



Heritage beef cattle genetics: A climate adaptation tool in desert rangelands

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Abstract

Climate trends are exacerbating the challenges associated with raising beef cattle in desert rangelands. In the North American Southwest, where longer heat spells and extended drought periods are becoming more common, increasing levels of costly external inputs are required to wean a crop of marketable calves every year. A group of scientists at the United States Department of Agriculture Agricultural Research Service Jornada Experimental Range provided leadership for an international team of researchers who examined the feasibility of using heritage Criollo cattle as a climate adaptation tool in desert ranching systems. Criollo cattle exhibit phenotypes thought to be largely shaped by natural selection which is known to favor rusticity traits at the expense of rapid growth rates and offspring weight. Over the past 20 years, the team studied grazing behavior, animal production (including meat quality and yield), and the economics of raising Criollo cattle. A recent special issue of *Journal of Arid Environments* titled '*Heritage cattle genetics as a potential climate adaptation strategy for producers in arid regions*' compiled 12 articles that report results from this large research effort. Fifteen years of research results largely confirmed anecdotal accounts regarding the desirable grazing traits present in Criollo cattle. Our data strongly suggest that Criollo heritage genetics could be an important adaptation tool for desert cow-calf systems. Raising Criollo cattle could be a means of strengthening the economic sustainability of desert beef cattle ranching systems

Introduction

Ensuring food and nutrition security in a hotter world with more frequent extreme weather events will require developing resilient crop and livestock genetics (Mbow et al. 2019). Modern high-producing crops and livestock have been selected for enhanced production in high-input systems. Over the past six decades, per capita food production worldwide increased 30% subsidized by a 100% and 800% increase in irrigation water and nitrogen fertilizer use, respectively (Mbow et al. 2019). The long-term sustainability of such approaches to agriculture and food production are increasingly uncertain.

Frequently overlooked indigenous and heritage crops and livestock possess remarkable drought and heat tolerance traits shaped by centuries of close-to-natural selection (Mbow et al. 2019). The value of natural vs. artificial selection was perhaps most eloquently articulated by Charles Darwin (1872) over a century ago. In ‘The Origin of Species by Means of Natural Selection’, Darwin frequently drew parallels between natural and human-driven selection of organisms (wild vs. domestic). He argued that ‘Man selects only for his own good: Nature only for that of the being which she tends’ (p.65). This powerful idea, which Darwin would likely word somewhat differently today, captures the essence of differences in climate adaptation potential of commercial vs. heritage crop varieties and livestock breeds. There is growing consensus nowadays about the urgent need to recuperate indigenous and heritage genetic material and assess its potential to contribute to climate adaptation and mitigation of global agricultural systems (IPCC 2019).

In this context, an international team of researchers in North and South America came together to summarize research findings from 15 years of studies comparing aspects of rangeland cow-calf systems that raise commercial (British) vs. heritage (Criollo) cattle. Criollo, also referred to as Creole cattle, are a heritage type of livestock brought to the Americas by conquistadors more than five centuries ago (Anderson et al. 2015; Armstrong et al. 2022). Spanish, Portuguese, and African breeds provided the genetic basis for these cattle that spread rapidly throughout the Americas. By the end of the 19th Century, commercial breeds had mostly displaced Criollos to marginal regions unsuitable for specialized beef and dairy newcomers (Armstrong et al. 2022). Anecdotal accounts of ranchers from South to North America who raise these cattle consistently point to their ability to thrive under harsh conditions. The objective of this paper is to summarize research published recently in a special issue of Journal of Arid Environments that focused on the use of heritage cattle genetics as a potential climate adaptation strategy for producers in arid regions (<https://www.sciencedirect.com/special-issue/103WLV70KVZ>). Much of this research was both motivated by and co-produced with ranchers seeking novel climate adaptation solutions.

Methods Overview

Foraging patterns and thermotolerance of Criollo vs. British beef cows

Grazing behavior results summarized here are from studies ranging from one to three years in duration conducted between 2005 and 2021 at sites in the Chihuahuan Desert, New Mexico, USA (Nyamuryekung’e et al. 2022; Roacho Estrada et al. 2023), Colorado Plateau, Utah, USA (Duni et al. 2023), California Chaparral, California, USA (Duni et al. 2023), Sierra Madre Foothills, Chihuahua, Mexico (Roacho Estrada, et al. 2023) and Arid Chaco, La Rioja, Argentina (Herrera Conegliano et al. 2022). Mean annual precipitation at research sites ranged from 600 mm at the California site to 207 mm in Utah.

Raramuri Criollo was the heritage breed used at the four North American sites, and Argentine Criollo was used at the South American site. Phenotypic characteristics, origin, and ancestry of each of these biotypes are discussed in detail by Armstrong et al. (2022). Commercial beef breeds included Black Angus (California, Chihuahua, and La Rioja), Red Angus (Utah), Hereford (Chihuahua) and Black Angus x Hereford crossbred cattle (Chihuahua and New Mexico). At each site cattle grazed undisturbed in extensive rangeland pastures.

