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# The Current Status and Potential Development of Genetic Resources of Indigenous Toraya Spotted Buffalo in Indonesia: A Systematic Review

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## ABSTRACT

Buffaloes are integral to the Asiatic market as they are crucial for agricultural work and transportation and provide a significant source of dairy and meat, contributing to various industries, local economies, and cultural practices across the region. Indonesia is a mega biodiversity country abundant in livestock genetic resources, including indigenous, local, and introduced breeds that play a crucial role in agriculture and the livestock industry. These genetic resources offer the potential for selective breeding and improving the quality of livestock populations through well-designed breeding programs, ensuring sustainable livestock production for the future. The current study was performed using the "Publish or Perish" software, and the data obtained was analyzed using the CADIMA web tool. The Toraya buffalo population is the largest in the Tana Toraja and North Toraja regencies and is widely distributed within South Sulawesi Province, Indonesia. The population of Toraya buffalo in this region reached 43674 heads. Toraya buffaloes exhibit diverse body color characteristics, such as black, gray, white, and mixed. Moreover, Toraya buffaloes possess distinct quantitative traits that set them apart from other swamp buffalo breeds. Although there are limited studies on Toraya buffaloes, the potential for broader and more comprehensive studies offers opportunities to uncover new information on the characteristics, genetics, reproduction, health, and management of Toraya buffaloes. The development of Toraya buffalo farms also holds significant economic promise, as it can lead to increased agricultural productivity and improved livelihoods for local communities by enhancing the quality by implementing well-planned breeding programs and leveraging reproductive technology, and genetics-based selection, growth, and productivity can be produced. To increase the population and productivity of Toraya buffaloes, a well-structured breeding program integrating reproductive technology and selection based on quantitative and molecular genetics is essential. The development potential of Toraya buffalo is vast, not only due to its high cultural value but also its superior quantitative traits compared to common swamp buffalo, positioning it as a potential national meat provider. The present review article aimed to discuss the characteristics and development potential of Toraya buffaloes, along with the implementation of reproductive biotechnology and molecular genetics to enhance the population, productivity, and quality of Toraya buffaloes in Indonesia.

**Keywords:** Genetic resource, Spotted buffalo, Swamp buffalo, Toraya buffalo

## INTRODUCTION

As a mega biodiversity country, Indonesia possesses a diverse array of livestock genetic resources, encompassing indigenous, local, and introduced livestock. These genetic resources hold significant importance for agriculture and the livestock industry, as they facilitate the selection and enhancement of livestock population quality through well-planned breeding programs, thereby ensuring sustainable livestock production in the future. Among the valuable livestock genetic resources, proper management and preservation of buffalo populations are crucial. Buffalo plays a pivotal role in overall social development contributions of draft power to meat, milk, and hide production (Pineda et al., 2021).

Buffaloes are a prominent livestock species that continue to be widely distributed and traditionally raised in Southeast Asia, particularly Indonesia. There are two subspecies of buffalo, namely the river buffalo (*Bubalus bubalis*) from South Asia and the swamp buffalo (*Bubalus bubalis carabanensis*) from Southeast Asia. Buffaloes play a vital role in rural communities and significantly contribute to the national supply of meat and milk. According to the 2021 data from the Indonesian Statistics Agency (Badan Pusat Statistik [BPS]), the national buffalo population reached 1.189.260 heads, distributed across Indonesia with varying population densities and agroecosystems. However, the general buffalo population has experienced a drastic decline in several regions over the past decades (BPS, 2021).

Buffaloes play a substantial role in the livestock economy, providing essential contributions to milk, meat, and labor. The potential for buffalo development as a meat source holds promising prospects, particularly in line with population growth, directly influencing meat demand in Indonesia. One such buffalo breed is the Toraya buffalo or



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striped buffalo, which represents a significant part of Indonesia's biodiversity and belongs to the swamp buffalo (*Bubalus bubalis carabanensis*).

