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Inherited Instincts: Unravelling the Genetic Tapestry of Cattle Behaviour

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ABSTRACT

Exploring the realm of behavioral genetics holds profound significance in research, given the intricate and varied behavioral manifestations displayed by domestic animals. These behaviors, marked by both commonalities and distinctions across species, wield considerable influence over animal well-being and productivity. This comprehensive review delves into the genetic dimensions of behavior, elucidating the application of behavioural genetics in breeding initiatives and its pivotal role in unravelling the inherent genetic diversity within these traits.In the context of cattle, temperament traits are pivotal components of their overall well-being, encompassing responses to various activities such as handling, milking, and challenges like human interactions during calving or engagements with conspecifics. The genetic foundations of these traits have been subjects of rigorous study, with heritability, quantitative trait loci (QTL) pinpointed. Despite notable variability in these traits, certain handling temperament traits exhibit moderate heritabilities, rendering them amenable to selective breeding. However, the integration of temperament traits into selection programs remains somewhat limited. Animals typically undergo screening for behaviors like fear and aggression. While estimated breeding values (EBVs) for temperament are occasionally determined, these traits are not consistently incorporated into selection indices, despite their potential economic, welfare, and human safety implications. Moving forward, opportunities lie in capitalizing on digital data collection methods and more extensive utilization of genomic information in the selection process.

KEYWORDS: Animal welfare, genetic parameters, milking temperament

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1. INTRODUCTION

Cattle with undesirable temperaments can create numerous issues during the milking process, leading to increased labor difficulties, a higher likelihood of accidents for both the animals and workers, and negatively affecting both the quantity and quality of milk produced (Taborda et al., 2023). In beef production, the ability of a cow to successfully raise and nourish a calf from birth to weaning is crucial, hinging significantly on the cow's mothering ability (Orihuela and Galina, 2021). Temperament traits in both dairy and beef cattle influence animal well-being and economic performance. Cattle with calm temperaments generally grow more quickly, are simpler to manage, transport, and feed, and often yield better-quality meat. On the other hand, cattle with more reactive temperaments may pose safety risks to both other animals and their handlers (Costilla et al., 2020).

Maternal behavior in mammals ensures offspring survival and health (Mills and Marchant-Forde, 2010; Geburt et al., 2015; Michenet et al., 2016). In cattle, maternal behaviors around calving include shelter seeking, nest building, parturition, cleaning the newborn, suckling, and forming a cow-calf bond (Chenoweth et al., 2014). The impact of maternal behavior on calf health, in the dairy industry with early cow-calf separation is common (Meagher et al., 2019). Reviews highlight the long-term effects of early separation on health (Beaver et al., 2019) and prolonged contact on calf behavior and welfare, showing positive influences on social behavior (Meagher et al., 2019). However, further research is needed to understand breed differences and the effects of interference on milk provisioning (Whalin et al., 2021). Individual variability in dairy cattle behavior affects performance, reproduction, health, and welfare (Sutherland et al., 2012; Haskell et al., 2014; Friedrich et al., 2015; Hedlund and Løvlie, 2015; Marçal-Pedroza et al., 2021). This review evaluates the role of behavioral traits in genetic selection, emphasizing their integration into selection processes and genomic selection (Barrozo et al., 2012).

The temperament of cattle during milking has a low to moderate heritability and shows genetic links to traits related to milk yield, ease of handling, health, and reproduction (Chang et al., 2020). Continuous phenotypes exhibit higher heritability compared to subjective scores (Stephansen et al., 2018). The consistency of three temperament traits evaluated by farmers is relatively high, ranging from 0.32 to 0.56 (Kramer et al., 2014). Milking temperament affects udder health (Santos et al., 2018), milk yield (Chang et al., 2019) and AMS performance (Wethal and Heringstad, 2019). Molecular genetic studies identified 135 QTLs associated with 15 cattle behavior traits (Anonymous, 2019), 71 QTLs in Holstein and Charolais crossbreds (Friedrich et al., 2016). The most significant number of QTLs related to temperament were found on BTA29, with overlapping QTLs on BTA10 and BTA29 (Friedrich et al., 2016).

Incorporating temperament into breeding programs is a not easy due to varied environmental factors and the necessity of considering G×E interactions. Van der Laak et al. (2016) found no G×E interactions for milking temperament between grazing and indoor systems in the Netherlands(Byrne et al., 2016). Bos indicus breeds, while more adapted to tropical conditions, are more reactive to milking and less productive (Paranhos da Costa et al., 2015). In Brazil, crossing Bos indicus with Bos taurus breeds like Holstein and Gyr accounts for 80% of milk production (Madalena et al., 2012). Developing novel and accurate phenotypes alongside genomic selection is crucial for improving dairy cattle temperament. Canada has seen substantial genetic progress in milking temperament, with over 0.60 units of improvement since adopting genomic selection (Anonymous, 2019), underscoring the potential of advanced genetic tools and precise phenotypic measurements to enhance cattle temperament and productivity.

