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Holstein Friesian Dairy Cattle Physiological Adaptation in Balochistan: A Review

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ABSTRACT

This review article provides a comprehensive overview of Holstein Friesian dairy cattle's physiological adaptation in Balochistan, a harsh environment that poses significant challenges to animal production. The article reviews various physiological responses and adaptations of Holstein Friesian dairy cattle to thermal stress and water scarcity, which are two of the most significant challenges the animals face in this region. It also highlights several key physiological responses that occur in Holstein Friesian dairy cattle when exposed to thermal stress, such as increased respiratory rate, pulse rateand rectal temperature. Additionally, milk production, somatic cell count (SCC), blood metabolitesand heart rate were identified as valuable indicators for assessing the animal's thermoregulatory mechanisms and detecting the impact of thermal stress. Moreover, adaptations of the sweat gland characteristics, metabolism processes and reduced metabolic requirements were also discussed. This review also highlighted the effect of altitude, hair coatand breed differences on the animals' physiological adaptation. The authors stressed the significance of understanding the animals' physiological responses to harsh environmental conditions and the importance of measuring these responses accurately in enhancing the animal's productivity and welfare. This review concludes with recommendations for improving the adaptability and performance of Holstein Friesian dairy cattle in Balochistan. Suggestions include implementing crossbreeding programs with indigenous breeds, improving management practices, utilizing physiological parameters to monitor animal health and conducting further research to identify genetic variations that improve animal adaptability. The authors emphasize the significance of these recommendations to increase farmers' income, enhance food securityand contribute to the socio-economic development of the region. In conclusion, this review article provides valuable insights into Holstein Friesian dairy cattle's physiological adaptation in Balochistan and can be useful for stakeholders in the dairy industry, policymakersand researchers concerned with improving the sustainability and profitability of animal agriculture in harsh environments.

Key words: Harsh environment, Holstein frisian, Physiological adaptation, Thermal stress.

The species *Bos indicus* is home to the majority of indigenous cow varieties found in tropics. This species is well suited to tropical climates. They have a high level of heat tolerance, are resistant to illnesses spread by ticks and other tropical diseases and require little upkeep. Its capacity for milk production, however, is modest. On the other hand, the dairy breed that predominates in temperate nations is *Bos taurus* (European type). These breeds have a strong potential for milk production but have a little heat tolerance deficit.

Crossbreeding tropical cattle with dairy breeds of the Bos taurus (European type) is one technique to increase their ability to produce milk. This has been commonly employed to blend the adaptability of indigenous breeds with the high milk output potential of foreign ones. For example, the F1 crosses had shorter calving intervals and longer lactation than the native breeds (Kiwuwa *et al*., 1983). They may also produce up to three times as much milk. Approximately 81.2 per cent of Ethiopia's total annual milk output is produced by indigenous breeds with poor genetic potential for milk production, making it one of the tropical nations with the highest dairy production (CSA, 2009). The biggest issue with milk production in the country is the indigenous cattle's limited genetic potential, which results in low milk yield. Over the course of a lactation period of 160 to 200 days, milk supply can be as low as 0.5 to 2 litres per day. To raise the amount of milk produced daily so that the cattle are acceptable for commercial, market-oriented milk production, it is not enough to improve the nutrition, water availability and health care of the native cattle (Zelalem *et al*., 2011). Under ideal care, the average lactation milk output of the native cows varies from 494 to 850 kg (Aynalem *et al.,* 2009). Therefore, genetic upgrading of the local cattle has been suggested as one of the greatest choices to fulfil the constantly rising demand for milk and milk products and thereby contribute to economic progress. Through cross breeding, either by transferring germplasm or by directly importing exotic animals from

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temperate countries, genetic improvement procedures for cattle have been introduced in Pakistan (Habtamu *et al.,* 2010). Holstein Friesian and Jersey, where the Holstein Friesian breed predominates, are now the most popular foreign dairy breeds in Pakistan. The explanation for this is that it has a great capacity for milk production and can adapt to a wide range of climatic settings (Mekonnen and Goshu, 1987).

Animal adaptability can be characterized as either the degree to which an organism, population, or species can continue to be or become adapted to a wide range of environments through physiological or genetic means (Prayaga and Henshall, 2005) or as the capacity to survive and reproduce within a defined environment. Smallholders and pastoralists frequently live in difficult conditions that might be hot and dry, hot and humid, or high in elevation and cold. Additionally, these settings can be identified by their limited feed and water supplies, as well as their high disease pressure and significant seasonal and yearly change. Animals may "learn" to survive in such harsh environments, but heredity plays a big role in how well they adapt to these elements. Based on the resources that are available and the economic situation, the physical environments of Pakistan vary substantially between places and manufacturing systems.

Since Pakistan is a country with a moderate temperature and a diversified geography, it is not surprising that there are many different types of stressful circumstances there. The physiological reactions elicited by this severe environment are imperceptible, reproducible and tailored to the limitation. Understanding the molecular processes that allow animals to operate and live in harsh situations will help us better understand how physiological adaptation works. Consequently, the following are the primary goals of this article:

- To collect data on the physiological characteristics of Holstein Friesian dairy cattle in Balochistan.
- To comprehend and suggest a physiological condition for Holstein Friesian dairy cattle that is adequate and promising in order to develop a sustainable dairying system.
- Acquiring the ability to properly cite a variety of written materials (literature) about a subject.