Swamp buffaloes are frequently used in traditional and religious ceremonies across various regions of Indonesia and indicate high social status within the community. Toraya buffalo is native to South Sulawesi, Indonesia, and has been officially designated as a local buffalo breed through Minister of Agriculture Decree No. 2845/Kpts/LB430/8/2012. The development of buffalo farming can be influenced by the presence of natural resources, social factors, and economic opportunities, potentially leading to changes in their geographical distribution (Rozaq and Sugiarto, 2020). Notably, the Toraja region exhibits a distinct and unique culture and belief system, with the Rambu Solo funeral procession being one of its famous traditions closely associated with the Aluk To Dolo belief. The reliance on buffaloes during the Rambu Solo ceremony has economic, social, and ecological implications (Syamsuddin et al., 2023).

The utilization of buffaloes in traditional ceremonies as sacrificial animals necessitates careful attention to the buffalo population in Toraja. The low birth rate resulting from traditions discouraging natural mating and the limited application of artificial insemination technology in male Toraya buffaloes have contributed to the decline in the Toraya buffalo population. As an essential measure, adopting reproductive technology is paramount to addressing the challenges facing Toraya buffalo. The present review article aims to discuss the characteristics and development potential of Toraya buffaloes, along with the utilization of reproductive biotechnology and molecular genetics to enhance the population, productivity, and quality of Toraya buffaloes in Indonesia.

## DATA COLLECTION

The literature searches were carried out using the publish or perish (POP) software version 8. The keywords Toraya buffalo and striped buffalo were used in searching the Google Scholar and Scopus databases published from 2005 to 2023. The literature obtained was then stored in RIS format and processed using the CADIMA web tool (CADIMA, 2020). The reference list, which combined 44 unique records according to CADIMA (with no duplicates), was then randomized, and full-text analysis was conducted for the final review. In total, six publications were selected from the field of reproductive biotechnology and molecular genetics. This study was approved by the Animal Ethics Commission of the National Research and Innovation Agency, Indonesia, with the license number 050/KE.02/SK/03/2023.

## POPULATION STATUS

Swamp buffaloes were domesticated in Thailand and subsequently spread to various regions (Wang et al., 2017; Zhang et al., 2020). They migrated northwards to China and southwards to Sumatera. Buffaloes from China also extended their distribution to the Philippines, while those from Sumatera spread to Indonesia, Sulawesi, and Nusa Tenggara islands. Sumatran buffaloes possess relatively superior genetic quality, compared to buffaloes from other Indonesian islands due to direct genetic inheritance from Thai buffaloes (Yusnizar et al., 2015). Zhang et al. (2020) reported that after being domesticated in Thailand, swamp buffaloes migrated in a southerly direction, traversing the Malay Peninsula and reaching Indonesian islands, including Sumatera, Java, Sulawesi, as well as the northern and northeastern regions of central China. They subsequently continued their expansion using the eastern island route, passing through Taiwan and eventually reaching the Philippines and Borneo.

Saputra et al. (2020) conducted a study based on microsatellite markers and identified two groups of swamp buffalo in Indonesia. The initial cluster consists of Aceh, North Sumatera, and Riau, while the subsequent group encompasses Central Java, West Nusa Tenggara, South Sulawesi, and ten other regions in Indonesia. Similarly, in a study by Rusdin et al. (2020), two distinct clusters were identified among eight Indonesian swine breeds, distinguished through cytochrome b gene markers. The primary cluster includes Aceh, North Toraja, West Nusa Tenggara, Banten, Kolaka, and Konawe, while the secondary cluster comprises Bombana Island, Bombana mainland, Kolaka, and Konawe, totaling eight distinct breeds.

Geographically, Toraja is located between 2-3 degrees south and 119-120 degrees east longitude, bordered by Enrekang district to the south, Luwu district to the east, Polewali district to the west, and Central Sulawesi to the north (Figure 1). The largest distribution of buffalo populations is found in the Toraja region, specifically the Tana Toraja and North Toraja districts, and the Toraya buffalo is an indigenous livestock breed prevalent in South Sulawesi Province, Indonesia. Toraya buffaloes have been raised for generations due to their role in religious rituals and close ties with local culture, including the rambu tuka (wedding ceremony) and rambu solo (death ceremony). The designation of Toraya buffalo as a local breed was confirmed by the Minister of Agriculture Decree Number 2845/ Kpts/ LB430/8/2012.

