Acta Scientific Veterinary Sciences (ISSN: 2582-3183)

Volume 5 Issue 8 August 2023

Clinical Review

Exploring Adaptive Genetic Traits in Domestic Farm Animals: A Comprehensive Review

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DOI: 10.31080/ASVS.2023.05.0718

Received: June 27, 2023

Published: July 25, 2023

Abstract

Through migrations, deliberate selection, and adaptability, the process of domestication resulted in the establishment of numerous cattle breeds. With a focus on small ruminants in particular, this paper compiles the information that is currently available on the genetic components of adaptation in key livestock species. The study covers a variety of facets of livestock's adaptation to humans, such as how domestication affects predator aversion, how cattle adjusts to hard environments, and genetic evidence of illness tolerance or resistance. It is essential to carry out demographic characterization, record production conditions, and put in place efficient data management procedures in order to guarantee the preservation of these priceless genetic resources. Additionally, molecular genetic research enables the comparison of genetic variation within and between breeds as well as the reconstruction of breed history and ancestral populations. It is noteworthy that the study also addresses bacterial infections and intestinal parasites.

Keywords: Domestication; Farm Animal Genetic Resources; Genetic Diversity; Adaptation; Disease Resistance

Introduction

Animal domestication was essential to the demographic and cultural growth of human civilizations. The great diversity of regional populations that we see now is the consequence of numerous forces that have affected the evolutionary history of cattle over time, including mutation, selective breeding, adaptation, isolation, and genetic drift. Adaptability is the ability of an animal to survive and reproduce successfully in a particular environment [39]. Adaptability is the degree to which an organism, population, or species can maintain or acquire adaptation to a wide range of environments through physiological or genetic means [7]. Smallholders, pastoralists, and their livestock usually live in difficult environments with harsh conditions. These habitats can include hot, humid climates, hot, dry regions, or even high-altitude regions with cold temperatures. Additionally, there is frequently a shortage of feed and water supplies in these locations. Their high disease pressure, which varies significantly on a seasonal and annual basis, presents additional difficulties [50]. Animals are able to learn new behaviours that help them adapt to difficult circumstances. However, the entire process of adaptation to such conditions heavily depends on genetic factors. Breeders can match the genotype with the environment using one of two methods. The environment is changed in industrial animal production systems to better meet the needs of the animals. The goal of minimal input smallholder and pastoral systems, on the other hand, is to protect animals that are already suited to their particular environment. There is strong evidence that cattle populations and breeds that have evolved over centuries in a variety of challenging tropical conditions have a wide range of distinctive adaptive features. These characteristics include the ability to withstand heat and sickness, tolerating water deprivation, and thriving on subpar diet. These creatures' adaptations allow them to live and function well in these harsh conditions [3,6,14,17]. The careful preservation and use of various genetic resources are highly valued by livestock farmers. With this strategy, it is ensured that the distinctive traits of cattle breeds can be successfully adapted to unforeseen social or commercial requirements as well as shifting environmental conditions. The availability of these genetic resources also benefits academics since they may examine them and gain a better understanding of domestication, selection, genetics, and evolution. In order to fulfil the changing demands of society, this collective effort supports the ongoing growth and improvement of livestock breeds [34]. There is strong evidence for the idea that populations and breeds of cattle that have spent ages evolving in a variety of difficult tropical conditions have a wide range of particular adaptive features. These characteristics include the ability to withstand heat and sickness, tolerating water deprivation, and thriving on subpar diet. These livestock breeds' adaptable traits allow them to thrive in such harsh situations and continue to produce [3,6,14,17]. Livestock breeders recognize the critical importance of responsibly conserving and utilizing diverse genetic resources. This is done to ensure that the unique traits and characteristics of these resources can be effectively adapted to meet unforeseen social or commercial demands, as well as to cope with the impacts of a changing climate. Furthermore, researchers greatly benefit from the availability of these genetic resources, as they can study and analyze them, contributing to a deeper understanding of various aspects such as domestication, selection, genetics, and evolution. This collective effort not only facilitates the preservation of valuable genetic diversity but also promotes the advancement of knowledge and innovation in the field of livestock breeding [34].