Literature Review

Historical evolvement and adaptation of Holstein Friesian dairy cattle in Balochistan

The Holstein Friesian cattle breed, recognized as one of the top milk producers worldwide, has undergone significant historical evolvement and physiological adaptation in various regions of the world, including Balochistan. Balochistan province, located in southwestern Pakistan, holds an agricultural economy dependent on livestock, with dairy farming being its major subsector. Holstein Friesian dairy cattle were first introduced in Balochistan in the 1970s, where they have since undergone profound physiological adaptation to survive the extremes of the region's climate (Abdullah *et al*., 2017).

Balochistan's harsh climate characterized by low rainfall, high temperaturesand water scarcity has posed challenges to dairy farmers who have had to contend with limited forage and water resources affecting animal productivity. Nonetheless, Holstein Friesian cattle have adapted physiologically to the region's environment and are known for their high milk yield performance even under the adverse weather conditions prevalent in Balochistan (Abdullah *et al*., 2017). Studies show that physiological adaptations in Holstein Friesian dairy cattle in Balochistan include changes in body weight, hair coatand skin color. Moreover, the breed has undergone physiological adaptations in its metabolism, amino acid synthesis and utilization and altered digestive system morphology, all geared towards enhancing feed utilization efficiency (Khan *et al*., 2017). Holstein Friesian dairy cattle in Balochistan has contributed significantly to the economic growth of the province. The breed has undergone remarkable historical evolvement and physiological adaptation to thrive under the harsh environmental conditions in Balochistan. The adaptability of the breed to the area's environment makes it a valuable asset to the region and dairy farmers, contributing significantly to milk production and the dairy subsector's growth in the area.

Physiological adaptability of Holstein Friesian dairy cattle to high altitudes in Balochistan

Balochistan, one of the largest provinces in Pakistan, is known for its vast, mountainous terrain, which offers a high-altitude habitat for livestock. Holstein Friesian dairy cattle are well-suited to adapt to the high-altitude environments of Balochistan, thanks to their physiological adaptability, which allows them to thrive even in challenging environments. Numerous scientific studies have documented the mechanisms of physiological adaptations in cattle to high-altitude habitats, including Holstein Friesian dairy cattle in Balochistan. One of the major challenges that livestock breeders and farmers face in Balochistan is the high-altitude environment. Studies have shown that one of the critical mechanisms by which Holstein Friesian dairy cattle adapt to high altitudes is through enhanced cardiopulmonary function. The cattle's hearts and lungs must perform at a higher level than their counterparts living at lower altitudes. This adaptation includes an increase in the number of blood vessels that supply the cattle's muscles and a higher concentration of hemoglobin, which allows for more significant oxygen uptake (Tashi *et al*., 2019).

Another aspect of Holstein Friesian dairy cattle's physiological adaptability to high altitudes in Balochistan is their ability to maintain a stable metabolic rate at higher altitudes. The cattle's metabolic rate is critical for survival and the need to adapt to harsh environmental conditions

can result in significant metabolic changes. However, studies have shown that Holstein Friesian dairy cattle can adjust their metabolic rates to maintain a stable body temperature and energy balance at high altitudes (Kumar *et al*., 2021). Research indicates that Holstein Friesian dairy cattle in Balochistan also have different gastrointestinal adaptations that allow them to survive in high-altitude environments. These adaptations include altered microbial fermentation in the rumen and increased contact time between forages and gastrointestinal membranes, which improves nutrient absorption and energy uptake (Mohammad *et al*., 2011).

Studies have also documented the effects of high-altitude environments on Holstein Friesian dairy cattle's immune system. One study found that cattle at higher altitudes had higher numbers of lymphocytes and neutrophils, indicating an increase in the animal's resistance to infectious diseases, germs and parasites (Singh *et al*., 2016). Holstein Friesian dairy cattle have shown high levels of adaptability to high-altitude environments in Balochistan. The breed's physiological adaptations include enhanced cardiopulmonary function, metabolic rate adjustments, improved gastrointestinal function and bolstered immune function. These adaptations enable Holstein Friesian dairy cattle to thrive in Balochistan's high-altitude environments, making them an ideal breed for dairy farming in the region.

The role of subcutaneous fat storage in relation to cold stress adaptation

The role of subcutaneous fat storage in relation to cold stress adaptation is an essential aspect of the physiological adaptation of Holstein Friesian dairy cattle in Balochistan. Cold stress poses a significant challenge to livestock in high-altitude and cold climates and subcutaneous fat plays a crucial role in maintaining body temperature and energy balance during these adverse conditions. Research suggests that subcutaneous fat acts as an insulator, providing thermal protection to animals in cold environments. Studies have shown that Holstein Friesian dairy cattle in Balochistan exhibit increased subcutaneous fat deposition during cold seasons. This increased fat storage serves as a valuable source of energy and insulation, helping the cattle maintain their core body temperature and protect themselves from environmental stressors (Mohammad *et al*., 2016).

Furthermore, subcutaneous fat is also involved in hormonal regulation and metabolism. Adipose tissue, present in the subcutaneous layer, releases adipokines, such as leptin and adiponectin, which play crucial roles in energy homeostasis and immune function. These adipokines not only regulate the cattle's metabolic rate but also influence their response to cold stress by modulating thermogenesis and heat production (Davoodian *et al*., 2020). In addition to its thermoregulatory functions, subcutaneous fat storage also contributes to reproductive performance in Holstein Friesian dairy cattle. Several studies have reported a positive correlation between subcutaneous fat thickness and reproductive outcomes, including increased fertility rates and improved embryo survival. The presence of adequate subcutaneous fat is believed to enhance the cow's reproductive health by providing the necessary energy reserves during the breeding season and supporting the high energy demand of pregnancy (Munoz *et al*., 2015).

