Open Access Library Journal
2026, Volume 13, e15171
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Strategies for Advancing Beef Cattle Breeding in Tanzania: A Review of Past and Current Practices and Future Directions

Kabuni Thomas Kabuni[1*], Timothy Parkinson[2], Richard Laven[2], Andy Peters[3], Erick Vitus Gabriel Komba[1]

[1]Department of Cattle Research, Tanzania Livestock Research Institute (TALIRI), Dodoma, Tanzania
[2]School of Veterinary Science, Massey University (MU), Palmerston North, New Zealand
[3]Roslin Institute, Royal Dick School of Veterinary Studies, The University of Edinburgh, Edinburgh, UK
Email: *kabuni.kabuni@gmail.com, ekomba@sua.ac.tz, R.Laven@massey.ac.nz, T.J.Parkinson@massey.ac.nz, Andy.Peters@ed.ac.uk

How to cite this paper: Kabuni, K.T., Parkinson, T., Laven, R., Peters, A. and Komba, E.V.G. (2026) Strategies for Advancing Beef Cattle Breeding in Tanzania: A Review of Past and Current Practices and Future Directions. *Open Access Library Journal*, **13**: e15171.
https://doi.org/10.4236/oalib.1115171

Received: March 14, 2026
Accepted: May 24, 2026
Published: May 27, 2026

Abstract

This review examines strategies for advancing beef cattle breeding in Tanzania, analysing historical and current practices, and proposing future directions. Historically, cattle breeding efforts began in 1905, with an initial focus on animal husbandry and disease research. Later work emphasized cattle breeding and established a central registry in 1951. Post-independence, Artificial Insemination (AI) services were introduced, but faced challenges including funding shortages and centralized services. Currently, although AI is the most used Assisted Reproductive Technology in Tanzania, its adoption remains limited due to centralized services, lack of skilled technicians, and high costs. The dominant use of natural mating, particularly with untested bulls, contributes to poor fertility and inbreeding among indigenous breeds like the Tanzania Shorthorn Zebu, which constitutes 95% of the cattle population. To improve the beef cattle breeding system, strategic investments are vital. These should include establishing nucleus breeding herds, implementing performance recording and genetic evaluation systems, improving AI and Embryo Transfer infrastructure, and exploring genomic selection technologies. Addressing feed and nutrition through improved pasture, dry-season supplementation, and feed processing technologies is also crucial. Furthermore, strengthening animal health programs, upgrading breeding facilities, implementing livestock identification systems, and building capacity through training and extension services are necessary. Policy interventions, financial incentives, and value chain development would further enhance the sector's growth, promoting sustainable practices and improving farmer livelihoods.

Subject Areas

Beef Cattle, Breeding Strategies

Keywords

Artificial Insemination (AI), Beef Cattle Breeds, Breeding Strategies, Genetic Improvement

1. Review Methods

This review systematically examined strategies for advancing beef cattle breeding in Tanzania. The search encompassed literature published up to the present, with a historical focus starting from 1905. Databases searched included Web of Science, Google Scholar, and Scopus. The search terms employed were related to "beef cattle breeding," "Tanzania," "artificial insemination," "assisted reproductive technologies," and "genetic improvement." Inclusion criteria focused on studies and reports detailing past and current practices, challenges, and future directions in Tanzanian beef cattle breeding. Exclusion criteria focused on studies and reports not detailing past and current practices, challenges, and future directions in Tanzanian beef cattle breeding were applied to ensure the relevance and focus of the selected literature.

2. Cattle Breeding and Research in Tanzania: A History

2.1. Pre-Independence Era

Modern cattle breeding started in Tanzania in 1905 whilst Tanganyika was a German colony. At that time, the Mpwapwa district of the Dodoma region (6˚20'54''S 36˚29'12''E) was selected to be the centre for veterinary activities in Tanganyika and to undertake research on animal husbandry and diseases [1]-[3]. The presence of mixed tropical (*i.e.* arid and semi-arid areas) and temperate climatic conditions within the district was one of the key drivers for the establishment of the Livestock Veterinary Centre in the town of Mpwapwa, with farms established at Ilolo (pasture research farm), Vianze, Mjitu, Chibwe-Changula (breeding tropical animals), Kiboriani (breeding temperate animals) and a main office at Kikombo [4].

Another driver was that both Koch and Theiler had undertaken research on East Coast Fever (ECF) in the area [5]. This ECF research stimulated animal disease research, particularly on tick-borne diseases within Tanganyika, and led to the construction of the first cattle dip in the entire East African region at Kikombo in 1907. Research at the Livestock Veterinary Centre ceased during the First World War (1914-1918) but, then, after the British took over Tanganyika, research was restarted and revitalised. Except for another break from the Second World War, the Livestock Veterinary Centre was an active research centre for

Tanganyika until independence in 1961 with British and European scientists undertaking a range of research there. These included Dr. H. M French, who was actively involved in animal breeding and husbandry research, and Drs. CJ Buckley and HG Hickson, who researched animal breeding. There was a considerable focus on cattle breeding. In 1951, the Central Livestock Registry was established to store records for all the livestock on all farms owned by the British colonial government. This registry, alongside the distribution of improved animals to government livestock farms and individual livestock farmers, gave an impetus to co-ordinated breeding programmes for cattle and other livestock species across Tanganyika.

2.2. Post-Independence Era

Tanganyika became independent in 1961. That was the same year that liquid nitrogen-based Artificial Insemination (AI) services were introduced, for the first time, into the Northern Zone of Tanganyika (primarily in the Kilimanjaro and Arusha regions). The intention for the introduction of AI services was to improve reproductive performance and productivity of dairy cattle. The AI service centre was based at the Tengeru Livestock Training Institute in Arusha, with Tengeru acting as both an AI service provider and a training centre for AI technicians. However, in the middle of the 1960s, the AI programme failed, due to insufficient funds and the lack of support from the government.

In 1967, AI services were re-introduced at Mpwapwa Research Centre, but this time using ambient temperature, rather than cryopreserved, semen. In 1968, AI services using frozen semen re-started, following the installation of a liquid nitrogen plant in its Animal Biotechnology Laboratory. Bulls of different breeds (dairy, beef and dual purpose) were kept at the centre for semen production for the AI service. However, in 1973, semen production activities at Mpwapwa were shifted to the newly developed National Artificial Insemination Centre (NAIC) at Usa River in Arusha [6]. This remained the sole site of frozen semen for AI in Tanzania until 2018, when the Tanzania Livestock Research Institute, with government support, refurbished its Animal Biotechnology Laboratory at Mpwapwa, by re-equipping it with equipment necessary for semen and embryo collection, processing, packaging, storage and utilisation.

