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Mithun *(Bos Frontalis)*: A Forest-Based Food Animal of The Eastern Himalayas

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ABSTRACT

Mithun *(Bos frontalis)* is a domesticated bovine native to the Eastern Himalayas, traditionally managed under forest-based systems and primarily utilized for meat by indigenous communities. Despite its cultural and nutritional importance, Mithun remains underrepresented in formal meat production research and development programs. This review critically evaluates existing literature with emphasis on meat production potential, carcass characteristics, meat quality attributes and biological determinants influencing growth and meat yield. Evidence from studies encompassing nutrition, growth physiology, genetics, reproduction and health management indicates that Mithun exhibits favorable meat composition, efficient utilization of fibrous forest biomass and inherent adaptability to low-input production environments. Available data also suggest the presence of genetic traits associated with disease tolerance and environmental resilience, which may indirectly influence meat productivity. Advances in reproductive biotechnologies, genomic characterization and microbiome research offer new opportunities for genetic improvement and conservation of meat-related traits. However, habitat degradation, genetic erosion, limited performance recording and lack of organized slaughter and processing infrastructure constrain its integration into structured meat value chains. The review highlights the need for targeted research on growth performance, carcass evaluation and meat quality parameters, coupled with conservation-oriented breeding and value-chain development. Positioning Mithun as a niche forest-based meat animal may support sustainable meat production and livelihood enhancement in the Eastern Himalayan region.
Keywords: Mithun, meat quality, carcass traits, sustainable meat production

Introduction

Mithun *(Bos frontalis)*, also known as gayal, is a distinctive bovine species of the Eastern Himalayas and Indo-Burma region, encompassing Northeast India, Bhutan, Myanmar, Bangladesh, and parts of China, where it holds substantial cultural, socio-economic, and ecological importance (Mondal et al. 2014[b] and Kumar et al. 2024). First scientifically described in 1802, Mithun is characterized by a robust body structure, distinctive horn morphology, and exceptional adaptation to mountainous forest ecosystems, enabling its long-term integration into indigenous livelihood systems (Lambert, 1804; Reddy et al. 2024 and Tenzin et al. 2023). Although traditionally described as a semi-wild or semi-domesticated species, recent DAD-IS and FAO assessments recognize Mithun as a domesticated livestock species, reflecting a revised understanding of its management and production potential (FAO, 2023). In India's North-Eastern states of Arunachal Pradesh, Nagaland, Manipur, and Mizoram, Mithun plays a central role in traditional rituals, social exchange, and barter-based economies, symbolizing wealth and social status (Dorji et al. 2021; Narendra and Chaithrashree, 2023). The species is conventionally maintained under extensive free-range or near zero-input systems, thriving in forested landscapes with minimal human intervention. Its natural resilience to rugged terrain, disease tolerance, and efficient utilization of fibrous forest vegetation underscore its relevance as a climate-resilient livestock species within low-input production systems (Mondal et al. 2014[a] and Van Schendel, 2024).

Despite its importance, Mithun remains comparatively understudied relative to cattle and buffalo. However, recent advances in genomics, reproductive biology, and nutritional sciences have renewed interest in its unique physiological and adaptive traits. Genetic studies indicate a close evolutionary relationship between Mithun and the wild gaur *(Bos gaurus)*, sustaining ongoing debate regarding its domestication history, genetic introgression, and possible hybrid origin (Uzzaman et al. 2014). Given the increasing focus on conservation genetics, sustainable livestock systems, and biodiversity management, a concise synthesis of current knowledge on Mithun is warranted. This review integrates available evidence on genomic characterization, reproductive biology, nutritional physiology, health challenges, and conservation strategies to outline a scientific framework for sustainable breeding, disease management, and agroforestry-based Mithun production systems. While comprehensive, this review does not claim exhaustive coverage, as emphasis has been placed on areas of greatest relevance and available scientific evidence.