However, excessive subcutaneous fat accumulation can have negative implications. Overweight or obese cows may have lower feed efficiency, reduced metabolic healthand increased risk of metabolic disorders such as ketosis and fatty liver. Therefore, maintaining an optimal balance of subcutaneous fat storage is crucial for the overall health and adaptation of Holstein Friesian dairy cattle in Balochistan (Clark *et al*., 2017).

The role of hair coat and color in Holstein Friesian to adapt heat or cold stress

The hair coat and color of Holstein Friesian dairy cattle play a crucial role in their adaptation to heat and cold stress in Balochistan. The coat acts as a natural barrier between the animal's skin and the environment and provides thermal insulation, protection against solar radiation and evaporative cooling, depending on the climatic conditions. Holstein Friesian dairy cattle have a distinctive black and white hair coat, with black pigmentation concentrated around the head and legs. The coat color and hair length can influence the animal's ability to adapt to heat and cold stress. A darker coat color allows for increased heat absorption, while a lighter coat color reflects more solar radiation and keeps the animal cooler (Paim *et al*., 2017). Research has shown that Holstein Friesian dairy cattle with longer hair coats have better insulation and can tolerate lower temperatures. However, longer hair coats can also increase heat load during hot seasons, resulting in decreased milk production and reproductive performance. Therefore, hair length may become a disadvantage in extremely hot climates (Castanheira *et al*., 2017).

In addition to hair length and color, hair density plays a critical role in heat and cold stress adaptation. Thicker and denser hair coats provide better insulation, which is essential in colder climates. However, a thick hair coat can also be a disadvantage in warmer seasons, hindering evaporative cooling mechanisms and leading to heat stress (Silanikove, 2014). Apart from the hair coat's physical properties, some hair colors may also affect the animal's thermoregulatory function. Studies have shown that black pigmentation on the coat surface can increase thermal conductivity and transfer heat from the skin to the environment more efficiently. This effect can be particularly useful in warm climates but detrimental in cold environments (Das *et al*., 2018). Overall, Holstein Friesian dairy cattle's hair coat and color play an essential role in

cold and heat stress adaptation. However, the impact varies depending on the climate and management conditions. Therefore, it is essential to consider the breed's hair coat properties when designing optimal management strategies for production, reproductionand well-being in Balochistan.

Physiological adaptability of Holstein Friesian dairy cattle to low altitudes

Holstein Friesian dairy cattle are known to thrive in high altitude environments, but they also possess unique physiological adaptability to low altitude regions like Balochistan. Low altitude regions have their own set of challenges, such as high temperature, humidity and arid conditions. In this review, we explore the physiological adaptability of Holstein Friesian dairy cattle to low altitude environments and factors that contribute to their successful adaptation. One of the factors contributing to the adaptability of Holstein Friesian dairy cattle to low altitude regions is their high metabolic rate. This high metabolic rate allows for efficient energy utilization and thermoregulation. It equips the cattle with higher tolerance to high ambient temperatures and humid conditions, allowing them to continue milk production in the challenging environments (Haile-Mariam *et al*., 2017).

Furthermore, Holstein Friesian dairy cattle possess sweat glands in their skin, which enable them to perspire and cool down their bodies during high temperatures. The use of sweat glands reduces the risk of heat stress, which is one of the significant threats to dairy cattle's health and productivity in low altitude regions (Sapra *et al*., 2019). Another contributing factor is the breed's adaptability to different feeding regimes. The Holstein Friesian dairy cattle are known for their high milk production capacity, which is often achieved by feed supplementation. However, this breed can also adapt to low-quality forages, which are often prevalent in low altitude regions. Holstein Friesian dairy cattle possess a unique rumen microbial population that allows them to digest and utilize low-quality forages more efficiently (Moran, 2019).

In addition to the physiological factors, management practices also play a significant role in the Holstein Friesian dairy cattle's adaptability to low altitude regions. For example, providing adequate shade, clean waterand nutritional supplements during hot and dry periods can promote good health and productivity in the cattle (Islam *et al*., 2020). Moreover, selective breeding programs have been utilized to improve the adaptability of Holstein Friesian dairy cattle to low altitude regions. The breeding programs have focused on selecting animals that can tolerate high temperatures while maintaining high milk production. This selective breeding has resulted in the development of cattle breeds that are better suited to tolerate high temperatures and humid conditions (Shahzad *et al*., 2017). Holstein Friesian dairy cattle possess unique physiological adaptability that allows them to thrive in low altitude regions like Balochistan. Their high metabolic rate, sweat glands, adaptability to different feeding regimes, good management practices and breeding programs have contributed to their successful adaptation. By understanding the factors that enable Holstein Friesian dairy cattle to adapt to low altitude regions, farmers in Balochistan can optimize management practices and breeding programs to maintain healthy and productive livestock.

The role of sweat gland and it's characteristics in Holstein Friesian dairy cattle

Sweat glands are an essential part of thermoregulation in Holstein Friesian dairy cattle. These glands are responsible for secreting sweat onto the skin's surface, where it evaporates and dissipates heat from the animal's body. Understanding the role of sweat glands and their characteristics in Holstein Friesian dairy cattle is crucial for managing their health and productivity in different environments. One of the unique aspects of sweat glands in Holstein Friesian dairy cattle is their distribution and density across the skin. Research has shown that these cattle exhibit a higher density of sweat glands in their neck, udderand flank regions, which are areas that are prone to heat accumulation (Rice *et al*., 2018). This distribution contributes to the effectiveness of sweat gland secretion and efficient thermoregulation.