Due to the enhanced genetic merit for milk supply, the dairy sector has noticed a deterioration in the average fertility and health of cows [40]. The two main causes of the drop in fitness attributes are identified by [19]. First off, because of their apparent lesser heritability or the difficulty in recording them, these features were not adequately included when building selection indices. Second, despite a thorough understanding of the underlying genetic mechanisms like selection and inbreeding depression, incorrect breeding programmes were adopted.

The lack of genetic variance should not be mistaken for the poor heritability of some fitness variables. The high genetic coefficient of variation seen for fitness measures, equivalent to some production traits, serves as evidence that low heritability frequently results from phenotypic variance being greater than the tiny genetic variance [16,19]. The incorporation of functional traits, such as functional longevity, persistency, fertility, calving ease, stillbirth, and somatic cell count, into a total merit index has been found to yield positive results in terms of annual monetary genetic gain. By considering these functional traits alongside production traits, the overall genetic improvement of the population can be enhanced. This approach recognizes the significance of breeding for traits that contribute to cow health, reproductive efficiency, and overall herd functionality, resulting in improved profitability and sustainability for dairy producers. [38,44,49,53,56,57]. Tick counts, fecal worm egg counts (FEC), rectal temperatures, and coat scores have been employed as indicator traits to evaluate the adaptability of beef cattle genotypes in tropical environments. These traits serve as valuable tools for assessing the suitability of specific genotypes in withstanding the challenges posed by tropical conditions. By monitoring tick counts, FEC, rectal temperatures, and coat scores, breeders and researchers can gain insights into the adaptability and resilience of beef cattle to the tropical climate. These indicators provide valuable information for selecting genotypes that can thrive and maintain optimal performance in such environments [39]. Regrettably, the evaluation of adaptive traits using indicators such as tick counts, fecal worm egg counts (FEC), rectal temperatures, and coat scores is often neglected, leading to a lack of knowledge regarding the genetic factors associated with adaptive qualities in livestock herds managed in tropical environments. This study aims to address this gap by providing a comprehensive overview of the current understanding of the genetics of adaptation in significant livestock species, with a particular focus on small ruminants. By consolidating existing knowledge, this work aims to shed light on the genetic mechanisms underlying adaptation and contribute to a better understanding of how livestock species adapt to and thrive in tropical environments.

Domestication

Wild animals are domesticated by a process of selective breeding and taming over many generations, which causes them to adapt to human-controlled conditions and become dependent on people for survival. Due to this fundamental transition, agriculture, established settlements, and the use of domesticated animals to provide a variety of goods and services have all had a huge impact on human societies. Animal domestication is said to have started around 10,000 years ago, at the same time when hunter-gatherer societies began to settle and develop farming communities. It is believed to have independently developed in the Near East, East Asia, Africa, and the Americas, among other places. Dogs, sheep, goats, pigs, cattle, horses, and chickens are just a few of the first creatures that were domesticated. Domestication is a crucial initial phase of the selection process, and it is essential to differentiate it from taming. The concept of domestication involves intentional breeding, where specific individuals are selected as reproducers and isolated from their wild counterparts. It also encompasses the provision of care, including shelter, food, and protection against predators, as well as controlled feeding practices. The key distinction between domestication and taming lies in the degree of human control over these aspects of animal management. In domestication, humans exert a greater level of influence and control over breeding, care, and feeding practices, distinguishing it from the relatively less controlled process of taming [23]. According to Gillespie (21), it is widely believed that the primary and most influential factor in the early stages of selection was adaptation to a specific environment. The ability of domesticated animals to successfully live, survive, reproduce, and produce in a given environment played a crucial role in the selection process. The early breeders and caretakers of domesticated animals likely favored individuals that exhibited superior adaptation traits, as these traits directly contributed to the survival and productivity of the animals in their environment. Therefore, adaptation to the environment was considered a key determinant in the selection of domesticated animals during early times.