The buffalo population in South Sulawesi Province reached 122.012 heads in 2021 (BPS, 2021), with the highest population found in Tana Toraja and North Toraja districts, accounting for 43.674 heads or 40% of the buffalo population in South Sulawesi. According to FAO (2022), the Toraya buffalo population was recorded as 19.239 heads, but detailed classification information was not provided. The distribution of Toraya buffalo populations is not limited to



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Toraja but also extends to other areas, including Enrekang Regency, Pinrang Regency, Maros Regency, and Takalar Regency.

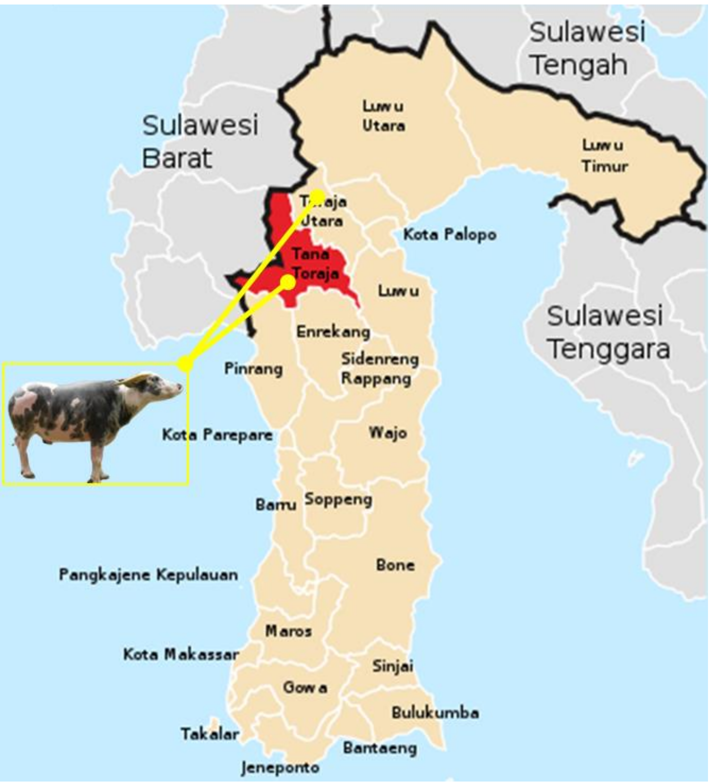


**Figure 1.** The map depicts the distribution of Toraya buffalo populations in the Tana Toraja and North Toraja districts of South Sulawesi Province, Indonesia.


**Figure 2**. Spotted color pattern types on Toraya buffaloes at Toraja Utara and Tana Toraja, South Sulawesi Province, Indonesia. **a**: Saleko, **b**: Lotong boko, **c**: Bonga, **d**: Sambo batu, **e**: Bulan (Albino), **f**: Toddi, **g**: Sorri, and **h**: White eyes (marbles). Source: The images were taken by the authors of this study.

## CHARACTERISTICS

Toraya buffaloes exhibit a range of body color characteristics, including variations of black, gray, white, and mixed patterns, setting them apart morphologically from other swamp buffaloes (Windusari et al., 2019). Generally, Toraya buffaloes have a distinctive reddish-white and black color pattern with white eyes. Their head color varies, encompassing shades of gray, black, and white, while their horns are curved from the side toward the back, and their ears are directed toward the sides (Figure 2). Based on Minister of Agriculture Decree Number 2845/Kpts/LB430/8/2012 and SNI 8292.4:2016, Toraya buffalo possesses its own unique characteristics (Table 1). In addition to having a uniform physical form, Toraya buffaloes exhibit distinctive features that distinguish them from swamp buffaloes, indigenous buffaloes, and other local breeds.



