Chapter

Assisted Reproductive Technologies as Veritable Tools for Improving Production Efficiencies of N'dama and Muturu Cattle Breeds in Nigeria-A Review

Cornelius Nwoga, Nnanna Ikeh, Matthew Onodugo, Paul Baiyeri and Ndubuisi Machebe

Abstract

Assisted reproductive technologies (ART) that have come to stay and are still being improved upon in developed countries are still in their infancy stage in developing countries like Nigeria. Nigeria's cattle population is estimated to be around 18.4 million. The number is far insufficient to meet the country's demand for meat, milk, and other cow products, let alone contribute to GDP. N'dama and Muturu are both Nigerian breeds that are resistant to trypanosomosis. They are humpless longhorn and humpless shorthorn types of beef cattle. The dairy and beef cow industries' inadequate adoption of ART is partly to blame for Nigeria's low cattle output. Sex determination, multiple-ovulation and embryo transfer (MOET), oestrus synchronization, artificial insemination (AI), in vitro fertilization (IVF), cloning, and genetic engineering are all examples of assisted reproductive technologies. It has been reported in humans, rodents and domestic animals, abnormal fetuses, newborns and adult offspring arise from ART. Improper matching of breeding animals mostly leads to overfat calves. This review centers on the applications and potentials of ART in the production of trypanotolerant N'dama and Muturu cattle breeds. Some unorthodox medicines which have proven effective in human reproduction can circumvent the shortfalls in the adoption of ART.

Keywords: assisted reproductive technologies, N'dama, Muturu, Trypanosomosis, Nigeria

1. Introduction

Assisted reproductive technologies (ART) have been successfully used to alleviate fertility issues in humans and to improve farm animal genetics. ART adoption has risen dramatically in recent years, and this trend is projected to continue [1].

ART has some drawbacks and restrictions. In vitro embryo production (IVEP), which was the predominant method for creating bovine embryos for transfer in 2017 [2], demonstrated reduced pregnancy rates after the transfer of in vitro-produced (IVP) embryos when compared to natural breeding, AI, or even transfer of in vivo-derived embryos [3–5].

The use of IVEP in cattle is limited due to a high percentage of pregnancy losses [6, 7]. Despite improvements in IVEP procedures over the years, current studies have found greater early and late embryo mortality in IVEP-derived pregnancies when compared to in vivo approaches such as AI or multiple ovulation and embryo transfer (MOET) [8, 9]. Calving difficulty and abnormal birth weight [10], disturbed fetal development [11, 12] and epigenetic dysregulation [13] have also been reported recently.

Cattle production accounts for a greater proportion of the economy of commercial and semi-commercialized farmers in undeveloped countries globally. It sustains the economy of most developed countries through meat, milk and skin production. Cattle have as well been on the forefront of researches in biomedicine and reproduction. With the recent promotion in biotechnology, cattle have been improved for better production efficiencies.

The cattle population in Nigeria at present is 18,404,661 million [14] and an annual growth rate of 1.5 percent is being estimated in the herd. It is disturbing that although developing countries account for about two-thirds of the World Cattle Population, while the developed countries account for about two-thirds of total beef population [15]. The three predominant production systems and their contributions to the total population are extensive (82.1%), semi-intensive (16.8%) and intensive (1.1%). Cattle population by geographic zones reveals the percentages as follows: North-West (52%), North-East (27%), North-Central (19%) and South (2%) [16] as shown in **Figure 1**.

Indigenous breeds dominate the cattle industry in Nigeria and they primarily serve the purpose meat production and for savings as well as milk production. Foreign breeds like Holstein Friesian, Brown Swiss, Jersey and their crosses can only be found in more intensive, specialized dairy farms [17]. Agricultural Policy for Nigeria [18] advocated the upgrading of local breeds of animals through the use of exotic breeds to a level not exceeding 50 percent to maintain hybrid vigor. Sequel to this, there is a high cost of importing an exotic bull or cow coupled with the physiological processes the animal must undergo before leaving a temperate region to the tropical region. Such processes like acclimation, acclimatization and adaptation must be achieved in time and space for a successful importation of an exotic breed into Nigeria. The economic implication of such venture is enormous.

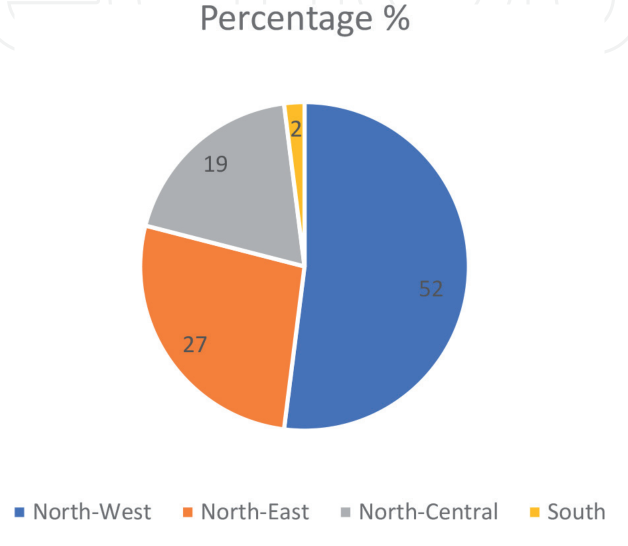

Figure 1.
Cattle population by geographic zones in Nigeria.

An easier approach to the above processes is the integration of ART into practices in the Nigerian cattle industry to boost production. There has been a significant increase in the utilization of ART, particularly AI and MOET, by developed and developing countries to produce millions of cattle. The adoption has led to a tremendous increase in both dairy and beef cattle production in several countries such as the United States and Brazil. In the national animal production research institute (NAPRI), Zaria, Nigeria, AI has been routinely performed since 1978.

Other interests include the monitoring of reproductive hormones and the improvement of oestrus synchronization and heat detection. Crossbreeding of the indigenous breeds of cattle with the exotic breeds is also on-going in an effort to upgrade their traits for beef production. Efforts have also been made to improve the milk productivity of indigenous cattle through crossbreeding with exotic cattle (Friesian) to produce crossbred cows (Friesian-Bunaji) with a genetic potential for increased milk yield per day [19].

Apart from NAPRI, AI is also performed in a few private commercial cattle farms. Unfortunately, these efforts impact a small proportion of cattle population in Nigeria. A recent study in northern Nigeria also revealed poor extension contact among dairy farmers, which blocks farmers from access to sources of improved dairy cattle technologies [20]. Tertiary institutions in Nigeria also present platforms for the utilization of ART in research that can improve animal reproduction and productivity. Many of these institutions have made considerable efforts in some areas of animal production, and in the treatment of reproductive diseases. Regrettably, there is a low potential for the application of ART, partly due to the absence of a number of equipment and facilities but also due to shortage of human skill or training [19] and the fear of the attendant consequences of embracing ART.

Clearly, an intensive application of ART will assist in improving reproductive efficiency and productivity in dairy and beef cattle farming in Nigeria through several approaches. Tertiary institutions and research institutes should be adequately funded and provided with modern research facilities, laboratories and equipment. Skills in ARTs should be incorporated and exploited in both teaching and research in animal science and veterinary medicine curriculums. There should be an increased synergy between farmers and researchers through agricultural extension services and above all, the farmers fears of post-ART consequences should be addressed through research.

The present turn of events in Nigeria demands that the discussion of the application of reproductive biotechnologies in cattle and their impact for future achievements be done.

The current discussion summarizes ART-based successes and implications in cattle breeding while also aiming to apply it to the effective enhancement of Nigerian dairy and beef herds.