Environmental and production system adaptation in domesticated farm animals

Domestic farm animals play a critical role in providing food, fiber, and other essential products for human consumption and use. Ensuring their well-being and productivity requires a deep understanding of environmental adaptation and production system management. An island off the northeastern coast of Scotland is home to a species of sheep known as North Ronaldsay sheep, which is remarkably adaptable. These sheep have evolved unusual means of surviving, largely by subsisting solely on seaweed. They get all the nutrients they require from the abundant kelp beds along the shore and the scant amount of freshwater available to them. Additionally, despite the lack of freshwater supplies, they have successfully adapted to tolerate the excessive presence of some elements, like sodium. The capacity of these sheep to subsist on a diet of Limnaria, a species of seaweed with very little copper concentration, is one distinguishing adaption. However, if given Limnaria, other sheep breeds prevalent in Scotland who are used to eating grass or hay might experience copper deficiencies. This demonstrates the distinct environmental and dietary adaptations made by the North Ronaldsay sheep [34].

"Human adaptation in domestic farm animals: insights into genetic responses

Animals' minimum reactions to human presence, such as demonstrating a short flight distance, serve as an example of how adaptable they are to humans. A low level of concern is also indicated by their absence of fear reactions. Longer flight lengths are indicative of more docile temperaments in animals, while shorter flight times are often associated with less desirable temperaments [39].

Even though domestic ruminants have been domesticated, they still react defensively to people. Although one of the benefits of domestication is the general decrease in fear of humans, routine management treatments including castration, tail docking, dehorning, vaccination, herding, and transportation of cattle and sheep can still arouse unpleasant feelings, notably terror. There is widespread agreement that these unpleasant feelings are detrimental to animal welfare [12]. A overview of heritability estimates for fear in dairy, beef, and sheep cattle was presented by [12]. Their research revealed that the dairy cattle's heritability estimates for fear ranged from 0.09 to 0.53. Reactions to handling were shown to have a moderate heritability value of 0.22 in beef cattle. The estimates of the heritability of fear in sheep ranged from 0.28 to 0.48. These results imply that management strategies used to raise ruminant cattle as well as genetic selection focused at lowering fearfulness could considerably improve the welfare of those animals. It is possible to carry out genetic selection programmes without negatively affecting other desirable productive features in order to reduce fear response to handling. It might even enhance some adaptive behavioural features, such maternal behaviour.

Predator response and behavioral adaptation in domestic farm animals

Animals that have been domesticated benefit from human defence against predators, which lowers the frequency of anti-predator behaviours. Relaxed selection pressures on these features are responsible for the decline in anti-predator traits. As a result, Mignon-Grasteau [31] hypothesised that domesticated animals may be more susceptible to predation than their wild counterparts in scenarios involving predators.

Feed Resource Adaptation in Domestic Farm Animals

Animals adapt to periods of feed scarcity through various strategies. These adaptations can include

- Developing low metabolic requirements: Animals can reduce their energy needs during periods of limited food availability, allowing them to conserve energy and survive with minimal intake.
- Ability to reduce metabolism: Some animals possess the ability to lower their metabolic rate during periods of feed scarcity. By decreasing their metabolic activity, they can stretch their available energy resources for a longer duration.
- Digestive efficiency and utilization of high-fiber feed: Animals adapted to feed scarcity often possess efficient digestive systems capable of extracting maximum nutrition from fibrous

and less-digestible feeds. This enables them to utilize low-quality forages and high-fiber diets more effectively.

- Deposition of nutrients as fat reserves: In preparation for periods of food scarcity, animals may accumulate and store nutrients, particularly in the form of fat reserves. These fat stores serve as an energy reservoir that can sustain them during times of limited food availability.

These adaptations allow animals to cope with and survive through periods of feed scarcity by minimizing their metabolic demands, optimizing digestion, and storing energy reserves for future use.

Genetic adaptation to extreme climates in domestic farm animals

Animals that are subjected to heat stress suffer negative effects on their physiological functions. In addition to abnormalities in protein, energy, and mineral levels, lower feed intake and utilisation, water metabolism disruptions, and altered enzymatic reactions, hormonal secretions, and blood metabolite levels are some of these impacts [29]. As a result, these elements influence lower reproductive and output performances. Additionally, when increased humidity and heat stress are present, the deleterious effect is amplified. Zebu cattle have unique genetic and biological features that make them well-suited for hot climes, according to Turner's [51] thorough investigation. These characteristics include their skin, coat, hide, haematological properties, body composition, growth patterns, and physiological characteristics. These distinctive genetic traits set zebu cattle apart from Bos taurus cattle. Zebu cattle differ from B. taurus cattle in that they have smooth coats, main hair follicles, and better developed sweat and sebaceous glands. Zebu cattle can effectively remove heat through evaporation because of these qualities, which allows them to maintain thermal equilibrium. They need to be able to do this in order to perform normally and at their best in hot situations [51]. An animal's ability to sustain euthermia (normal body temperature) under future cold trials improves as a result of physiological reactions that occur during the process of adapting to low temperatures [58]. Sheep suited to colder climates, where the degree of heat load is greater, tend to store more body fat beneath their skin than do sheep from warmer climates [8,15,18,24,35].