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Nooy-Palm (2003) reported several variations in terms of color combinations and markings among Toraya buffaloes, commonly referred to as “bonga”. The variations include Bonga saleko characterized by an almost equal combination of black and white with spots scattered throughout the body, Bonga sanga’daran distinguished by the dominance of black in the mouth area, Bonga randan dali’ displaying black eyebrows, Bonga takinan gayang featuring a black pattern resembling a long machete on the back, Bonga ulu exhibiting white color exclusively on the head, while the neck and body remain black, Bonga lotong boko’ showcasing a black color on the back, Bonga bulan having the entire body in white, Bonga sori presenting a white color only on the head.

There are variations in the qualitative traits of Toraya buffaloes, such as skin color, horn shape, dorsal line, white chevrons, and number of whorls. The skin color, horn shape, back line, and white chevrons on the neck are distinctive features that distinguish Toraya buffaloes from swamp buffaloes in general (Wang et al., 2017). However, the number of *unyeng-unyeng* and the white color of the feet tend to be uniform among Toraya buffaloes so that they can be used as consistent characteristics (Table 2). Furthermore, in studying the quantitative traits of Toraya buffaloes, focus is given to the body size and body weight of adult males and females to understand their stable growth patterns and consistent quantitative traits. As can be seen in Table 3, although Toraya buffaloes are categorized as swamp buffaloes, they (both males and females) have a larger body size and body weight than swamp buffaloes. Reproductive traits in female livestock refer to characteristics associated with the ability of females to reproduce. Some important female reproductive traits include sexual maturity, reproductive cycle, fertility, mating success, and gestation period.

Reproduction traits of Toraya buffalo are presented in Table 4. These reproductive characteristics encompass the male-to-female ratio, parent fertility, birth rate, age at puberty, oestrus cycle, and length of pregnancy (Perera, 2008; Komariah et al., 2012; Kep Mentan No.2845/ Kpts/ LB430/8/2012; Komariah et al., 2015; Nardi et al., 2017). Reproductive traits are economically important for sustainable food production, especially for monotocous livestock, such as buffalo (Shao et al., 2021). The reproduction characteristics are related to breeding and feeding management (Komariah et al., 2012). Komariah et al. (2012) reported that the first estrus cycle in female spotted buffaloes occurred at the age of 2.48 years. These buffaloes demonstrated 86.5% conception and 89% calving rates. The initial birthing event for spotted buffaloes typically happened at an average age of 3.74 years, with the earliest recorded at 2.87 years. The calving period extended over 12 months, leading to a calving interval of 2.04 years or 24 months. The onset of puberty in male buffalo exhibits variability similar to that in females and is primarily influenced by body weight rather than age. In optimal circumstances, the process of testicular spermatogenic cell divisions initiates around 12 months of age, and active spermatogenesis becomes evident when male buffaloes reach 15 months (Perera et al., 2008).

**Table 1**. The classification of color pattern in Toraya buffalo in South sulawesi, Indonesia

| Classification | Color patterns | Eye color |
|---|---|---|
| Saleko | Spreading black color patterns with a dominant reddish-white skin base color | White |
| Lotong boko | Black color patterns are found on the back with a dominant reddish-white base color | White |
| Bonga | Reddish white color patterns are found on the entire face, neck, legs, and tail | White |
| Lambo Batu | Predominantly white and black on the head | White |
| Bulan | White dominant albino buffalo | White |
| Toddi’ | Predominantly black with white spots on the upper face up to the nose | White |
| Sorri | Predominantly black with white spots on the face | White |

**Table 2**. Qualitative traits of Toraya buffalo in South Sulawesi, Indonesia

| References / Qualitatif traits | Toraya buffalo[1] | Toraya buffalo[2] |
|---|---|---|
| Body color | A wide variety of colors, including black, gray, white, and a mix of other colors. Color patterns on buffalo can be plain, large patches, small patches, or plain black spots. | Plain black to gray, predominantly black with white spots, predominantly white with black spots, and white stripes all over the body |
| Body shape | - | Large, compact, and rectangular body with sturdy legs |
| Head | Varies from gray, black, and white | Varies from white to black with a neckline of 1-2 stripes |
| Horns | Curved from side to back | Leading sideways and backwards |
| Ear shape | Upright towards the side | Leading sideways |
| Legs | - | Black and gray-white from knee to topline |