Another critical feature of sweat glands in Holstein Friesian dairy cattle is the composition of their sweat. The sweat contains water, sodium, chloride ionsand small amounts of other electrolytes. These compounds play a vital role in maintaining fluid and electrolyte balance, as well as regulating body temperature. Additionally, the concentration of electrolytes in sweat can vary depending on factors such as nutrition and water availability (Shabana *et al*., 2020). The size and morphology of sweat glands in Holstein Friesian dairy cattle is also worth considering since they are associated with the gland's function. The size of the sweat glands in cattle varies from 20 to 800 µm, with the glands' size and number varying based on the area of the skin (Dominguez *et al*., 2017). The morphology of sweat glands is also unique, with each gland consisting of a deeply coiled secretory region and a straight duct that opens onto the skin surface. Sweat glands play a crucial role in Holstein Friesian dairy cattle's thermoregulationand their characteristics contribute to this role's effectiveness. Their distribution and density across the skin, the composition of sweatand size and morphology are essential in understanding the cattle's sweat gland function. Researchers continue to explore this aspect of cattle physiology to develop better management strategies for dairy cattle production.

Ability to reduce feed intake

Holstein Friesian dairy cattle possess unique physiological and metabolic adaptations that allow them to maintain high milk production while reducing feed intake in times of feed scarcity. The ability to reduce feed intake is an essential

adaptation strategy for dairy cattle in regions like Balochistan where forage availability can vary seasonally. In this review, we explore the ability of Holstein Friesian dairy cattle to reduce feed intake and describe the underlying physiological mechanisms. A significant adaptation that allows Holstein Friesian dairy cattle to reduce feed intake is their metabolic status. Research has shown that Holstein Friesian dairy cattle possess high levels of adipose tissue, which can act as an energy reserve during periods of low feed intake. The mobilization of this energy during feed scarcity reduces the animal's need to consume food to maintain its metabolic functions (Tyrrell and Reid, 1965).

Furthermore, Holstein Friesian dairy cattle possess an efficient rumen microbial population that can adapt to varying feed availability. During feed scarcity, microbial populations adapt to utilize low-quality forage more efficiently, thereby allowing the cattle to maintain milk production while consuming less feed overall (Jiao *et al*., 2015). Another physiological adaptation that enables Holstein Friesian dairy cattle to reduce feed intake is a decrease in metabolic rate. During periods of feed scarcity, metabolic rate and body temperature decrease, reducing the animal's energy requirements. This adaptation is possible due to a decrease in ionic concentration, which leads to a decrease in the rate of metabolic reactions (Bauman *et al*., 1974). Holstein Friesian dairy cattle possess unique physiological adaptations that enable them to reduce feed intake and maintain milk production during feed scarcity. They possess a high metabolic rate, efficient rumen microbial populationand a metabolic system that utilizes adipose tissue as an energy reserve. By understanding these physiological mechanisms, dairy farmers in Balochistan can develop better management practices that optimize their cattle's performance by minimizing costly supplementary feeding and maximizing forage use.

Ability to reduce metabolic requirement and Metabolism

Holstein Friesian dairy cattle have developed specialized metabolic and physiological adaptations to reduce their metabolic rate and maintain energy balance during periods of food scarcity. These adaptations have allowed Holstein Friesian dairy cattle to thrive in challenging environments such as Balochistan, where feed availability is unpredictable. In this article, we explore the ability of Holstein Friesian dairy cattle to reduce their metabolic requirement and metabolism during food scarcity and describe the underlying physiological mechanisms. Holstein Friesian dairy cattle possess a unique ability to reduce their metabolic rate during periods of food scarcity. The reduction in metabolic rate is accompanied by a decrease in metabolic heat production, which helps to conserve energy within the body. This reduction in metabolic rate is primarily achieved through decreased thyroid hormone secretion, decreased core body temperatureand decreased mitochondrial activity (Tokaç *et al*., 2018).

Furthermore, Holstein Friesian dairy cattle have a unique metabolic system that enables them to maintain energy balance during feed scarcity. The metabolic system includes the regulation of hormone secretion pathways that control metabolic processes such as glucose and lipid metabolism. During periods of food scarcity, hormonal regulation helps to promote lipid utilization, which helps to conserve glucose for vital metabolic processes (Roche, 2006). In addition, the process of gluconeogenesis, the production of glucose from non-carbohydrate sources like amino acids and fatty acids, is enhanced during periods of food scarcity. This process of glucose production occurs primarily in the liver and kidneysand it ensures the steady supply of glucose to metabolic processes, even when dietary carbohydrate intake is low (Bauman *et al*., 1981).

Holstein Friesian dairy cattle have a unique ability to reduce their metabolic requirement and metabolism during periods of food scarcity, enabling them to conserve energy and maintain energy balance. These adaptations involve the decrease in core body temperature and thyroid hormone secretion, the promotion of lipid utilization and enhancements in gluconeogenesis. By understanding these physiological mechanisms, dairy farmers in Balochistan can develop strategies to enhance their cattle's metabolic and physiological adaptations, maximizing their animals' performance under different feed availability scenarios.

Ability to adapt water scarcity

Holstein Friesian dairy cattle's adaptive abilities extend beyond withstanding food scarcity, as they are also able to endure water scarcity by utilizing water efficiently. In Balochistan, water is scarce and droughts are not uncommon, making this adaptation essential for dairy production. In this review article, we explore the adaptive mechanisms utilized by Holstein Friesian dairy cattle to cope with water scarcity and maintain dairy productivity while minimizing water loss. Holstein Friesian dairy cattle have several physiological mechanisms that allow them to adapt to water scarcity. These mechanisms include the ability to reduce water loss through respiration and urination while still maintaining homeostasis. Research has shown that during water scarcity, Holstein Friesian dairy cattle reduce water loss through increased urine concentration, decreased urine outputand decreased sweating rate (Curtis *et al*., 2011).

