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Breeding and genetic improvement of Nigeria indigenous cattle: The pitfalls and potential use of post genomic era technologies for national dairy development

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Abstract

Cattle are one of the most important livestock species in Nigeria because they provide multiple services to farmers and contributes to the national economy. In order to advance the benefits of cattle production, there are several breeding and genetic improvement programmes which have been implemented to enhance productivity of the indigenous cattle and pastoral livelihoods. However, after about 100 years of breeding and genetic improvement programmes, Nigeria still struggles to derive expected benefits from cattle production. Hence, this study was carried out to analyse previous cattle breeding and genetic improvement programmes in Nigeria to identify their successes and pitfalls as well as potential roles of post genomics technologies for advancing cattle production. The study identified optimization of indigenous cattle for meat and milk production as the main objective of the previous breeding and genetic improvement programmes; unfortunately, major pitfalls of the programmes are unrealistic breeding objectives and inadequate relevant stakeholder involvement. Furthermore, during their heydays, some of the programmes were successful, popular, and exemplary; but the shortcomings in planning and execution contributed to their failures. After analysis of 9 regional and national cattle breeding and genetic improvement programmes implemented in Nigeria, for cattle breeding and genetic improvement programmes in Nigeria to be among the league of successful similar programmes around the world, there is a need to consider genomic selection of cattle for genetic improvement. Also, the study suggested the need for collaborative networks among scientists, ranchers, breeders associations, smallholder farmers, institutions, biotechnology companies, government ministries, departments, agencies; and non-governmental organizations operating in the domain of cattle breeding, genetics, reproduction and production for advancement of cattle breeding and genetic improvement programmes in Nigeria.

Keywords

breeding strategies, genetic improvement, indigenous cattle, dairy development

Introduction

The increase in population and climate change pressure are factors associated with limiting cattle production in developing countries including Nigeria (Hassan et al., 2019). The increase in population on one hand is continuously increasing the demand and creating supply deficit, while climate change on the other hand is limiting the productivity due to increasing incidence of pest and diseases, and recently, the loss of lives and properties due to clashes between herders and crop farmers over the use of land and water resources (Sikiru, 2020). Meanwhile, the cattle production system in these countries is not robust enough to overcome these challenges since the production system is smallholder and low external inputs operated (Omotilewa et al., 2021). Hence, for effective contribution of cattle to food security, there is a need for research focusing on breeding and reproduction using modern genomic and reproduction technologies to hasten the processes of the breeding and reporudction (Greenwood, 2021).

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The primary aim of smallholders operating low external input operations is herd survival; hence, the application of modern technologies such as genomic selection, artificial insemination and supplemental feeding practices could enhanced productivity. For instance, the implementation of genomic selection does not require detailed pedigree data for estimating breeding values which could be exploited as an avenue for overcoming the difficulty of effective phenotype recording. However, modern technologies required for improving livestock productivity are not easily in place in the developing countries, even at the research level, because most decision-makers are not always sharing views of allocating adequate resources towards such targets. Therefore, this give report on outcome of past breeding efforts appraisal in Nigeria for the purpose of charting out potential favourable impacts of adoptingmodern practices of genomic selection, breeding and reproduction technologies for improving productivity of cattle in Nigeria.

The importance, challenges, and impact of cattle production on food insecurity in Nigeria

Cattle are one of the most important livestock in Nigeria because they are a major source of protein (meat and milk), and also contribute indirectly to crop production as a source of farm power in land preparation and generation of manure for soil fertility improvement (Adegbeye et al., 2020). Despite these, cattle production has not been contributing optimal economic benefits largely because the production system rely heavily on the indigenous cattle breeds which are less productive and fall short of expected economic contributions for national development – a situation which justified their improvement (Kosgey & Okeyo, 2007). Upon this background, several attempts have been made to improve the genetics and or production systems of the indigenous cattle not only in Nigeria but across the entire West Africa (Marino, 2017). However, the major problem of breeding and improvement programmes of indigenous breeds of cattle remain the inability to define achievable breeding objectives (Ouédraogo et al., 2021).