[1]Kep Mentan No.2845/ Kpts/ LB430/8/2012, [2]SNI 8292.4: 2016



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**Table 3**. Quantitative traits of Toraya buffalo in South Sulawesi, Indonesia

| Quantitative traits | Toraya Buffalo[1] | | Toraya Buffalo[2] | | Swamp Buffalo[3] | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| Shoulder height (cm) | 127.1 ± 2.6 | 125.1 ± 2.6 | 112-128 | 110-124 | 110-120 | 105-115 |
| Body length (cm) | 140.1 ± 8.7 | 121.3 ± 2.3 | 118-149 | 114-136 | 110-125 | 105-120 |
| Chest circumference (cm) | 200.3 ± 5.4 | 190.3 ± 5.4 | 167-199 | 158-183 | 180-190 | 160-170 |
| Scrotal circumference (cm) | - | - | 22-26 | - | 20 | - |
| Body weight (kg) | 350-685 | 337-547 | - | - | 300-350 | 200-250 |

[1]KepMentan No. 2845/ Kpts/ LB430/8/2012, [2]SNI 8292.4:2016, [3]SNI 7706.1:2011

**Table 4**. Reproduction traits of Toraya buffalo in South Sulawesi, Indonesia

| Reproduction traits \ References | Toraya Buffalo[1] | Toraya Buffalo[2] | Swamp Buffalo[3] | Swamp Buffalo[4] | Swamp Buffalo[5] |
|---|---|---|---|---|---|
| Male to female ratio | - | 3:2 | - | - | - |
| Parent fertility (%) | 78.9 | 86.5 ± 0.07 | - | - | - |
| Birth rate (%) | 77.8 | 89 ± 0.05 | - | - | - |
| Age at puberty (years) | 2.8 | 2.48 ± 0.37 | 2.5-3.0 | 2.13 | 1.3-3.8 |
| Oestrus cycle (days) | 21-23 | 19.5 ± 7.48 | - | - | 17-26 |
| Length of pregnancy (months) | 10 | 11.8±0.79 | 10.15 – 10.85 | 11.8±0.79 | 10.52-11.8 |

[1]Kep Mentan No.2845/ Kpts/ LB430/8/2012, [2]Komariah et al. (2012), [3]Nardi et al. (2017), [4]Komariah et al. (2015), [5]Perera (2008)

## REPRODUCTIVE BIOTECHNOLOGY AND MOLECULAR GENETICS

The application of reproductive biotechnology and molecular genetics in Toraya buffalo holds significant potential to enhance population size, quality, and productivity. Several studies have been conducted to determine the molecular characteristics of Toraya buffalo, which identified phylogenetic analysis of Toraya buffalo through mitochondrial D-loop region (Sari et al., 2013) and genetic variation of Toraya buffalo based on cytochrome b gene marker (Rusdin et al., 2020). Reproductive technologies, such as artificial insemination (AI) and embryo transfer (ET), offer efficient and selective means to improve Toraya buffalo reproduction. Compared to cattle, artificial insemination is more difficult in buffaloes due to variable estrus cycles, reduced estrus behavior, and reproductive seasonality (Devkota et al., 2022). Gunawan et al. (2015) highlighted the positive impact of livestock biotechnology, particularly AI and ET, on society. These reproductive biotechnologies increase reproductive efficiency and shorten generation intervals (Visscher et al., 2000). Additionally, molecular genetics plays a crucial role in the development of Toraya buffalo.