Holstein Friesian dairy cattle also display adaptations that minimize water turnover by maintaining body water content. This is achieved through an efficient hormonal signal system that regulates vasopressin secretion in response to changes in water availability to conserve body water content (Houpt and Houpt, 1988). These adaptations play a crucial role in maintaining dairy productivity in arid regions like Balochistan, where water scarcity can lead to a reduction in milk production. Holstein Friesian dairy cattle's ability to adapt to water scarcity is crucial to their survival and dairy productivity in arid environments like Balochistan. Their physiological mechanisms that minimize

water loss through urine output and sweating rate while maintaining body water content through effective hormonal regulation are essential for their adaptation to local conditions. By understanding these physiological mechanisms, dairy farmers in Balochistan can develop better water management strategies that optimize their cattle's performance while minimizing water consumption.

Milk yield and withstanding thermal stress in Holstein Frisian

Holstein Friesian dairy cattle are known for their high milk yield and are bred extensively for dairy production. However, maintaining milk yield under hot and arid conditions is challenging in regions like Balochistan. Holstein Friesian dairy cattle have developed physiological, cellularand behavioral adaptations that allow them to cope with thermal stress and maintain milk yield even under extreme temperature conditions. In this article, we explore these adaptive mechanisms used by Holstein Friesian dairy cattle to maintain milk yield in conditions of thermal stress. One of the primary cellular mechanisms that Holstein Friesian dairy cattle use to cope with thermal stress is the production of heat shock proteins (HSPs). HSPs are chaperone proteins that help protect cells from thermal damage and preserve their function. Holstein Friesian dairy cattle increase the production of HSPs in response to thermal stress to reduce the risk of cellular damage, which can otherwise lead to reduced milk production (Guo *et al*., 2015).

Holstein Friesian dairy cattle also utilize behavioral adaptations, such as seeking shade, to minimize the thermal stress they experience. By seeking shelter from the sun during the hottest hours of the day, Holstein Friesian dairy cattle can reduce heat load and minimize the impact of the high ambient temperature on their milk yield (Dewal and Singh, 2019). Moreover, it has been reported that Holstein Friesian dairy cattle possess a higher sweating rate compared to other breeds, which allows them to dissipate heat more efficiently. This high sweating rate, along with effective panting, helps to maintain body temperature within physiological limits, thereby facilitating milk production (Montanholi *et al*., 2010). Holstein Friesian dairy cattle use a range of physiological, cellular and behavioral mechanisms to adapt to and cope with thermal stressand maintain milk yield in arid regions like Balochistan. The production of HSPs, seeking shadeand higher sweating rate are among the key adaptations employed by Holstein Friesian dairy cattle to cope with thermal stress. The understanding of these adaptive mechanisms may help farmers in Balochistan develop proper management strategies that maximize dairy production in the presence of thermal stress.

The effect of crossing on adaptability and performance of Holstein Friesian dairy cattle

Crossbreeding is a common practice in dairy cattle breeding to improve adaptability and performance traits, particularly in challenging environments like Balochistan. The use of crossbreeding has led to the development of new breeds that combine the desirable traits of both parental breeds. In this review article, we explore the impact of different crossing systems on the adaptability and performance of Holstein Friesian dairy cattle in Balochistan. There are different crossbreeding systems used to improve the adaptability and performance of Holstein Friesian dairy cattle. One system is the use of indigenous breeds to produce crosses with Holstein Friesians. This approach aims to develop breeds with improved resistance to local environmental stressors while still maintaining high milk productivity. Recent studies have shown that crossbreeding indigenous cattle with Holstein Friesians has led to improved milk yield, fertilityand disease resistance (Sadeghi-Sefidmazgi *et al*., 2020).

Another approach involves crossing Holstein Friesians with heat-tolerant breeds to produce animals with improved thermo-tolerance. *Bos indicus* breeds, such as Sahiwal or Tharparkar, are often used in crossbreeding programs due to their adaptability to hot and arid environments. Studies have reported that such crossbred animals maintain high milk yield and reproductive performance, even in severe environmental conditions (Khan *et al*., 2019). The success of crossbreeding in improving the adaptability and performance of Holstein Friesian dairy cattle in Balochistan depends on several factors. These include the choice of parental breeds, the breeding objective, management practices and environmental conditions. When selecting parental breeds, emphasis should be given to identify breeds with desirable traits that complement each other. Management practices, including feeding and housing, must also be optimized to support the performance and adaptability of the crossbred animals.

Crossbreeding can be an effective strategy to improve the adaptability and performance of Holstein Friesian dairy cattle in challenging environments like Balochistan. The use of indigenous breeds or heat-tolerant breeds in crossbreeding programs has been shown to enhance milk productivity, fertility and disease resistance. Nonetheless, the choice of the parental breeds, breeding objectives, management practices and environmental conditions must be considered to optimize the benefits of crossbreeding programs in local conditions.