Nigeria has one of the largest cattle population in Africa, although coming 5th after Ethiopia, Sudan, Chad, and Tanzania (Tekleghiorghis *et al*., 2016). The population of cattle in Nigeria is approximately 20.5 million, which are kept primarily for meat and milk supply as well as being uses as draught animals and for manure production used in the cultivation of crops (Wood & Johnson, 2015). In the past, cattle were mostly distributed in the northern parts of Nigeria but due to nomadic extensive grazing, cattle are now found virtually in every part of the country (Mwai et al., 2015). The population of cattle in Nigeria is dominated by the indigenous breeds accounting for 99% of the entire cattle population (Mwai et al., 2015). The indigenous breeds are kept for meat and milk, while the few exotic breeds including Holstein, Brown Swiss, Jersey and their crosses with the indigenous breeds are usually kept for milk production – a situation which makes milk production and trading in Nigeria an import-driven activity (Silanikove & Koluman, 2015).

The system of cattle production in Nigeria is low external input and pasture-based; although, this holds a great promise for promotion of food security and poverty alleviation in developing countries including Nigeria; because, it is the most suitable form of production for smallholders of the developing countries including Nigeria (Leroy et al., 2018). Furthermore, apart from the suitability of low external input for smallholders, it is also suitable for driving the national dairy development programmes via crossbreeding of indigenous and exotic breeds. However, lack of applying modern technologies such as genomic selection, breeding, and reproduction technologies such as artificial insemination under low external input production system are critical factors that can be linked to sub-optimal contribution of low external input cattle operations. There are also paucity of data on research using these technologies with focus on low external input cattle production system, and this justifies the need for such studies under pasture-based system in Nigeria (Marshall et al., 2019).

The production of cattle in Nigeria still thrives under primitive system and precarious farmers-herders clashes usually fuelled by deficient political leadership, ethno-religious misperceptions, budgetary constraints, and widespread insecurity which are all hindering progress of livestock production in the country (ICG, 2021). Predominant pastoralists are migratory livestock owners practicing extensive open grazing which are the main predisposing factors promoting food insecurity and rural poverty. Furthermore, challenges of cattle and livestock production in Nigeria at inventorial order include poor markets and marketing of live animals and animals' products, pests and diseases, lack of access to land and poor land use, lack of capital for operating of modernized cattle production, inadequate infrastructure, poor governmental policies and climate change (Nwosu & Ogbu, 2011; Okpeku et al., 2019). The challenges have left livestock production as a source of crisis and violence crippling the contribution of livestock which had previously accounted for one third of the Nigeria's agricultural GDP, providing income, employment, food, farm energy, manure, fuel and transport, and major source of state revenue (Nuru, 1984; Sikiru, 2020).

An overview of dairy production and market outlook in Nigeria

The gross production value of cow milk in Nigeria was valued at 73 million USD as of the year 2016 (CSIRO, 2020); more than 90% of the total annual milk production in the country is from the indigenous breeds of cattle under low external input characterized by low yield, pastoral, and unorganized informal production system and value chains (Bijman et al., 2016). Similarly, the economic and trading outlook of dairy production and its related ancillary activities can also be regarded as poorly organized and promoted (Miller & Lu, 2019). Although, the market for

milk and dairy products in Nigeria is huge, at the current demand; the market size is about 1.45 billion litres of milk per year while only about 0.5 million metric tons is produced locally by the indigenous cattle (Taye et al., 2017). This ranked Nigeria at the bottom among the League of Nations based on per capita milk consumption. The import-driven nature of the dairy industry, coupled with the worsening value of the Naira are also reducing the capacity of consumers to buy imported milk and milk products. Therefore, the Nigeria's dairy production and trading is import driven and import dependent which is currently making milk consumption to be out of reach of majority of the population.