In their respective studies comparing the Horro and Menz sheep breeds [1,35] and [15] found interesting patterns of fat deposition, highlighting the adaptation of these breeds to specific environmental conditions. The researchers reported that in Horro sheep, a significant proportion of total body fat was accounted for by the combined weight of tail and rump fat. On the other hand, the Menz breed exhibited a higher proportion of fat deposition in the subcutaneous and intramuscular depots. These findings confirm that these breeds have undergone preferential fat deposition as an adaptation mechanism to their specific environmental conditions.

The greater deposits of subcutaneous and intramuscular fat in the Menz breed can be attributed to its cooler habitat, characterized by lower temperatures. In contrast, the Horro breed inhabits a slightly lower altitude with a relatively warmer environment. These differences in fat distribution suggest that each breed has adapted to optimize their insulation and thermoregulation capabilities in response to the specific temperature conditions of their respective habitats. Sheep that have adapted to arid conditions typically exhibit a different fat deposition pattern. In these sheep, the fat deposits under the skin are often minimal, and the majority of the fat is concentrated on the rump and/or the fat tail [8]. This unique fat distribution pattern serves as an adaptation strategy to cope with thermal stress. The strategic placement of these fat depots, specifically the tail and rump, does not hinder heat loss from the body. This arrangement allows for efficient dissipation of heat, aiding in the regulation of body temperature in arid environments.

Genetic adaptation to water scarcity in domestic farm animals

Animals have the remarkable ability to adapt to water scarcity in various ways. They have developed a range of physiological, behavioral, and anatomical adaptations to survive and adapt to water scarcity. These strategies enable them to endure arid conditions and successfully navigate environments with limited water resources.

During times of drought, livestock that require little water intake and don't need to visit a water source every day have a unique advantage. These animals have greater access to feed since they can access wider pasture regions. Camels are a prominent example of a species that excels at conserving water. In hot summer conditions, camels can last up to 17 days without drinking water while subsisting on dry food, according to Schmidt-Nielsen [47]. Additionally, camels have been known to go up to 60 days without drinking water when grazing on greenery [45]. Due to these extraordinary adaptations, camels and other similar livestock may survive in arid regions by making efficient use of the water sources that are available and acquiring nutrition from sparse or dry vegetation. As a result, even during times of drought, they can cover large grazing areas and gather more forage. During drought conditions when feed resources are limited, livestock can prolong their survival by reducing their water intake. This reduction in water intake leads to a decrease in feed intake and metabolic rate. By reducing feed intake, animals can conserve energy and nutrients within their bodies for a longer period. The decreased metabolic rate helps to slow down the utilization of stored energy, allowing livestock to survive for an extended duration during the scarcity of feed. This adaptive response is an essential survival strategy for animals during droughts. By reducing water intake, livestock can allocate their limited resources more efficiently and endure longer periods without access to sufficient feed. Desert goats have been reported to be the most efficient among ruminants in terms of ability to withstand dehydration [46]. This mechanism helps them maintain their energy reserves and sustain their physiological functions until better forage or water resources become available. Desert goats have garnered recognition for their exceptional ability to withstand dehydration, making them the most efficient among ruminants in this regard [48]. Notably, the black Bedouin and Barmer goats, which inhabit the extreme deserts of Sinai in the Middle East and Rajasthan in India, have demonstrated remarkable water conservation abilities. Studies by [25-27] and [59] have reported that these goats often drink water only once every four days. This infrequent water consumption pattern showcases their adaptation to arid environments and their capacity to thrive with limited access to water resources. Their efficient water utilization enables them to sustain their physiological functions and survive in harsh desert conditions. Desert goats possess a physiological mechanism that enables them to cope with extreme water deprivation by effectively enduring dehydration and minimizing water losses through urine and feces. Studies by [5,26] and [59] have revealed that Barmer and Bedouin goats can experience water losses exceeding 40% of their body weight by the fourth day of dehydration. Despite these significant water losses, when these goats are subjected to intermittent or partial watering regimens during the summer, they tend to gain body weight by the end of the season.