3. Current Use of Assisted Reproductive Technologies in the Tanzanian Cattle Breeding System

Assisted Reproductive Technologies (ARTs) are modern reproductive technologies developed with a focus of enhancing animal productivity [7]-[9] through improving reproductive performance and enhancing genetic improvement [10]-[13]. The use of these technologies, especially in high-income countries, has positively contributed towards the transformation of the livestock sector and to food security. However, the only commonly used ART in Tanzania is AI; which may be accompanied by oestrus synchronisation, especially on large-scale public and private farms [14]-[16]. The use of MOET, sexed semen, *in vitro* embryo production (*in vitro* maturation (IVM), *in vitro* fertilisation (IVF), and *in vitro* culture (IVC)), trans-vagina ovum pick-up (OPU) and cloning in Tanzanian cattle are all exceedingly rare, to the extent that, other than AI, these procedures can best be described as being "in their infancy" in Tanzania. Natural mating is still, by far, the most common breeding method used by smallholder farmers. This significantly limits genetic improvement and, because the vast majority of breeding bulls are neither proven nor tested, results in an increased risk of venereal disease and a likely risk of inbreeding within a herd. These issues then lead to an increased incidence of infertility, poorer reproductive performance and reduced productivity.

Even the use of AI as a method of breeding cattle in Tanzania has always been limited [17]. The reasons for this are: primarily due to the centralisation of AI services at the NAIC in Arusha [15] [18]. This centralisation also resulted in a small number of trained AI technicians in the country, which further impedes the utilisation of AI services (**Figure 1**), outside of the northern regions of Arusha, Kilimanjaro and Tanga [19].

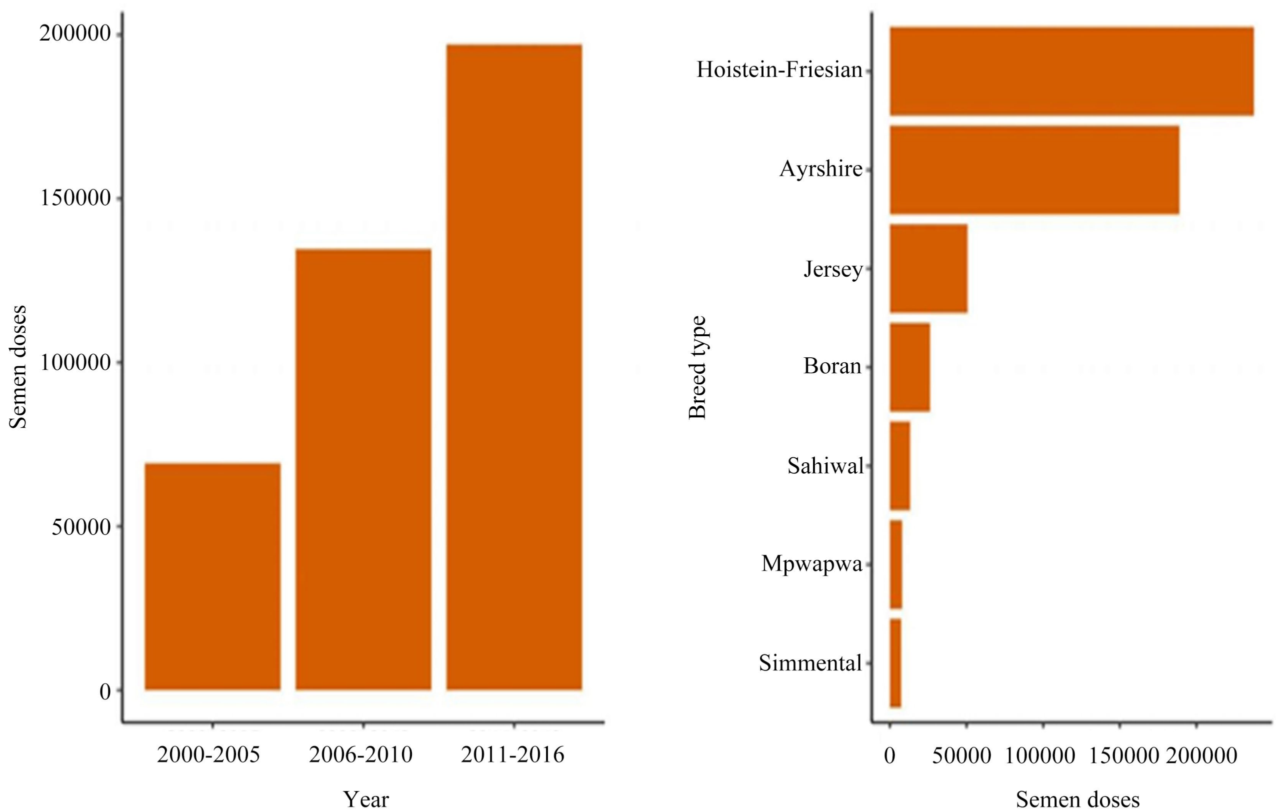

Figure 1. National Artificial Insemination Centre in Tanzania (NAIC) production trends and distribution of semen doses by breed between 2000 and 2016 (adapted from [19]).

The majority of inseminations are undertaken using semen from imported dairy cattle breeds (Holstein-Friesian, Ayrshire and Jersey; **Figure 1**), with much lower usage of in beef/dual purpose breeds (Boran, Sahiwal, Mpwapwa and Simmental). The pattern of use of AI, and the regions in which it is used are reflected by the location of the dairy industry in the northern part of the country (*i.e.* where the climate is temperate: [20] [21]: **Figure 2**) and in the highland zones in the southern part of the country (again, where a temperate climate permits dairy farming). The pattern of breeds used in AI similarly reflects that the majority of inseminations are in dairy cattle.

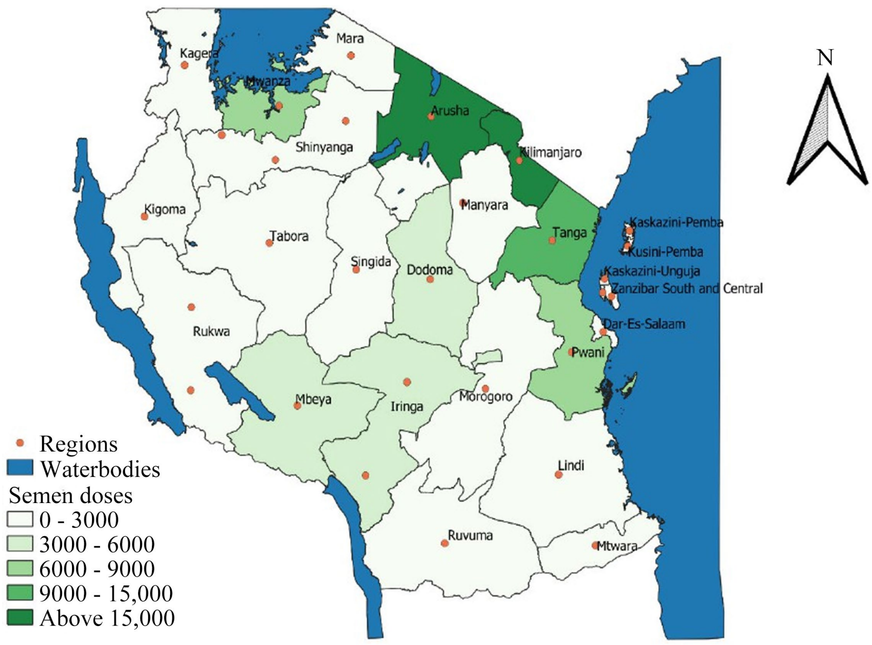

Figure 2. Adoption of Artificial Insemination (AI) technology in Tanzania based on distribution of semen doses from 2012-2016 (adapted from [19]).