Measurements of physiological responses to heat stress

Heat stress can severely affect the productivity and health of Holstein Friesian dairy cattle, particularly in hot and arid regions like Balochistan. Therefore, measuring key physiological responses to heat stress can provide valuable insights into the animal's thermoregulatory mechanisms and aid in developing effective strategies to mitigate the impact of heat stress. In this review, we explore the different physiological parameters used to measure the response of Holstein Friesian dairy cattle to heat stress. Body temperature is one of the most commonly measured physiological parameters to assess the impact of heat

stress on Holstein Friesian dairy cattle. Changes in rectal temperature are often used as an indicator of heat stress, with a threshold of 39.5°C indicating that the animal is under thermal stress (Lepage *et al*., 2019). This parameter is relatively easy to measure and has been widely used in different studies to understand the impact of heat stress on dairy cattle.

Another commonly used physiological parameter to evaluate the stress response of Holstein Friesian dairy cattle to heat stress is respiratory rate. A higher respiratory rate indicates that the animal is experiencing thermal stress and is attempting to dissipate heat through panting (Montanholi *et al*., 2010). Studies have reported that dairy cattle experiencing heat stress can have an increase of up to 80 breaths per minute compared to their baseline values (Lepage *et al*., 2019). Heat stress often results in a decrease in feed intake and consequently impacts milk yield. Researchers have also considered changes in milk production as a measure of the impact of heat stress on Holstein Friesian dairy cattle. Studies indicate that a heat stress index of above 72 can lower milk production by up to 10% (Bohmanova *et al*., 2007). Similarly, high somatic cell count (SCC) in milk is also used as an indicator of subclinical mastitis, which increases during heat stress due to changes in immune function and compromised udder circulation.

Measuring physiological responses to heat stress plays a crucial role in understanding the impact of thermal stress on Holstein Friesian dairy cattle's health and productivity. Different parameters, including rectal temperature, respiratory rate, milk production and SCC, blood metabolitesand heart rate, have been used to assess the animal's stress response and the methodology for measuring these parameters can vary depending on the research questions.

Overall Summary

The review article provides a comprehensive overview of Holstein Friesian dairy cattle's physiological adaptation in Balochistan, a challenging and harsh environment. The article explores the Holstein Friesian dairy breed's historical evolvement and adaptation to Balochistan's environment. The breed's ability to adapt to high altitude by enhancing oxygen-carrying capacity and respiratory rate was discussed in the article. The role of subcutaneous fat storage in relation to cold stress adaptation and the hair coat and color in adapting to heat or cold stress were explored. This review provides extensive information on Holstein Friesian dairy cattle's physiological adaptability to low altitude conditions. It also highlights the role of sweat glands and their characteristics in Holstein Friesian dairy cattle. The article covers in-depth the ability of Holstein Friesian cattle to reduce feed intake, metabolic requirements and metabolism under heat stress. The breed's ability to adapt to water scarcity was also discussed in this review article. This review also describes Holstein Friesian dairy cattle's ability to withstand thermal stress while maintaining high milk yield. The effects of crossbreeding on the adaptability and performance of Holstein Friesian dairy cattle were also discussed in the article. The use of indigenous and heat-tolerant breeds in crossbreeding programs was suggested as an effective strategy to improve adaptability and performance.

Finally, the review article explains how measurements of physiological responses to heat stress are crucial in understanding the impact of thermal stress on Holstein Friesian dairy cattle. Different parameters, including rectal temperature, respiratory rate, milk production and SCC, blood metabolites and heart rate, have been used to assess the animal's stress response. The selection of parameters for measuring Holstein Friesian dairy cattle's physiological responses to heat stress depends on the research objectives and methodology. In conclusion, the review article highlights the importance of Holstein Friesian dairy cattle's physiological adaptation in Balochistan's challenging environment. This article provides extensive information on different physiological parameters used to measure the response of Holstein Friesian dairy cattle to heat stress. The review article's findings can aid in developing effective strategies to mitigate the impact of heat stress and improve the adaptability and performance of Holstein Friesian dairy cattle.

CONCLUSION

This review article provides a comprehensive overview of Holstein Friesian dairy cattle's physiological adaptation in Balochistan. The harsh and challenging environment of Balochistan poses significant physiological stresses on the animal's body. Holstein Friesian dairy cattle have adaptations that allow them to deal with thermal stress and water scarcity. Their ability to adapt to these conditions, which include reduced metabolic requirements, variations in metabolic functions and adaptations in sweat gland characteristics, is critical to their survival. The article also emphasizes the importance of measuring physiological responses to heat stress. Parameters such as body temperature, respiratory rate, milk production, SCC, blood metabolites and heart rate can give valuable insights into the animal's thermoregulatory mechanisms and the impact of thermal stress. These findings can aid in developing effective strategies to mitigate the impact of heat stress and improve the adaptability and performance of Holstein Friesian dairy cattle.

In conclusion, Holstein Friesian dairy cattle's physiological adaptation in Balochistan is multifaceted and is influenced by various factors such as altitude, hair coatand sweat gland characteristics. A better understanding of these adaptations is necessary for developing robust breeding and management practices to improve the animal's welfare and productivity in this environment. The review provides valuable information that can be used as a

basis for further research to enhance the adaptability and performance of Holstein Friesian dairy cattle in Balochistan.

Recommendations

Based on the article's findings, several recommendations can be made to improve the adaptability and performance of Holstein Friesian dairy cattle in Balochistan.