This remarkable adaptation showcases the resilience of desert goats in conserving water and efficiently utilizing available resources. By minimizing water loss through urine and feces, these goats are able to maintain their hydration levels and sustain their physiological functions in water-scarce environments. Additionally, their ability to gain body weight under intermittent or partial watering conditions demonstrates their capacity to optimize their nutrient utilization and thrive even in challenging arid conditions.

Genetic tolerance and resistance to parasitic and bacterial diseases in domestic farm animals

Resilience or tolerance refers to the ability of a host to survive and maintain productivity despite being challenged by parasites. Studies by [1,6,55] have explored this concept and highlighted its significance.In the context of parasite challenge, resilience/tolerance encompasses various factors, including the host's immune response, genetic traits, physiological adaptations, and overall health status. A resilient/tolerant host is capable of minimizing the negative impact of parasites on its well-being, allowing it to sustain productivity and overall performance. understanding the mechanisms of resilience/tolerance, researchers and livestock managers can develop strategies to enhance the host's ability to combat parasitic infections and minimize their detrimental effects. This knowledge can contribute to improved animal welfare, productivity, and sustainable livestock production systems. When evaluating the degree of resistance to gastro-intestinal (GI) nematode parasites, researchers commonly assess worm counts at necropsy or fecal parasite egg counts (FEC) during the infection period in live animals. In the case of lambs, there is a strong correlation between FEC and worm counts, as noted by [55] FEC serves as a practical and non-invasive method for estimating the parasite burden in live animals. By examining the fecal samples, researchers can quantify the number of parasite eggs shed by the host, providing an indication of the level of infection. These egg counts are often closely related to the actual number of worms present in the gastrointestinal tract, allowing for a reliable assessment of the host's resistance to GI nematode parasites.

This approach enables researchers to monitor and compare the efficacy of different treatments, management strategies, or genetic factors that may influence the host's ability to resist or control parasitic infections. By understanding the relationship between FEC and worm counts, scientists can gain valuable insights into the host's immune response, genetic resistance, and overall resilience to GI nematode parasites. Certain tropical sheep breeds, based on anecdotal evidence, have been recognized as resistant to severe disease challenges and thrive in stressful environments. For instance, the West African Djallonke sheep is believed to exhibit resistance to both endoparasites and trypanosomosis [4,37]. Additionally, the Garole sheep in India has been observed to possess resistance to diseases [20].

Nimbkar [36] conducted a study in India to compare the resistance to Haemonchus contortus (a common internal parasite) among F1 Garole crossbred lambs, Bannur lambs, Deccani lambs, and 50% Bannur/50% Deccani lambs. The results indicated that lambs with 50% Garole genes exhibited significantly greater resistance to H. contortus compared to the other breeds and crosses tested. This finding supports the notion that genetic factors, specifically the presence of Garole genes, contribute to enhanced resistance against parasitic infections.

These anecdotal and research-based observations highlight the potential existence of inherent resistance traits in certain tropical sheep breeds. Further studies and genetic analyses are necessary to better understand the underlying mechanisms responsible for the observed resistance and to facilitate the development of strategies for sustainable disease management and breeding programs aimed at enhancing resistance in sheep populations. Studies conducted in the central highlands of Ethiopia have examined the resistance of Menz and Horro sheep breeds to endoparasites. According to research by [3,5,43,52], there were no significant differences in resistance to endoparasites between Menz and Horro sheep when exposed to natural pasture challenges.

However, under artificial challenge conditions, [22] found some evidence suggesting that Menz lambs may exhibit greater resistance to endoparasites compared to Horro lambs. This indicates that the resistance levels may vary depending on the type and intensity of the parasite challenge.

In a separate study by [2] conducted in southern Ethiopia, four Ethiopian sheep breeds were compared for their resistance to endoparasites, primarily Haemonchus contortus. The study reported that the Blackhead Somali breed native to semi-arid lowlands was the most susceptible, while the Arsi breed from humid highlands displayed the highest resistance to endoparasites.