According to Spötter and Distl (2006), molecular genetics provides genetic marker information that can aid in livestock selection. By utilizing molecular genetics techniques, breeders can produce offspring with desired characteristics, such as stripe patterns, eye color, horn shape, and coat patterns. Furthermore, molecular genetics can identify and map genes responsible for essential traits in breeding. Microsatellites, found in various parts of the genome, including coding and non-coding regions, have successfully been used to detect quantitative trait loci (QTL; Sellner et al., 2007). Methods like QTL mapping and molecular marker analysis allow researchers to establish connections between genetic patterns and phenotypic traits in Toraya buffalo, facilitating more effective and accurate parent selection based on genetic information. Additionally, genetic selection can be performed on candidate genes responsible for specific production traits, aiding in the identification and collection of genes associated with desired traits in the genome or chromosomes (Yuan et al., 2013).

The application of reproductive biotechnology and molecular genetics also significantly contributes to preserving genetic diversity. Through the identification of molecular markers, an analysis of the genetic diversity of the Toraya buffalo population can be conducted, aiding in sustainable breeding program planning and preventing the decline in genetic diversity resulting from intensive selection. Factors, such as the natural nature of buffalo with a challenging-to-detect breeding cycle, decreased genetic quality due to inbreeding, a shortage of males, and traditional husbandry practices slow down buffalo population growth. Notably, large-scale Rambu Solo events, particularly death ceremonies, involve the slaughter of multiple male buffaloes of the Saleko, Bonga, Lotong Boko, and Toddi breeds, along with some female buffaloes. Indonesian Statistics Agency reveals a high number of buffalo slaughters in the Toraja region, particularly in Tana Toraja and North Toraja districts (Indonesia), posing a threat to the future of the striped buffalo population if conservation efforts are not undertaken (BPS, 2021).

## ROLE OF REPRODUCTIVE BIOTECHNOLOGY

Reproductive biotechnology plays a crucial role in managing mating for genetic improvement, particularly through the utilization of artificial insemination (AI) and embryo transfer (ET) techniques in domestic animals (Srirattana et al., 2022). The



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combined use of AI and ET can effectively accelerate the dissemination of genetic superiority in both male and female animals. A notable impact of this approach is the increase in time and cost efficiency when implementing genetic improvement programs (breeding schemes, van Arendonk, 2011). However, research in the field of reproductive biotechnology for Toraya buffalo is still relatively limited, compared to other ruminants, which can be attributed to challenges in accessing research materials and resources related to Toraya buffalo. Currently, research on Toraya buffalo is limited in terms of scope and the number of conducted studies. Although some research has been conducted, further studies are needed to expand the understanding of Toraya buffalo. A more comprehensive and broader study would offer opportunities to explore new information concerning the characteristics, genetics, reproduction, health, and management of Toraya buffaloes. Such efforts would significantly contribute to the more effective and sustainable development and utilization of the potential of Toraya buffalo.

In the domain of reproductive biotechnology research for Toraya buffalo, some studies have been conducted on the preservation and cryopreservation of sperm from the epididymis and the application of artificial insemination using frozen epididymal semen (Surachman et al., 2009; Yulnawati et al., 2010; Yulnawati et al., 2013b). A summary of these studies can be found in Table 5. For instance, Kaiin et al. (2017) reported on the comparison of sperm X (female) and sperm Y (male) characteristics of spotted buffalo from Toraja, South Sulawesi (Indonesia). When an oocyte is fertilized, an X sperm will form a female embryo, while a Y sperm will form a male embryo. The Y sperm carries the SRY (sex-determining region Y) gene, responsible for initiating testes development in male animals, and the gene is absent in X sperm (Susilawati, 2011). The study revealed that sperm X has an area of 29.86 ± 1.56 µm2 with a head length of 8.65 ± 0.33 µm and head width of 4.31 ± 0.28 µm, while sperm Y has an area of 27.16 ± 1.57 µm2, head length of 7.78 ± 0.51 µm, and head width of 4.14 ± 0.19 µm. Consequently, it was found that male sperm has a smaller size than female sperm. It is evident that further research in the field of reproductive biotechnology for Toraya buffalo holds significant potential and should be pursued to harness the genetic improvement and development of this valuable livestock breed.