2. Cattle breeds and distribution in Nigeria

2.1 White Fulani (Bunaji)

White Fulani ranks first among number and distribution in all the cattle breeds in Nigerian [21, 22]. It is estimated that it makes up roughly 37% of the national herd [23, 24]. They can be found in Nigeria's Western, Northern, and Middle Belt regions. They are completely missing in Borno, where Rahaji and Wadara abound, and in the south-east, where Zebu is scarce. Bunaji are said to be superior to all other Zebu breeds in terms of disease resistance and hardiness, which has favored their expansion into the derived savannah and the humid zone's edge [21, 22].

Late sexual maturity, a long interval between calving, and a short lactation period are some of the breed's drawbacks. The Bunaji, on the other hand, are known for their genetic aptitude to be sturdy, heat tolerant, and suited to local conditions [24]. A white coat color, a relatively large size, and a height of about 130 cm are all phenotypes. At maturity, bulls and cows weigh about 500 kg and 325 kg, respectively. They have a prominent hump, a little belly flab, and medium-length, upcurving, lyre-shaped horns. The White Fulani has three key economic characteristics: milk production capacities of around 2,300 kg per lactation, the ability to fatten for beef cum milk production, and the bull's proclivity to be utilized as a draught animal. At NAPRI-Shika, Zaria, offspring of White Fulani and Holstein crosses have resulted in improved milk production [24]. The average age for first calving was 42–45 months, however it might go as high as 5 years in Fulani herds. They contribute a large portion of the beef consumed in Nigeria [24, 25].

2.2 Red Bororo (Rahaji)

The Rahaji cattle herd is Nigeria's third largest, accounting for around 22% of the country's total herd. Except for a small population in southern Kaduna during the rainy season and an isolated population in the north-east Mambila Plateau, it is generally restricted to Nigeria's arid and semi-arid regions [21, 22]. The Red Bororo is one of the largest Zebu breeds, and it is distinguished by its rich red coat, enormous ears, and long, thick horns [26, 27]. The breed is adored by Fulani pastoralists who integrate it into their herds of 'white' cattle for crossbreeding purposes. It is adversely affected by poor nutrition and it is susceptible to humidity-related diseases [21]. Due to high mortality rates among the animals orchestrated by the movement of the herders down south into the Middle Belt, a Fulani clan, the Rahaji, who traditionally herded the breed and imprinted their name on it, has strikingly exchanged their stock for Bunaji [22].

2.3 Sokoto Gudali

According to [23], Gudali accounts for roughly 32% of the national herd. In Nigeria, there are two distinct forms of Gudali: the Sokoto Gudali (Bokolooji) and the Adamawa Gudali. The Bokoloji is found primarily in Nigeria's northwestern region, but it has recently spread throughout the country [25–27]. The Bokoloji is nearly hornless and has a homogeneous cream, light gray, or dun coloration. It has a lot of dewlap and skin wrinkles on it. The hair is short, and the skin is pigmented and thickIt has droopy ears, which milkers appreciate. At the National Animal Production Research Institute (NAPRI), Shika, the Sokoto Gudali beat the White Fulani in terms of milk yield [24, 25]. The calving interval is 360–450 days. The females have well developed udders with good teats which make them to be regarded as indigenous dairy breed. The average weights at maturity are 330 kg for the female and 450 kg for the male. The average milk production per lactation of the female is 1,500 kg [25].

2.4 Adamawa Gudali

As its name suggests, the Adamawa Gudali is only found in Adamawa [21, 22]. It is thought to account for roughly 2% of the national herd [23]. In Nigeria, two prominent local kinds are recognized: the Banyo, who have Rahaji blood and big horns, as well as a white face and red eye patches, and the Yola, who have a Muturu admixture [28]. Since the 1950s, the Muturu characteristics have gradually vanished, and local herders no longer identify the Yola breed as a separate variation.

Adamawa Gudali has a similar conformation to Bunaji. Its horns are normally pied and medium in length, and its size ranges from medium to giant. The coat can be white, black, red, or brown. The pendulous hump, however, is the most reliable distinguishing feature between Adamawa Gudali and Bunaji. Both Kanuri and Fulani pastoralists share ownership of the land. Kanuri and Fulani both have mixed Adamawa Gudali and Wadara herds, Bunaji or Rahaji. Many farmers consider Adamawa Gudali to be the traditional race of the region, where they work in the fields. They are normally fattened in the compound and brought to market when they become too large to pull a plow successfully [25, 29].

2.5 Wadara

Wadara cattle are another Nigerian breed. They are light, medium-sized, and dark-red, black, pied, or brown in color. They have short horns and a little upright hump, and account for approximately 6.6 percent of the national herd. They are Borno's "indigenous" cattle, which the Koyam and other pastoralists refer to as "our" cattle. In literature, the Wadara is most commonly referred to as 'Shuwa,' after the Shuwa Arabs who also herd them. The Ambala, a kindred white-coated breed from Chad, is frequently imported into Nigeria [21, 22].

2.6 Azawak

The Azawak is another breed found in Nigeria and is an indigenous cattle the Azawak valley North-East of Nigeria. It is distributed along its North-Western border. It has medium-length horns. The color variations range from red for Azawak in Niger Republic to fawn, white, brown, pied and black color for those that enter Nigeria. They represent about 0.7% of the national herd. Except for minute population kept by indigenous herders in Nigeria throughout the year, the majority is seasonally transhumant [23]. They are majorly distributed along the border North and West of Sokoto but scanty populations are found in the North-West of Borgu and the border between Sokoto and Katsina [21, 22].

2.7 Muturu

The Muturu is a breed of West African dwarf shorthorn cattle with a small body. It has a blocky shape with fine-boned, short limbs. The body is compact, without a hump, and has a broad head and a straight back. Their horns are relatively short and have a somewhat dished face. In South-Central Nigeria, the Muturu are predominantly black or black and white. They are usually black and white on the Jos Plateau, but they are noticeably larger than those found in the lowlands. Northern populations are made up of brown, red, or tawny animals. Muturu cattle have a very disjointed distribution within Nigeria, implying a gradual retreat of a once-widely distributed population [25, 30]. Blench et al. [30] has examined Muturu's management, productivity, history, and distribution. Due to insufficient maps of Muturu distribution, accurate estimates of their numbers are difficult to come by. Muturu cattle are widely spread and less apparent than Zebu cattle, and they are generally kept in stalls where they are fed. As a result, published population figures are inaccurate. Northern Muturu data is lacking, and their trypano-tolerance has not been assessed, making them ineligible for inclusion in estimations of 'trypano-tolerant' cattle. International Livestock Centre for Africa [31], who estimated 120,000 Muturu, should be compared to [32], who estimated 60,000 Muturu, or 0.7 percent of the national herd. Akinwumi and Ikpi [33] found 85,000 people in five southern states after conducting a poll. Nigerian National Livestock Resource Survey [23], the first survey to take into account all of the populated islands, estimated a population of 115,000 in 1990 [15]. Isolated Muturu populations exist along the Republic of Cameroon border, extending into South-Eastern Borno and merging with Adamawa's Michika-Mubi area. In the dry savannah, small populations can be found in the Atlantika mountains, south-east of Yola, near Cham, east of Bauchi, and south-east of the Jos Plateau [21, 22]. Another Muturu group appears north of Tegina in the North-West, with widely varying coat colors, implying a link with the North-East populations. Muturu once inhabited much of southern Nigeria and the west bank of the Niger River, with its extinction in many parts occurring only recently. Either Keteku or Zebu have supplanted Muturu, or Muturu is no longer kept by communities. Muturu once inhabited much of southern Nigeria and the Niger Valley west of the river, but they have since vanished from many areas. Muturu has been replaced by Keteku or Zebu, or Muturu is no longer kept by communities.