Alongside the centralisation of AI services and the lack of skilled AI technicians, the high cost of AI services (compounded by very low conception rates that are achieved to AI and the consequent need for subsequent natural service or repeat insemination) have also been major barriers to the uptake of AI technology. The absence of sound herd fertility and health programmes [14] [15] [17] has also impeded the uptake of AI. Consequently, the AI delivery system in Tanzania is not currently meeting the production needs of the Tanzanian cattle industry. Although there are ongoing efforts to improve this situation through the efforts of non-governmental organisations (e.g. Land O'-Lakes Public Private Partnership for Artificial Insemination Delivery (PAID) programme, which has a focus on increasing the number of AI technicians), trans-national organisations (e.g. International Livestock Research Institute (ILRI) African Dairy Genetic Gains programme) and the Tanzanian government (e.g. upgrade of Mpwapwa Animal Biotechnology Laboratory), further investment and development is required to enable effective and efficient utilisation of AI within the Tanzanian cattle breeding system. There is little impetus for the use of other ARTs.

4. Challenges Affecting Uptake of Assisted Reproductive Technologies (ARTs) in the Tanzanian Cattle Breeding System

4.1. The Use of Indigenous Cattle Breeds

In Tanzania, as in most other East African countries, indigenous cattle breeds are principally derived from Zebu cattle (*Bos taurus indicus*: *B. indicus*), rather than Eurasian or African (*Bos taurus taurus*: *B. taurus*) cattle [22]. These indigenous breeds predominate in the traditional pastoral and agro-pastoral systems of the mixed tropical (*i.e.* arid and semi-arid areas) and temperate areas of the country [14] [23]-[25]. The most important indigenous breed in Tanzania is the Tanzania Shorthorn Zebu (TSZ), which accounts for 95% of the cattle in the country [26]. This breed has multiple strains, such as Singida White, Tarime, Sukuma, Chagga and Iringa Red, many of which are rare and geographically confined [26]. Several other Tanzanian breeds, which are principally derived from *B. indicus* also have some *B. taurus* genetics (e.g. Mpwapwa, Ankole and Boran breeds: [14] [25] [26].

Tanzania Shorthorn Zebu and strains/crossbreeds derived from them generally have slow growth rates, low mature weights, low milk yields and generally low productivity [14] [15] [26]. Nevertheless, TSZ and related cattle supply 95% of the beef and 70% of the milk consumed in Tanzania [26]. The low genetic merit of the TSZ and related breeds is compounded by variable, and often-low, planes of nutrition and shortages of water, all of which further depress cattle productivity [26]-[28]. All of these factors also affect fertility by impeding the functionality of the reproductive system [29]. Productivity is dependent on fertility [23] [24], so the impact of these factors on fertility exacerbates and accentuates their direct effects on productivity. Addressing the challenges that affect the fertility of cattle breeds in Tanzania is necessary for improving reproductive performance and for improving productivity, sustainability and owner incomes.

In order to improve the reproductive performance in a system, baseline data on current performance are needed [30]. However, whilst it is generally accepted that *B. indicus* cattle characteristically show poor reproductive performance [24] [31]; there have been few published reports on the reproductive performance and fertility of Tanzanian cattle breeds. The only published large-scale study of fertility of TSZ in the literature is that conducted by [23] [24] at Gairo (36˚45'E 6˚30'S) from 2001 to 2004 in three villages where cattle were usually grazed on communal land during the day and kept in kraals during the night. The study area normally gets rainfall of about 600 mm/year with ~90% falling between December and April. Data were collected from 275 lactations from 177 cows. Pregnancy or cyclic status was assessed every two weeks via transrectal palpation. They reported calving frequencies and the percentage of cows that were pregnant on a month-by-month basis. Using the later data in comparison to an expected 90-day calving to conception interval, they created an "expected percent pregnant" model. Comparison of the expected and actual data (**Figure 3**) highlights the underperformance of TSZ cattle.

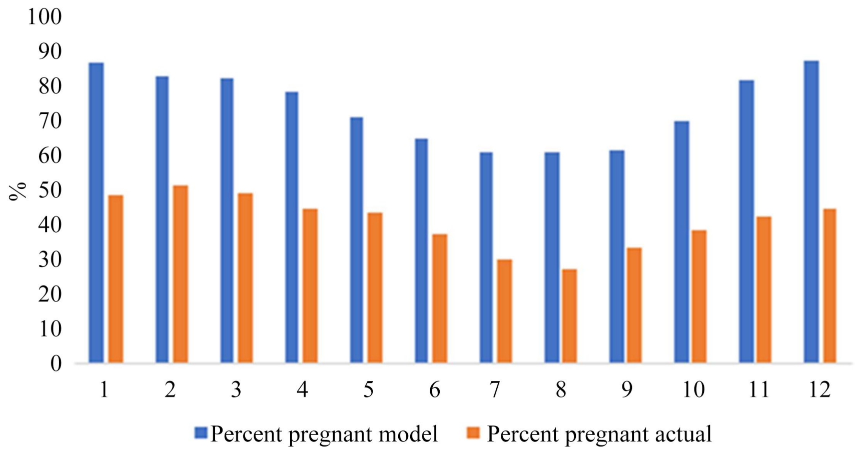

Figure 3. Expected proportion pregnant (based on monthly calving proportion and ~365-day calving interval) compared to actual proportion pregnant (data from [23]).

One of the aims of developing the Mpwapwa breed cattle was to develop a Tanzanian-adapted breed that had better productivity and fertility than the TSZ. At first at least, this was successful [2], but the performance of Mpwapwa cattle has subsequently declined in terms of fertility as well as productivity. For example, [32] in a study of prostaglandin use in Mpwapwa cattle, reported that of 100 untreated cattle only 49 became pregnant after natural mating during a 12 week breeding season.

4.2. Dominant Use of Natural Mating

Natural mating is thus by far the most common method of breeding, especially outside the main dairying areas, on farms where the main breeds are *B. indicus* based, and on smallholdings. These bulls are very rarely tested either for disease or breeding soundness, which almost certainly contributes to the generally poor fertility of Tanzanian cattle [33]. Nonetheless, their use requires little input from the farmer, whereas, especially for smaller farms, using any ARTs (even AI) would incur significant costs and would require significant changes in routine management.