These findings demonstrate that resistance to endoparasites can vary among different sheep breeds and may be influenced by environmental factors and the specific parasite challenges encountered. Further research is needed to better understand the underlying mechanisms of resistance in different sheep populations and to develop effective strategies for parasite control and breeding programs focused on enhancing resistance traits.

Numerous studies have investigated the heritability of relative nematode resistance in sheep, typically utilizing fecal egg counts (FEC) as an indicator of resistance. These studies have demonstrated that appropriately transformed FEC is a moderately heritable trait in lambs and can respond to selection.

Researchers such as [9,10,32,33] have quantified the heritability of relative nematode resistance in sheep. Through their investigations, they have determined that FEC, when appropriately transformed, exhibits a moderate degree of heritability. This means that a significant portion of the observed variation in FEC can be attributed to genetic factors.

Furthermore, these studies have shown that FEC, as a heritable trait, can respond to selective breeding. By selecting animals with lower FEC or higher resistance levels, breeders can gradually improve the overall resistance of a sheep population to nematode infections.

Understanding the heritability of relative nematode resistance and its response to selection is crucial for implementing effective breeding strategies aimed at reducing the impact of nematode infections in sheep. By identifying and selectively breeding animals with improved resistance, breeders can enhance the overall health and productivity of sheep populations. Significant efforts have been made in various countries, including New Zealand, Australia, Kenya, the United States, and several European countries (such as the UK, France, Italy, and Spain), to conduct studies in sheep aiming to identify quantitative trait loci (QTL) associated with nematode resistance or to detect associations with candidate genes. However, it should be noted that the results of these studies are not readily available in the public domain, as highlighted by [11].

While advancements have been made in this area of research, it is acknowledged that achieving substantial success in identifying QTL or candidate genes for nematode resistance in sheep has proven challenging. For example, [30] reported limited success in their endeavors.

The complex nature of nematode resistance, which involves multiple genetic and environmental factors, likely contributes to the difficulties encountered in these studies. Nonetheless, ongoing research and collaborations continue to explore the genetic basis of nematode resistance in sheep, with the hope of uncovering valuable insights that can contribute to the development of effective breeding strategies for enhanced resistance.

Although specific results may not be readily available to the public, these ongoing efforts signify the importance and commitment of the scientific community to address the challenge of nematode infections in sheep through genetic research.

Footrot is a bacterial disease that affects sheep and is primarily caused by the bacterium Dichelobacter (Bacteroides) nodosus (D. nodosus). It is a significant cause of lameness in both lambs and mature sheep, posing welfare concerns and resulting in substantial economic losses for sheep farmers.

The disease is characterized by inflammation and infection of the tissues surrounding the sheep's hoof, leading to painful lesions and lameness. It is highly contagious and can spread rapidly within a flock, particularly in moist and dirty conditions. D. nodosus thrives in environments with high humidity and organic matter, making it more prevalent in wet and muddy areas.

Footrot negatively impacts sheep welfare as it causes discomfort, pain, and impaired mobility. Infected sheep may have difficulty moving, grazing, and accessing water, leading to weight loss and reduced productivity. Additionally, footrot can result in secondary infections and affect overall health, potentially leading to more severe complications if left untreated. In addition to the welfare implications, footrot imposes significant economic losses on sheep farmers. The disease can reduce sheep productivity, lower growth rates, decrease wool quality, and increase treatment costs. It also requires ongoing management and control measures, including regular hoof trimming, foot bathing, and administration of antibiotics, which add to the financial burden. Assessing the genetic control of footrot and breeding for resistance is relatively straightforward due to the ease of scoring footrot severity under field conditions. Egerton and Roberts initially developed a footrot lesion scoring method for Australian Merino sheep, which was later refined into a system that categorized clinical signs into eight different categories [41].

This scoring system, demonstrated the presence of significant genetic variation in resistance to both virulent isolates of D. nodosus and natural challenge. Although the heritabilities of individual assessments of footrot severity were generally low to moderate, genetic correlations between different indicators were high, approaching unity. Furthermore, heritability estimates derived from repeated measurements approached approximately 0.30. These findings indicate that while footrot severity may exhibit moderate heritability at the individual assessment level, there is substantial genetic control underlying the overall resistance to footrot. The high genetic correlations between different indicators suggest that selection for resistance based on any of these indicators would likely result in improvements in overall resistance to footrot in sheep populations. The availability of a standardized and practical scoring system for footrot severity allows for efficient evaluation of resistance levels in breeding programs. By incorporating information on footrot resistance into selection decisions, sheep breeders can gradually improve the genetic resistance of their flocks, leading to reduced incidence and severity of footrot, as well as improved flock welfare and economic performance [42].