2.8 Keteku

Blench et al. [30] investigated the distribution and productivity of Keteku cattle in greater depth. Due to an increasing amount of Zebu blood in 'Keteku' herds, purelines of Keteku have become difficult to come by in recent years. Zebu cattle are being used to replace village herds as Fulani pastoralists migrate southwards, invading territories traditionally restricted to trypano-tolerant stock. The progeny of a Zebu x Savannah Muturu hybrid found near Biu in southern Borno and published in the literature [28] is a good illustration of how the local Zebu gene pool has become dominant. The name Keteku for a certain animal may represent the owner's cultural background as well as the animal's genotype. According to [31], the population of Keteku in Nigeria is 180,000 people. Keteku is less common than previously thought, with a wide range of distribution. It's unlikely that there are 100,000 of any kind.

Keteku is a variant of Borgu and is a stabilized Muturu x Zebu hybrid that is also trypano-tolerant [28]. It is also known as Kataku, Ketari, Borgu, Borgawa, and Kaiama. The Muturu and Bunaji characteristics are combined in this breed, with white, gray, and black being the most common colors, with red and brown appearing on occasion. It has longer horns, a smaller hump, and shorter legs than Muturu and Bunaji. In Nigeria, the populations of Keteku herds are limited to a narrow band along the Benin Republic border in the region known as 'Borgu,' as well as areas near to settlements in Northern Yoruba land. Throughout this region, Keteku coexisted with West African dwarf shorthorn, both filling the same niche [21, 22]. Keteku is sometimes purchased as an investment stock in the Ondo area by farmers who value its combination of size and trypano-tolerance. Keteku cattle have traditionally been raised on breeding farms and dispersed as part of livestock extension programs. Keteku is kept in the Government Livestock Centre in Ado-Ekiti [21, 22]. Crossbreeding of Zebu and Muturu is popular in various West African countries. Despite the fact that the two types came into touch, there have been few 'new' crossings of Zebu and Muturu in Southern Nigeria. Incompatibility and religious strictures have been cited by farmers in the South East for not crossbreeding the duo. In the Jos Plateau, ethnic competitions between the livestock farmers and animal production considerations have been cited as reasons for continuing genetic separation [21, 22].

2.9 N'dama

N'dama cattle are indigenous to Senegambia and neighboring areas in West Africa [29, 30, 34]. In 1939, N'dama cattle were introduced into Nigeria from Guinea for research purposes due to their trypanotolerance and larger size than Muturu cattle [30, 35]. N'dama cattle are humpless and have a medium-sized compact body with lyre-shaped black-tipped horns. The male has a large head and a small dewlap. Light brown N'dama are commonly brought into Nigeria, however black and pied N'dama are found in Guinea. They were sold to farmers and pastoralists in an attempt to boost local herds' resistance to trypanosomiasis. Outside of institutions, there are few pure N'dama due to herders crossing N'dama with Zebu, yet pockets of N'dama exist in Northern Yoruba region [21, 22].

2.10 Kuri

The Kuri is a humpless long-horn with a huge body [21, 22, 29]. Its exact historical origin is uncertain. Kuri horns are unique in that they are swollen and spongy, unlike those of any other breed. It is 1.5 meters tall and weighs up to 550 kilograms. In terms of size, it is one of the largest African cow breeds. Kuri cattle come in a variety of hues and have the capacity to sustain in semi-aquatic environments. The Kuri cattle population is primarily concentrated in the old Lake Chad basin particularly along the lake's eastern coasts. Kuri cattle can be found in Nigeria's Yobe valley and as far west as Gashagar. Kuri cattle are sent to Kano's North East district to be employed as traction animals. The breeds are crossed with the Zebu in Komadugu Yobe and are typically called Jetkoram in the literature [21, 22].

3. Herd size and productivity of cattle in Nigeria

3.1 Herd size

Only after several variables have been evaluated can the optimal herd size for an area and a population be estimated [34]. The notion of optimum herd size takes into account the current environmental conditions, the species biological capability (performance), herd management technique, resource utilization, and distribution in general principles [36]. The world's cattle population stands at 1,000,967,000 with the top ten producers being the India, Brazil, China, United States, European Union, Argentina, Australia, Russia, Mexico and Uruguay. The above data are based on the 2021 ranking of countries with the most cattle [37]. The average beef cow herds are 43.5 for United States [38], 69 Canada [39] and 41 for Nigeria [40]. Nigeria with an estimated cattle population of 18,404,661 million [14] and an annual growth rate of 1.5 percent could not feature among the first 17 countries as shown in **Table 1**.

However, the current paper is based on the literature evidence based on the assumptions in Nigeria. Cunnings [41] estimated the size of the Fulani cattle herd to be 100–150, while [42] estimated it to be 80–100. Another study [43] found that the average cattle herd size was 41, and that the majority of herders (46.4 percent) herded 41 to 60 cattle. The pastoralist herd size ranged from 16 to 69 animals per herd, according to a recent survey of pastoralist households in Zaria and surrounds by [34]. In the humid rainforest of Imo State, Nigeria, the majority of Fulani pastoralists (63.60 percent) maintained herd sizes of 41 to 70 heads, according to [43]. With a population of more than 170 million people, Nigeria requires a large number of cattle to meet its demand for cattle and cattle products. As long as more than 80% of the cattle population is in the hands of traditional herders, supply will not be able to meet demand. Cattle importation is thus practiced in order to bridge the deficit. The imported total was 5,142 heads per year in January 1996. In a study conducted by [44], the pastoralist's operational sizes were evaluated to determine the makeup of the herds in terms of the class of cattle—steers, lactating or non-lactating cows,

World			**1,000,967,000**
Rank	**Country**	**2021**	**% of World**
1	India	305,500,000	30.52%
2	Brazil	252,700,000	25.25%
3	China	95,620,000	9.55%
4	United States	93,595,000	9.35%
5	European Union	85,545,000	8.55%
6	Argentina	53,831,000	5.38%
7	Australia	23,217,000	2.32%
8	Russia	17,953,000	1.79%
9	Mexico	17,000,000	1.70%
10	Uruguay	11,946,000	1.19%
11	Canada	11,150,000	1.11%
12	New Zealand	10,063,000	1.01%
13	Egypt	7,850,000	0.78%
14	Belarus	4,300,000	0.43%
15	Japan	3,922,000	0.39%
16	Korea, South	3,744,000	0.38%
17	Ukraine	3,001,000	0.30%

Foreign Agricultural Service/United States Department of Agriculture [37].

Table 1.
Ranking of countries with the most cattle.

and calves. Small scale pastoralists (SSP), medium scale pastoralists (MSP), and large scale pastoralists (LSP) were the three kinds of pastoralists (LSP). According to the findings, the SSP had an average herd size of roughly 17 cattle, while the MSP and LSP had 32 and 73 cattle, respectively. Furthermore, the LSP had more lactating and non-lactating cows, as well as calves, than the SSP and MSP, whereas the MSP had the most steer in the herd [45]. The herd pattern in Zaria revealed a gender disparity, with more cows than bulls, with cows accounting for 60 to 75 percent of each herd on average. Keeping more cows than bulls is advantageous to pastoralists because a simulation of herd dynamics demonstrates that when female calves outnumber male calves in the kraal, the herd's maximum growth is achieved [36]. The herd size had a 50 percent preponderance of young animals, with females (35 percent) and males (35 percent) as the genders (15 percent). The breeding cows made up 49.1 percent of the herd, while the breeding bulls made up 6%. The number of breeding cows and young females in a herd impacts the profitability of any cattle operation to a large extent [46]. This helps to explain why the Fulani herd has such a high number of breeding cows and young females. Except for selected and retained breeding bulls, the young males, who had previously been plentiful, were sold out before to breeding to supplement the family's revenue. Because the mating ratio is usually 1 bull: 20 cows, keeping a large number of bulls in the herd is uneconomical [47]. The ratio of cows to young animals in the herd was practically equal, according to the data (0.98). The ratio of breeding bulls to young animals was low (0.14), implying that breeding bulls and cows were almost equal (0.15). The ratio of young males to young females was 0.42, indicating that young females outnumber young males [36].