4.3. Infrastructure, Expertise, Breeding Policy and Breed Associations

Because of the lack of support for their development, current ART-related infrastructure and expertise is not sufficient to effectively and efficiently accommodate even the current demand for AI in Tanzania [34]. Even for medium to large- scale dairy farms, which are the main users of AI, its use is strongly associated with proximity to NAIC ([19]: **Figure 2**). To get AI to the majority of Tanzanian cattle farmers (who are small scale pastoralists) would require significantly better infrastructure and a substantial increase in the number of people with relevant expertise. The government has developed a strategy towards doing so [35] but so far with little obvious effect beyond the refurbishment of NAIC and re-equipping of the Animal Biotechnology Laboratory at TALIRI Mpwapwa. Further, having a nationally coordinated livestock breeding policy, as well as active breed associations/societies, would provide valuable support for increasing the use of AI. There has been the potential of government support for such developments [35] [36], but implementation has been lacking.

5. Advancing Beef Cattle Breeding in Tanzania

In cattle breeding, there is a clear distinction between Breeding Soundness Evaluation (BSE) and performance testing, each serving different purposes in assessing a bull's reproductive potential. BSE is a comprehensive, veterinary-conducted assessment focused on the physical and reproductive health of the bull, evaluating physical soundness such as body condition, locomotion, and structural integrity; genital health through visual inspection and palpation of the testes, penis, sheath, and reproductive tract; semen quality via microscopic analysis or automated systems like CASA; and scrotal circumference, a heritable trait linked to sperm production and puberty onset [37]. Its primary goal is to predict fertility, providing a rapid, short-term result—usually within days—that reliably screens out sub-fertile or sterile bulls, thereby safeguarding reproductive success [38]. Conversely, performance testing measures growth traits such as weight gain, feed efficiency, and carcass quality over time, often using systems like Breed plan that incorporate multiple traits and heritability estimates; these tests are conducted under controlled conditions, with results typically available after months or years, reflecting the genetic contribution of the bull to progeny performance [39]. While performance testing is crucial for long-term genetic improvement by identifying sires that meet desirable benchmarks, it does not directly assess fertility. Performance testing offers rapid, quantifiable results for traits like growth and carcass quality, which can be quickly incorporated into selection decisions, but estimating the genetic contribution to beef traits involves complex calculations and multi-generational data, making it a slow and challenging process, especially since environmental factors can influence performance data and require adjustments [40]. In contrast, BSE results are immediate and straightforward—either a bull passes or fails based on physical and semen parameters—enabling timely decisions about breeding suitability, although it only predicts fertility and not genetic potential for growth or carcass traits [38].

In Tanzania's beef systems, where natural mating with locally sourced, untested bulls is common, leading to slow genetic improvement, these tools are crucial [41]. Applying BSE to communal or locally sourced bulls would involve veterinary checks to ensure they are physically fit and fertile, quickly identifying and removing sub-fertile animals. This immediate screening is vital for improving fertility rates in herds that primarily rely on natural service, complementing efforts to introduce AI by ensuring the bulls used, whether for natural mating or as semen donors, are reproductively sound.

The current beef cattle breeding practices in Tanzania heavily rely on natural mating, where farmers primarily use bulls bred on their own farms [41]. These bulls often lack formal performance testing, meaning their genetic potential for traits like growth rate and meat quality is largely unknown [42]. Consequently, the genetic improvement of Tanzanian beef cattle herds is slow and inconsistent [43]. AI, a technology that allows for the widespread use of superior genetics, remains underutilized in many regions [44]. This limited adoption of AI is due to factors such as cost, accessibility, low conception rates coupled with repeat service and a lack of awareness among farmers about its benefits [45]. Overcoming these challenges and promoting the use of AI, alongside more rigorous bull selection programs, is crucial for enhancing beef production and improving the livelihoods of Tanzanian cattle farmers [46]. By advancing the use of modern breeding technologies such as AI, Tanzania can unlock the full potential of its beef cattle and meet the growing demand for high-quality meat products [47]. This transition would not only benefit individual farmers but also contribute to the overall economic development of the country's livestock sector [48].

6. Future Directions-Proposed Strategies

The Tanzanian cattle breeding system has plenty of investment opportunities, as the government has created an enabling environment for both domestic and foreign investors in a so-called "win-win" situation [14] [15] [33]. Currently, there is a significant demand for ART services, especially AI, but this demand is unmet as the available service providers are few and cannot satisfy the market. Resolution of this problem is not, however, simple or based on a few strategies. Rather, based on the challenges and opportunities within the Tanzanian beef cattle breeding system, there are a broad range of investment areas necessary to underpin improvement of its performance and efficiency (**Table 1**).

Table 1. Potential strategies for improving cattle productivity in Tanzania.

Area of improvement	Principal strategies	Methodologies
Genetic improvement programs	Establishment of nucleus breeding herds	Invest in establishing and maintaining nucleus breeding herds of improved beef cattle breeds (both indigenous and exotic) at TALIRI centres and selected private farms. These herds will serve as heifer and bull banks of superior genetics for dissemination to the wider farming community.
	Performance recording and genetic evaluation	Implement comprehensive performance recording systems to track key traits such as growth rate, carcass quality, reproductive performance, and disease resistance. Use this data to conduct genetic evaluations and identify superior breeding animals.
	Artificial Insemination (AI) and Embryo Transfer (ET) infrastructure	Invest in AI and ET infrastructure, including semen and embryo production facilities, training of AI technicians, and provision of AI services to smallholder farmers. This will accelerate the dissemination of improved genetics.
	Genomic selection technologies	Explore the use of genomic selection technologies to identify superior breeding animals at a young age, reducing the generation interval and accelerating genetic progress.

Continued

Feed and nutrition	Improved pasture and forage production	Invest in research and development of improved pasture and forage varieties that are adapted to local environments and provide high-quality nutrition for beef cattle.
	Dry season feed supplementation	Develop and promote affordable and effective dry-season feed supplementation strategies, such as multi-nutrient blocks (MNBs) and silage production, to mitigate the impact of feed scarcity on livestock productivity.
	Feed processing and conservation technologies	Invest in technologies for processing and conserving feed resources, such as haymaking, silage making, and feed pelleting, to improve feed utilization and reduce wastage.
Animal health	Disease surveillance and control	Strengthen disease surveillance and control programs to prevent and manage outbreaks of economically important diseases of beef cattle.
	Veterinary infrastructure and services	Invest in veterinary infrastructure and services, including diagnostic laboratories, veterinary clinics, and training of veterinary personnel, to provide timely and effective animal health care.
	Vaccine production and distribution	Support the local production and distribution of vaccines for key beef cattle diseases.