2. DEFINITION OF TEMPERAMENT

Individuals involved in the care of cattle and other livestock acknowledge distinct variations in how animals respond to alarming or challenging situations. Moreover, these animals frequently exhibit consistent reactions when faced with recurring challenges (Boivin et al., 1994). Consistency in responses is observable in various scenarios, including reactions to a newborn calf, aggression or affiliation towards herd-mates (Boldt, 2008). In livestock management, "temperament" typically refers to an animal's reaction to being handled or moved by humans (Cue et al., 1996). This terminology has been widely adopted in the cattle sector, particularly in the context of beef cattle. Various descriptors, such as "maternal temperament" or "aggressive temperament," are utilized to specify the context of the animal's response, differentiating it from other situations. For instance, the term "handling temperament" may be employed to distinguish responses during handling from those in other contexts. Other studies use terms like "maternal temperament," "aggressiveness," or "sociability" to explore consistency in the animal's response beyond handling situations (Curley et al., 2008).

3. WHAT IS THE SIGNIFICANCE OF TEMPERAMENTIN LIVESTOCK SECTOR?

The importance of temperament lies in its influence on various facets of production, welfare, and human safety, with a specific focus on traits that can have adverse consequences in these realms. Handling temperament, in particular, has garnered significant attention due to its implications for the efficiency of farm management and animal well-being. Animals displaying unfavorable handling temperament, characterized by violent struggles and attempts to escape during confinement or handling (Dickson et al., 1970). Moreover, such behavior can markedly impede the efficiency of processes like weighing or drafting a group of animals. In the realm of dairy cattle, maintaining a calm response during the milking procedure is essential for process efficiency and minimizing residual milk volume (Curley et al., 2008). While docility in dairy cattle has been a trait selectively bred over generations, challenges stemming from difficult handling and milking behaviors have prompted ongoing investigations and the inclusion of "dairy temperament" in breeding programs globally (Cue et al., 1996). Additionally, there exist other temperament traits, such as maternal aggressiveness, resource-based aggression, and social motivation, which may receive less attention but are significant from the perspectives of animal welfare and human safety (Dickson et al., 1970). Similarly, resource-based aggression and social motivation are pivotal aspects influencing animal welfare, encompassing behaviors related to resource competition and social interactions within groups, respectively.

4. DEFINING AND MEASURING BEHAVIORAL TRAITS IN LIVESTOCK

It becomes imperative to employ selective breeding strategies to enhance temperament. To facilitate this selective process, a series of essential steps must be undertaken (Boldt, 2008). Initially, the trait, which in this context pertains to a specific behavior or response, requires a clear definition, usually accompanied by a delineation of the relevant context. Following this, a measurement system must be developed to enable swift, quantifiable, and reliable assessment of the trait, even by individuals without a scientific background. Subsequently, it is crucial to validate the measurement against other indicators of the trait whenever possible to ensure its accuracy in characterizing the response. Once validated, this measure can be applied in various capacities (Core et al., 2009). It can serve as a "screening" tool, leading to the culling or exclusion from breeding considerations of individual animals with poor temperament scores. Alternatively, the measure can be integrated into genetic improvement programs. This section will explore the progress made in defining and measuring temperament traits (Curley et al., 2008).

5. IMPLICATIONS FOR ANIMAL WELFARE, PRODUCTIVITY, AND HUMAN-ANIMAL INTERACTIONS

The behavioral characteristics exhibited by native cattle carry significant implications for their well-being, productivity, and interactions with humans (Boivin et al., 1994). A well-balanced temperament, marked by composed responses to handling and minimal stress, is essential for fostering positive welfare outcomes. Regarding productivity, certain behavioral traits, such as efficient foraging and adaptability to local environments, substantially contribute to the overall health and growth of indigenous cattle. Additionally, reproductive behaviors play a pivotal role in sustaining herds. The temperament traits influence human-animal interactions, impacting the ease of handling, milking procedures, and overall management practices. A harmonious relationship between humans and native cattle not only enhances safety for handlers but also cultivates a more efficient and cooperative environment. By acknowledging and integrating the implications of these behavioral traits, breeding programs and management strategies can be developed to optimize the welfare of indigenous cattle and the productivity of livestock systems, advocating for a comprehensive approach to sustainable and ethical animal husbandry (Cue et al., 1996).