3.2 Reproductive performance

Reproduction is the major determinant of profitability in a cattle enterprise. A cow needs to be re-bred in 80 to 85 days post calving to sustain a 365-day calving interval. Percentage of body fats in cows is directly linked to poor reproductive performance. Inadequate nutrition causes poor reproductive performance and researchers have discovered that for proper functioning of the reproductive system, a certain level of body fat must be attained. It becomes easier to develop more cost-effective a nutrition program if all of the farm's cows can be managed similarly. This is certainly relevant when a farm's entire herd of cows is maintained as a single herd, which is common in small production units [29]. All cows suffer from poor body condition at vital times due to year-round calving. Reduced income per cow, prolonged time before rebreeding, poorly conditioned calves at birth, low quality and scarce colostrum, decreased milk production, a high rate of dystocia, and lower calf weaning weights are all possible consequences. A longer interval between rebreeding and weaning will result in a younger, smaller calf at weaning the following year, resulting in lower profits if the animal is sold at weaning. Calves that were weak at birth may find it difficult to get reasonable amount of colostrums. This may give rise to high susceptibility to diseases, light weaning weights, decreased feedlot performance and poor carcass traits. As reported by researchers, there is clear evidence cows with a moderate body condition had a shorter delay between calving and initial estrus than cows with a bad body condition [29].

According to [44], 6–10 calving per cow per reproductive cycle is allowed by about 90.90% of pastoralists in Nigeria, while about 9.10% usually allow about 11–15 calving per cow. Therefore, majority of the aged cows are often slaughtered for sale in most abattoirs [48]. However, cattle production and breeding efficiency on Northern Nigerian grazing rangelands is low, especially during the dry season [49]. Cows, for example, have a two-year age at first calving and a two-year calving interval [50, 51], steers achieve slaughter weight between 24 and 30 months of age [52], and off-take rates range from 2 to 10% per year [49]. The median age at first calving for the reproduction was 4.75 years, according to [34]. The findings corroborated previous data on Bunaji cattle herds gathered from the Jos Plateau [52]. However, the result was higher than 37-month reported at the National Veterinary Research Institute, Vom, a government farm [53]. The difference is due primarily to the dry season's low amount and quality of feed on grazing fields [50, 54]. In such circumstances, providing feed supplements to boost cow output may be recommended. However, before any nutritional modifications are proposed, it's critical to figure out which nutrients are restricting cattle productivity in a certain zone [55]. Akpa et al. [34] equally reported a before breeding, the average age was 4.05 years for bulls in the pastoral cattle herds. This may be probably occasioned by poor nutrition acting together with other environmental stressors. Ndlovu et al. [56] made findings that the age at which young bulls reach puberty is affected by nutrition and feed intake. However, [47] suggested that where controlled breeding is being practiced, young bulls of about 15 months of age should not run with the cows in the pasture. Some researchers have used standard technical coefficients to compare results obtained in research institutions such as the National Animal Production Research Institute in Zaria or the National Veterinary Research Institute in Vom, as well as those in Nigeria's traditional model [44]. Data were collected on reproductive performance and milk to butter ratio. The results, *inter alia* showed that the proportion of milk to butter was 1 liter to 100 grams. When compared to the data above, it can be seen that the calving cycle in Nigeria ranges from 29 to 43 months. The average age at first calving is 30 to 42 months, with a productive life of between 9 and 14 years [44].

3.3 Productivity

The most important nutrients influencing milk and beef production in semi-arid environments are protein, energy, and minerals [57]. Some studies have revealed that energy and minerals are not the limiting requirements for grazing cattle, but rather protein deficits are the cause of cattle productivity losses [58, 59]. Blezinger et al. [57, 60] however, reported that rangelands fail to supply energy and minerals in adequate quantity during the early to mid-wet season. The consequence is a retarded growth rate of cattle which turns out to be a main stumbling block to boosting body weight growth [61, 62] and, as a result, impacting semi-arid beef production In the semi-arid areas, rangeland energy and mineral supplies in the late wet and dry seasons are usually perceived as sufficient to support cattle production needs on pastoral systems [59, 60]. Thus, in community rangelands in semi-arid areas, cattle production efficiency is sometimes governed by nutrient availability, which is affected primarily by temperature and seasonal rainfall distribution [54]. The traditional cattle sector in Nigeria is characterized by low productivity due to seasonality of quantitative and qualitative feed shortages, which is arguably the most significant barrier to improving smallholder enterprise production and productivity [63, 64]. Permanent land damage is prevented through grazing on large expanse of land. The pastoralists use the approach to maximize spatial resource use by allowing soil rejuvenation. Negative consequences of seasonal fluctuations in feed supplies have not been adequately established on performance parameters of pasture cattle in the Guinea Savannah Zone of Nigeria. Such data is required for the development of effective feeding and disease prevention strategies. Cattle, for example, are susceptible to stomach discomfort due to a seasonal shift in food [64]. The changeover from a forage-based to a finishing diet strong in grain aids marbling in beef, but it also causes gastric distress. This may have a negative impact on their development. Similarly, seasonal variations in the quantity and quality of feed supplies have an impact on beef cattle performance and carcass quality [64, 65].

3.4 Assisted reproductive technologies in animal production

Assisted reproductive technologies (ART) are widely used in humans and animals in many parts of the world to expand our understanding of reproductive processes and to improve reproductive efficiency. Oestrus synchronization, artificial insemination (AI), multipleovulation and embryo transfer (MOET), in vitro fertilization (IVF), sex determination, cloning, and genetic engineering are some of the technologies used in animal production [66]. These are powerful technologies capable of enhancing productivity, and when combined with bioinformatics will provide more impact in the future of animal production [66]. The cow is typically monotocous with an average gestation length of 40 weeks and therefore a relatively long generation interval. The rate at which a highly desirable cow can be used to enhance the genetic state of a herd is slow if no interference is made [67]. Hence ARTs are particularly useful in this species because of the low reproductive rates and long generation intervals. In the cattle industry, ARTs were initially developed to increase the production of calves from parent cattle with high genetic potentials, but now offer many opportunities for beef and dairy cattle production.

3.4.1 Oestrus synchronization

Oestrous synchronization involves the application of pharmacologic means to control oestrus and ovulation in farm animals. As a result, female animals are forced to go through oestrus (ovulation) at a specified, opportune time rather than when it would naturally occur. In general, the procedures rely on either artificially inducing premature luteolysis with luteolytic drugs (e.g. prostaglandin F2 alpha or its analogues) or temporarily suppressing ovarian function with progestagens.

Synchronization offers several advantages and facilitates the maximal and batch managements of AI and calving in cattle herds, thereby increasing productivity and decreasing costs in dairy and beef cattle production [68].

Synchronization may have some benefits in beef herds, such as decreasing the calving to conception gap, and hence the calving interval and possibly the calving season. Accurate detection of oestrus is critical to achieving high pregnancy rates particularly in large cattle herds. Hence oestrous synchronization offers another strategy to circumvent the critical problem of oestrus detection [69].

3.4.2 Artificial insemination (AI)

Artificial insemination has been utilized worldwide for more than 50 years. It is still the predominant technology applied for the improvement of reproductive efficiency and productivity in cattle through progeny testing and genetic improvement [67]. AI is the introduction of live spermatozoa into the genital tract of the female to cause fertilization by means other than natural mating. Semen from bulls can be extended and preserved at 4–5°C for a few days or frozen in plastic straws in liquid nitrogen at −196°C for years or decades. Semen from a few high-performance bulls can then be used to breed large number of cows leading to rapid genetic improvement and dissemination of new breeds within cattle populations [65].