7. Implementation Roadmap for Advancing Beef Cattle Breeding in Tanzania

This is a comprehensive, phased strategy designed to systematically enhance the nation's beef cattle sector. This roadmap clearly delineates responsibilities among key stakeholders, including the Government, the Tanzania Livestock Research Institute (TALIRI), National Artificial Insemination Centre (NAIC), Private AI Providers, and Farmer Organizations. The initial phase, encompassing near-term actions within the first two years, prioritizes the critical foundational elements for progress. This includes a strong focus on strengthening the existing Artificial Insemination (AI) infrastructure, ensuring it is robust and accessible. Concurrently, significant effort will be directed towards enhancing performance recording and data collection systems, which are vital for informed breeding decisions. Improving disease surveillance and basic animal health programs is also a key near-term objective to safeguard herd productivity. Moving into the medium-term, spanning two to five years, the roadmap outlines more advanced strategies for genetic improvement and technological adoption. A pivotal medium-term action involves establishing nucleus breeding herds, which will serve as centers of excellence for superior genetics. This will be complemented by the implementation of robust genetic evaluation systems to identify and propagate the best breeding animals. Furthermore, the roadmap emphasizes the expansion and optimization of AI and Embryo Transfer (ET) services, making these advanced reproductive technologies more widely available. Integrating improved feed and nutrition strategies is crucial for maximizing the genetic potential of the beef cattle. Finally, the medium-term phase includes the development and implementation of supportive policies and financial mechanisms to ensure the sustainability and widespread adoption of these advancements. Collectively, these near-term and medium-term actions are designed to systematically improve beef cattle breeding practices across Tanzania, ultimately leading to enhanced productivity, improved farmer livelihoods, and a more robust national livestock sector.

By strategically investing in these key areas, Tanzania could significantly improve the performance and efficiency of its beef cattle breeding system, leading to increased livestock productivity, improved farmer livelihoods, and enhanced food security.

Areas of investment that are more specific to AI uptake could strategically focus on: 1) provision of sufficient and reliable AI delivery systems; 2) production and distribution of high-quality fresh and frozen bovine semen; 3) production and distribution of liquid nitrogen (LN) gas to stakeholders if cryopreserved semen is to be used, 4) investing in capacity building to the AI service providers; and 5) ensuring minimum levels of qualification (e.g. Certificate in Animal Health & Production) for personnel involved in AI processes.

Of these strategies, the one that might yield the strongest immediate results is the use of chilled or ambient temperature semen diluents, in preference to cryopreserved semen. Historically, such diluents have been associated with relatively high conception rates, and relatively limited demands upon infrastructure.

8. Development of Non-Frozen Diluents for Bovine Semen

Preserving semen at ambient temperature or chilled to ~4˚C has some advantages over cryopreservation (−196˚C), as it is a much cheaper technique of preserving semen and requires much less expensive equipment and, hence, is much easier to use in the field [49]. However, semen preserved at ambient temperatures cannot be stored much beyond 3 - 4 days, which is a much shorter period than cryopreservation [50], in which life span appears to be prolonged indefinitely. The length of time over which cryopreserved semen can be stored and used is thus its main advantage, which also helps in disease control as the semen can be quarantined until the donor bulls are proven to be free of diseases transmissible via semen. However, in addition to being expensive, time consuming and requiring significant infrastructure, cryopreservation can adversely affect the function of sperm, particularly in terms of swimming characteristics and the time-course of sperm capacitation. Further, the semen of some bulls does not survive cryopreservation very well [51]. In consequence, the dilution rates of semen for cryopreservation is much less than for ambient/chilled diluents. For cryopreservation, semen is usually diluted to 80 - 100 × 10^6 sperm/mL (20 - 25 × 10^6 sperm/insemination dose), whereas insemination doses for semen extended in Caprogen diluent can be as low as 5 × 10^6 sperm/dose [52].

The earliest use of bovine semen in AI programs was based upon its dilution in simple egg yolk-buffer extenders [44] [53]. Chilling semen to ~5˚C slowed the metabolic rate of sperm, such that, under optimal conditions, it could retain adequate fertility for about 4 days. However, alternative methods were sought which improved the lifespan of store semen. Two main routes were followed: cryopreservation, or improved inhibition of sperm metabolism without freezing.

Following the discovery of cryoprotectants (as viewed by [53]), cryopreservation soon became the preferred method of storing and disseminating bovine semen. Advantages of the method are: 1) indefinite lifespan, provided the frozen state is maintained and 2) the ability to ensure that bulls remain disease-free before their semen is distributed through the AI network (WOAH Terrestrial Code). Its main disadvantages are: 1) the need for relevant infrastructure (primarily the ability to produce and store liquid nitrogen), the high loss of sperm during the freezing/thawing process, necessitating limited dilution rates of ejaculates and 2) sperm survival is highly variable between individual bulls. Hence, AI services based on cryopreserved semen have been most widespread in developed economies, or, in developing economies, for the importation of semen from genetically-improved sires.

Parallel research examined the feasibility of maintaining semen at ambient or chilled (*i.e.* unfrozen) temperatures. Chilled extension relied solely upon temperature to inhibit sperm metabolism, with the components of the diluent providing volume, nutrients and buffering. Chilled extension requires less complex infrastructure than cryopreservation, but still requires that reliable refrigeration can be sustained under the field conditions of an AI service. Further research examined the use of diluents that would maintain sperm viability under ambient temperatures or with only modest temperature control. Such systems were based on the use of bicarbonate/CO_2 to slow sperm metabolism: of which the development of the Illinois Variable Temperature diluent (IVT) was pivotal [54]. Many variations on the original IVT have been developed, and have been very widely used for AI of species whose semen tolerate cryopreservation very poorly.

The success of cryopreservation largely halted the application of non-frozen methods of preservation of bovine semen, until it was revived in the form of the Caprogen diluent [55]-[57].

9. Caprogen Diluent as a Modern for Non-Frozen Preservation of Bovine Semen

Caprogen diluent is a variant of IVT. As well as the bicarbonate buffering system, sperm metabolic rate is further reduced by removing oxygen from the diluent by saturating it with nitrogen gas. The diluent also contains catalase, to remove peroxides produced in the media by sperm metabolism and/or sperm death. The initial development of Caprogen diluent was focused on preserving bull semen at 5˚C. However, when it was stored at 15˚C - 27˚C, the semen yielded better fertility performances, and thus, its utilisation was then widely applied at ambient temperature [58].

Caprogen remains an important ambient-temperature semen diluent for bovine AI in New Zealand, where a very substantial proportion of dairy cattle inseminations uses unfrozen semen preserved in that diluent. Caprogen has been extensively utilised in the New Zealand AI industry over decades and has produced good fertility outcomes. Specifically, it allows for a smaller number of sperm in an insemination dose (as low as 2×10^6 total sperm/insemination: [59]), which allows each ejaculate to be divided into more insemination doses. Secondly, at least in the short term, sperm do not undergo the acrosome damage associated with cryopreservation, which may enable higher conception rates and/or greater leeway in the timing of insemination to ovulation. It is also less expensive than cryopreservation, as it does not require the industrial infrastructure required for producing liquid nitrogen; and hence there is potential for simplification and cost reduction in the supply chain between production and insemination. These benefits could improve the uptake of cattle AI in situations where cost and supply chain difficulties are presently prohibitive.

