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Review Article
Physiological and Anatomical Adaptation Characteristics of Borana Cattle to Pastoralist Lowland Environments

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Abstract

The Borana cattle are commonly found in Ethiopia and Kenya. They have their origin in Ethiopia and were initially introduced into Kenya by Oromo pastoralists migrating from the southern Ethiopia. The animals possess several adaptive mechanisms which are helpful for their survival in harsh environmental conditions but while doing so their productive performances are compromised. Adaptive characteristics to warm climates encompass a wide range of physiological functions, behavioral and morphological attributes. Therefore, the objective of this review is to provide the summarized information about physiological and anatomical adaptation characteristics of Borana cattle to pastoralist lowland environments. The animal shows several physiological adaptation mechanisms to cope up the adverse climate condition. To live and reproduce in a harsh environment, Borana cattle have developed physiological and anatomical adaptive traits of crucial importance for their survival. Some of these characters are ability to withstand periodic shortage of water through compensating higher water loss during periods of high heat load by concentrating urine, ability to withstand periodic shortage feed because they have physiologically adapted and develop lower maintenance requirements, ability to walk long distances in search of water and feed and ability to digest low quality feeds, tolerance to heat stress, some ticks and tick-borne diseases and other tropical diseases. The ability to change blood flow to the periphery is a feature of all vertebrates and it is a part of their evolutionary process as one of the first physiological functions of thermoregulation. Borana cattle has white, brown or red-coloured, light grey and dark grey coats and thin and smooth coat that is advantageous as it reflects direct solar radiation and also facilitate evaporative cooling. Borana cattle are much better adapted to high temperatures and dry conditions than *Bos taurus* cattle of European origin due to their high skin pore density allows them to successfully regulate their body temperature.

Key words: Adaptation, borana cattle, pastoral, physiology

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Borana cattle are commonly found in Kenya and Ethiopia. They have their origin in Ethiopia and were initially introduced into Kenya by Oromo pastoralists migrating from the southern Ethiopia. There are three recognized types: the Oromo Borana which is the smallest in size and is found in Ethiopia and the unimproved Borana and the improved Borana which are found in Kenya. The improved Borana, which is also known as Kenyan Borana, originated from the unimproved types of Borana that were bought by European ranchers from the Borana lowlands to central Kenya in the early 20th century[1]. To-date the improved Kenya Borana can be found in the highlands which are characterized by fertile pastures. Its breeding purpose was for beef production[2].

Borana cattle have as well proven to be excellent beef animals, especially under commercial ranching conditions in Kenya and other east Africa countries, including Tanzania, Uganda and Zambia. Results from a number of breed evaluations for beef production in the region and elsewhere indicated that Borana and their crosses are comparable or even better than other breeds[3]. Because of this potential Borana is one of the few African breeds that has been introduced to other parts of the world, including Australia and USA.

In Ethiopia, Borana cattle are also a good source of beef for local and international markets. For example, over 90% of the livestock exported for slaughter from Ethiopia come from lowland areas, where Borana cattle form the majority[4]. In addition, it is believed that about 20% of the cattle required for draught power by peasant farmers in the highlands of Ethiopia are obtained from lowland areas.

The Borana cattle in northern Kenya and southern Ethiopia have unique traits that make them suitable for the harsh environment in the lowlands and have ever been part of the pastoralists' identity. Almost all the traditional and cultural rites of the pastoralists in these areas revolve around the Borana cattle, which are also the main source of their income[2]. The breed is well adapted to semi-arid tropical conditions has a high degree of heat tolerance is tolerant to many of the diseases prevailing in the tropics and has the ability to survive long periods of feed and water shortage[5]. These properties have genetic basis and have been acquired by natural and human selection over generations[6].