Movement of preserved semen instead of live bulls would also improve trade, reduce production cost and also decrease the spread of cattle diseases usually transmitted by direct contact between cattle. The use of AI also prevents the rearing of bulls that involve added cost along with the possibility of causing injury or death to farmers or staff. Controlling and recording the time of AI helps to avoid indiscriminate mating (often observed in natural mating), thereby facilitating proper farm recordkeeping and fertility management.

3.4.3 Multiple ovulation and embryo transfer (MOET)

MOET was first proposed in 1987, and it demonstrated how MOET programs may increase genetic gains by raising selection intensity and shortening generation intervals [70]. Multiple-ovulation (superovulation) is a pharmacologic procedure that increases the number of oocytes released at ovulation by 2 to 10 times, hence raising the quantity of embryos that can be produced. Embryo transfer (ET), on the other hand, refers to the techniques used to collect embryos from a female (donor) and transfer them into the uterus of another female (recipient) where they develop to term. Typically, a cow ovulates a single oocyte during each reproductive cycle, and therefore may produce only 8 to 12 calves in her reproductive lifetime. However, utilizing the technology for MOET, it is possible to obtain 30 to 40 calves from a single cow over a period of a year [71]. Through MOET, the numbers of imported highly valuable and scarce cattle breeds could be multiplied rapidly, leading to increased genetic improvement of cattle populations [72]. Highly valued cows that are injured or too old to carry normal pregnancy could also be made to continue producing calves via MOET, rather than these animals being culled or sold for slaughter. Natural twinning ranges from 1 to 2% in beef cattle, but the efficiency of beef production could also be increased in intensively managed farms by inducing twinning using MOET. This technology also offers commercial advantage to farmers via a lower cost of importation of cryopreserved embryos compared to live cattle [68].

3.4.4 In vitro fertilization (IVF)

In vitro fertilization (IVF) is a technology via which fertilization and maturation of oocytes takes place outside of the female (in the laboratory). The method is also called *in vitro* embryo production. The resulting embryos are then transferred back to the same or different females for development. Mature oocytes can be collected by flushing the oviducts shortly after ovulation. Alternatively, immature oocytes can be obtained from abattoir ovaries or by aspiration of pre-ovulatory follicles using ovum pick up (OPU) from live cows. These oocytes must be cultured *in vitro* for 24 hours in sterile medium to allow for nuclear maturation prior to fertilization. Following *in vitro* maturation of oocytes, spermatozoa must also be capacitated using a capacitation medium (or alternatively by using ejaculated sperm) before they are capable of fertilizing the oocyte [66]. The technology offers the potential for large numbers of *in vitro* produced embryos together with exciting opportunities for other technologies in cattle reproduction such as sex determination, cloning, genetic engineering and embryo transfer.

3.4.5 Sex determination

This technology is useful when calves of a particular sex are considered to be more valuable than those of the opposite sex. For instance, dairy farmers would desire that the majority of their calves be female (replacement heifers for the milking herd) whereas beef farmers would prefer bull calves for their higher body mass and beef production potential. Sex could be determined either by semen sexing or embryo sexing. The presence of Y chromosome determines male offspring in mammals. In cattle, the X-bearing sperm contain 3.8% more DNA than the Y-bearing sperm. Thus, sperm can be separated using specific dye (Hoechst 33342) that binds to DNA and a flow cytometer/cell sorter. Embryos can also be sexed using several techniques including chromosome analysis (karyotyping), immunology, DNA analysis and detection of metabolic differences [66]. Sexed semen could be applied in farms to inseminate cows in order to create necessary sex calves, or to fertilize oocytes in vitro in order to produce required sex embryos. Sexed embryos could likewise be implanted into recipient cows to create sex-matched calves [73].

3.4.6 Cloning and nuclear transfer

These technologies involve cloning by embryo splitting to produce identical twins, triplets and quadruplets or the use of nuclear transfer to produce large numbers of genetically-identical or cloned cattle. In the nuclear transfer technique, the nuclei from either a blastomere (from early-stage embryos) or a somatic cell (other body cells) are fused individually to enucleated oocytes. The resulting zygotes are then cultured and transferred to recipient cows to develop till term. Interestingly, this technique has attracted much international attention since 1996 when the first mammal (the sheep, Dolly) was cloned [74] followed later by cloning in cattle [75]. With cloning technology, it is possible to exceed pregnancy rates of 100% in cattle farms. It also offers the potential for producing large numbers of genetically-superior cattle to drive increased dairy and beef production [69]. For instance, it normally requires 78 months to reach production flock status in cows, but this can be achieved within 33 months with the nuclear transfer technology [67]. The success rate for propagating animals by nuclear transfer is expected to increase along with a reduction in the cost as newer methods are developed in the technology.

3.4.7 Genetic engineering

Transgenic livestock (pigs and sheep) were produced for the first time in 1985 [76]. This technology involves transferring a selected gene into an embryo so that the resulting offspring carry and express that gene later in life. Animals that carry a copy of a desired foreign gene are referred to as being transgenic [69, 77]. Generally, transgenic technologies utilize embryo-mediated or cell-mediated genetic modification to generate an entire animal. In recent years, new technologies referred to as "gene editing" have also been added to the molecular tool box for genetic engineering of various organisms. Efficient and robust protocols are now available for producing sheep, goats, pigs, cattle and other species in which specific genes have been targeted for editing [78].

The technology has been applied to improve different aspects of animal production. In cattle, these include the enhancement of milk quality, muscle yield, disease resistance (mastitis, tuberculosis), or improved welfare such as the production of hornless dairy cattle [77, 79, 80]. Nevertheless, the application of genetic engineering in livestock production has been limited by several significant factors. These include the cost of large animals, long generation times, and most importantly, legal, ethical and public health concerns and considerations [78]. However, it is likely some of the newer technologies involving gene editing will become more acceptable particularly in the face of the increasing global animal protein demands and food insecurity. Already, the first genetically engineered salmon has received approval to be sold as food by regulatory agencies in the US and Canada [81]. It is likely that other international agencies will begin to reconsider regulatory gridlocks on animal products from genetic engineering. In Africa, and particularly Nigeria, genetic engineering of bovine embryos may offer opportunities for the production of cattle that retain the genetic predisposition to hardiness, adaptation to the tropical environment (e.g. heat stress) and tolerance to tropical diseases (e.g. trypanosomosis) while incorporating genetic potential for rapid growth and increased milk and beef production [82].

4. Main abnormalities observed as post-transfer consequences of bovine *in vitro*-produced (IVP) embryos in some breeds of cattle

4.1 Holstein x beef breeds

In Holstein x beef breeds, main abnormalities observed include problem of increased loss of embryos in Grade 2 IVP embryos, increased fetal size, increased fetal body weight in IVP, no placentomes in IVP [6]; increased birth weight, increased percentage dystocia, increased mortality in IVP in Holstein; Holstein x Angus cross-breeds [83]; increased birth weight and oversized calves at birth in IVP, increased percentage dystocia, increased heart weight at 13 months in IVP frozen in Simmental bulls [84]; increased percentage males, increased gestation length, increased percentage congenital malformations, increased birth weight, increased perinatal mortality and calving difficulty (all in IVP) in Holstein Friesian breed [85]; decreased pregnancy rates, increased percentage males, increased spontaneous abortion, increased birth weight, increased dystocia, increased calf mortality, increased abnormalities of the fetus and reduced intensity of labour in recipients (all in IVP) and removal of serum did not correct abnormalities in Holstein breed [3]; increased *IGF2* expression, increased dystocia and increased mortality in IVP in Holstein breed [86]; decreased fetal size in early pregnancy, decreased number of cotyledons, increased cotyledon size, increased birth weight in Angus; Angus x

Hereford cross-breeds [87] increased expression of genes (Heat shock protein family A (Hsp70) member 1A (HSP70.1), Sodium dimustase (Cu/Zn-SOD), Glucose transporter type 3 (GLUT3), Glucose transporter type43 (GLUT4), Basic fibroblast growth factor (bFGF), Insulin-like growth factor 1 receptor (IGF1R)) in blastocysts and increased calf birth weight in Holstein-Friesian breed [88].