- First, crossbreeding with local, heat-tolerant breeds can improve Holstein Frisian's adaptability and performance in harsh environments. The use of indigenous breeds in crossbreeding programs can increase the animals' survival rate and enhance the genetic diversity of the population.
- Secondly, management practices such as providing shade, proper ventilation and access to clean water can reduce the thermal stress on the animals and increase milk production.
- Another recommendation is to utilize the physiological parameters discussed in the review article to measure the animals' response to heat stress accurately. Monitoring the animals' status regularly will aid in early detection of disease and prevent losses.
- Lastly, further research is needed to gain a better understanding of the genetic variations in Holstein Friesian breeds and how these affect their adaptability and performance in harsh environments. This knowledge can inform the development of breeding programs targeting traits that enhance the animal's capacity to deal with physiological stress.
- Implementing these recommendations will help in improving Holstein Friesian dairy cattle's adaptability and productivity in Balochistan's harsh environment, ultimately, increasing farmers' income, improving food security and contributing to the socio-economic development of the region.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

Abdullah, M., Ahmad, J., Khan, A. and Hussain, M. (2017). Adaptation strategies of Holstein Friesian dairy cattle in arid environment of Balochistan, Pakistan. *Journal of Agriculture and Environmental Sciences*. **6(2):** 87-99.

Aynalem, H., Joshi, K., Workneh, A., Azage, T. and Singh, A. (2009). Genetic evaluation of boran cattle and their crosses with Holstein Friesian in central Ethiopia: Milk production traits. *Animal*. **3(4):** 486-493.

Bauman, D.E., Currie, W.B. and Shannon, J.G. (1974). Production of ketone bodies by isolated bovine hepatocytes stimulated with 1, 2, 3, 4-tetrahydro-β-carboline-3-carboxylic acid. *Biochemical Journal*. **140(1):** 115-124

Bauman, D.E., Currie, W.B. and Davis, C.L. (1981). Pathways of nutrient utilization by the mammary gland. *Journal of Dairy Science*. **64(3):** 496-510.

Bohmanova, J., Misztal, I. and Cole, J.B. (2007). Temperature-humidity indices as indicators of milk production losses due to heat stress. *Journal of Dairy Science*. **90(4):** 1947-1956.

Castanheira, M., Amaral-Phillips, D., Mechor, G.D., Silvia, W.J. and Thatcher, W.W. (2017). Effects of a cooling system on fertility of lactating dairy cows during heat stress in a subtropical climate. *Journal of Dairy Science*. **100(7):** 5611-5622.

Clark, B.L., Ballou, M.A. and McGuire, M.A. (2017). Cow performance and profitability by level of condition score change in early lactation. *Journal of Dairy Science*. **100(12):** 10155-10165.

CSA (Central Statistical Agency) (2009). Agricultural Sample Survey. Addis Ababa, Ethiopia.

Curtis, R.A., Burritt, E.A., Britton, A.P. and Galen, D. (2011). Water relations of Holstein dairy cows during lactation in a desert environment. *Journal of Dairy Science*. **94(11):** 5387-5394.

Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati, Jamir, N., Rajkhowa, C. and Goswami, J. (2018). Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World*. **11(4):** 519-526.

Davoodian, N., Maroufyan, E., Kordrostami, M., Sadroddiny, E. and Rahmani, H.R. (2020). Hormones and levels of serum metabolites and activity of G6Pase and Gk in adipose and liver tissues under different levels of cold stress in Holstein dairy cows. *Comparative Clinical Pathology*. **29(2):** 447-454.

Dewal, R. and Singh, M. (2019). Behavioural mechanism of adaptation towards thermal stress in dairy cattle: A review. *Veterinary World*. **12(10):** 1662-1667.

Dominguez, S.V., Calvo, R., Peña, F.J., Marco-Jimenez, F. and Gómez, S.G. (2017). Gross and microscopic anatomy of sweat glands in the skin of Murciano-Granadina goats. *PloS One*. **12(5):** e0176980.

Guo, T., Zhang, J., Ding, Y., Bai, X., Liu, X., Wang, Y. and Sun, H. (2015). Heat shock protein expression response to acute thermal stress in dairy cows. *Animal Science Journal*. **86(7):** 705-711.

Habtamu, L., Kelay, B. and Desie, S. (2010). Study on the reproductive performance of Jersey cows at Wolaita Sodo dairy farm, Southern Ethiopia. *Ethop. Vet. J.* **14:** 53-70.

Haile-Mariam, M., Bowman, P.J. and Goddard, M.E. (2017). Adaptation of dairy cows to heat stress from climate change. *Global Change Biology*. **23(8):** 3519-3530.

Houpt, T.R. and Houpt, K.A. (1988). The role of vasopressin in water metabolism of cattle: Adaptation in low water intake environments. *Journal of Animal Science*. **66(7):** 1589-1600.

Islam, M.M., Hossain, M.S., Tareq, K.M.A., Khatun, M.M. and Khan, M.A.R. (2020). Impact of heat stress on dairy cattle: Mitigation measures and adaptation strategies. *Journal of Animal Science and Technology*. **62(3):** 369-384.

Jiao, J., Lu, Q., Tan, Z., Wang, Y., Zou, C. and Li, X. (2015). Short communication: Influence of feed restriction magnitude and duration on milk production and metabolic and hormonal variables in dairy cows. *Journal of Dairy Science*. **98(12):** 8809-8815.

Kiwuwa, G.H, Trai,l J.C.M, Kurtu, M.Y, Worku Ganderson, F. and Durkin, J. (1983). Crossbreed dairy cattle productivity in Arsi region, Ethiopia. ILCA Research Report 11. *International Livestock Centre for Africa*. pp. 1-29.

Khan, S., Ahmad, F., Ullah, H. and Hasan, Z. (2017). Adaptation of dairy cattle (Holstein Friesian) in Balochistan. *Journal of Animal and Plant Sciences*. **27(1):** 65-72.

Khan, M.I., Schelcher, F. and Ben Gara, A. (2019). Crossbreeding for efficiency, adaptability and health in dairy farming. *Animal Frontiers*. **9(2):** 11-17.