6. BEHAVIORAL TRAITS IN INDIGENOUS CATTLE

Indigenous cattle demonstrate a diverse array of behavioral traits crucial for their adaptation, survival, and interactions within their respective environments. These behaviors can be broadly categorized into various dimensions (Kumar et al., 2015). Firstly, foraging behavior is influenced by their natural habitats, encompassing distinctive grazing patterns, preferences for specific vegetation, and adaptability to diverse forage sources, contributing to their resilience across ecosystems (Kumar et al., 2007). Reproductive behaviors, vital for herd sustainability, involve traits related to estrus detection, mating rituals, and maternal care, significantly impacting reproductive success and overall herd health (Sharma and Khanna, 1980). Social interactions within indigenous cattle herds involve complex dynamics, including dominance hierarchies, affiliativebehaviors, and communication methods such as vocalizations or body language, contributing to herd cohesion and stability. Maternal care is a critical dimension, with behaviorscentered on the protection and nurturing of calves, reflecting strong maternal instincts that ensure the well-being and development of offspring (Sharma and Khanna, 1980).

Temperament traits play a pivotal role, influencing responses to stimuli like handling, confinement, or human interactions. Desirable traits include calm and docile temperaments for ease of management, while aggressive or fearful temperaments may present challenges (Kumar et al., 2007). Cognitive behaviors, covering problem-solving, learning, and memory, contribute to adaptability and responses to novel situations. Exploratory behavior, driven by natural curiosity, aids in adaptation to new environments, resource discovery, and overall environmental awareness (Kumar et al., 2015). In response to challenges, indigenous cattle exhibit specific behaviors, whether facing environmental stressors, predators, or human interventions. Understanding these responses is critical for mitigating stress and ensuring the well-being of the animals. Lastly, aggression and dominance behaviors in social settings influence hierarchy establishment, impacting resource access, mating opportunities, and overall group dynamics (Kumar et al., 2007). The intricate interplay of these behavioral dimensions underscores the adaptability and resilience of indigenous cattle across diverse environments. Appreciating and understanding these behaviors are imperative for informed management practices, sustainable breeding programs, and the promotion of animal welfare within indigenous cattle populations (Sharma and Khanna, 1980).

7. SIGNIFICANCE OF BEHAVIORAL TRAITS IN INDIGENOUS CATTLE

The behavioral traits demonstrated by indigenous cattle carry profound significance across various facets of their existence (Kumar et al., 2007). Primarily, foraging behavior plays a pivotal role in their survival and adaptability to diverse ecosystems, influencing their feeding habits and capacity to effectively utilize available resources (Sharma and Khanna, 1980). Regarding reproductive behaviors, the inherent traits related to estrus detection, mating rituals, and maternal care are foundational for the sustainability and overall health of indigenous cattle herds. The dynamics of social interactions within the herd, including dominance hierarchies and affiliativebehaviors, contribute to the stability and cohesion of the group, thereby influencing their collective well-being (Kumar et al., 2007).

Maternal care behaviors ensure the successful rearing of calves, underscoring the importance of strong maternal instincts in safeguarding the offspring. Temperament traits, encompassing responses to handling and human interactions. Cognitive behaviors, including problem-solving and learning abilities, showcase the adaptability of indigenous cattle to varying environmental conditions. Exploratory behavior reflects their innate curiosity, aiding in resource discovery and environmental awareness (Kumar et al., 2015).

In the face of challenges, the specific responses exhibited by indigenous cattle indicate their resilience and ability to cope with environmental stressors, predators, or human interventions (Sharma and Khanna, 1980). Social motivation and affiliation underscore the importance of cohesive relationships within the herd, contributing to their overall social structure. Additionally, aggression and dominance behaviors play a role in resource access and the establishment of hierarchies, influencing the group dynamics of indigenous cattle populations. In essence, the intricate tapestry of behavioral traits in indigenous cattle not only attests to their adaptability but also serves as a critical foundation for sustainable management practices, breeding programs, and the preservation of their overall welfare (Kumar et al., 2007).

8. GENETIC BASIS OF BEHAVIORAL TRAITS

To integrate temperament studies into animal breeding, it is essential to establish and clearly define the breeding goal. Choosing a predictor trait, such as scoring milking behavior on a standard scale, based on functional and economic viability is crucial for the efficacy of the work plan (Haskell et al., 2014).