5. Latching the lacuna

Technology adoption and transfer have been major problems in developing countries owing to so many reasons. Principal among them is lack of technical know-how, poor or near absence of funding, diversion of released funds for specific projects/corruption and weak agricultural extension agents who are either unaware of recent findings or who reluctantly refuse to diffuse information from research institutes to farmers.

ART in Nigeria should be given a linear but additive approach starting with AI which is the oldest and most pliable form of it. This can be combined with sperm sexing in the long run. Individuals and corporate bodies san train manpower on semen collection, estrous synchronization and artificial insemination. Reproductive physiologists should brace up for the challenge in this field.

Nigerian is blessed with tropical herbs which are used in unorthodox medicines by herbalists. Some of these herbs have proven to be potent in managing pregnancies and parturitions in humans. The same crude technology can be extended to N'dama and Muturu. In humans, pregnancies that exceed forty weeks without labour and parturition are managed with these herbs to prevent the fetus from becoming overfat so that labour and normal vaginal delivery will set in a short time. This will be averted if the gravid woman was placed on these herbs as a routine during the course of the pregnancy. These two breeds became animals of choice due to their resistance to trypanosomosis which has made it possible for them to thrive where other breeds have failed to thrive without inoculation against trypanosomosis. Pregnancy complications arising from using say Holstein Friesian semen to upgrade the duo will be managed with these tropical herbs which abound in Nigeria. This will open up new frontiers in research on cattle which may help to solve some of the problems outlined in Section 2.4 of this work.

6. Conclusions

It is worthy of note that the cattle population in Nigeria of above 18 million may appear false and misleading as it was not captured in the FAS/USDA 2021 ranking of countries with the most cattle. If the figure were true, Nigeria would have come displaced Russia to rank 8th in the list of countries.

Assisted reproductive technologies will not only bridge the gap in meat and milk consumption of Nigerians but it will open up a goldmine which will reduce the unemployment rate in this region. This technology undoubtedly will start in Nigeria and spread to neighboring countries in Africa.

Cattle production in Nigeria, which hitherto was business of the North will become a smooth running business in the South if N'dama and Muturu which have adapted to the more humid and disease-tolerant southern climate are improved upon using the ARTs. This will go a long way to improve the economy of Nigeria and equally mitigate the farmers-herders crisis which has consumed so many lives and properties. Above all, it well help Nigeria to attain self-sufficiency in meat production in the near future, become an exporter of beef and dairy products.

Conflict of interest

The authors do not declare any conflict of interest.

Author details

Cornelius Nwoga, Nnanna Ikeh, Matthew Onodugo, Paul Baiyeri
and Ndubuisi Machebe*
University of Nigeria, Enugu, Nigeria

*Address all correspondence to: ndubuisi.machebe@unn.edu.ng

References

[1] Adamson GD, de Mouzon J, Chambers GM, Zegers-Hochschild F., Mansour R, Ishihara O, Banker M, Dyer S. International Committee for Monitoring Assisted Reproductive Technology: world report on assisted reproductive technology, Fertil. Steril. 2011;110:1067-1080. DOI:10.1016/J.FERTNSTERT.2018.06.039.

[2] Viana JHM, Vargas MSB, Siqueira LGB, Camargo LSA, Figueiredo ACS, Fernandes CAC, Palhao MP. Efficacy of induction of luteolysis in superovulated cows is dependent on time of prostaglandin F2alpha analog treatment: effects on plasma progesterone and luteinizing hormone profiles. Theriogenology. 2016;86:934-939. DOI:10.1016/J.THERIOGENOLOGY.2016.03.016

[3] Hasler JF. In-vitro production of cattle embryos: problems with pregnancies and parturition. Hum. Reprod. 2000;15: 47-58. DOI:10.1093/HUMREP/15.SUPPL_5.47 3-5.

[4] Pontes JHF, Nonato-Junior I, Sanches BV, Ereno-Junior JC, Uvo S, Barreiros TRR, Oliveira JA, Hasler JF, Seneda MM. Comparison of embryo yield and pregnancy rate between in vivo and in vitro methods in the same Nelore (*Bos indicus*) donor cows. Theriogenology. 2009;71:690-697. DOI:10.1016/J.THERIOGENOLOGY.2008.09.031

[5] Siqueira LGB, Torres CAA, Souza ED, Monteiro PLJJ,r Arashiro EKN, Camargo LSA, Fernandes CAC, Viana JHM. Pregnancy rates and corpus luteum-related factors affecting pregnancy establishment in bovine recipients synchronized for fixed-time embryo transfer. Theriogenology. 2009;72:949-958. DOI:10.1016/ J.THERIOGENOLOGY.2009.06.013.

[6] Farin PW, Farin CE. Transfer of bovine embryos produced in vivo or in vitro: survival and fetal development. Biol. Reprod. 1995;52:676-682. DOI:10.1095/BIOLREPROD52.3.676

[7] Wang JX, Norman RJ, Wilcox AJ. Incidence of spontaneous abortion among pregnancies produced by assisted reproductive technology. Hum. Reprod. 2004;1:, 272-277. DOI:10.1093/HUMREP/DEH078

[8] Pohler KG, Pereira MHC, Lopes FR, Lawrence JC, Keisler DH, Smith MF, Vasconcelos JLM, Green JA. Circulating concentrations of bovine pregnancy-associated glycoproteins and late embryonic mortality in lactating dairy herds. J. Dairy Sci. 2016;99 1584-1594. DOI:10.3168/JDS.2015-10192

[9] Sartori R, Prata AB, Figueiredo ACS, Sanches BV, Pontes GCS, Viana JHM, Pontes JH, Vasconcelos JLM, Pereira MHC, Dode MAN, Monteiro PLJJr, Baruselli PS. Update and overview of assisted reproductive technologies (ARTs) in Brazil. Anim. Reprod. 2016;13: 300-312. DOI:10.21451/1984-3143-AR873

[10] Bonilla L, Block J, Denicol AC, Hansen PJ. Consequences of transfer of an in vitro-produced embryo for the dam and resultant calf. J. Dairy Sci. 2014;97, 229-239. DOI:10.3168/JDS.2013-6943

[11] Chen Z, Robbins KM, Wells KD, Rivera RM. Large offspring syndrome: a bovine model for the human loss-of-imprinting overgrowth syndrome Beckwith–Wiedemann. Epigenetics. 2013;8:591-601. DOI:10.4161/EPI.24655

[12] Siqueira LGB, Dikmen S, Ortega MS, Hansen PJ. Postnatal phenotype of dairy cows is altered by in vitro embryo production using reverse X-sorted semen. J. Dairy Sci. 2017a;100:

5899-5908. DOI:10.3168/JDS.2016-12539

[13] Chen Z, Hagen DE, Elsik CG, Ji T, Morris CJ, Moon LE, Rivera RM. Characterization of global loss of imprinting in fetal overgrowth syndrome induced by assisted reproduction. Proc. Natl Acad. Sci. USA. 2015;112:4618-4623. DOI:10.1073/PNAS.1422088112

[14] Food and Agriculture Organization of the United Nations FAOstat [Internet]. 2018. Available from: http://www.fao.org/faostat.[Accessed: 2021-2105-01].

[15] RIM. Nigerian national livestock resource survey (IV). Report by resource inventory and management limited to FDL and PCS, Abuja, Nigeria. 1992

[16] National Agricultural Sample Survey (NASS). National Bureau of Statistics/Federal Ministry of Agriculture and Rural Development Collaborative Survey on National Agriculture Sample Survey (NASS), 2010/2011. 2011.