Status Of Mithun Population In India

India harbours the largest Mithun population globally, estimated at over 380,000 animals, with smaller populations distributed across Bhutan, China, Myanmar, and Bangladesh. Between 2012 and 2019, the Mithun population in India increased by more than 25%, a growth rate exceeding that of most other livestock species. Arunachal Pradesh emerged as the principal stronghold, where numbers rose from 249,000 in 2012 to 350,154 in 2019, representing a 40.62% increase. In contrast, Nagaland experienced a sharp decline from 34,871 to 23,123 animals (−33.69%), while Manipur showed a moderate reduction from 10,131 to 9,059 (−10.58%). Mizoram recorded positive growth, with the population increasing from 3,287 to 3,957 animals (+20.38%). These contrasting trends highlight both the resilience of Mithun in favourable environments and the vulnerability of populations under increasing ecological and socio-economic pressures.

Production Practices

Mithun is traditionally maintained under free-range systems, grazing on community-owned forest lands. In recent years, semi-intensive husbandry practices promoted by institutions such as the ICAR–National Research Centre on Mithun have been introduced to improve productivity through scientific breeding, feeding, and health management interventions (ICAR-National Research Centre on Mithun, 2024). Beyond meat production, Mithun also provides milk, leather, and draught power, with growing consumer preference for its meat and milk owing to their high nutritional value (ICAR-National Research Centre on Mithun, 2024).

In Arunachal Pradesh, seasonal management practices such as Lura regulate animal movement during cropping periods by confining Mithuns to designated forest areas, thereby minimizing crop damage and supporting biodiversity conservation through controlled grazing (Jini et al. 2015). However, the expansion of shifting cultivation systems such as jhum has reduced grazing areas and increased crop–livestock overlap. Although traditionally sustainable due to long fallow cycles, reduced fallow periods driven by population pressure have accelerated forest degradation and intensified human Mithun conflict (Tayo et al. 2013 and Dorji et al. 2021).

Mithun husbandry remains deeply embedded in indigenous traditions, particularly in Nagaland, Arunachal Pradesh, and Mizoram, where forest-based rearing and rotational grazing are widely practiced. These systems are characterized by minimal housing, uncontrolled breeding, and limited supplementary feeding, and are closely linked to cultural values associating Mithun with wealth, social status, and ceremonial significance (Chavan, 2018 and Dorji et al. 2021). Habitat degradation and agricultural expansion have necessitated innovative interventions such as bio-fencing, with Prunus cerasoides and Docynia indica identified as effective, eco-friendly containment options (Vadeo et al. 2023). In Bangladesh, Mithun farming is being promoted as a sustainable livelihood activity with conservation-oriented objectives (Islam et al. 2024).

Mithun farming contributes substantially to household income and food security in Nagaland, although its sustainability is constrained by high input costs, shrinking grazing resources, and limited institutional support (Biam et al. 2021). Reliance on undocumented traditional knowledge, coupled with youth migration and generational gaps, further threatens the continuity of effective husbandry practices (Tayo et al. 2013 and Dhama, 2017). Additionally, disease challenges such as foot-and-mouth disease hinder the integration of Mithun into organized livestock production systems (Borah et al. 2018). Few studies have reported that the semi-intensive Mithun farming system had strong potential to enhance sustainable livestock production and improve the livelihoods of tribal farmers in Nagaland (.

Phenotypic Diversity Of Indian Mithun

Systematic characterization of Indian Mithun populations remains limited, although empirical evidence suggests the existence of at least five distinct breeds or populations—Nagami, Arunachali, Manipuri, Mizo, and Assamese each exhibiting unique phenotypic and morphological attributes. Nagami Mithun, the first officially registered breed, is widely distributed across Nagaland (except Mokokchung) and adjoining areas of Manipur. It is characterized by a predominantly jet-black coat with a white to greyish-brown forehead, white stockings on all legs, a straight dorsal forehead line, hairy dewlap, and the longest horn length among Indian Mithun populations. The breed is larger and heavier than Arunachali Mithun and holds high cultural and ceremonial value among Naga communities (Mukherjee et al. 2014). Arunachali Mithuns display extensive coat colour variation, typically white with black patches, although patterns differ among tribes and regions. They possess shorter, slender horns, a thicker neck, and occasionally a convex dorsal forehead line. Marked intra-population variation exists among Mithuns reared by Galo, Apatani, Nyishi, Aka, and Adi tribes, reflecting strong links between phenotypic traits, tribal preferences, and traditional management systems such as *Lura*, rotational grazing, and sacred forest preservation (Tayo et al. 2013 and Chamuah et al. 2024). Manipuri Mithuns are smaller and more compact, adapted to the subtropical forests of Manipur. Over 60% exhibit a jet-black coat, often accompanied by dark brown shades, with a relatively higher prevalence of black stockings on the legs, exceeding 20% in some village herds. The recent identification of Assamese Mithun in the Dima Hasao district of Assam (2024) adds to India's Mithun diversity. These animals, found in remote forested villages inhabited mainly by the Zeme Naga community, typically show a black coat with white facial markings and white socks, with facial white patches ranging from extensive to minimal. Mizo Mithuns are relatively smaller and leaner, with a predominantly jet-black coat, white stockings, and white forehead markings. They closely resemble Nagami Mithun but possess shorter, slimmer horns and show limited piebaldism, with approximately 83% of animals exhibiting uniform black coloration.

