority of the genetic study undertaken to understand the tick resistance, exhibited by the host. The disease will be established into the host by a pathogen which is transmitted by susceptible vectors, hence the effectiveness of the selection should be based on the host, pathogen and vector.

DEFINITION OF TRAITS

A host can evolve two types of defence mechanisms to increase its fitness when challenged with a pathogen, one is resistance, defined as the ability of the host to resist the infection and resist the replication rate of the parasite, one the other, Tolerance defined as the ability of the host to limit the health effects of parasites without preventing the infection or controlling the parasite, but suffers little adverse effects. The sum of both resistance and tolerance gives the host's defensive capacity Bishop and Woolliams, 2014, another important trait is Resilience, defined as the ability of the host to retain productivity in the face of infection (Knap *et al*., 2020), this would lead to considerable investment for breeding companies, and the associated cost-benefit analysis requires a sound estimate of the economic values of these traits. Some recent studies have defined resistance and tolerance as components of disease resilience (Knap *et al.*, 2020).

DIFFERENCE BETWEEN DISEASE RESISTANCE AND TOLERANCE

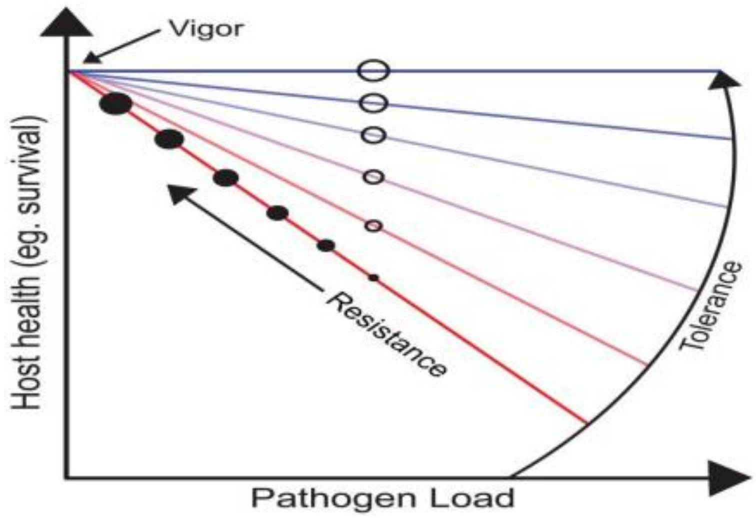

Figure 1 Host health vs pathogen load (McCavarille and Ayres, 2018).

Outline of host tolerance and resistance; with help of this dose-dependent curve, we can able to define the relationship between host health and pathogen burden, where the vigour represents the uninfected one, host resistance denoted by a dark circle is defined as a decrease in pathogen burden as host health increases, increase in host resistance are represented by an increase in circle size. In comparison, host tolerance (open circle) is defined as an increase in host health independently of the pathogen burden.

ASSESSMENT OF RESISTANCE/ TOLERANCE ANIMAL - ICEBERG CONCEPT

We should understand that typically a substantial number of animals which were exposed to infections remain uninfected and this represents the base of the iceberg indicative of resistant animals; another group of animals may become infected, but has not developed any clinical signs represents one step above the base of the iceberg, indicative of tolerant animals.

PHENOTYPES TO BE STUDIED

Identifying the phenotype is much more important for complex traits such as disease resistance/ tolerance traits because they are controlled by many genes, each with a different contribution to phenotype Machado *et al*., 2010, one such is packed cell volume (PCV), defined as the ability of the host to resist the development of anaemia in the face of infection can be assessed by PCV, thus can be correlated with the ability of an infected animal to maintain the PCV and thus can able to produce throughout the infective phase, So PCV is considered as a key trait for trypanotolerance (Murray *et al*., 1979). Other phenotypes available are skin thickness, coat colour, hair density and skin secretions (Shymu *et al*., 2015). This could provide the means of estimating heritability, thereby permitting rational breeding programmes to be instituted.

INDICATOR TRAIT FOR TICK RESISTANCE

Defined as a trait that may or may not be important in itself but it is selected as a way of improving some other genetically correlated trait. Indicator traits are usually easy to measure, having economic advantages and indicator traits are heritable in nature.

HERITABILITY ESTIMATES FOR TICK RESISTANCE

If the phenotype accurately reflects the genotype, then the selection will be quite accurate, but the phenotype is not always the true indicator of the genotype. In actual conditions, heritability estimates give us an estimate of what we can expect to achieve by the selection, because this h^2 of the trait is due to additive genetic variation, if the additive genetic variation is large, then the h^2 estimates will more accurately predict the genotype. The average h^2 for tick resistance is given in table 1(h^2 ranges from low to medium).

Table 2 The average h^2 for tick resistance from several studies in tropical beef cattle is 0.34 Davis *et al.*, 1993

Reference	Location	Breed	Challenge	h^2 (SE)
Fraga et al. (2003)	Brazil	Caracu	Natural	0.22
Henshall (2004)	Australia	HS	Natural	0.44
Prayaga and Henshall (2005)	Australia	Cross bred	Natural	0.13 (0.03)
Peixoto et al. (2008)	Brazil	Holstein X Gir	Artificial	0.21 (0.12)
Prayaga et al. (2009)	Australia	Brahaman	Natural	0.15 (0.10)
Budeli et al. (2009)	–	Bonsmara	Natural	0.17
Turner et al. (2010)	Australia	*B. taurus* a number of breeds	Natural	0.37
Machado et al. (2010b)	–	Gir X Holstein (F2)	Artificial	0.21

h^2 heritability, *SE* standard error, *F2* second filial generation, *HS* Hereford–Shorthorn (*B. taurus*) cross

Crossbred of *Bos taurus* and *Bos indicus* (F2 population), h^2 is 0.21 (Cardoso *et al.*, 2015). The heritability for tick burden in cattle is 0.30 which is sufficient to result in the success of some selection programmes for tick resistance in cattle (Shymu *et al.*, 2015).

HERITABILITY ESTIMATES FOR TOLERANCE

A recent study found that a locus conferring tolerance to *Theileria* infection in Boran cattle (Africa) having h^2 for *Theileria* tolerance is 0.65, thus allowing farmers to breed tolerant cattle which helps in the introduction of beneficial DNA to non-native breeds, enabling reduced disease-incidence and increased productivity (Wragg *et al*., 2022).

RECENT FINDINGS

Bos indicus breeds are naturally resistant to tick infestation and tick-borne diseases, revealed through high hemolytic complement activity; Red Maasai sheep of Kenya are considered more resistant than the Merino (Murray *et al*.1990). The Senepol breed (Red poll X N'Dama) showed increased tick resistance when compared to other pure taurine breeds O'Neil *et al*., 2010. N'Dama breed not only has the genetic capacity to control parasitism (Claxton and Leperre, 1991) but also to avoid anaemia and severe pathology associated with trypanosome infection (Murray and Dexter, 1988; Naessens, 2006), Hence N'Dama breed is native to Africa is naturally tolerant to Trypanosomosis. Trypanosoma-tolerant cattle was developed at International Livestock Research Institute and a cloned transgenic Boran calf named "Tumaini" was developed (Pal and Chakravarty, 2020).

Table 3 List of mammalian breeds reported to dad is showing resistance or tolerance to specific diseases/parasites

DISEASE	BUFFALO	CATTLE	GOAT	SHEEP
TRYPANOSOMOSIS		17	4	4
TICK INFESTATION/ TICK BURDEN	1	17		1
TICK BORNE DISEASES (unspecified)		4		
ANAPLASMOSIS		2		
PIROPLASMOSIS		4		

BASIC GENETIC APPROACHES FOR IMPROVEMENT OF DISEASE-RESILIENT BREEDS

DIRECT SELECTION

It is mainly based on clinical signs and records; the disadvantage is low h^2 and there is a need for maintenance of accurate health records (Thompson-Crispi *et al.*, 2014).

INDIRECT SELECTION :

This is a practice of improving one character by selecting another related character, in another word if we want to improve the character Y (Trypanosomosis), we might select another genetically correlated character X (PCV); the basis of the indirect selection is the high genetic correlation between the traits, it is preferred when two characters have high genetic correlation and high h^2 then the correlated response will be higher than direct response, hence greater accuracy of selection and intensity of selection for the correlated trait than for the trait of interest. It is applicable for traits that are too expensive or difficult to measure directly (Bourdan, 1999).

E.g., Skin thickness, skin secretion, hair density, coat type and coat colour influence the tick count (tick burden). Murray *et al*., 1990 and Hassan 1997 found that tick burdens were correlated with host coat colour and white-coated animals carried significantly more ticks when compared to brown and black-coated animals and also suggested that ticks picked by animals with black or brown coat colours die or leave before the attachment due to relatively raised temperature in the host skin (Hayati, 2020).

INDIRECT SELECTION USING TICK COUNT

Cavani *et al.* (2020) estimated the genetic correlation between *Babesia bovis* infection (IB) level and tick count (TC) in Hereford and Braford cattle, and found that the heritability of IB is low (0.10) and the genetic correlation also low (0.15) and they found some of the candidate gene (*LRCH1*) for IB involved in biological resistance processes.

INDEX SELECTION

It is a total score method, the index is a single numerical value, which is the total of scores given for each trait considered in the selection, each trait is weighted by a score and the individual scores are summed to a total score value of each animal, hence it is a combination of weighted factors and genetic information and it is used for multiple traits and it is used to predict the aggregate breeding value (Bourdan, 1999). E.g., Reis *et al*., 2017 conducted a study with the breeding goal of tick resistance in Hereford and Braford cattle, the objective of the study was to analyse the genetic gain obtained through different strategies to predict the GEBV (genomic estimated breeding value), they combined TC with Delta G Breeding Programme Index (DGI), 92% weightage allotted to DGI and 8 % to TC because their primary aim is to produce beef cattle, hence DGI comprising of 9 parameters given in below table 4.

Table 4 Delta G Breeding Programme Index (DGI) comprising of 9 parameters

PARAMETERS	SCORE GIVEN	% allotted
Pre-weaning gain (WG)	kg	25
Weaning Conformation (WC)	1-5 scale	4
Weaning precocity (WP)	1-5 scale	8
Weaning muscling (WM)	1-5 scale	8
Post weaning gain (PWG)	kg	25
Yearling conformation (YC)	1-5 scale	4
Yearling muscling, (YM)	1-5 scale	8
Scrotal circumference (SC)	cm	10

It helps in desirable to achieve faster genetic progress compared with laborious TC phenotyping of all selected candidates and traits have scales ranging from 1 to 5, with 1 being the worst and 5 the best rating score for the respective traits; they concluded that the genetic correlation between TC and the other traits were low, ranging from 0.19 to 0.13 and negative correlation with TC is favourable, hence greater productivity associated with lower TC.

MOLECULAR APPROACHES FOR SELECTION

CANDIDATE GENE APPROACH

Candidate genes are generally genes with known biological functions directly or indirectly regulating the developmental processes of the investigated traits, which could be confirmed by evaluating the effects of the causative gene variants in association analysis.

MAJOR CANDIDATE GENES

The bovine *TLR4* gene located on chromosome 8 is associated with bovine anti-tick capability; Toll-like receptors (TLRs) are important pathogen recognition receptors that activate innate and adaptive immune responses; various pathogen infections trigger the inflammatory responses by activating TLR signalling molecules, which build specific immunity by providing stimulating factor and cytokine inducing T-cell differentiation and releasing mediators of inflammation; plays an important role in immune responses because TLR expression remarkably increases around infected foci (Zhao *et al.*, 2013; White *et al.*, 2003; McGuire *et al.*, 2006). *STX5* gene is a prime candidate gene for tick resistance in sheep, showing a significant increase in its level of expression in the skin of animals that were highly resistant to ticks.(Ahbara *et* al., 2022). *FAF1* and *HBB* genes were responsible for *Theileria* tolerance in African cattle (Wragg *et al*., 2022).

MARKER-ASSISTED SELECTION (MAS)

MAS is an indirect selection where the trait of interest is selected, not based on the trait itself but mainly on the markers which are closely linked to it, genetic markers are basically landmarks on the chromosome for the purpose of the location of the gene of interest, it is identified by detecting and localizing the QTLs which influence the multi-factorial trait. Identification of molecular markers linked to resistance traits that could be used as an auxiliary tool in selection programs and it is used to select animals at a younger age to reduce generation interval and also to increase the genetic gain; it is preferred when traits are low heritable and traits that are measured late in life. E.g., Machado *et al*., 2010 cross-mapped six genomic regions associated with bovine tick resistance in the bovine F_2 population derived from the Gyr (*Bos indicus*) X Holstein (*Bos taurus*). For most QTL, they found that depending on the tick evaluation season (dry and rainy) different sets of genes could be involved in the resistance mechanism, they identified dry season-specific QTL on BTA 2 and 10, rainy season-specific QTL on BTA 5, 11 and 27 and also they found highly significant genomic wide region QTL for both dry and rainy seasons in the central region on BTA 23. Dube *et al*., 2019, the gen LUM used as a biomarker for resistance to ticks; this gene lumican induced resistance to ticks by promoting continued cellular regeneration, tissue repair and detoxification of tick bite site, instead of initiating host immune responses.

GENOME-WIDE ASSOCIATION STUDIES

It is a whole genome association study, is a process for inspection and screening of detectable common variants (SNPs) in an individual to identify variants associated with the trait under the study and helps to identify variants that are statistically associated with altered traits (altered traits may be of diseased or improved production when compared with reference population) and it is useful in finding the genetic variations underlying the complex diseases. E.g., Cavani *et al.*, 2020 estimated the genetic correlation between *Babesia bovis* infection level (IB) and tick count (TC) and they evaluated the predictive ability and application of genomic selection and they found the top ten single nucleotide polymorphisms from GWAS explained 5.04% of total genetic variance for IB, which were located on chromosomes 1,2,5,6,12, 16, 17, 18, 24, and 26 and they found some candidate genes participate in immunity system pathways, are involved in resistance to *B. bovis* infection in cattle.

Wragg *et al.*, 2022 found a 6 Mb genomic region through GWAS in association with tolerance to *Theileria* infection in African Boran cattle by identifying 57119 SNPs and 500 indels and also they identified the unique genetic patterns or footprints left behind the genomic regions subjected to selection that are identified as selection signatures. It is otherwise called selective sweeps or hitchhiking effect due to natural selection or positive selection favourable alleles are increased in frequency and fixed in a population and provide information regarding the evolutionary process involved in shaping genomes as well as selection sweep reduces the heterozygosity of regions surrounding the selected locus, one such is a paralogue of *FAF1* gene located on chromosome 15 in association with survival outcome by cell expansion during infection.

TRANSCRIPTOMICS STUDY

It is the study of the transcriptome, the complete set of RNA transcripts that are produced by the genome, under specific circumstances using high-throughput methods, such as microarray analysis. By comparing the transcriptomes, allows the identification of genes that are differentially expressed in distinct populations. E.g., Kurien *et al*., 2019 identified the up-regulation of *Heparan sulphate 3-0-sulphotransferase 1* (*HS3ST1*) in Vechur (*Bos indicus*) and crossbred (*Bos indicus X Bos taurus)* cattle of Kerala in response to *Rhipicephalus annulatus* infestation, this up-regulation of *HS3ST1* gene helps to trigger the anti-inflammatory effects of antithrombin, the fold change in expression of the gene exhibited at 24 hours after challenged with ticks when compared with the initial level in CBHF was 25.63 while in Vechur it was 1.952 Kurian *et al*., 2019. Another study is differential gene expression of *S100A8* in *the* skin where a significant 2.809 fold up-regulation was noticed in Vechur animals after

24 hours challenged with *Rhipicephalus annulatus* infestation while in CBHF animals, there is no significant differential expression (Kurian *et al*., 2019).

BTA	SNP position	Genes[a]	Var (%)
24	26,698,515	*DSC1, DSC2, DSC3*	0.853
16	62,734,784	*CEP350, QSOX1, LHX4, ACBD6, TOR1AIP1, TOR1AIP2, FAM163A*	0.640
1	32,883,377	*CADM2*	0.548
12	16,641,931	*LRCH1, ESD, HTR2A, RUBCNL, LRRC63, LCP1*	0.508
18	44,019,061	*PEPD, CEBPG, CHST8, KCTD15, SLC7A10, LRP3, WDR88, GPATCH1, FAAP24*	0.487
26	42,178,883	*ATE1, NSMCE4A, TACC2, BTBD16, FGFR2*	0.479
6	62,979,121	*ATP8A1, SHISA3, BEND4, SLC30A9, TMEM33, GRXCR1*	0.408
2	109,327,881	*Intergenic region*	0.377
17	34,752,485	*SPRY1, SPATA5, NUDT6, FGF2*	0.377
5	53,704,130	*SLC16A7*	0.367

[a]*Genomic coordinates for each gene based on the Bos taurus ARS.120 reference assembly were expanded by 500 kb upstream and downstream.*
BTA, Bos taurus autosome; Var, proportion of additive genetic variance explained by the single SNP.

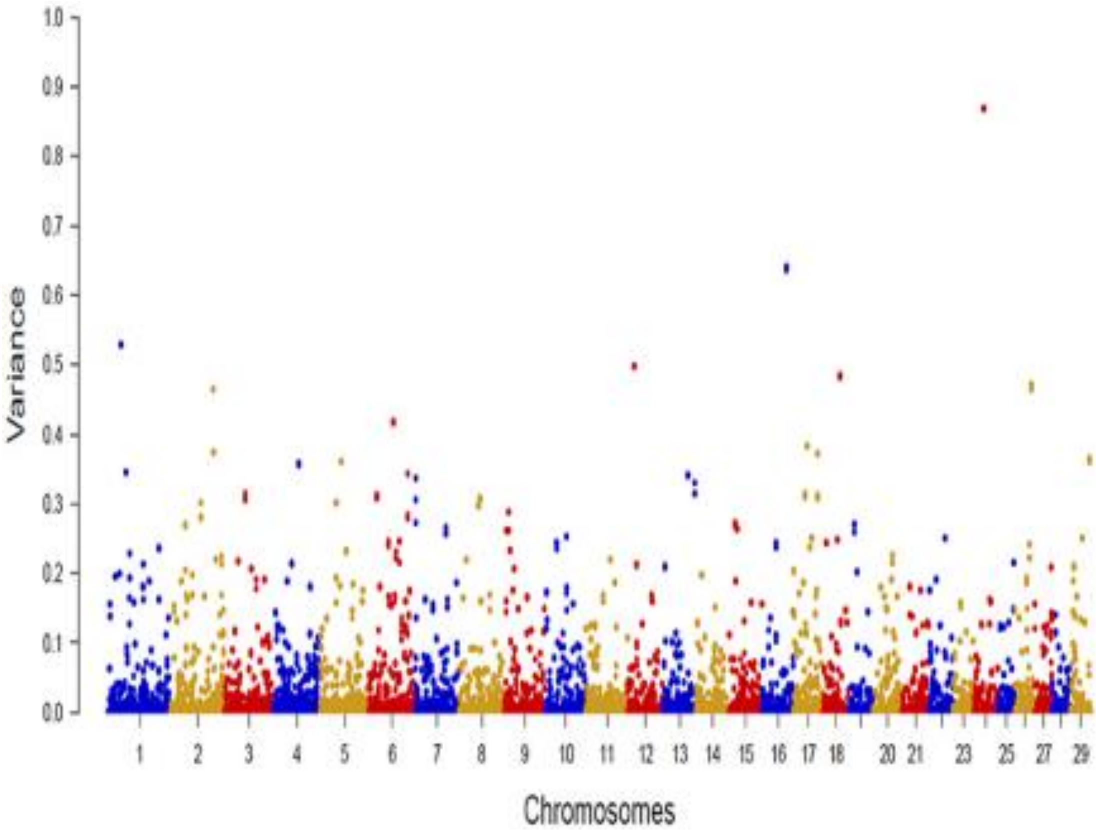

Figure 2 Genomic signature for Theileria tolerance in cattle (Wragg et al., 2022).