10. Use of Semen Extended at Chilled or Ambient Temperatures

Stored semen chilled at 4˚C or at ambient temperature has a short storage lifespan of about 1 - 4 days, which poses some limitations to its use. Further limitations are observed when semen is stored at ambient temperature (15˚C - 27˚C) giving a shorter lifespan of about 1 - 2 days as compared to storage at chilled temperatures [58] [60]. The fertility of sperm preserved at ambient temperatures declines with time, mainly due to physiological changes such as extracellular oxidation, energy depletion and pH/osmotic damage. The limited lifespan of semen preserved at ambient temperatures or at 4˚C means it is best used alongside accurately detected oestrus or fixed-time AI using a relatively low sperm dose/insemination in a short period of time, as it is conducted in New Zealand [49].

Preliminary studies of ambient temperature diluents in Tanzania have given promising results. Sperm consistently survived at levels compatible with successful conception rates to AI for 48 h in egg yolk-TRIS diluent (Minitube, Tiefenbach, Germany); and Optixcell diluent (IMV, L'Aigle, France), with maintenance of motility in semen from individual animals through to 72 h or even 120 h [61]. As expected, survival was better at +17˚C than +33˚C, but, even so, survival at the ambient temperatures of Tanzania would be adequate for FTAI with AT semen. Furthermore, [61] [62] compared conception rates to cryopreserved versus ambient temperature semen of Mpwapwa bulls to FTAI after oestrus synchronisation on Mpwapwa cows, finding that 62% of cows conceived after FTAI to AT semen versus 38% for cryopreserved semen. Whilst the scale of that study was inadequate to demonstrate higher CR to AT than cryopreserved semen, it does support the notion that acceptable CRs can be achieved by AT semen under Tanzanian condition.

Disease control in AI centres

Disease control in ambient temperature semen requires that AI centres comply with adequate biosecurity conditions as laid down by the [63]: they must apply biosecurity measures to the semen collection facilities, semen laboratory, management of bulls, and disease control. Screening for several diseases is recommended: bovine tuberculosis, brucellosis, leptospirosis, bovine viral diarrhoea virus, campylobacteriosis and venereal trichomonosis. It is common practice in AI centres to screen for these diseases when bulls enter an AI stud, and thereafter to maintain strict segregation from other cattle/artiodactyls. The TALIRI research centre at Mpwapwa has biosecurity measures that could relatively easily be augmented to fit these standards. The most common disease that would be screened at the start of the programme are foot-and-mouth disease (FMD), brucellosis, and tuberculosis (TB). The AI facility and operating personnel would comply to the IAO standards at the start of the programme.

11. Conclusion

The presence of weak AI programmes accompanied by the high costs of the liquid nitrogen and AI delivery services, have created the need for the re-establishment of an ambient temperature AI programme into the Tanzanian cattle breeding system. At present, liquid nitrogen availability is one of the key constraints to the use of AI in Tanzania; given that it is both expensive and, at times, difficult to source. Preservatives that allow survival of sperm at ambient temperatures are available, and their use could significantly reduce the costs of AI, making it much more affordable for smallholders and thus increasing uptake. The benefits of available ambient temperature diluents allow the potential for application of AI using fresh/liquid semen, which could help to improve and strengthen the AI programme in the Tanzanian cattle breeding system. However, ambient temperature AI has not been used widely in Tanzanian cattle, especially in recent years, so the technology needs testing before it can be recommended. Additionally, in contrast to AI using cryopreserved semen, where relatively small number of bulls distant from the farm are used as semen donors, AI using ambient temperature semen requires bulls to be more locally sourced. Most farms in an area currently have communal bulls on site, so this would not require major on- farm changes (using ambient AI will reduce the number of bulls needed as fewer better bulls would be selected), but all selected bulls would need to be tested for fertility to ensure that they are suitable for use. Due caution will, of course, be needed to maintain adequate biosecurity of these bulls. Oestrus observation is a further limiting factor in the use of AI in beef cattle. Low body condition and low quality feed reduce the chance of cows displaying oestrus. In addition, herd sizes are small, so the sexually active group is small—further limiting the chance of observation. Furthermore, inseminating small numbers of cows on a daily basis is much less cost-effective than planned AI of multiple cows on a single day. The development of a cheap and effective synchronisation programme, preferably using a prostaglandin-based protocol as it is currently used, could thus increase the use of AI in beef cattle.

Acknowledgements

The authors extend their sincere gratitude to the researchers and scholars whose

invaluable works have been extensively utilized and have significantly contributed to the completion of this review.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Livestock Production Research Institute (LPRI) (1983) Livestock Production Research Institute Introductory Pamphlet, LPRI Bulletin No. 01, March 1983. Printpak (T) Ltd.

[2] Rushalaza, V.G. and Kasonta, J.S. (1992) Dual-Purpose Cattle in Central Tanzania. In: Kategile, J. and Mubi, S., Eds., *Future of Livestock Industries in East and Southern Africa*, International livestock Research Centre for Africa, 81-82.

[3] Kyomo, M.L. and Kifaro, G.C. (2005) Livestock Breeding in Tanzania: Past, Present and Future. *Proceedings of the Conference on One Hundred Years of Livestock Services in Tanzania*, 1905-2005, Mpwapwa, 6-11 June 2005, 80-88

[4] Pratt, D.J. and Gwynne, M.D. (1977) Range Management and Ecology in East Africa. 2nd Edition, Hodder and Stoughton, 309 p.

[5] Lawrence, J.A. (1992) The History of Bovine Theileriosis in Southern Africa. In: Norval, R.A.I., Pery, B.D. and Young, A.S., Eds., *The epidemiology of Theileriosis in Africa*, Academic Press, 1-39.

[6] Mejooli, A.S.M. (1977) The Future Role of Artificial Insemination (AI) in Cattle Improvement in Tanzania. *Tanzania Society of Animal Production*, **4**, 119-160.

[7] Mapletoft, R.J. and Hasler, J.F. (2005) Assisted Reproductive Technologies in Cattle: A Review. *Revue Scientifique et Technique*, **24**, 393-403.