There are two distinguished sub types of the Borana cattle in the Borana zone: traditional large-framed Qorti and the smaller Ayuna. Both sub-types are the result of deliberate human selection along with adaptation to environmental changes[2]. The genes that Borana cattle carry are mainly the result of a long-term natural selection under harsh environmental conditions. However, in the evolution and development of Borana cattle, the role of their owners, the Borana people, cannot be overestimated. To live and reproduce in a changing environment, Borana cattle have developed adaptive traits of crucial importance for their survival. Some of these characters are ability to withstand periodic shortage of water and feed, ability to walk long distances in search of water and feed and ability to digest low quality feeds. In addition, Borana animals have developed some degree of tolerance to heat stress, some ticks and tick-borne diseases and other tropical diseases. Borana cows have also a long reproductive herd life, a good maternal ability and a good herd instinct[7]. Livestock undergoes various environmental challenges. Thermal stress is the most intriguing factor affecting livestock production in the ever changing climatic scenario. Adaptation is defined as the morphological, anatomical, physiological and biochemical characteristics of the animal which promote welfare and favor survival in specific environment. Environmental challenges negatively affect the growth, production and reproduction of livestock. Combined effect of temperature and humidity proved to be extremely fatal to the entire livestock population. Animal cope up with environmental challenges with various kinds of responses. These include physiological response, blood biochemical response, neuroendocrine response, molecular and cellular response, metabolic response and behavioral response. Physiological responses include alterations in body temperature, respiration rate, heart rate and skin temperature[8]. Adaptive characteristics to warm climates encompass a wide range of physiological functions and morphological attributes. Therefore, the objective of this review is to summarize the physiological and anatomical adaptation characteristics of Borana cattle to pastoralist lowland environments.

PHYSIOLOGICAL AND ANATOMICAL ADAPTATION CHARACTERISTICS OF BORANA CATTLE TO PASTORALIST LOWLAND ENVIRONMENTS

Physiological adaptation characteristics of Borana cattle to pastoralist lowland environment: The animals possess several adaptive mechanisms which are helpful for their survival in harsh environmental conditions but while doing so their productive performances are compromised. Among the various mechanisms, which helps to maintain homeostasis in animals, physiological adaptability was considered one of the primary response mechanisms by which the heat stressed animals survive the heat stress[9].

To live and reproduce in a harsh environment, Borana cattle have developed adaptive traits of crucial importance for their survival. Some of these characters are ability to withstand periodic shortage of water and feed, ability to walk long distances in search of water and feed and ability to digest low quality feeds, tolerance to heat stress, some ticks and tick-borne diseases and other tropical diseases[7]. From the two distinguished sub types of the Borana cattle, the Qorti has been known for its physiological adaptation to heat stress, drought tolerance and walkability, good mothering ability, docility and longevity. Information about the Ayuna is not yet documented, other than its partial origin from highland cattle[7].

The animal shows several physiological adaptation mechanisms to cope up the adverse climate condition. Some of the physiological determinants of adaptations to heat stress are respiration rate (RR), rectal temperature (RT), pulse rate (PR), skin temperature (ST) and sweating rate[10] (SR). In complementary, the numerous physiologic mechanisms for coping with heat stress have been reported by Blackshaw and Blackshaw[11] are: Sweating, high respiration rate, vasodilation with increased blood flow to skin surface, reduced metabolic rate, decreased dry matter (DM) intake and altered water metabolism are the physiologic responses that have negative impact on the production and reproduction of the cows[12]. All these physiologic responses are substantial and prolonged in *Bos taurus* than in *Bos indicus*[13,14]. Hence the consequences of exposure to heat stress for production of milk and meat are less pronounced in the later[15].

Evaporative cooling: In a hot environment, heat loss efficiency is essential in maintaining homeothermy[16]. Respiration rate is one of the ideal biomarkers of heat stress. The animals bring in respiratory evaporative cooling mechanisms through the process of multifold increase in Respiration rate[10]. Respiration is the intake of oxygen (O_2) and elimination of carbon dioxide (CO_2) under thermoneutral condition which leads to evaporation and dissipation of moisture from the respiratory tract to maintain thermal balance of respiratory system through evaporative cooling. Therefore, this mechanisms are very crucial in preventing the hypothermia which otherwise occur under heat stress conditions[17]. In homeostasis, pulse rate reflects the circulation and metabolic status. Ambient temperature, humidity, season and day timings may influence the cardio respiratory system[18]. Since cattle rely on respiration as a method to manage heat respiratory function is important. Cattle that had severe respiratory disease early in the feeding period will have decreased ability to regulate their heat load[19].

Animal core body temperature is represented using rectal temperature[9]. The cutaneous evaporative cooling mechanisms are brought through increased sweating rate. Further, every species has its own temperature neutral zone and the animal exposed to high temperature may rise their body temperature from the Temperature neutral zone. In addition, the animals are very sensitive to the upper critical temperature and it has been established that even 1°C rise in temperature from the Upper critical temperature can bring down the production of livestock species[20].