FUTURE PERSPECTIVES

SELECTION BASED ON GENOTYPE-ENVIRONMENT INTERACTION

Animals that are identified as top breeders in one environment may not be ideal in other environments, this issue is further exacerbated if progeny are raised in environments that differ from that of their parents, most of the current genetic evaluation systems assume homogeneous residual variances across environments, although evidence of residual heteroscedasticity has been reported, which is defined as heterogeneity of residual variances across contemporary groups such as milk yield and post-weaning weight Mota *et al*., 2016. E.g., the temperature humidity index (THI) in the selection, because observation made in Colombian cattle showed that THI values were associated with lower tick burdens and high tick infestation would be expected when animals experience higher thermal discomfort, hence, in future, selection based on G*E interaction representing a promising alternative for genetic evaluation of tick resistance, since they are expected to lead to greater selection efficiency and genetic progress.

NEW PHENOTYPES FOR IMPROVING DISEASE TOLERANCE

E.g., Deriving cellular phenotype traits, because *Theileria parva* is the causative agent for East Coast fever antigens having capable to identify the antigens that target the bovine major histocompatibility complex class I restricted cytotoxic T-lymphocytes (CTLs), and induced infection host (Nene *et al*., 2016).

EXPLICIT FOCUS ON DISEASE RESILIENCE

Mainly focusing on the production traits improvement in face of infection since it reduces production loss.

CONCLUSION

Candidate genes, genomic regions and many markers are identified in association with resistance and tolerance. In future, selection for tolerance and resilience to haemoprotozoan diseases will be a reality.

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SUSTAINABLE GOAT PRODUCTION: FUTURISTIC APPROACH TO ENSURE FOOD SECURITY

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INTRODUCTION

While climate change is a global phenomenon, its negative impacts are felt more severely by poor people in developing countries, who rely heavily on natural resources for their livelihoods. In arid and semi-arid areas, livestock is often considered to be one of the most important means of food and economic security for poor and marginal farmers. Elevated ambient temperature and inadequate and low-quality feed are the major factors which contribute towards the under-production of farm animals in tropical regions. Fig. 1 describes the various impacts of climate change on livestock production.

Given the significance of livestock to the economy of India in particular, efforts are needed to develop new concepts in animal science which could help understand the hidden intricacies of their responses to various environmental stressors which could aid in developing appropriate ameliorative strategies to improve production. This effort is therefore an attempt to project to the farming and scientific communities the various advances associated with climate change and livestock production and to highlight the various technologies available to sustain farm animal production in the changing climate scenario in the country in near future.

The livestock industry currently plays a crucial role in ensuring food supply and food security. At the present and future global population burst, competition for natural resources, feed quantity and quality, livestock diseases, heat stress, and biodiversity loss are just some of the ways in which climate change will impact livestock production. Despite the availability of numerous management and dietary solutions aimed at reducing the effects of climate change on livestock, these measures may only be providing a temporary fix. Understanding how animals adapt and endure their environments requires simplistic approaches. This chapter is an attempt to project to the audience the advantages of goats over other species which offers them the potential to survive the multiple environmental stressors associated with climate change and sustain their production.

EMERGING CONCEPTS IN CLIMATE CHANGE-ASSOCIATED LIVESTOCK PRODUCTION

GOAT AS IDEAL CLIMATE RESILIENT ANIMAL MODEL

The projected increased temperature and reduction in fodder production can cause a detrimental impact on farm animal production. In this context, the goat offers greater scope for sustaining livestock production due to its advantages such as higher thermo-tolerance, drought tolerance, ability to survive on limited pastures and high disease resistance over other species. Further, goats possess the ability to walk for long distances in search of limited pastures. All these advantages impart goats the potential to survive in varied geographical locations and are tipped to be a climate-resilient animal model in the changing climate scenario. In a recent review, Reshma Nair et al. (2021) clearly projected goats to be the species to experience very minimal heat stress levels as compared to other farm animals both by 2050 and 2100. Fig.1 projects the advantage of rearing goats over other species in the changing climate scenario.

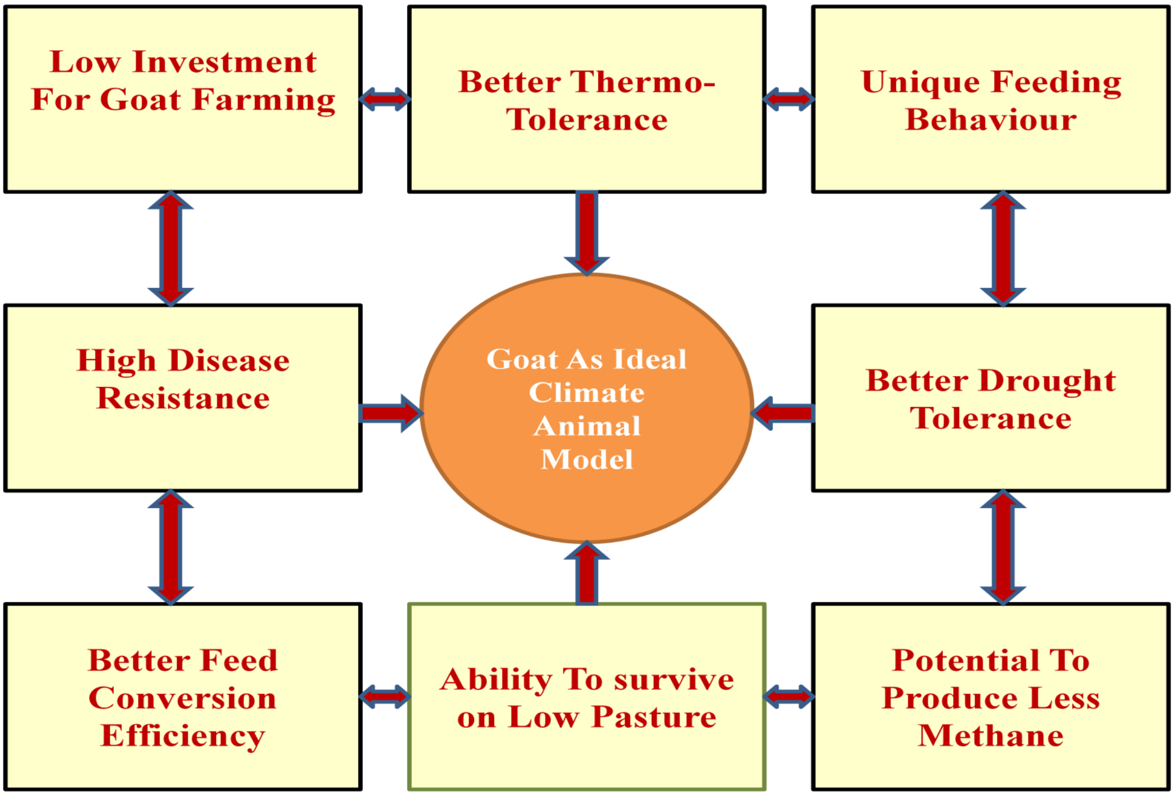

Fig.1. Scientific pieces of evidence for considering goat as an ideal climate animal model (Information synthesised from the International Journal of Biometeorology by Reshma Nair et al., 2021)

CONCEPT OF MULTIPLE STRESSES IMPACTING FARM ANIMALS

When exposed to one stress at a time, animals can effectively counter it based on their stored body reserves and without altering their productive functions. However, if they are exposed to more than one stress at a time, the summated effects of the different stressors might prove detrimental to these animals. Such a response is attributed to the animal's inability to cope with the combined effects of different stressors simultaneously. In such a case, the animal's body reserves are not sufficient to effectively counter multiple environmental stressors. Fig. 2 describes the concept of multiple stressors impacting livestock production.

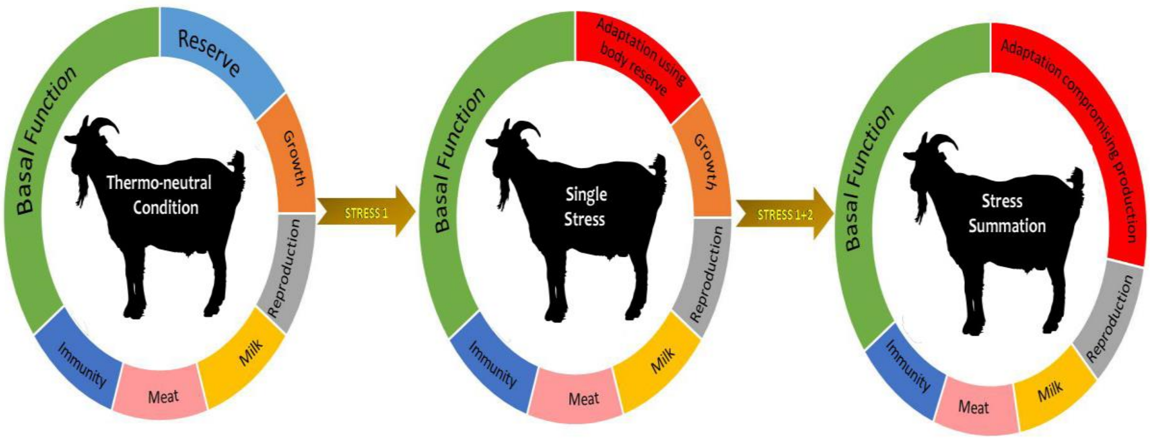

Fig.2. Pictorial representation of concept of multiple stressors on livestock production

2.3. ADVANCED THERMAL INDICES TO QUANTIFY HEAT STRESS RESPONSE

The temperature humidity index (THI) which is being widely used for quantifying heat stress response in farm animals has two drawbacks as it does not take into account solar radiation and wind speed. This has brought the drive in the scientific community to develop advanced thermal indices to address these drawbacks of THI indices. Heat load index is developed as an improvement which overcomes the perceived deficiencies in the THI index. The HLI uses two equations based on the threshold value of black globe thermometer:

$$HLI_{BG\geq 25} = 8{:}62 + (0.38 \times RH) + (1.55 \times BG) - (0.5 \times WS) + e^{(2.4 - WS)}$$

$$HLI_{BG< 25} = 10.66 + (0.28 \times RH) + (1.3 \times BG) - WS$$

WHERE, BG IS THE BLACK GLOBE TEMPERATURE IN °C, RH THE RELATIVE HUMIDITY IN %, WS THE WIND SPEED IN M/S AND E THE EXPONENTIAL.

2.4. INFRARED THERMAL IMAGER APPLICATIONS IN FARM ANIMALS

Traditional body temperature measurement requires handling and restraining procedures may increase the average body temperature of the animals. Therefore, there is a need for identifying non-invasive methodology to quantify heat stress response in livestock. Infrared thermography (IRT) is one such non-invasive method which has the potential to record animal body temperature without the need to restrain or relocate animals. Thus, this technology offers scope for understanding in depth the thermo-regulatory mechanisms in heat stressed animals. Fig. 3 describes the different body parts surface temperature using infrared thermography in goat.

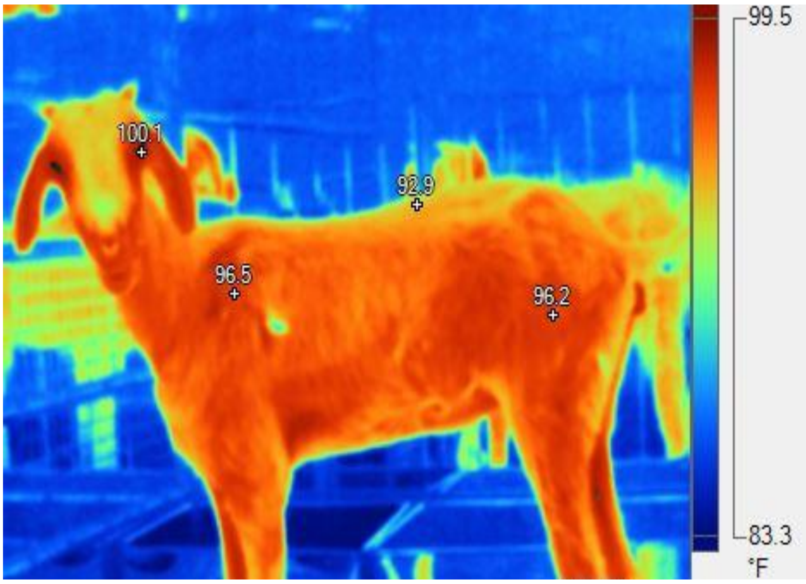

Fig.3. Surface temperature measurement in goat using infrared thermography

2.5. AGRO-ECOLOGICAL ZONE-SPECIFIC BREED IDENTIFICATION

Sustaining livestock production in the changing climate scenario requires efforts to identify the best indigenous breeds to survive in different agroecological zones. Such an effort could ensure that the most suited breeds to specific zones are recommended by the policymakers for dissemination to the local farmers. Therefore, promoting such recommended breeds among the local farmers may prove beneficial in improving their livelihood security. A classic example was provided by our own research which recommends the Salem Black breed to be the ideal breed to survive in Southern India. This warrants more research efforts, particularly in tropical regions to screen indigenous breeds for their climate resilience and to test their ability to survive in multiple locations.

2.6. RUMEN MICROBES ASSOCIATED WITH ADAPTIVE POTENTIAL

The ruminant animals and gut microbiota have evolved simultaneously while adapting to climatic and pastoral environments. Over the past few years, metagenomics has emerged as a powerful tool to study the rumen microbiome. Recent studies identifying the rumen microbial community for novel enzymes, uncultured methanogens, and other metabolic pathways have opened new insights in this area. However, there are very few metagenomics studies conducted on heat-stressed animals. This also is a potential area of research, which could open up new pathways towards amelioration and mitigation of heat stress in farm animals.

2.7. WHOLE TRANSCRIPTOMICS APPROACH-BASED ESTABLISHMENT OF CLIMATE RESILIENCE

Because of the complexity of climate change, no single approach is likely to be sufficient for understanding livestock adaptation. Modifications in animal management practices, reproduction, nutrition and health care are obviously required. However, these modifications may add up to partial fulfilment of the gap towards attaining sustainability in livestock production in the present climate change. A permanent solution can be addressed through genomic selection and practical breeding policies. These policies cannot be implemented unless robust understandings of the molecular biomarkers within the population are studied. Transcriptomics can be one of the tools of choice to achieve the above-mentioned. Through gene expression studies, and more specifically global gene expression profiling at the mRNA level, we can gain a deeper understanding of the mechanisms that govern the phenotypes and their regulation in livestock. Biological pathways and their regulation are governed by network of genes rather than a single master regulator gene. Here, a complex interaction of genes responding to intrinsic and external stimuli, rather than a master gene, will be responsible for economically relevant production traits in livestock. Optimizing livestock production systems via the identification of desired animals and their incorporation into accurate breeding programs or management could be a way forward approach

2.8. EPIGENETIC CHANGES ASSOCIATED WITH TECHNOLOGIES TO ASSESS CLIMATE RESILIENCE

Recently, the advent of epigenetics has become a concern globally to provide inputs on the relationship between ecosystems in context to the prevailing environmental condition. It is a novel field that controls gene expression without altering the nucleotide sequence in the DNA by the changes in the methylation pattern, histones, and chromatin remodelling. Certainly, the identification of epigenetic markers may pave way for developing more thermo-tolerant animals with better production efficiency and survivability. Such a robust approach might help in developing quality animals for the future to ensure sustainable livestock production in the changing climate scenario.

2.9. BIOMARKERS FOR HEAT STRESS IN GOATS

The following genes were found to be associated with thermo-tolerance in indigenous goat breeds. These genes could serve as biological markers for quantifying heat stress response in indigenous goat breeds. These markers are distributed across vital animal functions such as adaptation, growth, reproduction, metabolism and immunity. The identified traits are as follows: (1) Adaptation Traits: Heat shock protein 70 (HSP70), HSP90, HSP27, HSP110 & heat shock factor 1 (HSF1); (2) Growth Traits: Growth Hormone Receptor (GHR), insulin-like growth factor 1 (IGF-1), Thyroid Hormone Receptor (THR), leptin receptor (LEPR); (3) Reproduction Traits: Prolactin Receptor (PLR), follicle-stimulating hormone receptor (FSHR), luteinizing hormone receptor (LHR), estradiol receptor (ESTR); (4) Immune-related traits: toll-like receptor 3 (TLR3), TLR6, TLR8, interleukin 10 (IL10), IL18, tumour necrosis factor α (TNF-α), interferon β (IFN-β), and IFN- γ. Fig. 4 describes the various biomarkers for quantifying heat stress response in goats.

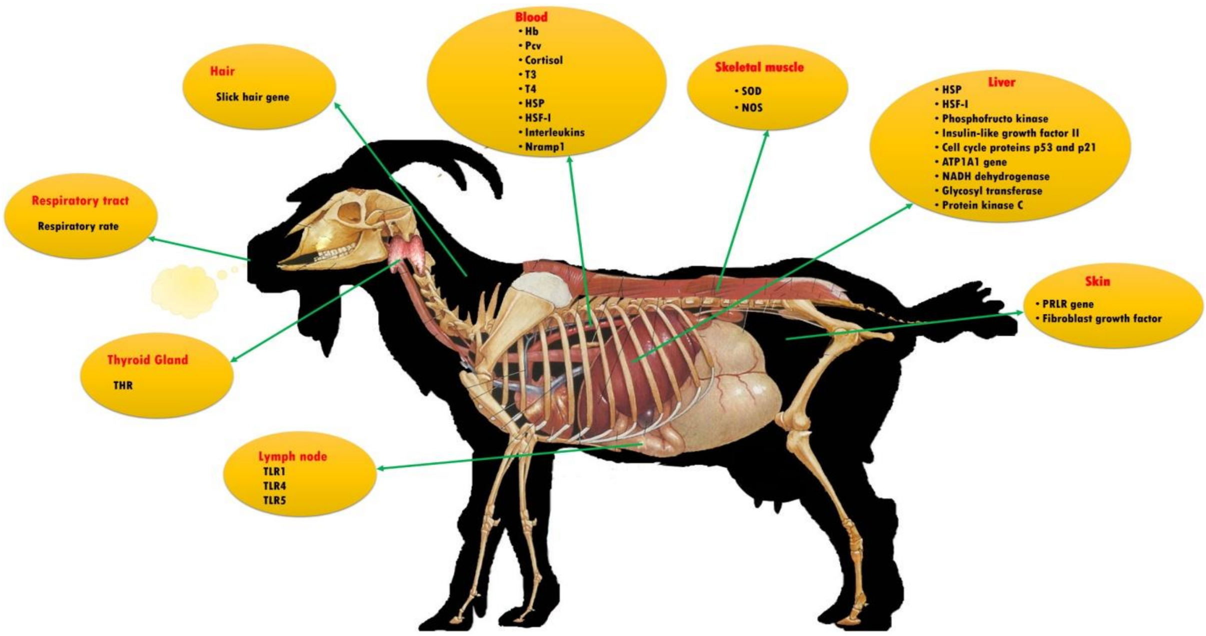

Fig. 4: Different biomarkers for heat stress in goats (Source: Sejian et al., 2018)

3. TECHNOLOGIES TO AMELIORATE HEAT STRESS IN FARM ANIMALS

There are several ameliorative technologies that should be given consideration to prevent economic losses due to environmental stresses. Reducing the impact of climatic stresses on livestock production requires multidisciplinary approaches which emphasize Animal genetics, nutrition, housing, and health. Better management of livestock may reduce the initiation of thermoregulatory mechanisms which allows for better energy utilization for growth and/or production. In the face of climate change, the continued development of heat stress management tools is needed to ensure the sustainability of animal-based agricultural enterprises. Fig. 5 describes the various strategies to sustain livestock production in the changing climate scenario.