Table 1. Comparative Features of Indian Mithun Populations

Feature	**Nagami Mithun**	**Arunachali Mithun**	**Manipuri Mithun**	**Assamese Mithun**	**Mizo Mithun**
Geographical distribution	Nagaland (except Mokokchung); adjoining Ukhrul (Manipur)	Arunachal Pradesh (multiple districts)	Manipur	Dima Hasao district, Assam	Mizoram
Population status	First officially registered breed	Large but poorly characterized	Moderate, declining	Newly identified (2024)	Small but stable
Body size	Large, heavy	Medium to large	Small to medium, compact	Medium	Small to medium, lean
Coat colour pattern	Predominantly jet black; white/grey/brown forehead	Highly variable; piebald (white with black patches)	Mostly jet black or dark brown	Black with white face patches	Predominantly jet black
Leg markings	White stockings on all legs	Variable	High prevalence of black stockings	White socks	White stockings
Forehead (dorsal line)	Straight	Often convex	Not prominent	Not documented	Not prominent
Horn characteristics	Longest horns; outward and slightly upward curved	Shorter, slender horns	Short to medium	Medium length	Short, slender, gently curved
Dewlap	Hairy	Variable	Not prominent	Not documented	Not prominent
Distinctive traits	Largest size; high ceremonial value	Strong tribal variation; muscular neck	Compact build; adaptation to subtropical forests	Unique facial white pattern	Similar to Nagami but smaller
Cultural importance	Very high among Naga tribes	High across Arunachal tribes	Moderate	High among Zeme Naga	High among Mizo tribes
Management system	Free-range, forest-based	Community forest systems (*Lura*, rotational grazing, sacred forests)	Forest-based free-range	Semi-wild forest-based	Forest-based free-range

Multifunctional Utility Of Mithun

Mithun is predominantly reared for meat production across its distribution range (Tanaka et al. 2011; Dorji et al. 2021 and Tenzin et al. 2023). However, its utility extends beyond meat to include milk, leather, draught power, and emerging biotechnological applications. Among tribal communities of Nagaland, Mithun's multifaceted value is traditionally summarized by the "4 M's"—Meat, Milk, Money, and Marriage reflecting its integrated cultural and economic importance (Narendra and Chaithrashree, 2023 and Karabasanavar et al. 2023). In Bhutan and Arunachal Pradesh, Mithun–cattle hybrids are utilized differentially, with male hybrids used for draught purposes and females producing higher milk yields than pure Mithun cows (Tenzin et al. 2023). Similarly, in Bangladesh, crossbreeding of Gayal *(Bos frontalis)* cows with Friesian bulls resulted in hybrid calves with superior body weight and daily liveweight gain compared to native Gayal (Huque et al. 2001; Girish and Karabasanavar, 2020).