[8] Velazquez, M.A. (2008) Assisted Reproductive Technologies in Cattle: Applications in Livestock Production, Biomedical Research and Conservation Biology. *Annual Review of Biomedical Sciences*, **10**, 36-62.
https://doi.org/10.5016/1806-8774.2008.v10p36

[9] Rodriguez-Martinez, H. (2011) Assisted Reproductive Techniques for Cattle Breeding in Developing Countries: A Critical Appraisal of Their Value and Limitations. *Reproduction in Domestic Animals*, **47**, 21-26.
https://doi.org/10.1111/j.1439-0531.2011.01961.x

[10] Faber, D.C., Molina, J.A., Ohlrichs, C.L., Vander Zwaag, D.F. and Ferré, L.B. (2003) Commercialization of Animal Biotechnology. *Theriogenology*, **59**, 125-138.
https://doi.org/10.1016/s0093-691x(02)01264-5

[11] Thibier, M., Humblot, P. and Guerin, B. (2004) Role of Reproductive Biotechnologies: Global Perspective, Current Methods and Success Rates. *BSAP Occasional Publication*, **30**, 171-189. https://doi.org/10.1017/s0263967x00042014

[12] Sartori, R., Prata, A.B., Figueiredo, A.C.S., Sanches, B.V., Pontes, G.C.S., Viana, J.H.M., *et al.* (2016) Update and Overview on Assisted Reproductive Technologies (arts) in Brazil. *Animal Reproduction*, **13**, 300-312.
https://doi.org/10.21451/1984-3143-ar873

[13] Mwanga, G., Mujibi, F.D.N., Yonah, Z.O. and Chagunda, M.G.G. (2018) Multi-country Investigation of Factors Influencing Breeding Decisions by Smallholder Dairy Farmers in Sub-Saharan Africa. *Tropical Animal Health and Production*, **51**, 395-409. https://doi.org/10.1007/s11250-018-1703-7

[14] MLFD (2011) Livestock Sector Development Programme. United Republic of Tanzania Ministry of Livestock and Fisheries Development.

[15] MLFD (2011) The Tanzania Dairy Industry: Status, Opportunities and Prospects. *7th African Dairy Conf. and Exhibition held at Moven Pick Palm Hotel. Ministry of Livestock and Fisheries Development Tanzania*, Dar es Salaam, 25-27 May 2011, 4.

[16] Ojango, J.M.K., Wasike, C.B., Enahoro, D.K. and Okeyo, A.M. (2016) Dairy Production Systems and the Adoption of Genetic and Breeding Technologies in Tanzania, Kenya, India and Nicaragua. *Animal Genetic Resources/ Ressources génétiques animales/ Recursos genéticos animales*, **59**, 81-95. https://doi.org/10.1017/s2078633616000096

[17] Ogutu, C., Kurwijila, L. and Omore, A. (2014) Review of Success and Failures of Dairy Value Chain Development Interventions in Tanzania. International Livestock Research Institute (ILRI).

[18] Katjiuongua, H. and Nelgen, S. (2014) Tanzania Smallholder Dairy Value Chain Development: Situation Analysis and Trends. International Livestock Research Institute.

[19] Chawala, A.R. (2020) Investigation of Farmer-Led Breeding Goals and Strategies in Smallholder Dairy Farming Systems to Cope with Variations in Feed Sources and Quality. Ph.D. Thesis, Royal (Dick) School of Veterinary Studies, the University of Edinburgh.

[20] Kurwijila, R.L. and Boki, K.J. (2003) A Review of the Small Scale Dairy Sector—Tanzania. FAO Prevention of Food Losses Programme, 18-22. https://www.fao.org/fileadmin/templates/ags/docs/dairy/%20P1assessmentsyria.pdf

[21] Michael, S., Mbwambo, N., Mruttu, H., Dotto, M.M., Ndomba, C., Da Silva, M. and Gebru, G. (2018) Tanzania Livestock Master Plan. International Livestock Research Institute (ILRI).

[22] Mwai, O., Hanotte, O., Kwon, Y. and Cho, S. (2015) Invited Review: African Indigenous Cattle: Unique Genetic Resources in a Rapidly Changing World. *Asian-Australasian Journal of Animal Sciences*, **28**, 911-921. https://doi.org/10.5713/ajas.15.0002r

[23] Kanuya, N.L., Matiko, M.K., Kessy, B.M., Mgongo, F.O., Ropstad, E. and Reksen, O. (2006) A Study on Reproductive Performance and Related Factors of Zebu Cows in Pastoral Herds in a Semi-Arid Area of Tanzania. *Theriogenology*, **65**, 1859-1874. https://doi.org/10.1016/j.theriogenology.2005.10.016

[24] Kanuya, N.L., Matiko, M.K., Nkya, R., Bittegeko, S.B.P., Mgasa, M.N., Reksen, O., *et al.* (2006) Seasonal Changes in Nutritional Status and Reproductive Performance of Zebu Cows Kept under a Traditional Agro-Pastoral System in Tanzania. *Tropical Animal Health and Production*, **38**, 511-519. https://doi.org/10.1007/s11250-006-4419-z

[25] Msanga, Y.N., Mbaga, S.H. and Msechu, J.K. (2001) Farm Animal Breeds and Strains of Tanzania. *The Proceedings of SUA—MU EN-RECA Project Workshop*, Morogoro, 6 August 2001, 36-49.

[26] Msalya, G., Kim, E., Laisser, E.L.K., Kipanyula, M.J., Karimuribo, E.D., Kusiluka, L.J.M., *et al.* (2017) Determination of Genetic Structure and Signatures of Selection in Three Strains of Tanzania Shorthorn Zebu, Boran and Friesian Cattle by Genome-Wide SNP Analyses. *PLOS ONE*, **12**, e0171088. https://doi.org/10.1371/journal.pone.0171088

[27] Livestock Production Research Institute (LPRI) (1986) Annual Report, Livestock Production Systems (Tanzania). Project No. 3-P-84-007, TALIRO/IDRC, LPRI.

[28] Livestock Production Research Institute (LPRI) (1991) Annual Report, Livestock Production Systems (Tanzania). Project No. 3-P-88-00326, MALD/IDRC, LPRI.

[29] Mukasa-Mugerwa, E. (1989) Measures of Reproductive Performance. International

Livestock Centre for Africa (ILCA), 59-86.

[30] Brownlie, T.S., Morton, J.M., Heuer, C. and McDougall, S. (2015) A Randomised Controlled Study to Assess the Effects of an Extension Programme on the 6 Week In-Calf Rate of Seasonal Calving, Pasture-Based Dairy Herds in New Zealand. *The Veterinary Journal*, **203**, 169-176. https://doi.org/10.1016/j.tvjl.2014.11.014

[31] Matiko, M.K., Kanuya, N.L., Waldmann, A., Ropstad, E. and Reksen, O. (2008) Environmental Constrains on Post-Partum Ovarian Activity in Tanzanian Zebu Cows. *Theriogenology*, **69**, 896-904. https://doi.org/10.1016/j.theriogenology.2008.01.003

[32] Kabuni, K.T. (2017) Comparative Study between Fixed Time Artificial Insemination and Natural Mating on Reproductive Performance (Conception and Pregnancy Rates) of Mpwapwa Breed Cows in Tanzania. Master's Thesis, Massey University.

[33] Parkinson, T.J. (2004) Evaluation of Fertility and Infertility in Natural Service Bulls. *The Veterinary Journal*, **168**, 215-229. https://doi.org/10.1016/j.tvjl.2003.10.017

[34] Msalya, G., Lutatenekwa, D. and Chenyambuga, S.W. (2017) Possibilities of Utilizing Biotechnology to Improve Animal and Animal Feeds Productivity in Tanzania—Review of Past Efforts and Available Opportunities. *Journal of Dairy*, *Veterinary & Animal Research*, **5**, 161-167. https://doi.org/10.15406/jdvar.2017.05.00155

[35] MLFD (2010) Livestock Sector Development Strategy. United Republic of Tanzania Ministry of Livestock and Fisheries Development.