Based on the data presented in Table 6, it is indicated that sperm derived from ejaculate and epididymis exhibit a similar level of quality in Toraya buffalo. Spermatozoa obtained from the epididymis, whether from slaughtered animals or livestock, represent a viable alternative sperm source for various reproductive technologies. The cauda epididymis serves as a storage site for sperm before its release during the ejaculation process (James et al., 2020). Chaveiro et al. (2015) reported that spermatozoa from the cauda epididymis demonstrate comparable motility and fertilization capacity to ejaculated spermatozoa. Studies on African buffaloes have also demonstrated that epididymal spermatozoa possess similar qualities to ejaculated spermatozoa (Herold et al., 2004; Herold et al., 2006).

The application of molecular genetics in livestock breeding, particularly for obtaining QTL and gene markers, presents a novel approach enabling the early selection of superior traits. This approach allows livestock breeding to focus on maintaining individuals with detected superior genes, consequently reducing the required resources and costs compared to breeding programs without applying molecular genetics. By utilizing molecular genetics techniques, livestock breeding programs can be more efficient and targeted, developing superior livestock with desired traits. Information on molecular genetics research on Toraya buffalo is limited and still in its early stages. In a recent molecular study focusing on non-functional traits related to coat color in Toraya buffalo, Yusnizar et al. (2015) reported Two distinct loss-of-function genetic mutations, including an early stop codon and a truncation site donor mutation in the microphthalmia-associated transcription factor (MITF), were found to be significantly linked to the presence of mottled coat color. The MITF gene controls the stripe color pattern in Toraya buffaloes, but the occurrence of stripe levels may be due to other additive/quantitative genes.

**Table 5**. Biotechnology reproduction research in Toraya buffalo, Indonesia

| **Reproductive technology** | **Research topic** | **References** |
|---|---|---|
| Artificial insemination applications | Frozen-Thawed Epididymal Sperm Quality and the Success Rate of Artificial Insemination in Spotted Buffaloes (*Bubalus bubalis carabanensis*) | Yulnawati et al. (2013a) |
| Epididymal sperm | Epididymal Sperm Quality of Buffaloes with Different Spotted Types | Yulnawati et al. (2013b) |
| Sperm cryopreservation | Quality of Epididymal and Ejaculated Sperms of Spotted Buffalo in Dextrose Supplemented Extender | Yulnawati et al. (2010) |
| Sperm preservation | Quality of Liquid Semen from Striped Buffalo Epididymis in Andromed Diluent with Sucrose Addition | Surachman et al. (2009) |
| Sperm sexing | Separation of X and Y sperm using the bovine serum albumin (BSA) column method | Kaiin et al. (2017) |


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**Table 6**. Sperm quality of Toraya buffalo, Indonesia

| Parameters \ Sperm quality | Ejaculate[1] | Ejaculate[2] | Epydidimis[3] | Epydidimis[4] | Epydidimis[5] |
|---|---|---|---|---|---|
| Volume (mL) | 4 | - | - | - | - |
| Color | Creamy | - | - | - | - |
| pH | 6-7 | - | - | - | - |
| Consistency | Moderate | - | - | - | - |
| Mass movement | ++ | - | - | - | - |
| Motility (%) | 75 | 70.0 ±0.0 | 65.00±0.0 | 74.17±1.86 | 65.0±0.0 |
| Concentration (x106) | 1.790 | 2695+ 1045 | 10.533±47 | 3578.33±740 | 10710±49 |
| Viability (%) | 79.4 | - | 76.00±2.83 | 85.02±2.35 | - |
| Abnormality (%) | 17 | 6.5 + 1.5 | 15.33±2.49 | 7.10±1.16 | 15.0±3.0 |
| IM (%) | 70.9 | 77.5±1.5 | 80.80±0.40 | 86.22±1.94 | 79.0±0.0 |

IM: Integrity membrane. Sources of table: [1]Kaiin et al. (2017); [2,5]Yulnawati et al. (2010); [3]Surachman et al. (2009); [4]Yulnawati et al. (2013b)

## DEVELOPMENT POTENTIAL TO INCREASE PRODUCTIVITY

The development of livestock resources, particularly buffaloes, aims to enhance the regional economy while considering the sustainability of natural resources. Besides fostering economic growth and improving community welfare, this development objective also entails preserving the environment and reducing social inequalities (Devkota et al., 2022). This approach is in accordance with the principles of sustainable development, which prioritize long-term environmental and economic viability. In the framework of sustainable development, livestock farming economic sustainability demonstrates the capacity to maintain a growing livestock population and positively impacts the welfare of livestock owners (Suyitman et al., 2016).