Mithun Meat

Mithun meat is highly valued in the Northeastern Hill Region (NEHR) of India for its superior nutritional quality. It contains high protein (14–19%), relatively low fat, and a favourable balance of essential nutrients compared to conventional cattle meat (Das, Baruah, et al. 2011). The species thrives under free-range forest systems, browsing on shrubs, tree leaves, and natural forages, which enhances sustainability and meat quality (Das et al. 2011 and Chavan, 2018). Recent studies have confirmed excellent water-holding capacity, functional properties, and consistent quality across age and sex classes, contributing to desirable texture and flavour (Lalchamliani et al. 2019, 2024). Advances in molecular tools, including rapid PCR assays, now enable reliable authentication of Mithun meat, reducing risks of adulteration (Mech et al. 2025a). Isothermal amplification is one of the simplest techniques for species identification of meat (Monika et al., 2021). Different isothermal techniques for species identification of Mithun & yak meat using polymerase spiral reaction have also been reported (Mech et al., 2025b & 2025c). Its cultural importance, premium market value, and efficient conversion of low-quality forage into high-quality protein highlight Mithun meat as a sustainable and niche food resource (Chavan, 2018; Girish and Karabasanavar, 2025).

Mithun Milk

Although Mithun produces limited quantities of milk, its composition is nutritionally rich, containing higher levels of essential fatty acids, proteins, vitamins, and minerals than conventional bovine milk (Devi et al. 2023; Tariku, 2024). Bioactive components such as lactoferrin and conjugated linoleic acid confer antimicrobial, antioxidant, and anti-inflammatory properties (Mondal et al. 2015). Physico-chemical analyses reveal higher total solids, fat, protein, density, and viscosity compared to cattle milk, indicating a concentrated nutritional profile (Zhimomi, 2021). Lactation studies report an average lactation length of 340 days, with peak yield of 1.46 kg/day around day 30, followed by declining volume but increasing fat and total solids, while protein and lactose remain consistently high (Mech et al. 2008). Milk letdown is hormonally regulated, with prolactin playing a central role (Mondal et al. 2007). Despite its quality, Mithun milk remains underutilized, and value addition could enhance rural livelihoods (Moyong, 2012).

Leather Production: Mithun exhibits superior growth performance and hides quality, making it a valuable resource for leather production. Comparative studies indicate that Mithun leather exceeds that of indigenous cattle in durability and texture, offering potential for commercial utilization (Das et al. 2014 and Mondal et al. 2014[b]). Growing demand for ethically sourced and high-performance leather further enhances its economic relevance (Chavan, 2018).

Mithun Urine: Biotechnological Applications: Beyond conventional uses, Mithun urine has shown potential in green synthesis of antibacterial copper oxide nanoparticles. These nanoparticles demonstrated effectiveness against *Staphylococcus aureus* and *Escherichia coli*, highlighting possible applications in biomedical and aquaculture sectors (Pelesinuo et al. 2023).

Challenges & Future In Mountain Ecosystems Of The Greater Himalayas

Mithun plays a critical ecological role in the steep, forested landscapes of the Greater Himalayas, where its adaptation to rugged terrain and low competition with other livestock make it an integral component of montane ecosystems (Mondal et al. 2014[b]). The species thrives under free-range conditions in subtropical forests with minimal human intervention; however, its populations are increasingly threatened by habitat loss, deforestation, and genetic dilution through crossbreeding with domestic cattle.

Challenges

Deforestation, agricultural expansion, and infrastructure development have substantially reduced grazing areas, intensifying human–Mithun conflict across community lands (Tayo et al. 2013 and Dorji et al. 2021). In Bangladesh, declining populations are linked to forest loss, weak breeding programs, and genetic dilution, rendering traditional management practices ineffective under contemporary pressures (Faruque et al. 2015, 2023). Molecular evidence indicates moderate to low genetic diversity in certain populations, notably in Bhutan, raising concerns over inbreeding and loss of adaptive alleles (Tenzin et al. 2016, 2023). Restricted gene flow, small population sizes, and geographical isolation further exacerbate genetic erosion (Uzzaman et al. 2014 and Mukherjee et al. 2018). Diseases such as foot-and-mouth disease, bluetongue, brucellosis, and parasitic infestations significantly impair productivity and reproductive efficiency (Rajkhowa et al. 2005; Pradhan et al. 2023 and Rout et al. 2024). Free-ranging systems increase pathogen exposure, while limited veterinary outreach in remote areas constrains effective control. Emerging conditions, including *Neospora caninum* infection and nasal hirudiniasis, further complicate health management (Zhimomi, 2021). Although semen cryopreservation protocols are standardized, field-level application remains limited due to lack of artificial insemination networks, cold-chain infrastructure, and trained manpower in tribal regions (Dorji et al. 2014 and Perumal, Srivastava, et al. 2014). Similarly, adoption of metabolomic and reproductive diagnostics is restricted by high costs, logistical challenges, and bioinformatics requirements, limiting their use beyond institutional settings (Sangwan et al. 2024). Technologies such as CASA and embryo transfer also face translational barriers under field conditions (Vikram et al. 2023). Despite high cultural and economic value, Mithun farming remains largely disconnected from formal value chains. Farmers face high input costs, limited market access, and inadequate policy support (Biam et al. 2021). Erosion of traditional knowledge due to urban migration and lack of systematic documentation further threatens sustainable husbandry practices (Dhama, 2017).