In all cases, study protocols were approved by the corresponding Animal Care and Use Committees. Raramuri Criollo cows used at the North American sites were on average 179 kg lighter than their commercial breed counterparts (388 vs. 564 kg for R. Criollo vs. beef breeds), whereas Argentine Criollo cows weighed roughly the same as their Angus counterparts (400 vs. 420 kg, for A. Criollo vs. beef breed). Five to eleven cows of each breed were fitted with GPS collars at each site. GPS data were used to calculate movement, activity, habitat use, and social cohesion metrics.

One of the Chihuahuan Desert studies included fecal sample collection for diet analysis (Estell et al. 2022). DNA metabarcoding was used to determine the proportion of plant species in fecal samples collected from 10 cows of each breed during the growing and dormant seasons for three consecutive years. DNA metabarcoding with

chloroplast gene *trnL* primers were used. Plant taxa were identified using the global and locally developed reference libraries (Estell et al. 2022).

Body temperatures were measured in another of the Chihuahuan Desert studies using temperature loggers affixed to a blank CIDR (Controlled Internal Drug Release device) devoid of hormones inserted intravaginally and set to record body temperature at 10 min intervals (Nyamuyekung'e et al. 2022). Temperature loggers were deployed on 6 to 11 cows fitted with GPS collars with temperature sensors in summer and winter during two consecutive years. Logger data were compared with GPS collar and weather station temperature sensor readings. Soil surface temperature was mapped via a 30 x 30 m pixel raster file derived from the thermal infrared band 10 of the Landsat 8 satellite.

Economics of raising Criollo vs. British cattle in the Chihuahuan Desert

The profitability of raising Criollo cattle in an alternative production system (grass finishing) in the Chihuahuan Desert was investigated by producing enterprise budgets for a herd of Raramuri Criollo cattle at the USDA ARS Jornada Experimental Range (Chihuahuan Desert Research site; Torell et al. 2023). Costs, returns, and beef production rates and practices for the typical commercial breed ranch (4662 ha; 150 Animal Unit Year) were defined from published budgets and summary statistics. Property and livestock taxes were defined using mill rates (\$1 in taxes per \$1,000 in taxable value) for Southwest New Mexico counties. Revenues for the herd were calculated based on expected sale weight and price for the year 2013, considering steers and heifers sold and retained, as well as cull animals (Torell et al. 2023).

Results

Foraging patterns and thermotolerance

Across all sites and seasons, compared to commercial cows, Criollo cattle traveled on average 2 additional km each day, explored twice the area (206 vs 110 ha/day for Criollo and British cows, respectively), grazed about the same amount of time (~ 9 h/day), and showed more dispersed foraging tactics by traveling greater distances and covering larger areas for every hour they spent grazing (see data summary in Cibils et al. 2023). Breed differences were typically greatest in the dormant season. Criollo cattle showed significantly greater ability than British breeds to make seasonal (dormant vs. growing) and annual (dry vs. wet) adjustments in foraging behavior (Cibils et al. 2023). Criollo and Criollo crossbred steers finished on grass in the Chihuahuan Desert showed grazing patterns similar to those of Criollo cows (McIntosh et al. 2021).

At the Chihuahuan Desert site, Criollo cows showed less herd cohesion, spent less time in each landscape pixel and revisited previously grazed sites less often (Nyamuyekung'e et al. 2022 and Spiegel et al. 2019) than their British counterparts. Criollo cows also spent less time grazing patches dominated by black grama (*Bouteloua eriopoda*), a palatable Chihuahuan Desert grass of high conservation value, and tended to include less of this species in their diets compared to commercial beef cows (Nyamuyekung'e et al. 2022, Estell et al. 2022). Criollo cattle diets tended to include more mesquite (*Prosopis glandulosa*) and Yucca (*Yucca spp.*) than diets of their British peers. At the Utah and California sites, Criollo cattle were more likely to forage in shrub dominated areas and tended to spend less time in sensitive riparian lowlands (Duni et al., 2023) compared to their Red and Black Angus counterparts.

Criollo cattle were better able to cope with Chihuahuan Desert summer heat relative to British cows; they exhibited lower body temperature and higher collar temperature (ambient heat in the proximity of the animal) during the hottest hours of the day. Breed differences in activity (Criollo > British) were greatest during the hottest hours of the early afternoon (Nyamuyekung'e et al. 2021).

Economics

Criollo cattle in the Chihuahuan Desert had lower operating and overhead costs when compared to British beef cattle. This reduction in costs allowed the Criollo cattle operation modeled in this study to have greater net returns to land and risk when compared to a typical desert beef cattle operation. Importantly, grass-finished Criollo steers in the Chihuahuan Desert exhibited excellent meat quality parameters (McIntosh et al. 2021), a finding that is consistent with earlier South American research (Anderson et al. 2015; Armstrong et al. 2022).

Discussion and conclusions

Fifteen years of research results largely confirmed anecdotal accounts regarding the desirable grazing traits present in Criollo cattle. These characteristics, which are thought to favor overall animal fitness, likely evolved through centuries of close-to-natural selection. Our data strongly suggest that Criollo heritage genetics could be an important climate adaptation tool for desert cow-calf systems. Raising Criollo cattle could be a means of strengthening the economic sustainability of desert beef cattle ranching systems. Research addressing the environmental, economic, and social sustainability (including tradeoffs) of raising heritage beef in desert ranching systems is currently underway (Spiegel et al. 2023).

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