Toraya buffalo, as one of the swamp buffalo breeds, exhibits significant potential for development. This potential is tied to the cultural customs of the people of South Sulawesi, particularly the people of Tana Toraja, where buffaloes play a crucial role and symbolize cultural ceremonies and social status (Mangopang et al., 2018; Saputra et al., 2020; Warman et al., 2022). The number of buffaloes sacrificed in a traditional feast directly correlates with a person's social status, increasing demand for buffaloes during such ceremonies, especially the Rambu Solo (death ceremony). The high demand for Toraya buffaloes often exceeds their availability, necessitating buffalo imports from areas outside Tana Toraja, North Toraja, Takalar District, and other regions in West Sulawesi Province, Indonesia (Anshar, 2013). In the past, traditional ceremonies in Toraja typically demanded only two buffaloes as a standard requirement (Sapu Randanan). However, modern practices now vary based on an individual's financial capacity, with some ceremonies involving hundreds of buffaloes as a gesture of respect for deceased relatives (Rombe, 2010), contributing to a decline in the buffalo population.

In Toraja society, a specific valuation scheme is utilized to determine the value and price of Toraya buffaloes. Research conducted by Saleh and Asnawi (2014) stated that the selling price of Toraya buffaloes in Bolu Animal Market, North Toraja Regency, is determined based on certain characteristics, such as striped motifs, eye color, horn model, tail condition, and spotted coat color. Socio-cultural factors heavily influence the pricing of Toraya buffalo. Despite being considered livestock, their value falls under the art category, making the price of buffaloes incomparable to other livestock commodities. The more the buffalo fulfills the socio-cultural criteria, the higher its price will be.

The potential for the development of Toraya buffalo livestock is immense in Indonesia. Toraya buffaloes are distinct from swamp buffaloes, offering more specific and focused development opportunities (Rohaeni et al., 2023). One of the primary assets is the high artistic value associated with the Toraya buffalo and its close ties to Toraja traditional ceremonies. This creates a consistent and sustainable demand for Toraya buffalo, deeply rooted in local culture and tradition. Moreover, Toraya buffalo development holds significant economic potential. By increasing the population and productivity of Toraya buffalo through planned breeding programs and the application of reproductive technology and genetic-based selection, superior animals can be produced in terms of quality, growth, and productivity. This opens up opportunities for farmers to increase their income by selling Toraya buffaloes, which have a high market value. Comprehensive support is required to optimize this development potential, including further extensive research, breeder development, access to reproductive and genetic technologies, and supportive policies. With a holistic and sustainable approach, Toraya buffalo development can positively impact local communities, the environment, and the regional economy.

## CONCLUSION

To increase the population and productivity of Toraya buffalo, the implementation of a planned breeding program combining reproductive technology and selection based on quantitative and molecular genetics is necessary. The development potential of Toraya buffalo is immense; it not only possesses high cultural value but also exhibits superior



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quantitative characteristics, such as growth rates and increased meat yield, compared to swamp buffalo in general, positioning it as a potential national meat provider.

## DECLARATIONS

### Availability of data and materials

All data are presented in the published manuscript.

### Authors' contributions

This study was carried out with the contribution of all authors. Tulus Maulana collected information and drafted the manuscript. Hikmayani Iskandar collected information and contributed to writing the manuscript. Syahruddin Said and Asep Gunawan revised the manuscript. All authors read and approved the final version of the manuscript.


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### Ethical consideration

The author checked plagiarism, misconduct, data fabrication and/or falsification.

### Competing interests

The author declares no conflicts of interest.

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