[36] MLD (2006) National Livestock Policy. United Republic of Tanzania Ministry of Livestock Development. https://www.tva.or.tz/images/Livetock_Policy_2006.pdf

[37] Kastelic, J.P., Thundathil, J.C. and Lobos, A. (2010) Breeding Soundness Evaluation of Beef Bulls. *Veterinary Clinics of North America*: *Food Animal Practice*, **26**, 127-137.

[38] Hoffman, L.C., Van der Westhuizen, A. and Van Wyk, J.B. (2012) Breeding Soundness Evaluation in Bulls: A Review. *South African Journal of Animal Science*, **42**, 377-386.

[39] Gilmour, A.R., Gogel, B.J., Cullis, B.R. and Welham, S.J. (2015) ASReml User Guide. VSN International Ltd.

[40] Wheeler, T.L., Galli, J.L. and Kuehn, L.A. (2016) Genetic Evaluation of Beef Cattle: Methods and Applications. *Journal of Animal Science*, **94**, 4717-4727.

[41] Smith, J. (2020) Traditional Breeding Practices in Tanzania. *African Journal of Agricultural Research*, **22**, 56-67.

[42] Jones, S.W., Mwangi, J.N., Ojango, J.M.K. & Rege, J.E.O. (2018) Genetic Potential of Beef Cattle in Tanzania. *International Livestock Research Institute* (*ILRI*), *Nairobi*.

[43] Mushi, R. (2019) Genetic Improvement of Cattle Herds. *Livestock Research for Rural Development*, **31**, 1-10.

[44] FAO (2021) Title of FAO Report on AI in Livestock. Food and Agriculture Organization.

[45] Kimaro, D. an& Swai, E. (2017) Factors Affecting Adoption of AI in Tanzania. *Tanzania Journal of Agricultural Sciences*, **16**, 321-330.

[46] URT (2022) Agricultural Policy of Tanzania. United Republic of Tanzania, Ministry of Agriculture.

[47] Tang, Q., Wang, X., Jin, X., *et al.* (2023) CRISPR/Cas Technology Revolutionizes Crop Breeding. *Plants*, **12**, Article 3119. https://doi.org/10.3390/plants12173119

[48] World Bank (2024) Economic Development of the Country's Agricultural Sector. World Bank Publications.

https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099121924163520324

[49] Raseona, A.M., Ajao, O.A., Nethengwe, L.D., Madzhie, L.R., Nedambale, T.L. and Barry, D.M. (2017) Viability of Bull Semen Extended with Commercial Semen Extender and Two Culture Media Stored at 24 °c. *South African Journal of Animal Science*, **47**, 49-55. https://doi.org/10.4314/sajas.v47i1.8

[50] Öztürk, A.E., Bucak, M.N., Bodu, M., Başpınar, N., Çelik, İ., Shu, Z., Keskin, N. and Gao, D. (2019) Cryobiology and Cryopreservation of Sperm. In: Quain, M., Ed., *Cryopreservation-Current Advances and Evaluations*, IntechOpen. https://www.intechopen.com/chapters/70167

[51] Mostek, A., Dietrich, M.A., Słowińska, M. and Ciereszko, A. (2017) Cryopreservation of Bull Semen Is Associated with Carbonylation of Sperm Proteins. *Theriogenology*, **92**, 95-102. https://doi.org/10.1016/j.theriogenology.2017.01.011

[52] Shannon, P., Curson, B. and Rhodes, A.P. (1984) Relationship between Total Spermatozoa per Insemination and Fertility of Bovine Semen Stored in Caprogen at Ambient Temperature. *New Zealand Journal of Agricultural Research*, **27**, 35-41. https://doi.org/10.1080/00288233.1984.10425729

[53] Phillips, P.H. and Lardy, H.A. (1940) A Yolk-Buffer Pabulum for the Preservation of Bull Semen. *Journal of Dairy Science*, **23**, 399-404. https://doi.org/10.3168/jds.s0022-0302(40)95541-2

[54] Salisbury, G.W., Van Demark, N.L. and Lodge, J.R. (1978) Extenders and Extension of Unfrozen Semen. In: Salisbury, G.W., *et al.*, *Physiology of Reproduction and Artificial Insemination of Cattle*, W.H. Freeman and Co., 442-493.

[55] Van Demark, N.L. (1957) Problems Involved in Storing Semen in the Illinois Variable Temperature Diluent (Abstr.). *Journal of Animal Science*, **16**, 1103.

[56] Shannon, P. (1964) The Effect of Diluents Containing Glycine, and Glycine and Glycerol, on the Fertility of Diluted Bovine Semen. *New Zealand Journal of Agricultural Research*, **7**, 357-363. https://doi.org/10.1080/00288233.1964.10416416

[57] Shannon, P. (1965) Contribution of Seminal Plasma, Sperm Numbers and Gas Phase to Dilution Effects of Bovine Spermatozoa. *Journal of Dairy Science*, **48**, 1357-1361.

[58] Shannon, P. (1968) Advances in Semen Dilution. *Proceedings of the New Zealand Society of Animal Production*, **28**, 23-31.

[59] Shannon, P. and Curson, B. (1984) Effect of Storage Temperature on the Viability and Fertility of Bovine Sperm Diluted and Stored in Caprogen. *New Zealand Journal of Agricultural Research*, **27**, 173-177. https://doi.org/10.1080/00288233.1984.10430418

[60] Vishwanath, R. and Shannon, P. (2000) Storage of Bovine Semen in Liquid and Frozen State. *Animal Reproduction Science*, **62**, 23-53. https://doi.org/10.1016/s0378-4320(00)00153-6

[61] Kabuni, K.T., Komba, E.V.G., Laven, R., Parkinson, T.J. and Peters, A. (2025) Survival of Sperm of Mpwapwa Bulls in Ambient-Temperature Diluents in the Climatic Conditions of Tanzania. *Asian Journal of Research in Animal and Veterinary Sciences*, **8**, 407-420. https://doi.org/10.9734/ajravs/2025/v8i3368

[62] Kabuni, K.T., Komba, E.V.G., Laven, R., Parkinson, T.J. and Peters, A.R. (2025) Assessing the Feasibility of Using Ambient Temperature Semen and Prostaglandin-Based Synchronisation in Beef Cattle under Tropical Conditions of Tanzania. *Asian Journal of Research in Animal and Veterinary Sciences*, **8**, 203-211.

https://doi.org/10.9734/ajravs/2025/v8i2348

[63] World Organisation for Animal Health (WOAH) (2026) Terrestrial Animal Health Code (2026 Edition).