[17] Commonwealth Scientific and Industrial research Organization (CSIRO) [Internet]. 2020. Available from: https://research.csiro.au/livegaps/wp-content/uploads/sites/37/2020/Nigeria-dairy-production-factsheet-Jan-2020.pdf [Accessed: 2021-2105-01].

[18] Agricultural Policy for Nigeria. Federal Ministry of Agriculture, Water Resources and Rural Development, Lagos. 1989

[19] Oguejiofor CF. Prospects in the utilization of assited reproductive technologies (ART) towards improved cattle production in Nigeria. Nig. J. anim. Prod. 2019;46:5, 73-80.

[20] Saleh MK, Atala TK, Omokore DF, Ahmed B, Ali FS, Kajang GY. Performance o f improved dairy cattle technologies among farmers in northern Nigeria. Journal of Agricultural Extension. 2016;20:1.

[21] Blench RM. Ethnographic and linguistic evidence for the prehistory of African ruminant livestock, horses and ponies. The Archaeology of African Food, Metals and Towns; 1993. 71-103p.

[22] Meghen C, MacHugh DE, Sauveroche B, Kana G, Bradley DG. Characterization of the Kuri Cattle of Lake Chad using Molecular Genetic Techniques. In R. M. Blench and K.C. MacDonald (Ed.) The origin and development of African livestock. University College Press, London; 1999. 28 – 86p.

[23] Nigerian National Livestock Resource Survey (NNLRS); 1990. 627 – 649p.

[24] Alphonsus C, Akpa GN, Barje PP, Finangwai HI, Adamu BD. Comparative evaluation of linear udder and body conformation traits of bunaji and friesian x bunaji cows. World Journal of Life Science and Medical Research. 2012;2:4, 134-140.

[25] Payne WJA, Wilson RT. Animal husbandry in the tropics, 5th edt. Blackwell Science, Oxford, UK; 1999.

[26] Katie T, Alistair F. The complete book of raising livestock and poultry-A small holder's guide. University Services Ltd., Yaba Lagos; 1986.

[27] Williamson G, Payne WJA. An introduction to animal husbandry in the tropics. Longman Group, London; 1990.

[28] Gates GM. Breeds of cattle found in Nigeria. Farm and Forest. 1952;11: 19-43.

[29] Babayemi OJ, Abu OA, Opakunbi A. Integrated animal husbandry for schools and colleges, First edition. Positive Press Ibadan, Nigeria; 2014. 20 – 122p.

[30] Blench RM, De Jode A, Gherzi E, Di Domenico C. Keteku and Ndama crossbred cattle in Nigeria: History, distribution and productivity. In C. Seignobos and E. ThysParis (Ed.) Des Taurins au Cameroun et Nigeria.: ORSTOM/IEMVT, Maisons-Alfort; 1998. 293-310p.

[31] International Livestock Centre for Africa (ILCA). Trypanotolerant livestock in West and Central Africa. Addis Ababa. ILCA Monograph. 1979;2:2, 241-340.

[32] Ngere LO. The Gudali of Nigeria—review. In Animal genetic resources in Africa: high potential and endangered livestock. Second OAU expert committee meeting on animal genetic resources in Africa, Bulawyayo, Zimbabwe, OAU, Nairobi, Kenya; 1983. P. 77-81.

[33] Akinwumi JA, Ikpi AE. Trypanotolerant cattle production in Southern Nigeria. Report to ILCA Humid Programme, Ibadan; 1985. 101 – 258p.

[34] Akpa GN, Alphonsus C, Abdulkareem A. Evaluation of herd structure of white Fulani cattle holdings in Zaria, Nigeria. Scientific Research and Essays. 2012;7:42, 3605-3608.

[35] Starkey PH. N'Dama cattle – a productive trypanotolerant breed. World Animal Review. 1984;50: 2-15.

[36] Iro IS. Fulani herding system. Data analyst in Washington, DC. USA; 2009.

[37] Foreign Agricultural Service/United States Department of Agriculture. Ranking of countries with the most cattle. Retrieved on 20/08/2021 from www.beefmarketcentral.com/story-world-cattle-inventory-ranking-countries-146-106905; 2021.

[38] United States Department of Agriculture National Agricultural Statistics Service. Census of Agriculture. Retrieved on 20/08/2021 from www.nass.usda.gov/Publications/AgCensus/2017/index.php

[39] FAST FACTS. Canada's beef industry-average herd per farm. Retrieved on 20/08/2021 from www.cattle.ca/assets/8562411068/CBIfastfactsENGAug3b-WEB.pdf; 2016.

[40] Kubkomawa HI. Indigenous breeds of cattle, their productivity, economic and cultural values in sub-saharan Africa: A Review. International Journal of Research Studies in Agricultural Sciences. 2017; 3: 1, 27-43. DOI: http://dx.doi.org/10.20431/2454-6224.0301004

[41] Cunnings I. Baggara Arabs. Oxford University Press, London; 1966.

[42] Iro IS. The Fulani herding system. African Development Foundation, Washington; 1994.

[43] Adisa RS, Badmos AHA. Socioeconomic correlates of perceptions of sustainability of pastoral livelihood among cattle herdsmen in Kwara state, Nigeria. Agrosearch. 2009;10:1and2, 21-30.

[44] Okoli IC, Enyinnia NC, Elijah AG, Omede AA, Unamba-Opara CI. Animal reproductive management practices of Fulani pastoralists in the humid rain forest of Imo State, Nigeria. Journal of Animal Science Advances. 2012;2:2, 221-225.

[45] Usman H, Nasiru M. Commodity chain analysis of cattle marketing in Nigeria; A case study of K.R.I.P area Kano state. A report submitted to ADENI project/NAERLS Zaria, Nigeria; 2005.

[46] Mbap ST. A note on heritability estimates of birth weight and calving interval of white Fulani cattle. Nigerian

Journal of Animal Production. 1996;23:122, 101-102.

[47] Whitley E. Cow café: The importance of breeding soundness examination [Internet]. 2008. Available from http://www.cattlenetwork.com [Accessed: 2016-2107-02].

[48] Newman JA, Thompson WA, Penning PD, Mayes RW. Least-squares estimation of diet composition-from nalkanes in herbage and feces using matrix mathematics. Australian Journal of Agric. Res. 1990;46:793-805

[49] Okoli IC, Ebere CS, Emenalom OO, Uchegbu MC, Esonu BO. Indigenous livestock production paradigms revisited. 111: An assessment of the proximate values of most preferred indigenous browses of Southeastern Nigeria. Anim. Prod. Invest. 2001;4:99-107.

[50] Mapiye C, Chimonyo M, Dzama K. Seasonal dynamics, production potential and efficiency of cattle in the sweet and sour communal rangelands in South Africa. Journal of Arid Environ. 2009;73:4, 529-536.

[51] Nqeno N, Chimonyo M, Mapiye C, Marufu MC. Ovarian activity, conception and pregnancy patterns of cows in the semi-arid communal rangelands in the Eastern Cape Province of South Africa. Anim. Reprod. Sci. 2009;23:18-48.

[52] du Plessis I, Hoffman LC. Effect of chronological age of beef steers of different maturity types on their growth and carcass characteristics when finished on natural pastures in the arid sub-tropics of South Africa. South African Journal of Animal Science. 2004;34:1, 1-12.

[53] Synge B. Factors limiting cattle productivity in highland areas of Nigeria. Centre for Tropical Veterinary Medicine, Easter Bush, Roslin, Midiothian, Scotland; 1980.

[54] Ologun AG. Seasonal and breeding variations in birth weight and age at first calving of exotic, local and crossbred cattle in a Tropical environment. Journal Anim. Sci. 1980;5:1, 151-153.