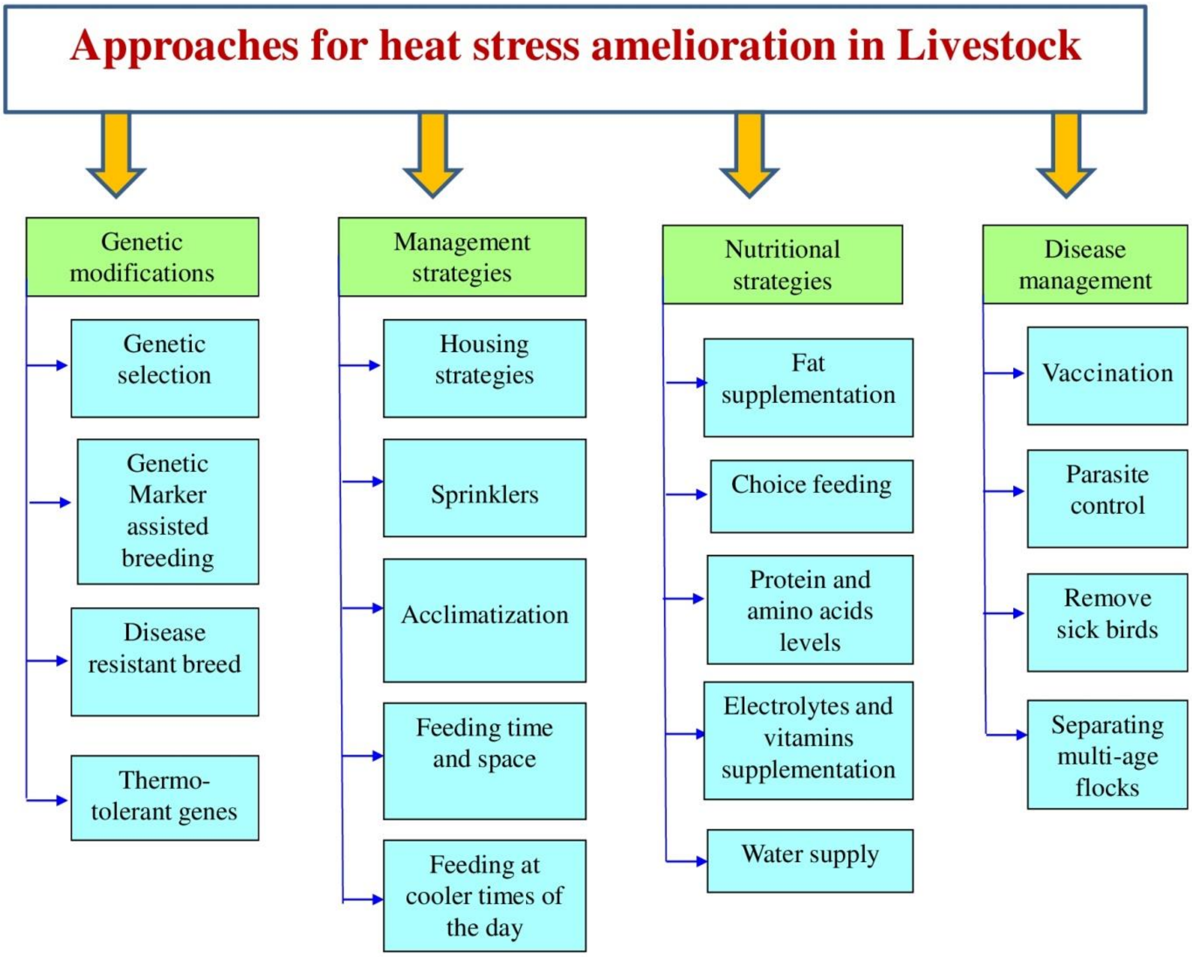

Fig.5. Various technologies to sustain livestock production in the changing climate scenario (Source: Sejian et al., 2018)

4. CONCLUDING REMARKS

Responding to the challenges of global warming necessitates a paradigm shift in the practice of agriculture and in the role of livestock within the farming system. Scientific research can help the livestock sector in the battle against climate change. Therefore, the future research efforts involving various stakeholders including the policy makers must ensure the following aspects to sustain livestock production in the country:

- New indices that are more complete than THI to evaluate the climatic effects on each animal species must be developed and weather forecast reports must also be developed with these indices, to inform the farmers in advance.
- Advanced molecular biological tools should be employed to quantify the heat stress response in farm animals.
- The existing breeding programs have concentrated only on production traits. However in an effort to sustain livestock production in the changing climate scenario, the existing breeding programs must be redefined with the amalgamation of production, adaptation and low methane emission traits.
- Research must continue developing new techniques of cooling systems such as thermo-isolation.
- Above all appropriate agro-ecological zone specific breeds needs to be identified to disseminate it to farmers for ensuring optimum economic return which could improve the livelihoods of the poor and marginal farmers across tropical regions.
- Livestock farmers should have key roles in determining what adaptation and mitigation strategies they support if these have to sustain livestock production in changing climate.
- The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of climate change adaptation strategies.

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SUSTAINABLE LIVESTOCK FEEDING-INDIAN PERSPECTIVE

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INTRODUCTION

Sustainable feeding is an integral component of achieving sustainability in animal agriculture. Recently there has been an increasing trend wherein different livestock production systems across the globe exploit sustainable animal diets. The perception of 'sustainable animal diets' provides due credit to the factors such as the environment, natural resource management, socio-cultural welfare and ethical integrity along with the nutritional criterion in the production of safe feed to obtain safe edible animal products (FAO, 2014). This approach is holistic in nature with the 3 Ps of sustainability- Planet, People and Profit, implying ecological soundness, social equity and economic growth, (IUCN, 2005), respectively. The feed or feeding system is considered to be sustainable if it is profitable; socio-culturally acceptable and beneficial to people; and protects the environment and natural resource base or the planet. In the context of the

In the present-day scenario of shortage of resources especially water, climate change, environmental pollution and loss of biodiversity, sustainable livestock production and 'sustainable animal diets' need to be adopted on a priority basis.

FEED SUSTAINABILITY- AN INDIAN PERSPECTIVE

A few steps towards feed sustainability can be taken by utilizing more regenerative agricultural systems in the production of feed, and waste materials as feed and selecting the ingredients in such a way that optimizes the feed-to-food conversion efficiency. Since the concept still needs to be adopted in the Indian feeding system, the following criteria, most of which are pertinent to the planet dimension, may be adopted in the preliminary phase. The following 7 criteria have been considered in the backdrop of recent natural disasters- floods, cyclones and droughts in many Indian states.

RESTORATIVE LAND USE AND BIODIVERSITY PRACTICES

A minimal land footprint may be used in the production of feed and fodder without converting land into an ecologically fragile zone. All those land management practices would attempt to build soil health, and increase biodiversity.

MINIMISE GREENHOUSE GAS EMISSIONS

India, being the owner of the highest bovine wealth, and a high proportion of low yielders, the feed production and feeding practices may be oriented in a direction to reduce GHG emissions. The methane emission power of most of Indian feeds and fodders are calibrated calling for judicious use and thus low methanogenic feeds can be categorized under sustainable feeds.

NON-COMPETITION WITH THE HUMAN FOOD CHAIN

It would be an easily adoptable criterion in the Indian scenario where our feed production is dependent on coproducts and byproducts of the food industry that are inedible to humans.

MINIMIZES POLLUTION

Feed production should minimize air and water pollution. Inefficient application and overuse of fertilizers have caused major damage to the environment, particularly water pollution, and soil erosion and causing harm to human health.

MINIMIZES FRESHWATER CONSUMPTION

The water footprint of the feed should be minimized and recycled through efficient operations so that reserves are not depleted and water for humans is prioritized.

SUPERIOR QUALITY

Sustainability cannot be attributed unless the feed provides the prescribed quality which in turn supports the health and well-being of the animal. However, this dimension is easily taken on based on the recent FSSAI directive ‘Commercial feeds shall comply with the relevant BIS standards, as may be specified by the Food Authority from time to time, and carry BIS certification mark on the label of the product”. The above directive is applicable to feed all meat and milk-producing animals.

LOW COST

Since feed is the most expensive input in livestock farming, any efforts to make low-cost feed will drive the enterprise in a sustainable way. However, our feeding system based on locally available feeds and crop byproducts would easily fit into a sustainable feeding strategy.

FODDER SUSTAINABILITY: ISSUES AND MANAGEMENT

CURRENT SCENARIO: STAGNATION IN THE AVAILABILITY OF GREEN FODDER

The cereals crop residues and coarse cereals straws/hay contribute about 71 per cent of overall feed resources used for animal feeding, followed by green fodder at 23 percent while concentrated feeds account for 6 per cent, only. In spite of intensive efforts for revitalizing the fodder resources, a current deficit of 23.4%, 28.9 % and 11.24 % are estimated for dry fodder, concentrates and green fodder, respectively. The deficit in feed resources can be connected to the following facts. Fodder crops are cultivated only on about 4.9 % of the gross cropped area of the country and this area has been static for the last 25 years. Yet another reason for stagnation in the availability of green fodder is an inadequate fodder seed production, market linkages and very low seed replacement rate. According to an estimate, only 25 per cent of requisite forage seeds are available, that too of 15- 20 years old varieties (NITI Aayog, 2018). There has been an encroachment of over 10 million hectares of pasture land with poor replacement by agricultural land. Fodder species are not cultivated scientifically and systematically in over 105 arid and drought-prone districts. (NITI Aayog, 2018).

We could not attain any significant outcomes in dry fodder management also. This is attributed to crop diversification from cereals to commercial crops affecting the availability of crop residues. Worsening the situation, no effective solution is available for burning of available crop residues in fodder surplus States like Punjab and Haryana year after year.

FODDER RESOURCES MANAGEMENT:

The National Livestock Policy, 2013 put forward the following action points for livestock feeding in order to achieve sustainable development in the livestock sector.

1. ENRICHMENT OF STRAW QUALITY

Enrichment and densification of crop residues would be encouraged by using existing and newly developed technologies. Biotechnological techniques, which can develop recombinant microbes to digest straws, utilize lignin and its by-products and release carbohydrates through a solid-state fermentation process, shall be developed by involving research organizations of the government and private sector.

In view of the small proportion of total cropped area under fodder crops and sluggish growth therein, crop breeding should focus on high-yielding and high-quality fodder and forage varieties. Economic incentives (input subsidies for growing forage crops) and vertical integration of the livestock subsector, by developing marketing and processing infrastructure and institutions, would result in farmers bringing more land into fodder crop production. Crop breeding programs should emphasize the breeding of dual-purpose crops for their superior quality straw/ stover without sacrificing grain yield.

2. CEREALS AND OIL MEALS

The area under cultivation of coarse grains has gone down over the years resulting in a shortage of feed ingredients and concentrates. One of the major constraints in the poultry sector is poor quality feeds/unavailability of balanced diets with seasonal fluctuations in demand and supply. Efforts would be made to enhance the availability of coarse grains and oil meals for the livestock and poultry sector. Non-conventional animal feed resources would be exploited to make available protein and energy for livestock feeding.

3. PRODUCTION OF FODDER AND FODDER SEEDS

Efforts will be made to increase the production of quality fodder seeds through necessary incentives, arranging foundation seeds of different high-yielding fodder varieties and modern scientific farming procedures etc. Coordinated efforts are also needed to increase the area under fodder cultivation, especially through the use of barren and fallow lands and silviculture. Fodder cultivation in degraded land and forest land would be taken wherever possible with the help of the farming community. Round the year availability of quality fodder through the promotion of hay, silage and fodder banks etc. will be emphasized. Non-conventional sources of feed such as azolla, processed vegetables and fruit wastes etc. will be promoted.

4. COMPOUND FEED AND BALANCED RATION

The quality of compound feed is extremely important for enhancing production and productivity as well as farm economics. Balanced ration with locally available ingredients will be encouraged. The livestock and poultry owners will be educated about the benefits of quality feed, balanced ration, bypass protein and bypass fat. Feed quality standards would be strengthened. The quality of packaged balanced feeds shall be regulated in accordance with BIS standards. The use of special feed supplements and area-specific mineral mixtures and ration balancing would be promoted.

5. DEVELOPMENT OF PASTURE LAND AND COMMON PROPERTY RESOURCES

Common property resources available for grazing in rural areas have not only shrunk in size but have become less productive because of neglect and overgrazing. Physical availability and production potential of pastures and grazing community lands will be assessed and steps will be taken to rejuvenate such lands by planting fodder trees and grasses. It is therefore imperative to check the quantitative and qualitative deterioration of common grazing lands through technological (watershed management, reseeding with improved grasses), social (participatory management), and policy interventions (legal action against encroachment). Integrated land use planning with livestock as a component will be encouraged through Panchayati Raj Institutions.

GOI INITIATIVES FOR FODDER RESOURCES MANAGEMENT

The Department of Animal Husbandry and Dairying, Government of India had been implementing the 'National Livestock Mission' with a 'Sub Mission on Feed and Fodder Development' since 2014-15. Under the Sub Mission, financial assistance is provided to the Animal Husbandry Departments of the States/UTs for feed and fodder development under the following components:

- Fodder Production from Non-forest wasteland/rangeland/grassland/non-arable land/ Forest land;
- Fodder Seed Procurement/ Production and Distribution;
- Distribution of tractor mountable Fodder Block Making units, hay baling machines/reapers/forage harvesters, and Chaff Cutters;
- Establishment of silage making Units, bypass protein production units, Area Specific Mineral Mixture /Feed Pelleting/Feed Manufacturing Units;
- Establishment/modernization of Feed Testing Laboratories;

In the erstwhile National Livestock Mission, which had been operational from 2014 to 2021, a dramatic achievement was attained in the feed & fodder sector.

REALIGNED NATIONAL LIVESTOCK MISSION

The revised scheme of the National Livestock Mission (NLM) aims towards Employment generation & Entrepreneurship development.

The realigned National Livestock Mission will have the following three Sub-Missions:

(a) Sub-mission on Breed Development of Livestock and Poultry

(b) Sub-mission on Feed and Fodder Development

(c) Sub Mission on Innovation and Extension

a) Sub-mission on Breed Development of Livestock and Poultry: proposes to bring sharp focus on entrepreneurship development and breed improvement in poultry, sheep, goat and piggery by providing the incentivization to the Individual, FPOs, FCOs JLGs, SHGs, Section 8 companies for entrepreneurship development and also to the State Government for breed improvement infrastructure.

b) Sub-mission on Feed and Fodder Development: This Sub-Mission aims towards strengthening of fodder seed chain to improve the availability of certified fodder seed required for fodder production and encourage entrepreneurs to establishment fodder Block/Hay Bailing/Silage Making Units through incentivisation.

c) Sub-mission on Innovation and Extension: The sub-mission aims to incentivize the Institutes, Universities, and organizations carrying out research and development related to sheep, goat, pig and feed and fodder sector, extension activities, livestock insurance and innovation. Under this sub-mission, assistance will be provided to the central Agencies, ICAR Institutes and University farms for applied research required for the development of the sector, extension services including promotional activities for animal husbandry and schemes, seminars, conferences, demonstration activities and other IEC activities for awareness generation. Assistance will also be provided for livestock insurance and innovations.

FUTURE DIRECTIVES

The key driving forces for feed and fodder development in the coming years would be productivity enhancement, a shift to commercial production systems and convergence with other flagship schemes of the government like MGNREGA, RKVY and Watershed program (NITI Aayog, 2018).

The Fodder and Feed Security Mission is proposed so that an impetus can be given to the livestock sector making it a competitive enterprise for India, and also to harness its export potential with the following targets.

1. Additional production of green fodder of 250 million tons by bringing 10 million ha gross fodder cropped areas;
2. Collection and management of additional 150 million tons of dry fodder;
3. Fortification and enrichment of 150 million tons of dry fodder;
4. Enhance additional availability of 35 million tons of concentrates;
5. Bringing 2 million ha area under perennial grasses
6. Bringing 5 million ha as catch crops and intercropping of fodder crops in horticultural/ Plantation areas. (NITI Aayog, 2018).

CONCLUSION

The sustainable increase in livestock productivity, which is key to meeting the large, current and future, demand for livestock products, cannot be achieved without the use of Sustainable Animal Diets. Sustainable Animal Diets are expected to be beneficial for the animals, the planet and society, and are likely to generate socio-economic benefits, in terms of poverty alleviation and food security efforts. The active participation of researchers, policymakers, industry and farmers is needed for accomplishing sustainable animal diets. It is important to note that the realization of sustainable animal diets is a journey and not an end, and the aim should be to move towards these diets considering the agroclimatic and social dimensions of our country.

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FUNCTIONAL DAIRY BEVERAGE MARKET IN INDIA: EXPLORING GROWTH HORIZONS IN THE POST-COVID SCENARIO

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ABSTRACT

The COVID-19 pandemic virtually shattered our food system and altered our relationships with food in several ways. The epidemic has had a significant influence on consumers' eating and drinking habits throughout the world. These have created enormous potential for innovation in food research and development. It is observed that health-conscious people would prefer more health-promoting beverages to strengthen their immunity. Several reports disclose that food consumers in India demand functional beverages more extensively than before to include in their daily food baskets. This paper explores India's functional dairy beverage market trends in the post-COVID-19 (Corona Virus Disease-19) scenario. The review results shed light on some crucial factors propelling branded dairy-based functional beverages' consumption, especially in the post-COVID-19 scenario. These would guide food marketers to segment and position their functional food offerings, mainly beverage variants. This attempt would be a primer to guide future studies investigating consumers' attitudes and purchasing behaviour of branded dairy-based functional beverages in India. Moreover, the study findings enable policymakers to craft food policies to uphold the noble cause of moulding a healthy generation.

Keywords: Dairy-based Functional Beverages, COVID-19, Consumption Behaviour, Non-Communicable Diseases (NCDs), Food and Beverage Marketing

INTRODUCTION

According to a recent survey report by the Confederation of Indian Industry (CII) and Grant Thornton India LLP, India will become the world's fifth-largest consumer market by 2025. The survey also revealed that food and drinks are the most popular consumption category in Indian markets. The colossal Indian agriculture supports the food and beverage industry to flourish. India adorns the position of being the world's largest producer of milk and buffalo meat production in the world. Following the liberalization of the Indian economy in the early 1990s, company barriers were reduced, creating a favourable industrial climate for the food and agro-processing sector (*CII Social Impact Report*, 2019). The sector has gained more market access with the emergence of various retail formats such as malls, hypermarkets, and supermarkets.