Milking temperament has been associated with udder health (Curley et al., 2008), survival (Cue et al., 1996), rectal temperature, and milk production (Core et al., 2009), reproductive efficiency (Sewalem et al., 2011), milking speed (Gauly et al., 2001), performance in automatic milking machine systems (Schrooten et al., 2000), and body and udder conformation (Cue et al., 1996; Sewalem et al., 2011). Comprehensive study on dairy cattle temperament found correlations with production, physiological parameters, and their genetic parameters (Pryce et al., 2000).

Cattle behavioral traits exhibit heritability, indicating a genetic link with performance traits. Increasing number of these traits are being recognized as dependent on the effects of single genes (Gibbons et al., 2009). Milking temperament has emerged as a particularly significant behavioral trait among cattle. The heritability estimates for temperament in cattle vary widely (Boivin et al., 1994). For Holstein–Friesian and Jersey cattle, temperament heritability estimates stand at 0.22 and 0.25, respectively (Boldt, 2008). Additionally, dairy cattle exhibit a temperament heritability of 0.61, while beef cattle have a heritability of 0.31 (Curley et al., 2008).

Nutritional habits, such as the duration and speed of feeding in hybrid cattle of Bostaurus and Bosindicus, demonstrate relatively high heritability, with values of 0.36 and 0.5, respectively. Social/behavioral and reproductive activities, on the other hand, exhibit low to medium heritability. Cattle temperament has been identified as a behavioral trait correlated with milking function and milk production (Kramer et al., 2014). Anxiety in cattle has been shown to decrease longevity (King et al., 2006). The relationship between temperament and dietary patterns is notably influenced by the carcass efficiency trait (King et al., 2006). In Limousin heifers, there exists a strong genetic correlation between obedience and fertility (Hiendleder et al., 2017). According to dairy cattle population evaluations, over 90%

of milking cattle are reported to possess a reasonably calm or very calm disposition (Hoppe et al., 2010). Notably, selecting more nervous cattle for milking has been associated with decreased herd production efficiency (Hayes et al., 2009).

Boldt (2008) similarly found comparable heritability estimates (0.36 for non-restrained and 0.23 for restrained tests), suggesting that variations may arise from potential sampling bias. Discrepancies in measurement protocols, recording methods, or breed differences could also contribute to variability in temperament trait estimates with the same name. Heritability tends to be higher in Bosindicus breeds and crosses than in Bostaurus breeds of British and continental European origin, potentially influenced by breeding history and environmental conditions. Maternal genetic effects on offspring temperament seem minimal. Several methodological factors contribute to variations in heritability estimates. Objectively measured traits generally yield higher heritability than subjective scores. Repeated measures and a younger age at scoring result in higher heritability, possibly due to habituation to handling. Animals displaying distinct temperament differences when young may shift towards a calmer demeanor as they age, reducing genetic and phenotypic variation. Additionally, repeated testing in a short timeframe or familiarity with humans may reduce phenotypic variation. Rearing conditions, such as indoor versus range rearing, and potential sex effects further influence temperament traits in cattle, with conflicting findings in the literature. Despite a larger number of records, heritability for dairy cattle handling temperament measures are generally lower than those for beef cattle. This disparity may stem from individual farmers scoring their own dairy cows, potentially resulting in lower inter-observer reliability compared to assessments conducted by trained assessors, commonly observed in beef cattle studies. Alternatively, the inherently low variation in temperament among dairy cattle could contribute to the lower heritability observed. Regarding aggression and dominance traits, studies with adequate sample sizes suggest low heritability (Table 1). However, maternal traits display a range of heritability from low to moderate, possibly influenced by trait definition quality, indicating potential for improvement through selective breeding.

A comprehensive examination of temperament trait heritability studies indicates that handling temperament traits generally possess moderately high heritability suitable for inclusion in multi-trait selection programs. Recent extensive research across different breeds has affirmed and expanded upon earlier findings by Burrow (1997). These heritability estimates align with those of key productivity traits targeted for selection in the cattle sector, such as milk yield (e.g., 0.25 by Curley et al., 2008; 0.27 by Boldt (2008). While some cases exhibit high variation in heritability estimates, this may be attributed to differences between observers or the type of protocol used, suggesting that training assessors and establishing precise protocols could address these variations.