Exposure of ruminants to hot environment also increased skin temperature. Examination of both Nguni and Borana cattle breeds showed higher skin temperature during summer[21]. This higher skin temperature could be directly attributed to the vasodilatation of skin capillary bed to enhance the blood flow to the skin periphery for facilitating heat transfer to the surroundings[22]. The ability to change blood flow to the periphery is a feature of all vertebrates and it is a part of their evolutionary process as one of the first physiological functions of thermoregulation. Finch[23] observed that the Bos indicus cattle has higher conductance than *Bos taurus*. Pereira *et al.*[24] reported marked differences between sensible heat losses in *B. taurus* breeds during different levels of heat stress. Nevertheless, the increase of the environmental temperature leads to an inevitable evaporative cooling[25,26]. Revolutionarily, pulmonary heat loss seems to precede the sweating[16]. The ability to sweat seems to be a relatively recent product of evolution. In wild and domestic bovines, both sweating and pulmonary heat loss had relevance in homeothermy[9].

Sweating is one of the effective mechanisms in animals considered sweating species for excreting excessive heat from body. Sweating is influenced by weather parameters such as wind velocity, air temperature, relative humidity and thermal and solar radiation. Whereas other factors that affect the efficacy of evaporative cooling from the skin surface are fur or hair coat physical and optical properties, density and thickness of hair coat, hair length and both hair and skin colour[27]. Higher sweating rate in black cows (800 W m^{-2}) than white cows (500 W m^{-2}) according to conducted experiment on dairy cows and reported by Hillman *et al.*[28]. Da Silva *et al.*[29] further established that light hair coats exhibited higher reflectivity than dark hair coats having wavelengths ranging from 300-850 nm. Borana cattle are much better adapted to

high temperatures and dry conditions than *Bos taurus* cattle of European origin due to their high skin pore density allows them to successfully regulate their body temperature[30].

Adaptation to water and feed shortage: Pastoral cattle production in southern Ethiopia is becoming increasingly vulnerable to impacts of climate variability and rangeland resource degradation, giving rise to livestock diversification[31]. Until the 1980s, the Borana rangelands were in good condition and the production system was regarded as one of the most productive in East Africa[32]. Similarly, Oba *et al*.[33] described the Borana rangelands as heterogeneous in soil types and vegetation cover with high suitability for grazers, which may account for the fact that cattle pastoralism has been a centuries-old mainstay of the Borana community[4,32]. More recent accounts indicate that the rangeland has become degraded in quality and shrunk in size due to invasion of woody plants, decline of herbaceous biomass and fragmentation of communal grazing areas[24-36]. Accordingly, increased climate variability compounded with rangeland resource degradation might have exacerbated cattle vulnerability to climatic risks, putting enormous pressure on the traditional livelihoods of cattle keeping pastoralists[31].

Cattle are generally the livestock species most sensitive to adverse effects of climate change[37,38]. Lunde and Lindtjorn[39] have demonstrated that the highest vulnerability to climate variability is found in arid environments. In line with this, several studies have documented herders' responses to changing environmental conditions, such as pursuing alternative livelihood strategies[40], crop farming, diversification of herd composition or switching to other species[41,42]. Accordingly, there has been an increased shift from vulnerable to adapted species from cattle to goats[41] and cattle to camels in Africa[42] and from cattle to sheep in Latin America[37].

The main feed resources of the Borana cattle are natural pastures (herbaceous vegetation composed mainly of grasses and forbs and browses such as shrubs, tree leaves and pods), which show marked seasonal variation in availability and quality based on variability of rainfall distribution. Productivity of animals in terms of milk production, growth rate and reproductive performance is generally low[43].

Excessive heat causes decreased food intake and disturbances in protein and energy metabolism, mineral balance, enzymatic reactions, hormones and metabolites secretion in the blood[44]. Metabolic disorders caused by thermal stress lead to reduced milk production, growth and reproductive rates and increases the susceptibility of animal diseases causing economic loss[45]. Climate change causes an increase in average temperature and reduced rainfall, putting the sustainability of the livestock production system in risk[46], especially in countries such as Brazil, which already has high air temperature averages and grazing systems dependent on the rainy season. Selection has been mainly directed towards productive characteristics but should include robustness, efficiency, reduced emission intensity and adaptability to heat stress in the future[47]. Digestibility is affected by many factors e.g., rate of feed consumption, feed quality, nutrient composition, rates of passage of digesta and volumes of ruminal and postruminal digestive organs[48]. All of these factors are influenced by thermal stress. At high temperature, decreased feed intake evokes increased digestion by decreasing the passage of digesta and increasing the ruminal volume[49]. These physiological alterations are more helpful for animals consuming higher forage diets[50].