India, with a population of over 1.3 billion, is undoubtedly a big global consumer market. Annual household consumption in India is predicted to triple by 2030, propelling the country to the fifth-largest consumer base globally (Memon, Pawase, Pavase, & Soomro, 2021). With a median age of 28 years, the Indian population is substantially younger than many other Asian countries. The urban population is growing, with 34.5 per cent residing in cities. Almost half of the population in India comes under the age of 30 years, and most start working and earning themselves quite earlier to acquire a better standard of living. Higher-income consumers have more spendable money. Rising urbanization and a fast-growing youthful population drive the food and beverage business, transforming customer needs. The youth population with more disposable incomes propel the growth of the Indian food industry (*India Food & Drink Report - Q4*, 2021).

CHANGING PRIORITIES IN FOOD & BEVERAGE CONSUMPTION

A lion-share of Indian consumers consider food and beverages with added health benefits appealing, and it is expected that natural and organic energy drinks sales will touch the mark of 32 billion USD by 2025, which accounts for roughly 40% of the beverage market (Kondekar, 2019). Rapid urbanization connected with the influx of professionals in urban centres and exposure to western lifestyles is aiding the spectacular growth of India's processed food and beverage segment. India's food and beverage market slowly transform from carbohydrate and fat-rich diets toward protein- and vegetable-rich foods. The non-alcoholic beverage business in India is valued at around USD 16 billion. Tea and coffee are the most popular beverages, followed by soft drinks (carbonated beverages and juices), health drinks, milk-based beverages, flavoured beverages, and energy drinks. Unpackaged tea and coffee make up about half of all tea and coffee consumed worldwide (Memon et al., 2021). It is estimated that over the 2021-2025 period, there will be real growth in food and drink spending as wages increase. India's young population promises enormous growth prospects for food and beverage investors in the future years (*India Food & Drink Report - Q4*, 2021).

Consumer reaction to food products is a very complicated and continually changing area. It encompasses various scientific fields, including food science, nutrition, dietetics, psychology, physiology, biochemistry, and marketing science. As one would anticipate in such a field of study, the vocabulary applied to characterize consumer behaviour ideas, and the methods for assessing them varies from one study area to another. Consumer acceptability of food products is one such idea, and several logical theories have emerged representing various aspects of food acceptance that are being researched. When designing new food products, it is critical to understand consumer preferences and expectations. Furthermore, global dynamics impact nutrition trends, influence eating habits and disrupt proper diet balance. Numerous variables impact the development of new food items. Demographics, socioeconomics, culture, politics, and the environment heavily influence consumer habits and eating trends. Indeed, global challenges such as climate change, global population ageing, exploitation, food waste, unfair trade, and animal suffering, to name a few, are altering consumer attitudes toward healthy, plant-based, sustainable, and socially conscious food choices. It should be emphasized that, due to the emergence of new technologies, customers now have easier access to information and an unparalleled ability to fight for change (Arenas-Jal, Sune-Negre, Perez-Lozano, & Garcia-Montoya, 2020). Food scientists should keep an eye on the significant and emerging trends shaping the food industry in this context and adapt formulas and technologies to address consumer needs.

The past few decades witnessed a general trend that consumers are increasingly aware of healthy eating and are more sensible about health maintenance through a balanced diet. Consumers today are increasingly mindful of a healthy lifestyle and the detrimental consequences of poor eating habits. The prevalence of lifestyle illnesses is the source of this worry (Shamal & Mohan, 2019). Healthy food products are now an integral part of the human diet. Gone are those days wherein a "one-size-fits-all" marketing strategy could be adopted in food products marketing. Food marketers, too, need to do a lot of homework to devise personalized and customized marketing strategies for the present-day food consumer. This trend escalated the demand for *Dairy-based Functional Beverages* that offer additional benefits beyond satiety and essential nutrition.

FUNCTIONAL BEVERAGES – THE 'TREND-SETTERS' TODAY

A *functional beverage* is defined as "a non-alcoholic drink that contains non-traditional ingredients, including herbs, vitamins, minerals, amino acids or added raw fruit or vegetable ingredients, which is claimed to provide specific health benefits beyond those of general nutrition—e.g., boosting or enhancing the immune system or heart health, improving joint mobility, increasing sense of well-being, increasing energy and satiety (Segen's Medical Dictionary, 2011)". Functional beverages endow boundless blends of herbs, spices, probiotics, antioxidants, vitamins and adaptogens with health, mood, and energy-boosting properties customized to each potential consumer market segment. The functional beverages segment represents the "most prominent and fastest-growing part of the functional food industry", comprising the food, beverages, and food supplement sectors (Tolun & Altintas, 2019). Many previous studies revealed the necessity to promote specific nutrient-based food items that have proved effective against certain diseases, infections, and metabolic disorders. The rise of functional beverages has been attributed to specific critical factors such as increased consumer awareness of health deterioration due to the busy life, poor food choices and a sedentary lifestyle, scientific advancements in nutrition research, increased awareness of the link between diet and health and a highly competitive, crowded food market. There is a mounting demand for "healthiness-on-the-go beverages with functional attributes," especially among millennials. Customers choose daily beverages containing natural ingredients and variations in the composition enabling hydration to the body added with performance and prevention of specific illnesses.

Functional beverages, as the most active category in the functional food products basket, have the merits of (i) convenience and the flexibility to customize in tune with customer demands for content, shape, size and overall appearance; (ii) ease of storage and distribution in case of shelf-stable and refrigerated products; (iii) opportunity to pool, hold and sustain nutrients and bioactive compounds in the best active form possible (Kausar, Saeed, Ahmad, & Salam, 2012; Sanguansri & Augustin, 2010). Commercially available functional beverages could be classified as (i) "Vegetable and fruit-based beverages", (2) "Dairy-based beverages including probiotic drinks", and (3) "Sports and energy drinks" (Corbo, Bevilacqua, Petruzzi, Casanova, & Sinigaglia, 2014). Customers now purchase these health-based food products to prevent "Non-Communicable Diseases (NCDs) like diabetes, cardiovascular diseases, chronic lung disease, osteoporosis, and Alzheimer's disease". They aim to optimize body immunity to maintain good health and general well-being (Khan, Grigor, Winger, & Win, 2013). The baby-boom generation is affluent. As they age, they are prepared to expend more on items that add to their quality of life.

To rightly uphold what Hippocrates said once, *Let food be thy medicine,* consumers today endorse that plant medicine has the vast potential to heal many ailments. For example, turmeric added in a golden milk mocktail has been well known for its anti-inflammatory properties. These functional beverages enable people to make crucial health decisions in daily life, such as drinks, eateries, and personal care products. These beverage brands listen to their target market and offer them what they desire. Consumers today have numerous choices that must be pulled down to a brand's feel – it's packaging, message, voice and the brand experience at home (Dockendorf, 2019). Moreover, the busy life in urban centres calls for better aesthetics in food and beverage availability to upkeep higher standards of living (Nazir et al., 2019).

COVID-19 PANDEMIC AND THE DAIRY-BASED FUNCTIONAL BEVERAGES

COVID-19 is undoubtedly one of the century's most dreadful public health emergencies. Many countries in the world are still amid this catastrophe. A study on the U.S. population released by the Hartman Group in January 2021 declared that "the issue of immunity has never been more important than it is now", and consumers "are incorporating supplements, functional foods and wellness strategies more and/or for the first time since the COVID-19 pandemic occurred." The COVID-19 pandemic has profoundly influenced food consumption habits, patterns, and behaviours. Customers today recognize the importance of improving their body immunity to protect their general well-being. Consumers acknowledge the connection between diet and health. They recognize that they must focus primarily on boosting their body immunity to ensure general well-being. This could be a prime reason for a recent surge in dairy-based functional beverage sales containing antioxidants, probiotics, prebiotics, 'super fruits', and other ingredients with immune-boosting properties. During this post-pandemic time, they prefer health-based foods and beverages to avert the incidence or worsening of Non-Communicable Diseases (NCDs) or *Lifestyle diseases* like diabetes, cardiovascular diseases, chronic lung disease, *osteoporosis*, and *Alzheimer's* disease. Consumers are now looking at food products and food brands through a different lens. An era has taken off wherein consumers will be more 'fastidious' for healthier and sustainable food products. Companies, especially in the food and health sector, must cope with ever-changing consumer behaviour patterns to win their target market during the post-pandemic period (Qi & Ploeger, 2021). It must always be acknowledged that hygiene and sanitation aspects alone won't suffice. A nutritious diet loaded with vitamins, minerals and bioactive components is critical for boosting our immune system (Makroo, Majid, Siddiqi, Greiner, & Dar, 2020). Beverages, especially dairy-based ones, are good ways to get functional ingredients into the body.

During the COVID-19 pandemic, "because no adverse effects were reported to date, natural herbs, antioxidants, prebiotics, nutraceuticals, probiotics or functional foods were judiciously used in the management of common colds and flu at least to prevent secondary respiratory infections in the population (Rastmanesh, Marotta, & Tekin, 2020)". The research world has not yet received any concrete evidence to prove that the intake of certain foods with beneficial ingredients would support our body to fight against the novel Coronavirus infection. But many of the previously concluded research studies support that *functional beverages* would bestow specific beneficial effects on the human body, improve overall health, and help the body fight against certain invasive viruses. Such foods and beverages in preventing diseases and their treatment are getting scientifically proven and well acclaimed. A few recently concluded clinical studies revealed that zinc, curcumin and zincionophores possess immense antiviral properties against viral infections. Dairy-based beverages are good ways to get functional ingredients into the body. With the outbreak of COVID-19, food marketers in India have proved exceptional in their agility to the changing realities, and they responded well with innovative solutions. The result was excellent functional beverage products of dairy origin developed with scientific backing focused on consumer health, nutrition, and general wellness such as 'Haldi Milk' or 'Golden Milk' which is a fine fusion of lifestyle and Ayurveda. Hypermarkets and Supermarkets are now flooded with many dairy-based functional beverages claiming to offer better immunity and added health benefits; consumers would be confronted with a gamut of apprehensions about choosing or not choosing these for their daily food basket. Marketers should take note of such changes in consumer behaviour and value the ever-increasing focus on health by consumers. It is for sure that adopting a health-based strategy would dictate food business success in the likely future. The correct market information would enable the beverage industry to conceive and develop Branded Dairy-based Functional Beverages with desired features that better address consumers' health needs. With the increased use of online shopping modes and food delivery apps, functional beverage brands will have a massive e-commerce growth trajectory in the years to come (N Thamaraiselvan, Jayadevan, & Chandrasekar, 2019). As reported in several recently concluded studies, food marketers should focus on 'opinion' leaders and subject experts in their Integrated Marketing Communication campaign to positively influence the subjective norms of potential BFB customers (Natarajan Thamaraiselvan, Jayadevan, & Jegan, 2022). It is possible to experiment with celebrity endorsements in functional beverage advertisements and sales promotion activities. Food marketers are advised to build their strategy around consumer confidence, duly communicating the trust appeals and reassurance. The dairy companies shall work out suitable options for easy availability of functional beverage products at the consumer's doorstep through m-commerce and e-commerce platforms at competitive prices.

CONCLUSION

The COVID-19 pandemic virtually shattered our food system and modified our associations with food in many different ways. The pandemic has profoundly impacted the eating and drinking habits of consumers globally. These have endowed massive opportunities for innovations in food research and development. The perception of health risks associated with COVID-19 has influenced people's food purchase and consumption behaviours. It is observed that health-conscious people would prefer more health-promoting beverages to strengthen their immunity. Several reports disclose that food consumers in India demand functional beverages more extensively than before to include in their daily food baskets. Markets are now flooded with healthy dairy-based beverage brands, having added 'functional' ingredients and health boosters. Consumers in the dairy-based functional beverage market are increasingly interested in products having organic or natural ingredients. They distrust artificial food colourings and sweeteners, which are harmful to health. This scenario offers dairy/food processors an excellent opportunity to develop and market their functional beverage products competitively with the judicious use of natural ingredients that possess established health benefits. Augmenting public health through health and nutrition-related food products marketing in the post-pandemic period is much needed in a developing economy like India.

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RESEARCH INTERVENTIONS FOR SUSTAINABLE LIVESTOCK PRODUCTION-ADAPTATION STRATEGIES

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ABSTRACT

Climate change adaptation strategies in the livestock sector have become a crucial area of focus in recent years, as the impact of changing weather patterns and extreme weather events on livestock production continues to be felt by farmers around the world. A number of strategies have emerged aimed at building resilience and mitigating the negative impacts of climate change on livestock, including improved feeding regimes, tree planting to provide shade and shelter from heat stress, water management practices to conserve scarce resources and reduce losses due to droughts or floods, and breeding for heat tolerance. These strategies are not only designed to protect animal health and welfare but also ensure livelihoods are secure in the face of an increasingly uncertain climate future. Adoption of these adaptation measures will require significant investment, technical expertise and changes in behaviour by farmers, policymakers as well as other stakeholders involved in the livestock value chain.

INTRODUCTION

Climate change is increasingly impacting livestock producers and the animals they raise (Perkins-Kirkpatrick and Lewis, 2020). Research interventions offer organic and inexpensive ways to help adjust operations and practices in order to increase resilience and adaptation to projected climates. Proper implementation of research interventions will help ensure the survival of livestock producers and promote better animal welfare (Thornton et al., 2009).

A primary research intervention is related to the selection of animals (McAlpine et al., 2009). Livestock selection affects hardiness and thus an animal's ability to adjust to changing climates. The efficiency of feed, and milk production, as well as coat and foot characteristics, should be considered when selecting animals. Research is increasingly showing that short-haired, smaller-framed animals generally fare better in higher temperatures than long-haired, larger-framed animals.

In addition to the selection of animals, researchers suggest the use of housing systems better suited to warmer climates (Robinson et al., 2014). Increasing the airflow and natural ventilation inside animal sheltering encourages cooler environments and allows for better dispersal of heat. This can be achieved by altering the size, shape, material, and/or orientation of housing for certain species, or simply utilizing design features such as curtains or shade structures.

A second research intervention involves changes to husbandry practices. Specifically, with higher temperatures comes the need to provide cool and reflective surfaces in the animals' environment (Collier et al., 2019). This is necessary to dissipate the animal's body heat either by increased airflow or cooling through the water. Keeping the animals' water cool and providing various methods of cooling through fanning, spraying, and cooling pools should be considered. It is also important to make sure the animals' environment is as dust-free as possible to ensure healthy airflow.

Lastly, researchers recommend providing extra nutrition in preparation for hotter climates. During extreme temperatures, animals will likely require more energy to mitigate stress as well as extra nutrients to combat dehydration. If needed, additional supplements such as protein, minerals, and vitamins may be implemented to respond to changing climates.

Climate change has been an increasing concern and is thus a pressing issue to consider when discussing livestock adaptation (Herrero et al., 2015). As the global climate warms and weather patterns become more unpredictable, the adaptation of livestock is needed to ensure livestock production systems are sustainable and productive.

One way to ensure livestock adaptation is through the use of technology and innovation. The use of data collection, monitoring and modelling systems have allowed production practices to become more precise and efficient. The use of data-driven technology and monitoring systems allows livestock owners to be able to track various aspects of the production system and make timely adjustments accordingly. Such data can lead to informed decisions on livestock system management practices such as what type of breeds or genetics to implement or improve adoption of precision feeding, as well as improving feeding strategies, animal welfare and health practices.

Additionally, the use of genetic engineering has allowed livestock to be bred for greater heat tolerance and less energy required for growth (Brito et al., 2021). With the increased number of heatwaves, having animals with better tolerance can ensure their performance and production are not significantly affected. Heat-tolerant breeds which have been developed through genetic engineerings, such as hairless chicken and pig breeds, can be more resilient to heat and thus could maintain a better level of productivity (Rexroad et al., 2019).

It is also important to invest in different types of feed that could be more sustainable and resilient to climate change. Feeds that are more drought-tolerant can be used as a form of coping during times of environmental stress. As plants yield more biomass and are more resilient to environmental extremes, they can also provide varying nutrients to animals that can aid in the production of higher-quality products and thus make the livestock industry more efficient.

CONCLUSIONS

In order to ensure that livestock adaptation to climate change is successful, it is essential for appropriate and innovative practices to be implemented. Technologies such as data-driven systems, genetic engineering, and efficient and resilient feed can be used to help production systems become more efficient and resilient in the face of climate change. With these tools, livestock adaptation to climate change can become a reality, ensuring the long-term sustainability of the livestock industry. Ultimately, research interventions are rapidly becoming necessary for responding to warming climates. The selection of animals and the use of housing systems better suited to hotter climates, along with changes to husbandry practices and the inclusion of additional nutrients, can help prepare livestock producers and their animals for changing temperatures.

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MANAGEMENT OF ANIMAL GENETIC RESOURCES FOR SUSTAINABLE PRODUCTION

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ABSTRACT

A system or procedure is sustainable if it is acceptable now and if its effects will be acceptable in future, in particular in relation to resource availability, consequences of functioning and morality of the action. Earlier definitions considered the system to be unsustainable when the resources became exhausted to the point where it was no longer available to the system or it affected the functioning of the system. Due to the increase in human population and consumption of animal products, livestock production systems become more complex and intensive in their use of both human and environmental resources. Achievement of sustainable livestock production becomes more challenging every year due to either an increase in the scarcity of resources or an increase in the fragility of system interactions. The livestock sector in India plays a key role in addressing many sustainable development goals by supporting livelihoods, generating income and employment opportunities, and contributing to healthy diets and climate resilience. It is an integral part of the Indian economy supporting the livelihood of more than two-thirds of the rural population. Livestock provides milk, egg and meat as nutritious food; draught power for agriculture; fibre; manure and domestic fuel; and hides and skin. On the contrary, in developing countries, animal production is marked by a high level of vulnerability, which is exacerbated by a number of problems, including climate change. This is further complicated by the occurrence of infectious and non-infectious diseases or seasonal fluctuations in feed resources resulting from the additional environmental stressors. To effectively address these challenges, it is important to characterize and protect the animal genetic resources (AnGR) of the country. The diversity of animal genetic resources is broad, both in variety and variability in terms of species, breeds, populations and unique genotypes. The management and preservation of biodiversity are crucial for ensuring the sustainability of agriculture and livestock production. Indigenous AnGR is known for its adaptability to changing climates and ability to withstand extreme conditions. Also, it plays a vital role in providing livelihood security to billions of people around the world. So, it is important to promote the conservation and genetic improvement of indigenous breeds as livestock rearing is closely linked to the agricultural economy. Understanding the existing information on animal

production systems together with the prevailing challenges may help in the development of the breeding plan for a sustainable production system. Therefore, in this review, we will evaluate the current status of AnGR management, the importance of AnGR management for sustainable animal production and the need for effective management strategies, and breed improvement programmes and pathways for sustainable management of AnGR to meet the future demands of the country.

INTRODUCTION

Animal genetic resources (AnGR) are defined as the genetic diversity in domesticated animal species with economic or other socio-cultural values that can be found among species, animal breeds within species, and cryopreserved materials such as embryos and frozen semen (Kantanen *et al*., 2015). In general, the term 'animal genetic resources' is used to refer to all animal species, breeds and strains that are of economic, scientific and cultural interest to humankind in terms of food and agricultural production for the present or the future. The sustainability and robustness of animal production systems and future food security require accessibility to a wide diversity of animal genetic resources (Hoffman, 2010; Pilling and Hoffman, 2011). A system or procedure is sustainable if it is acceptable now and if its effects will be acceptable in future, in particular in relation to resource availability, consequences of functioning and morality of action (Broom *et al*., 2013). AnGR, serve as a raw material for animal breeders by encompassing the genetic diversity of animal populations and providing the foundation for animal breeding and genetic improvement programmes (FAO, 2007). The diversity of animal genetic resources is broad, both in variety and variability in terms of species, breeds, populations and unique genotypes (NAAS, 2001).