Conservation and Sustainable Management

Long-term conservation of Mithun requires integrated approaches combining genetic improvement, sustainable land use, and community participation. Incorporation of Mithun-preferred species such as *Prunus cerasoides* and *Docynia indica* into agroforestry systems provides sustainable forage while reducing crop damage through eco-friendly bio fencing (Vadeo et al. 2023). Scaling up semen cryopreservation and hormonal synchronization through national breeding programs is essential (Karunakaran et al. 2007; Dorji et al. 2014 and Mondal et al. 2014[a]). In situ herd management must incorporate genetic monitoring to mitigate inbreeding risks (Mukherjee et al. 2022 and Chotso et al. 2024). Although Mithun efficiently utilizes forest forages with moderate to high protein content (B. Prakash et al. 2008 and Geng et al. 2017), documented micronutrient deficiencies necessitate targeted supplementation strategies (Prakash et al. 2013). Use of urea–molasses–mineral blocks has shown positive outcomes (Sung Chin Tial et al. 2023). Decentralized veterinary services and parasite control are critical given the high disease burden (Yepthomi et al. 2024). Integration of ethno-veterinary knowledge and herbal remedies offers cost-effective alternatives in remote regions (Chamuah et al. 2024). Goswami et al. (2025) reported that, owing to the high osmotic fragility and unique physiological characteristics of red blood cells, Mithun are expected to be more disease-resistant compared to other livestock species. Further, Joshi et al. (2025) reported that that immunologic dysregulation, inflammation and oxidative stress mediate less severe ketosis (SCK) in the early postpartum mithun cows. Systematic documentation of traditional practices such as rotational grazing and behavioral management is essential to empower communities and engage younger generations in Mithun conservation (Chavan, 2018 and Dorji et al. 2021).

Future Prospects

Low-cost, field-adapted reproductive tools, including seed germination inhibition tests and urinary biomarker strips, offer practical alternatives for pregnancy diagnosis in remote areas (Perumal, 2011 and Sangwan et al. 2024). Community-managed salt-lick stations can serve as low-contact hubs for health monitoring, mineral supplementation, and periodic veterinary intervention. In areas where artificial insemination is impractical, community-based breeding bull rotation systems can help maintain genetic diversity without reliance on cold-chain infrastructure. Advances in genomic resources, including reference genomes for Mithun and Gayal, facilitate identification of immune and adaptation-related markers for breeding programs (Mei et al. 2016; Wang et al. 2017 and Mukherjee et al. 2019, 2022). Additionally, biosynthesis of copper oxide nanoparticles from Mithun urine represents a promising avenue for green nanobiotechnology with antimicrobial and aquaculture applications (Pelesinuo et al. 2023).

Conclusion

Mithun represents a keystone livestock species of the Eastern Himalayas and Indo-Burma biodiversity hotspot, uniquely adapted to forested montane ecosystems under low-input conditions. Genomic evidence confirms close ancestry with wild gaur across Indian, Bhutanese, and Bangladeshi populations, highlighting the need for population-specific conservation strategies. Despite advances in reproductive biotechnologies, health constraints, infrastructural limitations, and socio-economic gaps continue to hinder large-scale adoption. Addressing these challenges through integrated genetic, ecological, and community-based approaches is essential for sustaining Mithun populations and the fragile montane ecosystems they support.

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Declaration Of Competing Interest

There are no conflicts of interest to declare.

Ethics Statement

Not applicable

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