9. QTL AND GWAS

Over the last three decades, considerable worldwide research has focused on uncovering the molecular genetic foundations of various traits in livestock. Researchers have concentrated on pinpointing quantitative trait loci (QTL) that account for some trait variations, developing detailed genome maps for farm animals, and investigating

Table 1: Heritability of behavioural traits in muilch cows

Trait	Sample size (n)	Heritability	Breed	Reference
Milking temperament (1–9; direction not stated)	656 bulls	0.15	Holstein friesian	Schrooten et al., 2000
Milking temperament (1–9; nervous-quiet)	44,672	0.07±0.001	Holstein friesian	Pryce et al., 2000
Milking temperament (1–9; direction not stated)	16 grandsires; mean sons: 54.5	0.07	Holstein friesian	Hiendleder et al., 2003
Milking temperament (1–5; nervous-calm)	1,940,092	0.13±0.014	Holstein friesian	Sewalem et al., 2011
Milking temperament (1–5 good to poor)	4695	0.25±0.06	Jersey	Visscher and Goddard, 1995
Milking temperament (1–50: excitable-docile)	12,646	0.12±0.02	Holstein friesian	Lawstuen et al., 1988
Milking temperament (1–4; quiet to restless)	319	0.19	Dairy crossbreds	Sharma and Khanna, 1980
Dominance/Aggression	105	0.40	Holstein friesian	Beilharz et al., 1966
Maternal temperament score	162	0.32	Hereford	Brown, 1974

the relationships between molecular genetic markers and specific traits (Garrick et al., 2011). Various studies have identified QTLs linked to behavioral traits in multiple breeds, with chromosomes 1, 8, 9, 16, and 29 being highlighted. For instance, research by Garrick et al. (2011) connected the DRD4 gene on chromosome 29, which plays a role in curiosity and novelty-seeking behaviors in mammals, to performance in a docility test. A comprehensive database of behavioral QTLs is available at www.animalgenome.org/cgi-bin/QTLDB/index.

While some livestock traits are determined by a single locus or a few loci, many are polygenic, influenced by hundreds of loci. Dense genome maps with SNP and genotyping platforms enable genome-wide association studies (GWAS). In beef cattle, studies have linked temperament traits to specific genes, such as those regulating sodium ion transport and influencing nervous system responsiveness. As mathematical techniques advance and genotyping costs decrease, more studies assessing temperament traits are expected (Hayes et al., 2009).

The development of dense genome maps and the accessibility of cost-effective genotyping have revolutionized molecular genetics in livestock breeding. Genetic predictions now leverage data from tens to hundreds of thousands of SNPs, rather than focusing on a limited number of loci. Genomic selection, grounded in genome-wide association studies (GWAS) using a reference population, is seen as highly beneficial for improving hard-to-measure traits like temperament. Genomic breeding values can be estimated using only molecular genetic data, and these values are increasingly integrated with phenotypic data to boost prediction accuracy (Fisher et al., 2001).

The dairy and beef industries are shifting toward utilizing genomic estimated breeding values (GEBVs). Although most genomic research has concentrated on traits related to productivity and reproduction, the expenses and practical difficulties associated with phenotyping and genotyping may initially restrict the application of this method for temperament-related traits.Nonetheless, conducting assessments alongside economically important traits in each study can help overcome these constraints.

10. BARRIERS

There are various technical and motivational obstacles that impede the inclusion of temperament traits in selection indexes for cattle. A significant technical issue is the requirement for economic values to assess the importance of the trait within the selection index (Shrode, 1971). Although economic weights for temperament traits have been established for Bostaurus cattle, thorough estimates are still insufficient. Furthermore, gaps in knowledge regarding the genetic and phenotypic correlations between temperament and other parameters in selection indexes present challenges. In certain regions or countries, there is a lack of research on the relationships between productivity, meat quality, fertility traits, and temperament (Fell et al., 1999). Incorporating new traits, such as calving ease, into selection indexes necessitates an understanding of their relationship with temperament. The organizational structure within breed societies or national governmental bodies also influences this process. Producers' motivations are shaped by factors like breed traits, with Bosindicus breeds typically exhibiting more challenging temperaments compared to Bostaurus breeds. The view of specific breeds as skittish encourages breed societies to assess and enhance temperament evaluation methods (Shrode, 1971). The farming practices in a particular area influence the need and motivation for genetic selection. In Europe, smaller farms often allow for greater human interaction, which may lessen the demand for genetic selection. Some European producers view a certain level of reactivity as beneficial for survival and competitiveness. This highlights the importance of providing informed extension and advisory services to raise awareness about the detrimental impact of poor temperament on productivity and profitability.

11. CONCLUSION

Genetic improvement, along with investments in suitable housing and handling systems, plays a pivotal role, particularly with the growing scale and intensification of dairy enterprises. As herd sizes increase and labour availability declines, genetic enhancement gains significance, supported by automation and genomic advancements for identifying superior animals. There is a lot of scope of behavioural genetics in indigenous cattle, as previously very scanty emphasis had been given for selection of indigenous cattle for behvioral traits.

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