Animal genetic resources are considered the most valuable and strategically important asset for a country. These resources play a vital role in addressing many sustainable development goals for a country by providing livelihood security to billions of people around the world, generating income and employment opportunities, and contributing to healthy diets. Farm animal provides milk, egg and meat as nutritious food; draught power for agriculture; fibre; manure and domestic fuel; and hides and skin. However, despite the importance of AnGR, many livestock breeds are at risk of extinction around the world. This loss of genetic diversity reduces the options available for future breeding programs and can have negative impacts on food security, rural livelihoods and cultural heritage. Due to the increase in human population and consumption of animal products, animal production systems become more complex and intensive in their use of both human and environmental resources. Moreover, AnGR are threatened by a range of factors, including genetic erosion, loss of diversity, unsustainable use (FAO, 2007), and climate change. These threats pose a significant risk to the long-term viability of animal populations and to the ability of animal production systems to adapt to changing environments and to maintain the biodiversity of animal species. Also, the management of AnGR is influenced by a range of socio-economic and policy factors, such as limited resources, conflicting interests, and complex genetic and environmental interactions. As a result, the achievement of sustainable animal production becomes more challenging every year. Effective management of AnGR is therefore essential for ensuring their long-term viability and for supporting the development of sustainable animal production systems.

In this review, we have provided an overview of the current status of the management of AnGR for sustainable production. We have discussed the importance of AnGR for sustainable animal production and the need for effective management strategies. We have provided an overview of the various approaches used for managing AnGR, including *in-situ* and *ex-situ* methods of conservation, phenotypic/genetic characterization and evaluation, breeding programs and genetic improvement of AnGR. Finally, we have highlighted the pathways for sustainable management of AnGR.

THE IMPORTANCE OF ANGR FOR SUSTAINABLE ANIMAL PRODUCTION:

Animal genetic resources have numerous benefits for agriculture, food security, animal health and welfare, and the environment. Aside from cultural and religious considerations, all breeds of domestic livestock and poultry species contribute significantly to food and agriculture in terms of milk meat, wool, fibre, egg, manure, fuel, and draught power. The use of various AnGR has been influenced by variations in regional demand for animal products. AnGR have been developed and selected over centuries for various adaptive traits such as improved digestion, thermo-tolerance, disease resistance, fertility, longevity, and improved production traits, with social, cultural, economic, and ecological significance. From economic point of view, AnGR can have various different types of value for conservation, and it can be categorized as follows:

- Food value: Milk, meat, eggs and their byproducts
- Energy value:
    - Draft power: Cattle, buffaloes, camel and horse
    - Pack animals: Mules, yak and donkeys
    - Fuel power: Dung cakes and logs
- Ecological value:
    - Soil fertility: Dung (large ruminants), faeces (small ruminants), urine
    - Scavengers: Pig and poultry
- Therapeutical value: Milk of cattle, buffalo, camel, goat and donkey

- Pharmaceutical value: Milk and blood proteins
- Entertainment value:
  - Sports: Horse polo, cart races, camel races, bird fights, horse dancing
- Diversity value:
  - Adaptive traits: Thermo-tolerance, disease resistance, utilization of coarse fibres, higher milk constituents
  - Biodiversity: A large number of breeds, strains/lines and varieties
- Social value: Employment generation, women empowerment, barter system, pride of possession.

NEED FOR MANAGEMENT OF ANGR

- Fast growing human population and increasing demand for animal products
- Diversity as genetic security
- To conserve unique characters/genes (such as disease resistance, and heat tolerance)
- High production in a low-input system
- To improve the socioeconomic status
- Employment generation

GLOBAL SCENARIO OF ANGR

To meet the food demand in the upcoming global scenario, management of animal genetic resources would be challenging for sustainable agriculture and livestock production. The food and Agricultural Organization (FAO) of the United Nations support policy work towards sustainable livestock from a social, economic and environmental perspective, and the development of methods and tools to support science and evidence-based policies. FAO promotes sustainable, inclusive and efficient livestock transformation for better production, better nutrition, better life and a better environment, leaving no one behind. In the year 2007, FAO adopted the Global Plan of Action (GPA) for Animal Genetic Resources (also known as Interlaken declaration) was the first internationally accepted framework for the management of AnGR diversity in recent times. The courtiers only realized the significance of maintaining an inventory of native germplasm as a necessary step for preserving it in the long term after the implementation of the global plan of action.

As per the report of Global Databank for Animal Genetic Resources (managed by the FAO, which forms the basis of the Domestic Animal Diversity Information System (DAD-IS), a total of 8774 extant breeds belonging to 38 species (20 mammalian and 18 avian species) were reported across

182 countries, in 2014. Among these, 7718 are considered local breeds (i.e., they are found in one country) with 510 classed as regional transboundary breeds (i.e., they are found in more than one country within a single geographical region), and 546 are considered as international transboundary breeds (i.e., they occur in more than one geographical region) (FAO, 2015). The report also highlighted those breeds, primarily local, which are considered to be at risk, due in part to replacement by more highly productive breeds (FAO, 2015). Especially, selective breeding for highly productive types has led to growing concerns about the erosion of genetic resources of livestock specifies culminating in decreased genomic diversity, which could make species susceptible to a yet unforeseen future challenge (FAO, 2015).

According to the Animal Genetic Resources Strategy for Europe, there are currently around 8,800 recorded breeds in the world, with approximately 7% already extinct, 24% at risk of extinction, and 50% with unknown status (Anonymous, 2021). Only eight of the 40 domesticated mammalian and avian species provide more than 95 per cent of the human food supply from livestock (Anonymous, 2021). Additionally, several breeds are in danger of inbreeding due to a lack of genetic diversity within the breed. According to the World-Wide Fund for Nature's (WWF) Living Planet Report-2022, there has been a significant decrease of 69% in global wildlife populations from 1970 to 2018, demonstrating a severe biodiversity crisis (WWF, 2022). This significant disturbance to the ecosystem should be taken as an urgent warning to take action to stop the decline and protect endangered species from extinction.

CURRENT STATUS OF ANGR IN INDIA

The Indian subcontinent is one of the mega biodiversity centres, where the domestication of plants and animals took place in ancient times. The region boasts an incredibly wide and diverse range of biodiversity. In India, the domestication of animals such as cattle, buffalo, sheep, goats, pigs, camels, horses, donkeys, yaks, and mithun has been a long-standing practice. In the case of poultry, the region has chickens as well as ducks, geese, quails, turkeys, pheasants, and partridges. Other species like elephants, dogs, and rabbits are also significant in certain areas. Due to the loss of many breeds over time, the conservation and sustainable use of animal genetic resources (AnGR) have become an essential and pressing issue for the country. In India, AnGR has been documented in terms of distribution, use, and morphological characteristics. Most cattle and buffalo breeds are kept at state-owned farms where growth, production, and reproduction data are recorded and maintained. For other AnGR species, there are few farms where performance data on maintained breeds are regularly recorded. Figure-1 shows the current status of indigenous livestock, poultry, and dog breeds that have been characterized/registered (total of 212) in India by ICAR-NBAGR, Karnal (NBAGR, 2022). Table-1 lists the total livestock population (species-wise) and total poultry population of India, as per the 20th Livestock Census Report (DAHD, 2019).

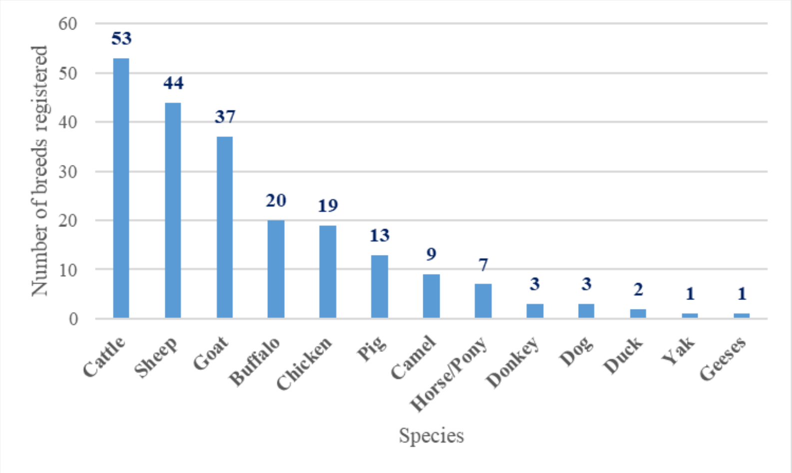

Figure-1: Registered breeds of India as per ICAR-NBAGR, Karnal

Table-1: Total livestock (species-wise) and total poultry population of India

Species	Population (in million) as per Livestock census-2007	Population (in million) as per Livestock census-2012	Population (in million) as per Livestock census-2019	% Change over previous census
Cattle	199.08	190.90	193.46	1.34
Buffalo	105.34	108.70	109.85	1.06
Sheep	71.56	65.07	74.26	14.13
Goat	140.54	135.17	148.88	10.14
Pig	11.13	10.29	9.06	-12.03
Mithun	0.26	0.30	0.39	29.52
Yak	0.08	0.08	0.06	-24.90
Horse/Pony	0.61	0.62	0.34	-45.22
Mule	0.14	0.20	0.08	-57.09
Donkey	0.44	0.32	0.12	-61.23
Camel	0.52	0.40	0.25	-37.05
Total Livestock	**529.70**	**512.06**	**536.76**	**4.82**
Total poultry	**648.90**	**729.21**	**851.81**	**16.81**

*The per cent change is calculated upon absolute values.

Recently, ICAR-NBAGR, Karnal has published a "National Breed Watchlist-2022" based on data from the 20th Livestock Census conducted by the DAHD, Govt. of India. The Watchlist highlights the current risk status of India's native livestock and poultry breeds (Table-2). The main objective of this program is to work with state animal husbandry departments and universities to preserve and conserve the genetic resources of indigenous livestock and poultry.

Table-2: Risk status of livestock and poultry breeds in India (adapted from National Breed Watchlist-2022)

Species	Cattle	Buffalo	Sheep	Goat	Pig	Horse	Camel	Chicken
Critical	-	-	Tibetan	Teressa	-	-	-	-
Endangered	Belahi, Krishna Valley, Khariar, Pulikulam	-	Karnah, Katchaikatty Black, Nilgiri	Chegu, Sumi-Ne	Angoda Goan, Tenyoi Vo	Bhutia, Kachchhi Sindhi, Manipuri, Spiti, Zanskari	Malvi, Mewati, Mewari	-
Vulnerable	Mewati, Punganaur, Siri, Ponwar, Vechur	Chilika, Toda	Gurej, Jalauni, Kendrapada, Poonchi, Rampur Bushair	Konkan Kanyal	-	-	Jalori, Kharai, Marwari	Kalasthi

AVAILABLE DATABASES ON ANIMAL GENETIC RESOURCES

An information system is a combination of persons, databases and procedures to store, control and provide information for various levels of management. The database is an essential component for the effective implementation of an information system. Developing and maintaining a database on Animal Genetic Resources (AnGR) allows for the analysis of livestock breed diversity on a national, regional, and global scale. It also helps in the evaluation of breeds regarding their risk of extinction and in the creation of breed improvement and conservation programmes. Different information systems/databases pertaining to AnGR are listed in Table-3.

Table-3: Information systems/databases related to animal genetic resources

Sl. No.	Database/ Iinformation system	Details	Web source
1.	Animal Genetic Resources of India-Information	The AGRI-IS database was developed in 2002 by ICAR-NBAGR, Karnal, India. This database includes information on all of India's native breeds of domestic livestock and poultry species. The database includes breed descriptions, farm information, semen and	http://14.139.252.116/agris/breed.aspx

	System (AGRI-IS)	vaccine production, and information on population, animal breeding, animal health infrastructure, and animal products such as milk, meat, eggs, and wool, etc. Additionally, the database stores photographs of male and female animals of various breeds.	
2.	Geographical Information System (GIS) on AnGR	A GIS on AnGR of India has been developed at ICAR-NBAGR, Karnal with the underlying database available in AGRI-IS to view breed habitat in map form. The GIS provides an integrated view of all information related to a specific theme and can be explored and compared based on geographic coordinates. This enables users to extract and display breed habitats on a map. AnGR can be classified and visualized based on geographic regions and traits such as body length, heart girth, body weight, and milk yield. Maps, including legends, can be saved as PDF or image files.	www. nbagr.icar.gov.in
3.	Domestic Animal Diversity Information System (DAD-IS)	The DAD-IS is a crucial tool for implementing the Global Strategy for the Management of Farm Animal Genetic Resources (AnGR). It is developed and maintained by the Food and Agriculture Organization of the United Nations. DAD-IS provides access to searchable databases of breed information and photos, and links to other online resources on livestock diversity. Additionally, it contains the contact information for all National Coordinators for the Management of Animal Genetic Resources. DAD-IS enables the analysis of livestock breed diversity on national, regional, and global levels, including breed extinction risk status.	https://www.fao.org/dad-is/en/
4.	Domestic Animal Genetic Resources Information System (DAGRIS)	The DAGRIS was developed by the International Livestock Research Institute (ILRI) in Nairobi, Kenya. It is based on the need for information on the extent of existing diversity, characteristics, and use of indigenous farm animal genetic resources in developing countries to ensure their sustainable utilization for now and in the future. Given the absence of a systematic database on this information, ILRI developed DAGRIS as a web-based platform for information on selected indigenous farm animal genetic resources (breeds/ecotypes of cattle, sheep, goats, chickens, and pigs) with plans to expand it to cover geese, turkeys, and ducks. DAGRIS currently covers Africa and selected	http://dagris.ilri.cgiar.org/

		Asian countries, with plans to expand to developing countries in Asia and Latin America and the Caribbean. This information system is designed to efficiently compile, organize, and disseminate information on the origin, distribution, diversity, current use, and status of indigenous farm animal genetic resources, based on past and present research results. The underlying concept is that such information is essential for the development of breed improvement and conservation programs.	
5.	European Farm Animal Biodiversity Information System (EFABIS)	EFABIS is being maintained and updated by the European Regional Focal Point (ERFP) and the European Association for Animal Production (EAAP), who have recognized the importance of documenting and disseminating information about animal genetic resources in Europe and raising awareness about their conservation and sustainable use. EFABIS includes passport, descriptive, and performance data, as well as information about the populations and other data of animal breeds in Europe. It is currently managed by the Food and Agriculture Organization of the United Nations (FAO) on behalf of both EAAP and ERFP. As a neutral platform, EFABIS facilitates the distribution of national data provided by European National Coordinators. It is an integral component of the global Domestic Animal Diversity Information System (DAD-IS).	https://www.animalgeneticresources.net/index.php/animal-genetic-resources/efabis-information-system/

MAIN REASON OF GENETIC EROSION TO ANGR: THREATS TO THE DIVERSITY

Genetic erosion is defined as the permanent reduction in the number, evenness and distinctness of alleles, or combinations of alleles, of actual or potential agricultural importance in a defined geographical area (FAO, 1999). It is a cause for concern on both a national and global level, with numerous animal breeds facing the risk of extinction. According to FAO (2007), there are eight factors contributing to the genetic erosion of AnGR:

i. Indiscriminate crossbreeding
ii. Introduction or increased use of exotic breeds
iii. Week policies or institutions
iv. Lack of profitability or competitiveness
v. Production system intensification
vi. Diseases/ disease management

vii. Loss of pasture or production environment

viii. Poor control of inbreeding

Genetic erosion, or the reduction of genetic diversity in a defined geographical area, is a growing concern for animal genetic resources (AnGR) and is caused by various factors such as limited use of specific breeds in breeding programs, lack of breeding plans, unrestricted interbreeding, and more. Inbreeding leads to a loss of genetic diversity and decreased reproductive fitness. The global community has become increasingly concerned about the evaluation and preservation of genetic diversity in domestic animals. Understanding the factors that cause genetic diversity is crucial for the effective management of livestock populations. Worldwide efforts are being made to conserve livestock diversity. Threats to animal genetic resources can be sudden and require prompt action in some cases, such as armed conflicts, disease outbreaks, droughts, and other environmental emergencies. Monitoring the risks at a national, regional, and global level by tracking the size, structure, and distribution of breed populations will be beneficial in setting up early-warning systems and response mechanisms. It's important to keep a watchful eye on the trends in these populations to identify breeds that are at risk of extinction and prioritize conservation efforts. Additionally, threats to AnGR must be clearly identified and their potential impacts better assessed, so that action can be taken to combat them or minimize the risk they pose to diversity.

SUSTAINABLE DEVELOPMENT GOAL 2

The United Nations has recognized the significance of preserving animal genetic resources (AnGR) biodiversity through its Sustainable Development Goals (SDGs) set in 2015, wherein it appealed for the management of all genetic resources worldwide specifically to promote sustainable agriculture and achieve food security. The aim of SDGs is to create a better future for everyone, everywhere by ending poverty, protecting the planet, and improving lives. In particular, the 17 Goals adopted by all UN member states aim to end hunger and promote sustainable agriculture by 2030. Sustainable Development Goal 2 (Zero Hunger) has 8 targets (https://sdgs.un.org/goals/goal2), including Target 2.5 (Indicator 2.5.1: Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities; and Indicator 2.5.2: Proportion of local breeds classified as being at risk of extinction) are well related to the farm animal biodiversity. The target also promotes fair access to benefits derived from genetic resources and associated traditional knowledge. Sustainable livestock production systems contribute to food security, economic development, environmental stewardship, and sociocultural necessitates, and are essential for achieving the majority of the UN SDGs. They are important for improving human nutrition, health, and economic productivity. To promote these systems in low- and middle-income countries, concerted efforts are necessary.

NATIONAL MISSION TOWARDS ZERO NON-DESCRIPT ANGR IN INDIA

ICAR-NBAGR, Karnal is committed to achieving the United Nations towards the Sustainable Development Goal 2: Zero Hunger. As a result, the Bureau has launched a nationwide documentation effort of all native animal genetic resources, titled "Mission towards Zero Non-descript AnGR of India", in partnership with various stakeholders on 11th August 2021. Different regions of the country have been surveyed, including Ladakh, Maharashtra, Jharkhand, Mizoram, Meghalaya, Arunachal Pradesh, Sikkim, Tripura, Manipur, and Assam. Projects on documentation of AnGR are being implemented in 22 states/ Union Territories in collaboration with State Animal Husbandry Departments, ICAR institutes (including Krishi Vigyan Kendra) and State Veterinary/Agricultural Universities. As a result, ten new populations of native AnGR have been identified after the launch of the mission (NBAGR, 2021). Under SDG Indicator 2.5.1, the bureau has also cryopreserved germplasm for native animal breeds in form of semen and somatic cells for long-term conservation and has conserved many threatened breeds through the involvement of livestock keepers and stakeholders in the network program. Documentation of AnGR is the most crucial in the management of AnGR biodiversity in the country. ICAR-NBAGR is the nodal agency for the management of the national wealth of AnGR, especially working on identifying, and characterizing breeds, documenting new germplasm, and conserving native livestock and poultry diversity in India.