The Borana, a Bos indicus breed, is recognized as one of the most productive indigenous cattle breed under the prevailing harsh conditions of east Africa. The Borana is capable of surviving and reproducing under the harsh climatic, nutritional and management conditions of east Africa while maintaining good productivity on poor forage and low water availability[51]. Because they have physiologically adapted and develop lower maintenance requirements than *Bos taurus* cattle. Borana cattle are resilient and adaptable. Across Australia in tropical, sub-tropical and even temperate environments like Tasmania Borana herds are found thriving. During dry conditions, Borana cattle can tolerate periods of water and feed shortage. This is largely due to their ability to move with ease over harsh territory and to digest low quality feed. The Borana is a non-selective feeder and browser. It will graze on shrubs, trees and dry unpalatable grasses that often go untouched by other breeds[30,52].

Borana cattle can tolerate periods of water shortage[30]. Higher drinking frequency and increased water intake were reported for various livestock species during summer[22,53]. Breeds adapted to desert regions compensate higher water loss during periods of high heat load by concentrating urine[54].

Anatomical adaptation characteristics of Borana cattle to pastoralist lowland environments

Borana cattle body size characteristics: The Borana cattle are a small to medium sized animal. There are different types of these the animal[19]. From the Ethiopian Borana cattle type the Ayuna type was described as shorter in height, smaller in body size but more sturdy to adapt to degraded rangeland conditions. The phenotype of Qorti was described by the community in the study area as being of tall height with comparatively long legs, broad back, long neck, pending

dewlap, short horns, small hump and a short tail[55]. The Orma Borana breed is the smallest of the Borana breeds and smaller than the Kenyan Borana. The weight of the mature Orma Borana bulls ranges from 250-395 kg. On the other hand average live body weight of the mature cows vary from 225-355 kg. The Kenyan Borana breed was developed from the Orma Borana, Borana and Somali Boran[56]. Due to the size and well-developed hindquarters of the Kenyan Borana, it is differentiated from other Borana cattle. Heavy cattle cannot handle heat stress compared to lighter weight cattle. Increased fat deposition prevents cattle from regulating their heat effectively[19].

The Kenyan Borana cattle are slightly larger than the Orma Borana cattle and on an average. The average live body weight of the mature Kenyan Borana bulls range from 550-850. While live body weight of the mature cows vary from[56] 400-550 kg.

Hair coat type and color: Solar radiation is a critical component that can lead to death loss from heat stress. Typically, proportionality more black hided cattle die during heat waves then other hide colors[19].

Coat colour was one of the important morphological traits which imparts adaptive ability to heat stressed livestock. For example, light-/white-coloured coats in animals are recognized as being advantageous in hot tropical regions as it reflects 50-60% of direct solar radiation compared with the dark-coloured animals[20]. Highly pigmented skin protects the deep tissues from direct short wave UV radiation by blocking its penetration[2].

The original and the most preferred coat colour for Borana cattle was light grey for the body and dark grey around the dewlap[55]. The relative merits of dark and light colored cattle in hot areas are recognized by pastoralists such as the Maasai and Orma. In discussion with these pastoralists, they found that they recognize the differential water intakes of black and white cattle on a once-a-day watering regime and that the absolute capacity of the gut results in similar intakes after 3 days without water. The Maasai regard white cattle as superior in the hot, lowland areas of Magadi and this superiority is attributed largely to greater heat tolerance. The pastoralists also recognize that food intake is markedly depressed after 2 days of dehydration and use appetite as a guide for the watering frequency of cattle. With increasing altitude, heat stress declines and therefore the relative advantages of light cattle colors in offsetting the heat load similarly decline. A reduction in air temperature with altitude, particularly at night can be expected to pose problems of cold stress on Borana cattle, which are physiologically adapted to hot conditions[57]. In fact, Robertshaw and Katongole[58] have shown that Borana cattle increase their metabolic heat production when starved at a lower critical temperature of 24°C. Even with increased metabolic heat production, body temperature falls indicating poor insulation of this breed. The energetic cost of cold thermogenesis and concurrent occurrence of a heat debt must, therefore, be considerable for animals on submaintenance diets, especially in areas such as Amboseli and Athi River where night temperatures fall below 10°C and Nguruman where they probably drop below 40°C. However, black cattle could save energy when the sun rises by rapidly absorbing radiation rather than sustaining cold thermogenesis in order to repay the heat debt[59].