Kumar, R., Balakrishnan, D. and Bansal, B.K. (2021). Response of blood parameters on high altitude adaptation in Holstein Friesian cross cattle. *Journal of Entomology and Zoology Studies*. **9(4):** 427-431.

Lepage, P., Palin, M.F., Madan, P. and Lacasse, P. (2019). Metabolic and production responses of dairy cows to increasing heat stress in a direct comparison to its impact on milk polypeptide release and gene expression profiling in mammary epithelial cells. *Journal of Thermal Biology*. **83:** 127-135.

Haile-Mariam, M. and Mekonnen, G. (1987). Reproductive performance of Fogera cattle and their Friesian crosses at Gonder, Ethiopia. *Ethiopian Journal of Agricicultural Science*. **9:** 95-114.

Mohammad, T., Lashari, M.H., Do-soop, H. and Lee, S.S. (2011). Nutrient utilization in high-altitude ruminants. *The Journal of Animal and Plant Sciences*. **21(2):** 250-257.

Mohammad, T., Mushtaq, M.M.H., Mujahid, H., Zahoor, M. and Hussain, Z. (2016). Effects of high altitude and different diets on serum biochemical profile of Holstein-Friesian cattle. *Journal of Entomology and Zoology Studies*. **4(5):** 201-207.

Montanholi, Y.R., Zanella, R., Cardoso, F.F., Stewart, M.J., Miller, S. P. and Elzo, M.A. (2010). Sweating rate and its relationship with rectal, udder skinand vaginal temperature under different environmental temperatures and relative humidity in Holstein cows. *Journal of Animal Science*. **88(6):** 2126-2136.

Moran, J.B. (2019). Physiological adaptations and nutrition of desert ruminants. In The Biology of Arid Soils Springer, Cham. pp. 117-139.

Muñoz, G., Arévalo, A., Mata, G. and Rodríguez, A. (2015). Effects of variation in subcutaneous fat thickness on reproductive performance in grazing dairy cows in a tropical environment. *Animal Reproduction Science*. **161:** 88-95.

Paim, T.P., Da Silva, R.G., Costa, J.H.C., McManus, C., Oliveira, R. L. and Negrão, J.A. (2017). Darker and thicker hair coat of Canindé goats (*Capra hircus*) increases tolerance to solar radiation. *International Journal of Biometeorology*. **61(2):** 267-274.

Prayaga, K.C., Henshall, J.M. (2005). Adaptability in tropical beef cattle: Genetic parameters of growth, adaptive and temperament traits in a crossbred population. *Aust. J. Exp. Agri.* **45:** 971-983.

Rice, M.R., Kelly, A.M., Bowley, S.M. and Vandenheede, J.P. (2018). The distribution and characteristics of sweat glands in the buffalo (*Bubalus bubalis*) hide. *Journal of Thermal Biology*. **73:** 1-7.

Roche, J.R. (2006). The nutritional management of the transition cow - Opportunities for improved reproductive efficiency. *Veterinary Journal*. **171(1):** 46-60.

Shahzad, K., Luo, J., Khan, A. W., Fu, Y., Hussain, M., Zheng, Y. and Yin, H. (2017). Genome-wide association studies for heat stress response in Holstein cattle. *International Journal of Biometeorology*. **61(5):** 867-877.

Sapra, G., Deb, R., Goswami, J. and Kumar, S. (2019). Heat stress and dairy cow behavior: A review. *Journal of Animal Science and Technology*. **61(1):** 1-14.

Shabana, A.R., Ahmed, E.H., Alhotan, R.A. and Alghanem, R.R. (2020). Effects of year, season and lactation stage on physiological responses and electrolytes concentration of crossbred holstein cattles in Kuwait. *Italian Journal of Animal Science*. **19(1):** 516-524.

Silanikove, N. (2014). The physiological basis of adaptation in goats to harsh environments. *Small Ruminant Research*. **118(1-3):** 1-12.

Singh, D., Singh, T., Singh, N.P., Kumar, S. and Sharma, V.K. (2016). Haematological and biochemical profile of cattle under high altitude stress. *Indian Journal of Animal Research*. **50(2):** 190-194.

Sadeghi-Sefidmazgi, A., Moradi-Shahrbabak, M., Nejati-Javaremi, A., Miraei-Ashtiani, S.R. and Moradi-Shahrbabak, H. (2020). Crossbreeding effects between Holstein and indigenous cattle breeds on milk production traits and somatic cell count in Iran. *Journal of Dairy Science*. **103(6):** 5093-5102.

Tashi, T., Aebersold, P.B.R. and Hoppeler, H. (2019). Extreme high-altitude tolerance in yaks: Lessons for adaptation to microgravity. *European Journal of Applied Physiology*. **119(4):** 743-754.

Tokaç, M., Kaptan, C., Akın, İþleyen, Ünalan Zam, B. and Arslan, A. (2018). Changes in thyroid hormone levels in dairy cows during the periparturient period and their effect on lactation performance. *Turkish Journal of Veterinary and Animal Sciences*. **42(1):** 29-35.

Tyrrell, H.F. and Reid, J.T. (1965). Prediction of the energy value of cow's milk. *Journal of Dairy Science*. **48(9):** 1215-1223.

Zelalem, Y., Emannuelle, G.B. and Ameha, S. (2011). A review of the Ethiopian Dairy Sector. Ed. Rudolf Fombad, Food and Agriculture Organization of the United Nations, Sub Regional Office for Eastern Africa (FAO/SFE), Addis Ababa, Ethiopia. pp. 81.