GLOBAL PLAN OF ACTION FOR MANAGEMENT OF ANGR

The intense selection and improvement of animal husbandry practices have led to increased meat, milk, and egg output in production systems. This rapid progress, with an average annual production increase of 2%, demonstrates the potential of animal genetic resources to contribute to food security and rural development (FAO, 2007). However, these efforts are primarily focused on short-term production and ignore the long-term consequences and environmental impact of intensive production systems, including the reduction of genetic diversity. To address this issue, FAO launched the Global Strategy for the Management of Farm Animal Genetic Resources in 1993 to guide national, regional and global efforts to strengthen the contribution of domesticated animals and their products to food security and rural development and to prevent the erosion of animal genetic resources. In 2007, the international community adopted the first-ever Global Plan of Action for Animal Genetic Resources, comprising of 23 strategic priorities grouped into four strategic priority areas (Table-4) to combat the erosion of animal genetic biodiversity and promote sustainable use. This plan consists of three parts: the rationale, strategic priorities for action, and implementation and financing. Although national governments hold the primary responsibility for implementing the Global Plan of Action, non-governmental and intergovernmental organisations are also expected to play a significant role.

Table-4: Strategic Priority Areas for management of AnGR

Strategic priority Area 1	Characterization, inventory and monitoring of trends and associated risks
Strategic priority Area 2	Sustainable use and Development
Strategic priority Area 3	Conservation
Strategic priority Area 4	Policies, Institutions and capacity-building

DEVELOPMENT OF LONG-TERM PLANNING AND STRATEGIC BREEDING PROGRAMME

The following criteria should be considered according to FAO (2007) for developing a long-term planning and strategic breeding programme:

i. Efforts to improve underutilized breeds, especially within low to medium external input production systems.
ii. Assessments of the impact of exotic animal breeds and the development of measures for producers to realize positive impacts and prevent negative impacts.
iii. Training and technical support for the breeding activities of pastoralist and farming communities.
iv. Integration of improved husbandry practices in AnGR development programmes.
v. Establishment of recording schemes to monitor changes in non-production traits (e.g., health, welfare) and adjust breeding goals accordingly.
vi. Development of backup collections of frozen semen and embryos from current breeding schemes to ensure genetic variability for the near future.
vii. Provide information to farmers and livestock keepers to assist in facilitating access to AnGR from various sources.

CONSERVATION OF ANGR

Conservation is the practice of protecting the abundance of biological diversity of genetic resources from loss and extinction and ensuring the preservation of those genetic resources for the use of future generations. It also refers to all human activities, including strategies, plans, policies, and actions, undertaken to ensure that the diversity of animal genetic resources is sustained in order to contribute to food and agricultural production and productivity or to sustain the ecological and cultural values of these resources now and in the future. There are three main approaches for conserving animal genetic resources: *in-situ* conservation, *ex-situ in-vivo* conservation, and *ex-situ in-vitro* conservation.

In-situ conservation of animal genetic resources focuses on maintaining and preserving genetic diversity within natural populations by protecting the habitats and ecosystems where animal species reside. It is considered the optimal method for conserving a breed and can be achieved through various means, such as institutional herds, farmers' herds, or organizations like gaushalas or dairy cooperatives.

Ex-situ in-vivo conservation involves preserving live animals (typically in limited numbers) outside of their natural breeding areas. This method is carried out through the maintenance of organized herds in facilities such as research stations, zoos, or breeding parks. *Ex-situ in-vitro* conservation involves the preservation of living cells, such as ova, embryos, semen, somatic cells, or other animal tissue, or DNA, for long period by storing them cryogenically in liquid nitrogen. This method is exemplified by gene banks.

PRESENT STATUS OF CONSERVATION OF ANGR IN INDIA

In India, mostly livestock keepers/farmers, gaushalas, breed societies and institutional herds are maintaining and continuously improving the economically important species/breeds. The population of these breeds is either growing or available in sufficient numbers with sufficient genetic diversity. However, breeds that are not economically beneficial to farmers require intervention, which often involves preserving their semen in cryocans. In some instances, other biological materials such as ova, embryos, or even somatic cells are being stored.

NATIONAL GENE BANK

Cryopreservation of germplasm, in the form of gametes (such as semen and ova), cells (such as somatic cells and stem cells), embryos, and DNA, is an important strategy to avoid future extinction and monitor temporal genomic changes within a breed. By preserving whole embryos and utilizing reproductive biotechnologies such as embryo cloning and splitting, a greater number of animals can be produced. Germplasm of all breeds or distinct populations can be preserved in the form of gamete, cell, and embryo. The ICAR-NBAGR has established the National Gene Bank to cryopreserve the germplasm of various breeds and populations. According to the Annual Report 2021 of NBAGR, the National Gene Bank has currently stored germplasm of 50 native breeds/populations in the form of semen (approximately 2.5 lakh doses) and 20 breeds/populations in the form of somatic cells (4800 vials). The livestock species whose semen doses have been preserved so far include cattle, buffalo, goat, sheep, camel, yak, and equine. A DNA bank has also been established at ICAR-NBAGR, Karnal as a DNA repository of native livestock and poultry breeds. At present DNA of 169 animal breeds/populations has been cryopreserved for medium-term conservation.

BREED SOCIETIES AND NGOS

A Breed Society is an officially recognized group of stakeholders working towards the improvement of a specific livestock breed, while an NGO, or Non-Government Organization, is a registered group of individuals united in their pursuit of a shared goal. In addition to Government agencies and gaushalas, breed societies also play an important role in involving several stakeholders and highlighting the importance of local breeds, documenting their features and undertaking value addition leading to the conservation of the breed. Also, NGOs play a vital role in highlighting the role of the local breed in improving the local livelihoods. There are several NGOs in the country working on livelihood issues based on local livestock or the local breed. NGOs like Sahjeevan in Bhuj of Gujarat and Sustainable Agriculture & Environment Voluntary Action (SEVA) in Madurai of Tamil Nadu have made significant contributions to saving the local breeds from further dilution.

PASTORALISM

Pastoralism plays an important role in the management of animal genetic resources, particularly in regions where pastoralism is a traditional way of life and where livestock is an essential component of the livelihood and cultural heritage of local communities. Pastoralists have a deep knowledge and understanding of the behaviour and ecological requirements of their livestock, as well as the selective pressures and environmental factors that have shaped the genetic makeup of their herds. They also play a key role in maintaining a diversity of animal genetic resources through their traditional breeding practices and management strategies. This diversity is essential for ensuring the resilience and adaptability of livestock populations to changing environmental conditions and diseases. To effectively conserve and manage animal genetic resources in pastoral systems, it is important to engage with and support pastoralist communities, including by recognizing their rights and contributions and incorporating their knowledge and practices into management strategies.

GENETIC IMPROVEMENT OF ANGR

The knowledge of genetic diversity among livestock breeds is essential for genetic improvement, environmental adaptation, and conservation of breeds (Groeneveld *et al.*, 2010). Implementing a livestock breeding programme is a challenging task that involves a number of different elements. Breeding systems and selection methods are the primary tools available for breeders to bring about genetic improvement in the population. The goal of a breeder is to choose animals with the best genes (highest breeding value) from the population and mate them in a way that their offspring will have a higher average performance than their selected parents. Breeding programmes and genetic improvement strategies are critical for the sustainable development of animal production systems. These programmes aim to enhance the genetic merit of animal populations by selecting individuals with desirable traits such as increased productivity, disease resistance, or better adaptation to changing environments. The strategies for genetic improvement should be based on a thorough understanding of the genetic and environmental factors affecting animal performance and should consider the potential trade-offs between different traits and the long-term viability of animal populations (FAO, 2007).

Genetic gain for a particular trait in a population of AnGR can be accomplished by altering four components: (1) enhancing the genetic variation within the population, which has limited control; (2) shortening the generation interval by choosing younger animals as parents for the next generation; (3) improving the accuracy of selection, which is indicated by the reliability of each animal's genetic assessment and the precision of the underlying genetic evaluation method; and (4) increasing the intensity of selection, meaning that the top-performing animals are used as parents to a greater extent.

SELECTION OF BULLS UNDER CONSERVATION PROGRAMS

The indigenous cattle population has either declined or been diluted due to the implementation of a widespread crossbreeding program in the country. In some breeds, the size has decreased dramatically, requiring urgent attention to conserve unique traits such as disease resistance, heat tolerance, feed efficiency, and draft ability, which make them economically viable. In such cases, the bull selection program should also focus on maintaining the breed characters in addition to the maintenance of the genetic variability and other economic viability. Selecting bulls can greatly improve the profitability of the dairy enterprise. In an organized progeny testing plan, an informative breakdown of an opportunity for genetic improvement by selection revealed that sire selection could provide a great opportunity for genetic change, as sire selection can contribute 68 per cent of total possible genetic improvement (Rendel and Robertson, 1950). As a result, the sire is known as more than half of the herd, from a breeding perspective. Traditional bull selection for dairy cattle through artificial insemination is based on pedigree and progeny testing, but this method has limitations, such as the long duration of the progeny testing program and limited scope to improve lowly heritable traits (such as disease resistance, reproduction, fitness), and traits which are measured late in life or after death.

Although the traditional progeny testing programme allows the transmission of superior germplasm in a large population which was one of the major contributing factors in the increase in milk production globally, other non-productive traits were ignored or given less weightage. The methodology of animal breeding programmes needs to be revised regularly at a suitable time interval to combat the impact of changing environment, diseases and reproductive issues. Hence, incorporating a broader range of traits in the breeding strategy, including production, health, fertility, and longevity, along with consideration of environmental stressors will lead to a more sustainable breeding program. The application of marker assistant selection and genomic selection can also augment the selection programmes.

MOLECULAR APPROACHES FOR ASSESSING THE DIVERSITY OF ANGR

A genetic variation is a valuable tool available for animal breeders, which can be used to improve breeds and select a superior animal. Genetic markers refer to any stable and inherited variation that can be measured or detected by a suitable method and can be used subsequently to detect the presence of a specific genotype or phenotype which is otherwise difficult to detect. Advancement in the field of molecular biology and bioinformatics has led to the identification of variations at genomic levels which can be used as markers for the selection of individuals for increasing production. The rapid progress in mapping strategies and automated sequencing techniques was the key to the success of the human genome project. In addition, livestock genomics rides on the wave of the human genome project, and there have been massive advances in the field in the last decades. The extensive exploitation of polymorphism revealed by DNA sequence analysis has led to the development of genetic markers and linkage maps in mammals. This type of polymorphism, represented by allelic differences, is valuable in population and phylogenetic studies as well as inheritance analysis. The sequencing and characterization of polymorphic fragments produce useful markers. The detection of polymorphism has advanced from RFLP to modern DNA chip or microarray technology. DNA-based markers, also known as molecular markers, have advantages over other types of markers like allozymes and immunogenetic markers. These markers are highly polymorphic at the DNA level, follow Mendelian inheritance, and are not affected by the environment. They can reveal variations in both coding and non-coding regions of DNA. Molecular markers that detect variation in non-coding DNA are called neutral genetic markers and do not provide information about genes or their functions. They are useful in investigating processes such as gene flow, migration, and dispersal, and have applications in landscape ecology. In contrast, functional genetic markers can detect variations in coding regions or genes. Some examples of these markers are mentioned below.

i. First generation marker (hybridization-based): Restricted Fragment Length Polymorphism (RFLP).
ii. Second generation markers (PCR-based): Examples, Random Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), minisatellite, microsatellites (or simple sequences repeats or short tandem repeats), PCR-RFLP.
iii. Third-generation markers (DNA-based): Single nucleotide polymorphisms (SNP).

MARKER ASSISTED SELECTION FOR ANGR IMPROVEMENT

Nowadays, DNA markers are used to assist breeding and selection and to build the basis for novel breeding approaches such as marker-assisted selection (MAS) and more recently genomic selection (Williams, 2005). Marker-assisted selection (MAS) is a selective approach in which the relative breeding value of a parent is predicted using genotypes of markers associated with the trait. This approach has become more widely used with the advancements in DNA sequencing, high-throughput genomic technologies and automated SNP genotyping. These advances have shifted the focus from single gene/Quantitative Trait Loci (QTL) to entire genomes, which can provide a more comprehensive understanding of genetic variation and its impact on important traits. By using molecular techniques to identify variations in specific regions of DNA, marker-assisted selection can help identify the most desirable phenotype even when they are influenced by non-additive gene action or epistatic interactions between loci. Also, this approach allows for the early selection of the best breeding stock. Once the association between genetic markers and performance have been identified, they can be utilized in a breeding programme. Another focus area is to identify genes that have economic significance, in order to distinguish functional differences among indigenous animal genetic resources. One of the major advantages of using markers for selection is that they can be determined from easily collected samples, such as hair or blood. Marker information can be used to predict an animal's genotype before the animal has records for the trait or even for animals which will never express the trait. For instance, it is possible to predict whether a male has genes for good female reproductive performance or predict meat quality in an animal without having to slaughter it. Hence, marker-assisted selection can not only improve the efficiency of the current breeding methodology but also create opportunities for selecting new traits.

GENOMIC SELECTION FOR ANGR IMPROVEMENT

Genomic selection is a variant of marker-assisted selection in which genetic markers covering the whole genome are used so that all QTLs are in linkage disequilibrium with at least one marker

(Meuwissen *et al.*, 2001). The development of genotyping array has opened a new opportunity to explore key genes responsible for various traits and provides the possibility of utilizing genomic selection in the dairy industry. In comparison to traditional marker-assisted selection (MAS), which only focuses on specific regions that are likely to affect the desired trait, leaving most of the genome and genetic variation unaddressed, genomic selection places greater emphasis on those regions with the largest effects and still properly accounts for the less definite genetic variation in the rest of the genome. Now, animal breeders can select animals based on genotypes at an early age due to the increasing availability of marker data in livestock and advancements in genomic selection techniques (Meuwissen *et al.*, 2001). The integration of genomic information and advanced statistical methods has led to more accurate predictions of an animal's genetic potential. The advancements have led to a better understanding of the genetic architecture of economically important traits and helped in making decisions in breeding programs. With the advancements in whole-genome sequencing and the use of high-density SNP arrays, genomic selection has become a reality. This method is based on conventional breeding techniques and relies on the recording of pedigree and phenotypic data. Genomic selection can double the genetic gain per year in dairy cattle with a reduction of more than 90% in costs for proving bulls (Schaeffer, 2006). As the cost of sequencing decreases to a level where the sequencing of each and every individual becomes affordable, whole genome data can be used in genetic evaluations. A simulation study revealed a 40% gain in accuracy in predicting genetic values by using the sequencing data over the data from 30,000 SNP arrays alone (Meuwissen and Goddard, 2010). The use of whole-genome sequence data helps to predict the Genomic Estimated Breeding Values (GEBVs) of individuals with greater accuracy.

The steps of genomic selection start by obtaining a large group of animals (either a reference or training population) with accurate phenotype data for the desired trait(s) and genotyping them using a whole-genome SNP array (Fig 2)The resulting data act as a reference for developing a statistical model that predicts the effect of each SNP on the desired trait(s). Based on this prediction equation, a genomic estimated breeding value (GEBV) is calculated for each animal. In the next step, the accuracy of the GEBV is validated. Finally, the genomic breeding value of new animals can be estimated based on their genotypes from the SNP array, even in the absence of any accurate phenotypes. Genomic selection can be applied to all major livestock species as genome-wide single nucleotide polymorphism (SNP) panels or full sequence data is now accessible.

ADVANTAGES OF GENOMIC SELECTION

- Shortens the generation interval and increases the accuracy of selection at a young age

- Tracks all the genetic variances and yields accurate effective breeding value even without phenotypic evaluation of the actual selection candidates
- Can be used in non-pedigreed populations
- Could be effective in traits that are sex-limited, expensive to measure, only measured on relatives, lowly heritable, occurring late in life or those determined post-mortem.

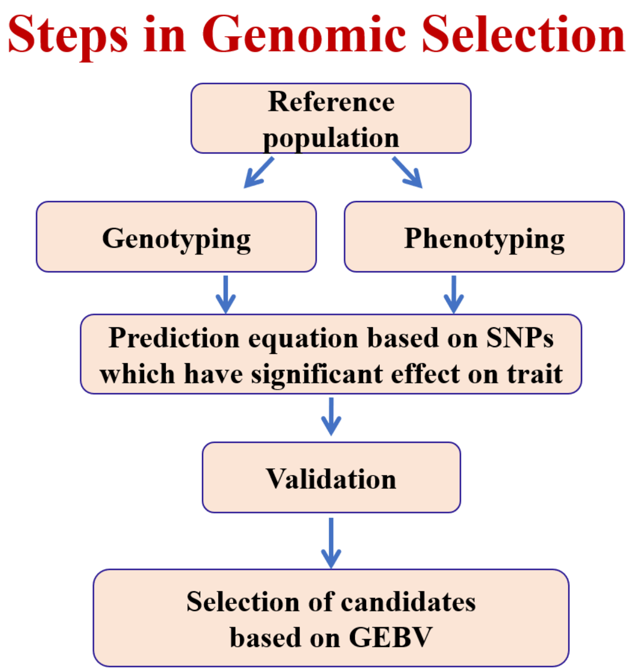

Figure-2: Schematic diagram depicting timeline of breeding programme using genomic selection in dairy cattle

ADVANCES IN EVALUATION TOOLS: CHANGING THE SELECTION METHODOLOGIES

Previously, the focus in dairy farming was primarily on improving milk production, which may have affected the reproductive performance and health status, affecting overall profitability. The rising temperatures and unpredictable weather conditions caused by global warming and climate change, as well as increased greenhouse gas emissions, pose a significant threat to the productivity and welfare of livestock globally. To ensure better and sustainable production, traits such as body structure, udder health, resilience to disease and heat stress, reproduction, ease of calving, and male fertility may be taken into consideration.

The main tool used to assess udder health is the somatic cell score. In the United States, genetic evaluations for somatic cell scores have been available since 1994. Optimal reproductive performance is always desired from a herd. For the same, evaluation of female and male fertility traits is also inevitable. More recently, Daughter Pregnancy Rate (DPR) was introduced in 2003, in addition to the traditional system of measurements such as days from calving to first breeding and non-return rate. This shift in emphasis from production traits to functional and adaptability traits highlights the need to re-evaluate our breeding goals and regularly assess and revise breeding programs for sustainable livestock production.

A large number of cows are being inseminated in the program so that records of sufficient daughters are achieved for sire evaluation despite significant data loss (Kumar *et al.*, 2015). In the progeny testing programme of crossbred cattle in India, as high as 33.7% of the data is reported to be lost due to different causes largely due to the sale of the animals (Das *et al.*, 2017). In Indian conditions, collecting milk production data from the farmers appeared to be difficult, because the farmers as well as technicians were not motivated enough with incentives and proper feedback (Ducrocq *et al.*, 2018). The absence of a National Animal Identification System (NAIS) severely hampers the data recording in the field, resulting in failure to execute the selection schemes and also to quantify the impact of improvement programmes (Gowane *et al.*, 2019). Consequently, it is important to establish or strengthen a reliable recording system to keep track of changes in non-production traits, such as animal health and welfare, so that breeding goals can be adjusted accordingly in developing countries, including India. The impact of selection on genetic diversity should be taken into account in breeding programs and efforts should be made to maintain the desired level of genetic variability.