Usually coat color of the Kenyan Borana cattle is white with spots but brown and red coat colors have also been found. Both bulls and cows usually have horns and their horns are relatively smaller in size[56]. Their fine, short, glossy coats reflect sunlight and shield them from the hot sun. Their coat and usually dark pigmented skin, protects them from sunburn and reduces their risk of developing sun cancers[30,52].

Skin hair coat length, thickness and hair density also affect the adaptive nature of animals in tropical regions, where short hair, thin skin and fewer hair follicles per unit area are directly linked to higher adaptability to hot conditions[60]. Animals subjected to heat stress established an extreme temperature difference between the hair coat surface and the skin[61]. Studies conducted in Florida by Lucena and Olson[62] depicted that breeds of cattle with short, sleek hair coats possess higher thermo-tolerance than those of unadapted temperate breeds. Da Silva[63] reported that coat layer thickness was found to be greater for animals bred in temperate regions.

Pest, tick and disease resistance: The Borana cattle are very hardy breed of cattle. They are very well adapted to local conditions as they have been in Africa for over a thousand years. They have well resistant to parasites and are known for their fertility, hardiness, docility and early maturity. The breed also shows high resistance to ticks, heat and eye diseases. It can also endure scarcity of water and can live on low quality feed. The breed mature pretty earlier than most other Bos indicus cattle breeds[56]. They are able to adapt to harsh conditions and have a high resistance to pests and disease[52]. External parasites, such as ticks and buffalo fly, have a significant impact on cattle health and productivity. They are difficult, costly and time consuming to manage. The following traits provide Borana cattle with a higher level of resistance to biting insects and tick infestation: (1) A highly sensitive and motile skin. Borana cattle have a thick, well-developed layer of subcutaneous tissue that causes the muscles beneath their

skin to contract and move in reaction to insects landing on and biting them. It enables them to vigorously shake off external pests, (2) A very short coat. This makes it difficult for insects to attach onto a Borana's hide and bite, (3) A waxy secretion from their skin. The secretion of an oily substance makes the Borana a less desirable host for ticks and flies and (4) A long tail with a big well-formed twitch. The long tail used to ride off the flies[30,52].

European breeds tend to be susceptible to eye infections, whilst Borana are rarely troubled by them. The Borana has prominent, protective eyebrows and long eyelashes. These protect their eyes from bright sunlight, dust and other irritants all factors that predispose cattle to Pinkeye (Moraxella bovis eye infection)[30]. Although the Borana cattle tend to present poor response to trypanosomal infection, the Orma Borana maintained in the tsetse-infested regions of the east coast demonstrate a degree of trypanotolerance[64].

Horn nature: Borana cattle both bulls and cows usually have horns and their horns are relatively smaller in size as reported by Roy's Farm[56]. When comparing the same kind of breeds with and without horns some differences in productivity and body size can be seen. There was significant differences in different traits on shorthorn and Longhorn cattle, which are two North American breeds[65]. Shorthorn is both heavier and higher and has a higher body condition score than Longhorn. Even milk production is higher in Shorthorn cattle[65,66]. These findings in literature indicate that horns have a negative effect on the animal, posing a higher energy need for maintenance and have probably effects on physiology of the animal when comparing with comparable breed with known horns, even though the author, despite the efforts, failed to find literature that directly investigates the impact of horns in cattle[67].

CONCLUSION

Borana cattle have developed physiological and anatomical adaptive traits of crucial importance for their survival in hot pastoral environment. Physiologically they adapted the ability to withstand periodic shortage of water and feed, ability to walk long distances in search of water and feed and ability to digest low quality feeds, tolerance to heat stress, tolerate some ticks and tick-borne diseases and other tropical diseases. Anatomically they are a small to medium sized; white, brown or red-colored coats; thin and smooth coat type; A highly sensitive and motile skin, very short coat, waxy secretion from their skin and long tail with a big well-formed twitch and have short horns which has positive effect on physiology of the animal.

SIGNIFICANCE STATEMENT

This review discover the Physiological and anatomical adaptation characteristics of Borana cattle to pastoralist lowland environments. That can be beneficial for clarifying the characteristics of Borana cattle because they are widely distributed to different continents like Africa, Asia and America which differ in agro-ecology and climate. This literature review will help the researcher to uncover the critical areas of physiological and anatomical characteristics or the secret behind Borana cattle to survive and produce within different environmental condition furthermore.

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