Resource allocation theory in domestic farm animals: balancing production and fitness traits

The theory of resource allocation helps us to understand how animals divide up their few resources, such as time, energy, and nutrients, among a variety of competing physiological functions and features. Utilising domestic farm animals, this theory has been used to investigate the trade-offs between fitness and productivity qualities, such as growth and milk output. In domestic farm animals, selection for increased production traits, driven by economic and market demands, has often led to unintended consequences for fitness traits. For example, intense selection for high milk production in dairy cows may result in reduced fertility or increased susceptibility to diseases. Similarly, selection for rapid growth in meat-producing animals can lead to reduced longevity or compromised immune function. Resource Allocation Theory helps to understand these trade-offs by examining how the allocation of resources to different traits affects the overall fitness of animals. It recognizes that resources allocated to one trait are no longer available for other traits, creating a limited resource pool. The challenge for breeders and animal managers is to find the optimal balance between production traits and fitness traits to ensure the long-term sustainability and welfare of the animals. In van der Waaij's study (2004), it was observed that production takes precedence over resource allocation, which differs from the natural selection process. When selection is based on observed production and there are limitations on resource intake, the selection pressure shifts towards resource intake. This leads to a higher allocation of resources for production, potentially at the expense of overall fitness. Inadequate resource allocation to fitness-related traits can have negative consequences such as reduced health, fertility, and available energy for maintenance. Consequently, this can impact the rate of reproduction and the probability of survival. Supporting this perspective [13], and [28] suggest that as resources become scarce, there is a negative correlation between production traits and fitness-related traits.

The outcomes of a modeling study conducted by [54] reveal that environmental sensitivity, characterized by a negative correlation between observed production and the probability of survival, manifests rapidly upon the occurrence of metabolic stress. These findings underscore the prompt development of heightened sensitivity to the environment in response to metabolic stress, ultimately influencing the likelihood of survival.

Conclusions on Genetic Adaptation in Domestic Farm Animals

Genetic adaptation is the process by which farm animals evolve to survive and thrive in their environment. Different breeds of livestock have different genetic variations that allow them to adapt to different environmental conditions. For example, some breeds of cattle are more tolerant of heat stress, while others are more resistant to disease.

Genetic adaptation is important for livestock farming because it helps to ensure the survival and productivity of livestock populations. By understanding the genetic diversity of farm animals, we can develop more productive, resilient, and sustainable livestock populations.

Here are some specific examples of genetic adaptation in farm animals

- **Heat tolerance:** Some breeds of cattle, sheep, and goats have been shown to be more tolerant of heat stress than others. This is due to genetic variations that affect the animals' ability to regulate their body temperature.
- **Disease resistance:** Different breeds of livestock vary in their susceptibility to various diseases. For example, some breeds of chickens are more resistant to Marek's disease, a viral disease that can cause paralysis and death in poultry. This is due to genetic variations that affect the animals' immune system.
- **Feed efficiency:** Some breeds of livestock are more efficient at converting feed into energy and growth than others. This is due to genetic variations that affect the animals' digestive system.

By understanding and harness the genetic diversity of farm animals, we can develop more productive, resilient, and sustainable livestock populations.

Here are some ways to harness genetic adaptation in farm animals

- **Selecting breeding animals:** Farmers can select breeding animals from within their herds that have the desired genetic traits for heat tolerance, disease resistance, and feed efficiency.
- **Crossbreeding:** Farmers can crossbreed different breeds of livestock to combine the desirable genetic traits of each breed.
- **Genetic engineering:** Scientists are developing new genetic engineering techniques that can be used to introduce specific genetic traits into livestock populations.
- **Genetic adaptation is a powerful tool** that can be used to improve the productivity and sustainability of livestock farming. By understanding and harnessing the genetic diversity of farm animals, we can develop more resilient and productive livestock populations that are better suited to their respective environments.

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