PATHWAYS FOR SUSTAINABLE MANAGEMENT OF ANGR

Ensuring the sustainable management of AnGR is crucial to meet the future demands of a country. This requires the development and implementation of pathways that balance the conservation of genetic diversity with the efficient use of AnGR to support food security and livelihoods. To achieve this, a multi-disciplinary and holistic approach is needed, incorporating the perspectives and knowledge of various stakeholders, including pastoralist communities, farmers, researchers, and policymakers. Key strategies for sustainable AnGR management include: (i) maintaining and improving the diversity of AnGR through conservation and sustainable use, (ii) improving the quality and availability of data and information on AnGR, (iii) integrating AnGR into livestock breeding programs, (iv) ensuring the equitable access and benefit-sharing of AnGR, and (v) promoting the integration of AnGR into broader policies and programs for sustainable agriculture and rural development. In addition, the development and implementation of policies and regulations that support sustainable AnGR management, as well as investment in research, education and capacity building, will be critical for the success of these pathways. Ultimately, sustainable AnGR management requires a collaborative and inclusive approach that recognizes the important role that AnGR plays in meeting the needs of current and future generations.

CONCLUSION

The effective management of Animal Genetic Resources (AnGR) is essential for ensuring sustainable livestock production, food security, and the conservation of biodiversity. This review has highlighted that the management of AnGR is a complex and multi-disciplinary process that requires collaboration between animal breeders, geneticists, animal scientists, economists, policymakers, knowledge of pastoralist communities, farmers and other stakeholders at the international, national, and local levels. It has also emphasized the importance of incorporating AnGR into breeding programs, improving data and information management systems, promoting equitable access and benefit-sharing, and integrating AnGR into broader policies and programs for sustainable agriculture and rural development. Identification, evaluation, phenotypic and genetic characterization, documentation, conservation, biosecurity, intellectual property rights, and genetic improvement with respect to AnGR is essential for the management of AnGR for sustainable production. In order to conserve the AnGR, a global digital gene bank could be established to store genomic databases, genetic information, transcriptomics, metabolomics, nutrigenomics, and other information about all breeds and populations available around the world. This bank would be a valuable asset to conserve information on AnGR and its genetic diversity for future generations. These approaches will ensure that AnGR is conserved for future generations and utilized in a sustainable manner to support the needs of current and future generations.

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RESEARCH INTERVENTIONS FOR SUSTAINABLE LIVESTOCK PRODUCTION-MITIGATION STRATEGIES

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ABSTRACT

Climate change mitigation in livestock production is a critically important issue that requires innovative solutions from agricultural stakeholders. The presence of methane, a potent greenhouse gas (GHG), within animal manure, and enteric fermentation by livestock, has led to much attention focusing on ways to reduce those emissions. A range of strategies have been proposed for mitigating GHG emissions in livestock production, including improved feed quality and quantity control; dietary alterations that optimize digestion; enteric fermentation suppression; methane capture technologies to generate energy or curtail releases into the atmosphere; nutrient management strategies that account for soil carbon enhancement; and finally yield improvement through farm practices such as genetic selection. All these measures aim at reducing GHG concentrations resulting from the various stages of livestock-production processes starting from feed production, and livestock husbandry up to processing. With the increasing demand for protein foods globally and emerging challenges attributed to climate change impacts, meeting consumers' nutritional needs while balancing with sustainability concerns is the key in making strides toward efficient mitigation mechanisms.

INTRODUCTION

A growing number of research interventions are recognizing the important role of the livestock sector in sustainable development and reinforcing the need to address food security and climate change with specific interventions tailored to the livestock sector (Cheng at al., 2022). Livestock production is essential for the livelihoods of millions of people around the world. Unfortunately, this sector has also been linked to adverse impacts on human health, animal welfare, and the environment. In order to mitigate the undesirable impacts of livestock production, research has identified a variety of interventions which can reduce emissions, improve welfare, and enhance nutrition and food security (Choi et al., 2020).

INTERVENTIONS

One important intervention involves introducing alternative sources of protein, such as insects and lab-grown meat, which are both more sustainable than conventional livestock production. Substituting traditional livestock proteins for these alternative sources in human diets can reduce the environmental burden associated with producing livestock and improve the welfare of animals (Palangi et al., 2022). Additionally, improving animal nutrition is a promising intervention. For example, supplementing feed with legumes can reduce the excretion of methane and other carbon dioxide-equivalent (CO_2e) gases. In addition, research is being conducted on feed additives to reduce enteric methane production by livestock (Goma et al., 2022).

Integrating crop and livestock farming is another effective strategy to reduce emissions associated with animal production (Thornton and Herrero, 2001). Agroforestry systems, in which trees and pastures are used together, have been designed to reward farmers financially while improving crop yields and reducing environmental degradation. In addition, research has shown that pasture-based production systems are better for animal welfare and enhance biodiversity, as these systems allow for more natural behaviour for animals. Practices such as rotational grazing and fodder banking can also increase the production efficiency of smallholder farms and prevent land degradation.

Finally, knowledge management and information sharing among farmers is also an important intervention for sustainable livestock production. Access to accurate and timely information can increase farmers' capacity to manage their resources, leading to improved yields and reduced emissions (Monteiro et al., 2021). By incorporating digital technology, such as mobile phones, farmers can better track grazing areas, feed and water availability, and disease management, further improving production efficiency.

Climate change is one of the most pressing global issues and is important to address immediately to ensure a safe future. The livestock sector is a large contributor to the world's carbon emissions, making it a priority within climate change mitigation efforts. Numerous innovations have been implemented in the livestock industry over the years as a means of reducing the sector's impact on climate change (de Souza Filho et al., 2019).

One of the more prominent innovations utilized in the livestock sector is the use of renewable energy sources for running farm operations. Farms have begun to install solar panels and wind turbines to reduce their reliance on electricity from non-renewable sources. This has the added benefit of cheaper electricity for the farmers with the capital expenditure of the solar panels being offset by reduced electricity bills. Additionally, some farms utilise anaerobic digestion of animal manure to get biogas which can then be used as an energy source to run farm operations. The usage of these renewable energy sources reduces the emissions associated with running farm operations (Hou et al., 2020).

Besides renewable energy sources, farmers have started using better grazing management and soil management practices. These include rotational grazing, cover cropping and conservation tillage. Rotational grazing involves the altering of grazing patterns to ensure that the plants are not overgrazed and have time to regrow, while cover cropping involves the planting of specific species of crops after harvesting to add fertility to the soil while conserving soil moisture and reducing erosion. Conservation tillage involves minimal mechanical disturbance of the soil and helps retain a large portion of the crop residues on the soil surface to be used as organic matter for soil nutrition. These methods reduce methane emissions from the soil along with reducing erosion and water pollution (Cheng et al., 2022).

One of the other innovations is the swapping of traditional animal feeds with more carbon-friendly ones (Grossi et al., 2019). For instance, soybean meal and maize are some of the popular animal feeds which are incredibly carbon-intensive due to the large amounts of mains electricity needed to manufacture them. Alternatives such as barley and alfalfa are more sustainable and offer lower emissions than traditional animal feeds. Furthermore, some livestock farms are now rearing animals on diets that include feed made from by-products found in the food supply chain, such as leftover food or browned-off fruits and vegetables. This helps in reducing food waste and provides additional nutrition to the animals (Scoones, 2023).

The above innovations have made a marked improvement in reducing the carbon footprint of the livestock sector. However, there is still a long way to go before this sector can fight climate change in a meaningful way. As such, governments, farmers and industry players must work together to develop more innovative solutions and implement them on a wider level.

CONCLUSIONS

There are a variety of research interventions which can mitigate the environmental and social impacts of the livestock sector. By implementing alternative sources of protein, improving nutrition, integrating crop and livestock farming, and utilizing knowledge management, we can reduce the environmental burden associated with animal production and improve the welfare and production efficiency of smallholder farms.

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GENETIC BASIS OF HEAT STRESS RESPONSE IN RUMINANTS

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ABSTRACT

Agriculture and livestock sectors are among the most sensitive economic sectors which fluctuate with climate. The change in environmental variables like ambient temperature, relative humidity, wind and rainfall has been considered potential hazards in livestock growth and production. High environmental temperature and humidity induce heat stress in livestock which affects its production and health. Heat stress has been of major concern in reducing animal productivity in tropical, subtropical and arid areas. The environment and the genetic factors play hand in hand in causing heat stress in ruminants which in turn show their response through changes in their behaviour, physio-biochemical parameters and through alterations in gene expression caused by disruption of the central dogma. By using certain biomarkers, bioclimatic indices and farm instruments, heat stress can be easily detected in farm animals. Other than the managemental aspects of reducing heat stress, genetic tools such as whole transcriptome analysis, GWAS, techniques like gene editing, gene silencing and metabolite profiling can be used to improve the heat stress response in ruminants.

INTRODUCTION

Heat stress can be defined as the progressive dangerous effect caused by the imbalance between heat production within the body and heat dissipation (Zeng *et al*., 2022). In general, warm-blooded animals have a range of temperatures where they do not expend additional energy to maintain their core body temperature this indicates that most of the energy will be diverted for production and this is called as the thermo-neutral zone, which is normally in the scale range of 5℃ and 25℃ for most of the farm animals. The upper and lower critical ambient temperature range points define the limits of the thermo-neutral zone. When the temperature exceeds the upper critical temperature point it results in heat stress. The thermo-neutral zone is highly influenced by the age of the animal, breed, species, feed composition, mode of insulation through fat, skin, hair coat and the specific housing shed conditions (Yousef, 1985).

FACTORS CAUSING HEAT STRESS IN RUMINANTS

Heat stress-causing factors can be divided into two types; environmental and genetic factors. The environmental factors that impose heat stress on livestock include high ambient temperature and relative humidity, direct and indirect solar radiation and less air movement (Şireli *et al.*, 2017). The ability to tolerate heat is breed and species dependent, small ruminants like sheep and goat perform better in drastic environmental conditions than other ruminants (Al-Dawood, 2017) and (Bakheit *et al.*, 2017), their behaviour, morphology, physiology and genetics help them in adapting to these adverse thermal-stress environments (Nejad and Sung, 2017). Adaptations that occur morphologically over many generations which helps them to survive in a given environment include body shape, size, the colour of the skin and coat, hair type and their ability for fat storage (Chedid *et al.*, 2014). Buffaloes are more likely to suffer from thermal stress if they are exposed to solar radiation and are not provided with cooling showers (Frisch and Vercoe, 1979). Buffalo can't handle extremes of both heat and cold, the presence of very few sweat glands under their skin in comparison to cows makes them more uncomfortable in extreme environmental conditions (Ahmad and Tarik., 2010). Calves and heifers are more tolerant to thermal stress due to the production of less metabolic heat and good heat dissipation efficiency (Wang *et a*l., 2020). The Indian cattle breeds are more tolerant to heat stress than the exotic cattle breeds due to the presence of numerous voluminous baggy-shaped sweat glands under their skin and a high density of hair follicles (Wang *et al.*, 2014).

THE GENOTYPE-ENVIRONMENT INTERACTION

The genes not only interact among themselves but they also interact with the environment the animal encounters. The environment is important because it modifies the gene expression for most of the economic characteristics in farm animals. The interaction of genes with the external environment through climate, nutrition and managemental practices is called the genotype-environment interaction.

IMPACT OF HEAT STRESS ON RUMINANTS

An increase in environmental temperature affects the normal rumen physiology of the animals leading to metabolic disorders (Soriani *et al.*, 2013). Heat-stressed animals will have a drastic reduction in feed intake which results in a negative energy balance (Baile and Forbes, 1974), there will be a reduced VFA production which leads to subacute ruminal acidosis (Zhao *et al.*, 2019).

Heat stress causes high CO_2 expiration which causes respiratory alkalosis (Jessen. 2001), it also adversely affects the milk yield and its composition. Exposure of late pregnant animals to heat stress causes a reduction in colostrum quality and the concentrations of IgA, IgG, fat, casein, lactose and lactalbumin also drops down (Bernabucci *et al.*, 2019).

Heat stress negatively affects reproduction in ruminants by causing impairment to the tissues and organs related to reproduction in both sexes which results in infertility, decreased oocyte quality and conception rate, reduced oestrous expression in females and testicular degeneration in males (Niyas *et al*., 2018).

TYPES OF RESPONSE TO HEAT STRESS

Behavioural response: It is a primary response that the animals show during heat stress which includes increased water intake, decreased feed intake, wallowing, shade-seeking behaviour, increased standing time, panting, etc. (Ratnakaran *et al*., 2017).

Physiological response: An immediate response to thermal stress can be given by rectal temperature, respiratory rate, and heart rate (Helal *et al*., 2010). It also causes alterations in haematological parameters such as packed cell volume, haemoglobin, red blood cells and the plasma concentration of protein and albumin in ruminants (Okoruwa, 2014; El-Masery and Marai, 1991).

Biochemical response: Heat stress causes a decrease in thyroid activity which in turn leads to a decline in enzymes such as lactate dehydrogenase and alkaline phosphatase (Helal *et al*., 2010). An increase in the serum level of alanine aminotransferase in goats was reported by Sharma *et al*. (2011). An increase in cortisol and prolactin levels in goats was reported by Sivakumar *et al*. (2010). A decline in T_3 and T_4 levels in buffalo heifers was described by (Korde 2004) and an increase in serum cortisol by (Dantzer and Mormede 1983). A decline in serum glutamate pyruvate transaminase, aspartate transaminase and alkaline phosphatase in buffalo heifers was reported by Vijayakumar *et al*. (2001).

Cellular response: Common response of cells to heat stress includes disruption of the central dogma, inhibition of cell cycle progression, mis-aggregation of proteins, disruption of cytoskeletal components and changes in the membrane permeability (Burdick *et al*., 2011; Saxena *et al*., 2012). The cellular heat stress response is considered to be more important than the above-mentioned responses because it affects the gene expression by heat shock transcription factor (HSF) activation and its binding with the heat shock element (HSE) which in turn leads to an alarming rate of increase in heat shock proteins (HSP) that aids in protein refolding and its extracellular secretion activates the immune system (Collier *et al*., 2008).

QUANTIFICATION OF HEAT STRESS

Heat stress response can be quantified by using biomarkers, bioclimatic indices and instruments that are used at the farm level.

BIOMARKERS

Non-invasive physiological parameters such as respiratory rate, rectal temperature, heart rate and pulse rate are the commonly used biomarkers to assess heat stress response. Heat stress causes an increase in the concentration of amino acids such as alanine, aspartate, glutathione, glycine and threonine in blood, hence blood amino acid profile can be used as a biomarker (Cowley *et al*., 2015 and Guo *et al*., 2018).

Thiobarbituric acid reactive substance (TBARS) assay can be used to determine the reactive oxygen species status in heat-stressed animals, Glutaredoxin in skin cells of cattle also acts as an oxidative stress marker (Maibam *et al*., 2018). Antioxidant enzymes such as glutathione peroxidase, superoxide dismutase, catalase and plasma malondialdehyde (Chauhan *et al*.,2014 and Rathwa *et al*., 2017) and an alteration in the blood concentration of interleukins (increase in IL-6 and decrease in IL-12) as reported by Sheikh *et al*., 2017 and upregulation of colour genes such as PMEL and MC1R (Mountjoy, 1994) during heat stress make all of them suitable to be used as biomarkers.

Heat stress damages the blood-milk barrier which leads to an increase in the levels of pyruvate, lactate, acetone, and arachidonic acid in milk as well as in the plasma (Cheng *et al*., 2015). Liver proteomics can also be used to study the oxidative changes in the liver caused by heat stress (Skibiel *et al*., 2018).

BIOCLIMATIC INDICES

Temperature Humidity Index (THI) can be used as a rough estimate of the effect of thermal stress on production (Polsky *et al*., 2017). It was observed by Armstrong (1994), that the THI above 75 can affect dairy cows with high producing capacity. Sindhu *et al*. (2019) categorised thermal stress in crossbred dairy cattle into three classes based on THI such as zone of comfort (THI <72), mild stress (THI 78) and high stress (THI 91). According to Koluman *et al*. (2016), a THI of 70 and below is considered as the zone of comfort and THI above 78 is considered more stressful to small ruminants. Other models such as heat load index (HDI) which takes solar radiation also into account, Tunica dartos index which is commonly used for goats and the equivalent temperature index for cattle are also used.

FARM INSTRUMENTS

Variables such as reticulo-rumen temperature, surface temperature, animal activity, blood pressure, and electrocardiogram can be detected at the farm level by using certain special instruments such as radio frequency identification (RFID) ceramic boluses, Automatic measurement system for cattle's surface temperature (AMSCST), accelerometer and infrared thermography.

STRATEGIES TO IMPROVE HEAT STRESS RESPONSE

The two strategies that are generally followed to improve heat stress response are the short-term strategy and the long-term strategy. The short-term strategy includes nutritional interventions such as the provision of cool, clean drinking water (Vermunt, 2010), Increasing dietary energy density (Sammad *et al*., 2020), dietary cation-anion difference (DCAD)- supplementation (Wildman *et al*., 2007), Vitamin supplementation (Di Costanzo *et al*., 1997), Dietary yeast and fungal supplementation (Sammad *et al*., 2020).

Under the long-term strategy comes genetic selection and environmental modifications such as the provision of shade, cooling ponds, and sprinklers (Atrian and Shahryar, 2012). Genetic selection involves the classification of heat-tolerant animals within the herd of high producers by taking the recordings (Amamou *et al*., 2019) and allied phenotypes (Carabaño *et al*., 2019) into consideration.

GENETIC IMPROVEMENT OF HEAT STRESS RESPONSE

Climate-resilient livestock production is possible by using certain genetic tools to identify and characterize candidate genes responsible for heat tolerance and by knowing the biological pathways in which these genes are involved, refinements can be made in the existing breeding policies.

COMMONLY USED GENETIC TOOLS

WHOLE TRANSCRIPTOME ANALYSIS

It is the study of the complete set of RNA transcripts produced under specific circumstances using high throughput methods like RNA-Seq analysis which generates sequences that are compared with the respective genome assembly to estimate the differently expressed transcripts. Many transcriptomic studies related to thermal stress were conducted in bovines. Khan *et al*., (2020) studied the reason why the breed Tharparkar is more heat tolerant than Vrindhavani crossbreds by reporting the upregulation of six heat tolerant genes such as G*PX3, CALR, HSF1, CAT, SOD1* and *GSK3A* in Tharparkar breed.

GENOME-WIDE ASSOCIATION STUDIES (GWAS)

A powerful strategy is used to screen the whole genome to identify SNPs associated with the trait and the putative candidate genes are identified within the QTL regions after defining them based on the location of SNPs. In a GWAS study for heat stress response in crossbred cattle (Gir X Holstein Fresian F_2 population), six SNPs on BTA17 and three putative candidate genes such as *LIF*, *TXNRD2* and *DGCR8* involved in the regulation of HSP genes, microRNA processing and redox homeostasis maintenance respectively were identified (Otto *et al*., 2019).