[55] Angassa A, Oba G. Relating long-term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in southern Ethiopia. Agric. Syst. 2007;94:715-725.

[56] Ndlovu T, Chimonyo M, Muchenje V. Monthly changes in body condition scores and internal parasite prevalence in Nguni, bonsmara and Angus steers raised on sweet veld. Trop. Anim. Health Prod. 2009;41:7, 1169-1177.

[57] Blezinger BS. Age at puberty and scrotal circumference are important factors for bull selection. In cattle today. USA, Kansas Publishers limited; 2008.

[58] Devendra C, Sevilla CC. Availability and use of feed resources in crop-animal systems in Asia. Agric. Syst. 2002;71: 1-2,59-73.

[59] Tainton NM. Veld management in South Africa. University of Natal Press, Pietermaritzburg, South Africa; 1999.

[60] Chimonyo M, Kusina NT, Hamudikuwanda H, Nyoni O. Effect of work stress and supplementary feeding on body conformation, ovary activity and blood parameters in a smallholder farming system. Asian-Australian Journal of Animal Science. 2000;13: 8,1054-8,1058.

[61] Poppi DP, McLennan SJ. Protein and energy utilization by ruminants at pasture. Journal of Animal Science. 1995;73:278-290.

[62] Shabi Z, Arieli A, Bruckental I, Aharoni Y, Zamwel S, Bor A, Tagari H. Effect of the synchronization of the degradation of dietary crude protein

and organic matter and feeding frequency on ruminal fermentation and flow of digesta in the abomasum of dairy cows. Journal of Dairy Sci. 1998;81:1991-2000.

[63] DelCurto T, Hess BW, Huston JE, Olson KC. Optimum supplementation strategies for beef cattle consuming low-quality roughages. Journal of Animal Science. 2000;77:1-16.

[64] Olaloku EA, Debre S. Research priorities for the development of appropriate feeding systems for dairy production in sub-saharan Africa. In J. E. S. Stares, A. N. Said and J. A. Kategile (Ed) The complementarity of feed resources for animal production in Africa. Proceedings of the Joint Feed Resources Networks Workshop held in Gaborone, Botswana, 4th to 8th March 1991.African Feed Research Network. ILCA, Addis Ababa, Ethiopia; 1992 p. 399.

[65] Barje PP, Adebayo JH, Lamidi OS. Comparative evaluation of groundnut haulms and lablab (lablab purpureus) as dry season supplements for lactating cows and their calves under smallholder peri-urban dairy production in Nigeria. Savannah Journal of Agriculture. 2011;6:2,1-2,5.

[66] Ball PJ, Peters AR. Reproductive biotechnologies. In: Reproduction in cattle. Third ed. Oxford, UK: Blackwell Publishing Ltd.; 2004 191-214 p.

[67] Sejian V, Meenambigai TV, Chandirasegaran M, Naqvi SMK. Reproductive technology in farm animals: new facets and findings: a review. Journal of Biological Sciences. 2010;10:686-700.

[68] Chakravarthi PV, Sri Balaji N. Use of assisted reproductive technologies for livestock development. Veterinary World. 2010;3:238-240.

[69] Pineda MH. Embryo transfer in domestic animals. In: Pineda, M. H. (ed.) McDonald's Veterinary Endocrinology and Reproduction. Fifth ed. Ames, Iowa, USA: Iowa State Press; 2003. 547-571 p.

[70] Paul AK, Yoisungnern T, Bunaparte N. Hormonal treatment and estrous synchronization in cows: A minireview. Journal of Advanced Veterinary and Animal Research. 201;2:10-17.

[71] Smith C. Genetic improvement of livestock using nucleus breeding units. World Animal Review. 1988; 65:2-10.

[72] Thomasen JR, Willam A, Egger-Danner C. Sørensen AC. Reproductive technologies combine well with genomic selection in dairy breeding programs. Journal of Dairy Science. 2016;99:1331-1340.

[73] Pellegrino CA, Morotti F, Untura RM, Pontes JH, Pellegrino M., Campolina JP, Seneda MM, Barbosa FA, Henry M. Use of sexed sorted semen or fixed-time artificial insemination or fixed-time embryo transfer of in vitro-produced embryos in cattle. Theriogenology. 2016;86:888-893.

[74] Wilmut I, Schnieke AE, McWhir J, Kind AJ, Campbell KH. Viable offspring derived from fetal and adult mammalian cells. Nature. 1997;385:810-813.

[75] Kato Y, Tani T, Sotomaru Y, Kurokawa K, Kato J, Doguchi H, Yasue H, Tsunoda Y. Eight calves cloned from somatic cells of a single adult. Science. 1998;282:2095-2098.

[76] Hammer RE, Pursel VG, Rexroad CEJr, Wall RJ, Bolt DJ, Ebert KM, Palmiter RD, Brinster RL. Production of transgenic rabbits, sheep and pigs by microinjection. Nature. 1985;315:680-683.

[77] Carlson DF, Lancto CA. Production of hornless dairy cattle from genome-edited cell lines. Nature Biotechnology. 2016;34:479-482.

[78] Laible G. Production of transgenic livestock: overview of transgenic technologies. In: Niemann, H., Wrenzycki, C. (eds.) Animal Biotechnology 2. Springer, Cham; 2018.

[79] Wu H, Wang Y, Zhang Y, Yang M, Lv J, Liu J, Zhang Y. TALE nickase-mediated SP110 knockin endows cattle with increased resistance to tuberculosis. Proceedings of the National Academy of Sciences of the USA, 112:E1530-E1539; 2015.

[80] Van Eenennaam AL. Genetic modification of food animals. Current Opinion in Biotechnology. 2017; 44:27-34.

[81] Waltz E. First genetically engineered salmon sold in Canada. Nature. 2017; 548:148.

[82] Mwai O, Hanotte O, Kwon Y-J, Cho S. African indigenous cattle: unique genetic resources in a rapidly changing world. Asian Australasian Journal of Animal Science. 2015;28:911-921.

[83] Behboodi E, Anderson GB, BonDurant RH, Cargill SL, Kreuscher BR, Medrano JF, Murray JD. Birth of large calves that developed from in vitro-derived bovine embryos. Theriogenology. 1995;44:227-232. Doi:10.1016/0093-691X(95)00172-5

[84] McEvoy TG, Sinclair KD, Broadbent PJ, Goodhand KL, Robinson JJ. Post-natal growth and development of Simmental calves derived from in vivo or in vitro embryos. Reprod. Fertil. Dev. 1998;10:459-464. DOI:10.1071/RD98126

[85] van Wagtendonk-de Leeuw AM, Aerts BJ, den Daas JH. Abnormal offspring following in vitro production of bovine preimplantation embryos: a field study. Theriogenology. 1998;49:883-894. DOI:10.1016/S0093-691X(98)00038-7

[86] Blondin P, Farin, PW, Crosier AE, Alexander JE, Farin CE. In vitro production of embryos alters levels of insulin-like growth factor-II messenger ribonucleic acid in bovine fetuses 63 days after transfer. Biol. Reprod. 2000;62:384-389. DOI:10.1095/BIOLREPROD62.2.384

[87] Bertolini M, Mason JB, Beam SW, Carneiro GF, Sween ML, Kominek DJ, Moyer AL, Famula TR, Sainz RD, Anderson GB. Morphology and morphometry of in vivo- and in vitroproduced bovine concepti from early pregnancy to term and association with high birth weights. Theriogenology. 2002b;58:973-994. DOI:10.1016/S0093-691X(02)00935-4

[88] Lazzari G, Wrenzycki C, Herrmann D, Duchi R, Kruip T, Niemann H, Galli C. Cellular and molecular deviations in bovine in vitro-produced embryos are related to the large offspring syndrome. Biol. Reprod. 2002;67:767-775. DOI:10.1095/BIOLREPROD.102.004481