FUNCTIONAL GENOMICS

A rapidly evolving field of molecular biology which utilises the vast array of data produced through genomic and transcriptomic research. It identifies and describes the gene functions and interactions and investigates changes at a whole genome level rather than going for targeted gene by gene investigations. The functional genomic approaches used in heat stress studies are:

i) ***Genome editing:*** The process of transferring polymorphisms related to heat stress from one breed to another using molecular scissors like CRISPR/Cas9 (RNA-guided endonuclease) through electroporation into the zygotes in-vitro after collecting it from the donor females. The embryos are then transferred to the recipient to give birth to genetically superior animals only after confirming the genome editing by using a portable biopsy sequencing method. (eg)., mutations in the bovine prolactin receptor gene (PRLR) result in cattle with a short sleek hair coat called the slick phenotype.

ii) ***Gene silencing:*** An epigenetic process of gene regulation that describes the “switching off” of a gene by RNA interference mechanism with the involvement of small interfering RNA (siRNA) which when directed to a targeted mRNA causes degradation, thereby interrupting the protein synthesis. The importance of the SOD1 gene in granulosa cells of heat-stressed cows was studied by silencing the particular gene which leads to apoptosis (Khan *et al*., 2021).

iii) ***Metabolite profiling:*** In animal breeding, the external phenotypes are considered as traits of economic importance. Metabolomics generates metabotypes/ metabolic phenotypes which are considered intermediate phenotypes that are involved in different metabolic pathways which lead to those traits of economic relevance. This is performed by using three platforms such as gas chromatography/ mass spectrometry (GC/MS), Liquid chromatography/ mass spectrometry (LC/MS) and Nuclear Magnetic Resonance (NMR). In comparative metabolic profiling of serum and urine in three beef cattle breeds of Southern China (Xuanhan yellow cattle, Simmental crossbred and cattle-yak) using GC/MS, it was concluded that the local breed (yellow cattle) is more heat tolerant than others due to higher glycolytic activity and strong anti-oxidant defence system (Liao *et al*., 2018).

BREEDING CATTLE FOR CLIMATE RESILIENCE

Climate resilience mainly for heat tolerance has to be considered along with the past breeding programmes. Since adaptation traits are less heritable; they may or may not be expressed during environmental changes which makes framing strategies to promote region-specific climate-resilient breeding difficult. So, Selective breeding can be practised by identifying the heat-tolerant animals in a herd of high producers so that, the animals produce high even under heat stress.

FUTURE CONSIDERATIONS

The environment is an epigenetic factor, and approaches to study the epigenetic regulation of gene expression have not been explored much, bisulfite sequencing to study the methylome patterns can be opted for this purpose. The effect of heat stress on rumen microbial ecology in small ruminants had been studied by metagenomics but it has not been attempted in large ruminants. Finding out the selection sweeps or selection signatures related to the heat stress response is also a new approach which requires attention.

CONCLUSION

Based on the various genetic tools discussed above, it may be possible; to identify target genes that are upregulated during heat stress and establish them as bio-markers and incorporate them in breeding programmes to establish a higher degree of heat tolerance within livestock species. ***"omics"*** strategies can be used to counter the harmful effects of environmental stresses that are expected to come out with the changing global environment.

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COMMERCIAL LIVESTOCK BREEDING: A KERALA PERSPECTIVE

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INTRODUCTION

The livestock sector in Kerala is livelihood intensive and also a major contributor to Gross State Domestic Product (GSDP), it could be as high as 40 per cent of the agricultural GSDP in Kerala. Livestock production has been traditionally practised in the State mainly as an extensive, low-input subsistence system integrated with crop production.

Cattle, buffalo, goat, pig, poultry, and duck are the major livestock population reared in Kerala. In Kerala, nearly 94% of the livestock population is concentrated in rural areas, and 80% of the livestock farmers are marginal farmers and agricultural farmers. Women constitute 60% of the workers in this sector.

The State's livestock population has increased by 6.34% during the 20th livestock census conducted in 2019 when compared to the previous enumeration in 2012. The livestock count has increased to 29,08,657 from nearly 27,35,170 in 2012 when the population witnessed a steep fall from around 35,87,470 registered in 2007. Goats (46.73%) and cattle (46.14%) comprised a major share of the livestock population in the state. Of the 13,41,996 cattle population, 94% is crossbreed variety. The total milch cattle population is 6,68,997, an increase of 5.06% over the previous census. Registering an increase of 9.08%, the goat population stood at 13,59,161. The count of pigs has nearly doubled to 1,03,863 from the previous census.

KERALA – OVERVIEW

The state of Kerala is located on the southwestern tip of India. The area of the state is comparatively small (38,857 sq. km.). Its coastline extends for 560 km along the Arabian Sea. Topographically, the state can be divided into three regions: lowlands (below 10 metres), midlands (10-100 metres) and highlands (above 100 metres) of MSL.

Constraints Of Dairying in Kerala: NOT WELL SUITED FOR DAIRYING !!!

- Land & Livestock holdings

- Small & fragmented
- Medium & large – less than 10%
- Marginal & small holders – more than 78%
- Number of holdings increase with growth in population
- Consequent shrinking in size of holdings
- None of natural attributes for economic dairying
- Year round hot humid climate
- Relentless pressure on land for human needs
- Acute scarcity of fodder
- The average land holding is below 0.5 ha
- 48% of Kerala's population is urban
- Most of Agri. Crops don't yield any byproducts/residue useful for cattle feeding
- Heavy rainfall and consequent mineral depletion

HISTORY OF DAIRYING IN THE STATE

Absence of any appreciable physical uniformity to describe them as a breed

- ❑ Non-descript bullock mothers with mature body weight 180-200 kg.
- ❑ The cows yield less than 300 kg/yr and the wet average of 1.005 litres/ day
- ❑ The calving interval of almost 3 years.

INDO – SWISS PROJECT, KERALA (1963)

The Indo-Swiss Project Kerala (ISPK) was constituted under a bilateral agreement between the Government of India and the Swiss Confederation in 1963 with the aim of evolving a new breed of cattle adapted to the local environment. By mid-1970s, the Government of Kerala decided to constitute an autonomous body named the Kerala Livestock Development and Milk Marketing Board (KLD & MMB) under the Companies Act 1956, integrating the production, procurement, processing and marketing of milk under one umbrella

OBJECTIVE

To evolve a new breed of cattle adapted to the local environment for effective utilization of the natural resources/grassland in the high ranges of Kerala. Later the project grew into a state-level organization to promote the livestock and dairy sector of the state

DAIRY CATTLE BREEDING PROGRAMME KERALA

- 1964 - Cross breeding of ND cattle
- 1965-66 Deep frozen semen introduction in South East Asia
- 1969 - official policy of the government for increasing milk production
- Pioneering work on large-scale cross breeding
- 1974 - Recommendation of the National Commission on Agriculture - cross breeding should be a major strategy for increasing milk production
- Crossbreeding gained momentum and economic relevance in the mid-seventies
- Operation Flood - provided the market stimulus and much-needed price support for milk.
- Technical programme - ND cattle as foundation stock - breeding with exotic donor breeds
- Exotic donor breeds used initially were Jersey, Brown Swiss and Holstein Friesian
- Choice of the exotic donor - now narrowed down to Jersey and Holstein - with Holstein predominating the market by popular choice

SUNANDINI- THE MINOR MIRACLE (1979)

The breed characters :

- Mature body weight 350 – 400 kg
- Age at first calving 28 – 32 m
- First lactation milk yield 3500 – 4000 kg
- Overall lactation milk yield 4000 kg
- Milk fat percentage 4.00 %

BREEDING POLICY OF KERALA 2018

- Only HF & JY are to be used as exotic donors.

- The level of exotic inheritance is to be limited to 50% in a small holding population. Farmers with good resources could be provided with semen from bulls with exotic inheritance up to 75%.
- Germplasm provided by KLD Board alone may be used in the state.
- The present PT program shall continue. More Parameters like milk constituents & type characters are to be included in bull selection.
- F1 CBJY & F1 CBHF bulls are to be included in the PT program. Comparative study of milk production potentials of bulls selected from bull mother farm & PT are recommended.
- ET program to be used for next-generation bull calf production. Top 10% of cows with respect to production, and reproduction to be used as donors for the ET program
- Female sex-sorted semen may be provided to farmers without subsidy.
- Awareness program to be conducted for Veterinarians, AI technicians, and farmers on the accuracy of BV obtained by PT in comparison with other methods of selection.
- Conservation programs for local indigenous breeds like Vechur shall be undertaken. Interested farmers may take up the development & dissemination of Indian dairy breeds.
- The existing selection & breeding program for the Malabari breed shall continue. It is recommended to expand the AI network of Malabari Goats to the entire state.
- Conservation of Attappady black goat shall continue.
- All AI technicians in the existing AI centres of the state shall register with the concerned licensing authority.

BREEDING PROGRAMME FOR GOATS

The breeding Policy for goats primarily aims at increased meat production for meeting not only its local demand but also to explore export avenues. As a result of the consistent use of goat milk in rural areas, a new dimension to goat farming has been incited to boost the rural economy as an upcoming new horizon for breeding goats for milch purposes also. Hence, on this background, desired genetic improvement amongst the goat population will help in reaping the benefits of dual-purpose breeds through the use of identified breeds. Priority for this purpose will be given to selective breeding or upgradation of the recognized local indigenous breeds like Malabari and Attappady Black. Efforts will be made for identifying the local indigenous goat breeds through rigorous phenotypic characterization. Besides using these local indigenous breeds, a strategy will be adopted to evolve sturdy goats which would sustain and thrive in Kerala's highly humid rainfall areas, through the upgradation of the identified sturdy goat and after finalizing desired phenotypic characters. Exotic/indigenous dual-purpose goat breeds with the twinning trait will also be considered for improvement of a nondescript goat through importation after fetching suitable genetic material on an experimental basis.

CONSERVATION PROJECTS OF MALABARI AND ATTAPPADY BLACK GOATS.

- Selective breeding or upgradation of the recognized local indigenous breeds like Malabari and Attappady Black.
- The Board has established an elite herd of Malabari goats at Dhoni Station. It is a 250 Doe-level nucleus herd for the production of superior Malabari kids.
- KLD Board also has a project on the conservation of Attappady goats.
- The goats having breed-specific characters were selected and inducted to the goat farm and established a herd of Attappady black goats.
- It is a 30 Doe level breeding unit and now the board distributes female animals to the goat farmers, especially in the Attappady Regions.

FIELD PERFORMANCE RECORDING.

- As part of the conservation of Malabari goats Board also conducts a Field Performance Recording programme of Malabari goats in the natural breeding tract of the breed. i.e. in Kozhikode district.
- Production performance of the kids and does are recorded and the kids of superior does will be selected for breeding purposes.

ARTIFICIAL INSEMINATION IN GOATS.

In order to hasten the process of genetic improvement in goats through assisted reproductive techniques, artificial insemination in does by the preferred use of frozen semen can be suitably done. Quality breeding bucks selected and developed by KLDB's Goat Breeding Centers will be used for frozen semen production. The sets of breeding bucks to be used for semen production will be analyzed cytogenetically viz, karyotyping etc. It would be ensured that the bucks will be subjected to Field Performance Recording (FPR) trials. Kerala Livestock Development Board has an elite herd of Malabari and Attappady Black goats in the Dhoni farm of the board. The Board has started trials on deep freezing of frozen semen from early 2000 onwards and has successfully standardized the protocols for the production of frozen buck semen subsequently board started commercial production of frozen buck semen. The conception rate at the farm level is $\geq$ 40 %. The existing AI centres having facilities for cattle AI are suitably equipped to do AI in goats. All these centres are also provided with trevis for restraining the goats by lifting the hind quarters during AI, a headlamp for locating the cervix for AI and a vaginal speculum for the process of AI. There are 948 such Goat AI centres in the state and 70000 doses of frozen semen are distributed through these centres per annum. The strengthening of the AI centres is being done in a phased manner and AI technicians are also trained to do goat AI.

EMERGING TRENDS

- The farmers used to rear 2-4 goats in their households to meet the demand for milk and also as a source of income by selling the goats for meat purposes.
- Now goat husbandry is becoming a commercial venture and farmers have already started to rear 20-50 goats in one unit.
- They also rear Indian Goat breeds like Jamnapari, Beetal, Sirohi, Black Bengal etc. So the demand for frozen semen of these breeds arises.
- In light of these emerging trends, KLD Board have already started the production of frozen semen of Beetal, and Sirohi breeds of goats

BREEDING PROGRAMME FOR PIGS

Pig rearing has a higher potential to contribute to more economic gain, especially for small and marginal farmers. Owing to their fecundity, early maturity, and short generation interval, pigs are ideal animals for intensive farming. In addition, the initial investment and maintenance are minimal. A pig may use a large range of feedstuffs, i.e. Forages, seeds, degraded feed and garbage and turn them into precious nutritious meat. Pigs play an important role in fulfilling the wide gap between the production and availability of animal protein due to their faster growth and higher prolificacy. The piggery sector in Kerala is gaining slow but steady momentum. The pig population in the State has shot up by 86.19% over a seven-year period, reveals the 20th Livestock Census carried out by the Statistics Division of the Animal Husbandry Department.

Kerala Livestock Development Board imported pure-line breeds of pigs, Large White Yorkshire, Landrace &Duroc from the UK in 1999 to augment the piggery production of the state. KLDB developed a well-defined breeding programme for its Pig Breeding Centre (PBC) and had been able to maintain pure line breeds & produce two-way & three-way cross-bred pigs with the imported parent stock. PBC had been supplying good quality breeder and fatteners pigs to farmers of the state & Govt./Private firms within Kerala & other states, since its inception. A genetic upgradation of the quality breeding stock available in the state is the need of the hour to bring a positive change to the piggery sector of the state. This can be achieved by the importation of improved germplasm in the form of live pigs. A sound breeding policy for pigs needs to be framed for the State for enabling the importation of live pigs.

The Pig Breeding Policy of Kerala is aimed at getting a hybrid vigour for low heritable traits like a reproductive trait in the F1 and also for medium heritable traits like growth traits in F1 and fattening stock. The high heritable trait like carcass traits will improve by selection within the nucleus lines.

OBJECTIVES:

1. Genetic improvement of the pure line exotic breeds maintained at the nucleus herd by importing superior quality swine germplasm in the form of live pigs.
2. Maintenance of superior germplasm by selective breeding.
3. Crossbreeding of exotic breeds for the inheritance of desirable traits in two-way cross females.
4. Dissemination of elite germplasm through semen collection and artificial insemination with extended chilled semen.
5. Maintenance of genetically upgraded two-way cross females and terminal males in multiplier herds.
6. Maintenance of good quality three-way cross finishers with better feed conversion efficiency and average daily gain in farmers' herds.
7. Development of the piggery sector in the state with respect to breeding, feeding, management, housing and marketing.

CURRENT STATUS

- There are around 5000 registered pig farms in the state.

- Providing livelihood to thousands of families and also helping in recycling food waste from hotels and other organic waste into edible meat, thus making pork production an environmentally sustainable enterprise.
- Nearly, 9000 live pigs are being slaughtered every week in the state and only one-third of the demand is supplied from pig farms within the state.

USE OF EMBRYO TRANSFER - IVF ACTIVITIES LIVESTOCK BREEDING

Kerala Livestock Development Board (KLDB) started Embryo Transfer as a pilot project at its Mattupatti farm in the Idukki district during 1990 – 91. Crossbred cows were successfully superovulated, and embryos were collected and transferred to the recipient cows. The first calf was born on 31.01.1991 at Mattupatti. International standards and strict quality control measures are followed in the production, preservation, and transfer of embryos.

The activities in connection with the production of embryos through In Vitro Fertilization (IVF) was started at ET and IVF centre, KLDB, Mattupatti from October 2020 onwards. KLDB is having a well-established lab with the adequate equipment for carrying out IVF activities.

Below given are the steps involved in the In Vitro production of embryos.

OVUM PICK UP (OPU)

Transvaginal ultrasound-guided oocyte aspiration (TVOR), transvaginal follicular aspiration (TVA), or ovum pick-up (OPU) is a rapid and minimally invasive technique for retrieving oocytes repeatedly from a donor animal.

IN-VITRO MATURATION (IVM)

The oocytes with Grades A, B and C will be selected and washed with washing media cultured in vitro maturation Media (and plates will be incubated in the mixed gas incubator (CO_2: 6 - 7 %, O_2: 5 % and N_2: 88 %) at 38.5oC for 22 hrs for maturation.

IN VITRO FERTILIZATION (IVF) CO-INCUBATION OF OOCYTES AND SPERMS.

The oocytes will be washed thrice in the IVF media and transferred to the IVM media drops which were equilibrated. 20 oocytes were transferred to one drop. Then after assessing the motility and concentration optimum amount of semen was incubated with the oocytes in mixed gas incubator Oocytes and capacitated sperms will be co-incubated for 18 hrs) in Mixed gas incubator (CO_2: 7 %, O_2: 5 % and N_2: 88 %) at 38.5oC.

IN VITRO CULTURE (IVC): CULTURING OF PRESUMPTIVE ZYGOTES

They will be washed thrice in vitro Culture media and then put into the pre-equilibrated IVC media. Then the presumptive zygotes will be cultured in Mixed gas incubator (CO_2: 7 %, O_2: 5 % and N_2: 88 %) at 38.5oC for 7 days. Then the embryos will be evaluated on the 7th day for checking blastocyst formation.

EMBRYO TRANSFER TO OVERCOME HEAT STRESS

- The reproductive performance of Holstein cows compromised by HS can be improved by embryo transfer (ET). Early-stage embryos are more susceptible to HS than later-stage embryos (blastocysts) –Hansen et al., 2009.
- ET improves pregnancy rates in summer because embryos are transferred after the time at which they are most sensitive to HS.

THE BENEFITS OF IVF TECHNOLOGY

- can produce a large number of offspring from a single dam in a short span of time
- with no need for super ovulation, thus can avoid costly hormones
- that can produce calves from infertile cows having active ovaries.
- by using sex-sorted semen female calves can be produced extensively.
- conservation of indigenous cattle.

ABIMANYU: First IVF Vechur calf in the country. Frozen embryos were used for the ET.

GENOMIC SELECTION

Genomic selection is a modern breeding approach that involves selecting animals for breeding based on their genetic makeup or genotypes, rather than just their observable traits or phenotypes. This technique has gained popularity in livestock breeding because it allows breeders to make more accurate predictions about an animal's potential performance and traits. With genomic selection, breeders analyse an animal's DNA to identify specific genetic markers associated with desirable traits. By comparing an animal's genotypes to those of its relatives and other animals in the population, breeders can make more accurate predictions about the animal's potential performance and select animals for breeding with the most desirable genetic profiles.

Genomic selection has been particularly effective in improving traits that are difficult or expensive to measure directly, such as disease resistance, fertility, and meat quality. It has also enabled breeders to accelerate the rate of genetic gain in their populations, which can lead to faster and more efficient improvements in the quality and productivity of livestock. Centre for Applied Livestock Genomics (CALG) under KLDB is carrying out genomic-related activities.

- A new era in genetic improvement of Livestock
- Enables to do the job of improving productivity faster
- KLDB possesses both the germplasm (long storage semen of test bulls since the 1980s) and its phenotypic performance as authentic records of its daughter's milk yield –a unique advantage

ADVANTAGES OF GENOMIC SELECTION

- Young bull calves born out of nominated mating- blood sample collected- compare with the Reference Population - if found with good genomic value, use as semen donor for large scale Artificial Insemination (AI) purpose.
- The rate of genetic progress will be improved as these bulls will have the advantage of efficient genomic selection at an earlier age and farmers get the services of these young sires.
- Faster genetic progress is possible with higher accuracy and shorter generation interval.

CONCLUSION

The livestock sector plays play a crucial role in the rural economy, providing income, employment and food security to the rural and urban households of Kerala. Thus commercial breeding activities focussing towards the genetic upgradation of the livestock population will definitely boost the economy of the state.