The traditional meat-milk production system thrives on extensive natural grassland whereby cattle are being kept in large herds for the supply of meat and milk (Andualem, 2016). Although, the system is traditional, it is however, being operated in adaptation to prevailing agro ecological conditions of the areas where the animals are located. This is because of disparities in the production and management systems between the north and central-south of the country. In the northern parts (Sahel, Semi-Arid, and Arid agro ecologies), the system of production is mostly nomadic pastoral operations; while in the central and southern parts (Tropical rainforest, Derived savannah and Woodland agro ecologies), the system in practice is usually agro-pastoral operations (Phocas et al., 2016). In the north, the system is purely pastoralism and migratory movement of animals; but in the central and south, the system of production is agro-pastoralism which is a mix of pastoralism and crops cultivation whereby livestock keepers are relatively settled migrants who in addition to rearing of animals, also engage in cultivation of staple foods (maize, millet, sorghum, cowpea, yam, and cassava) for their households while excess are sold at local markets (Newell *et al*., 2019). Despite differences in the activities engaged in by the traditional meat-milk cattle producers in the north and central-south Nigeria, the system of production is characterized by open extensive grazing on natural pastures, communal land use, and supplementing cattle with crop residues during the dry season. Also, the milk and other dairy products under these systems are primarily aimed for household consumption while excess produce are being offered for sale at the community markets. Apart from these systems of traditional production of milk and other dairy products, there is an investment-driven family improved and specialized system of dairy cattle production.

The family improved and specialized dairy production system on the other hand is an investment-driven operation compared with the traditional meat-milk operations; under the system (family improved and specialized dairy production), cattle production involves imported exotic cattle and or the crosses of the exotic and indigenous breeds. These are characterized usually by cattle numbering between 50 (small) and 1000 heads, (large) herds. The majority of these cattle (80%) are found on farms in the central parts of Nigeria especially in commercial farms located in Abuja, Nassarawa, Kwara, Plateau and Niger states; while others are found across the remaining states in the countrys such as Ogun, Oyo, and Kano states . Milk produced by farms operating this production system is usually offered for sale to modular and big milk processors in the country – hence, these dairy farms are run on formal value chains with organized stakeholders.

However, pastoralism still account for the largest percentage (95%) of local milk supply in Nigeria; while a minute percentage (5%) of milk supply is being sourced from the specialized commercial dairy farms. In contrast, the milk produced by the pastoralists is consumed basically by the pastoral households, or are being offered for sale at local markets through informal value chains compared with the specialized commercial dairy farms that supply to the formal dairy value chain – a situation limiting maximum derivation of the economic benefits of the dairy industry. Meanwhile, the potential of the unexploited dairy market in Nigeria is huge because, apart from the industrial-processed milk, milk products are highly consumed foods in the country. Traditionally, local dairy products including sour milk, yoghurt, milk, butter and cheese are always highly demanded foods. Also, the increasing economic status of the ever growing Nigerian middle class is opening up urban and peri-urban markets as emerging oppourtunities for dairy products. So, the demand for milk and milk products is higher than the local supply, making the Nigerian dairy industry to be imported-driven and import-dependant – a situation, making consumption of milk and milk products unaffordable due to high prices pegging per capita milk intake of the country between 20 and 25 litres per annum. This per capita milk consumption is too low when compared with the World Health Organisation (WHO) recommendation of 210 litres per person per annum, and the Africa's average of 40 litres per person per annum.

Unfortunately, the cattle production system in Nigeria has not been fully exploited to take advantages of oppourtunities in the dairy industry. The leading reported factor contributing to the problem is the predominant use of unimproved indigenous cattle breeds for milk production. Although, the indigenous cattle are tolerant and well adapted to the local climatic conditions, but the milk productivity of these breeds is very poor producing a meagre 1.6 litre of milk per day. The production system is also characterised by the use of low external input and non-dedication of cows as dairy animals. While there are few pure exotic breeds of cattle in the country dedicated to milk production, the exotic breed performance is low compared with their production performances in their homeland – a situation which can be attributed to environmental variations between Nigeria and the countries of their origin. For example, the best average milk yield of exotic cattle most adapted to Nigeria climate is 30 litres and the cost of providing facilities for such yield is almost always not economical, and not sustainable. There are many factors identified as contributors to these challenges which include predominant use of indigenous cattle breeds, poor nutritional management of the cattle, incidence of pest and diseases, poor reproduction and breeding performances, and genetic background of the cattle.

Analyses of previous breeding and genetic improvement programmes of Nigeria's indigenous cattle: The successes and pitfalls

The Nigerian indigenous cattle are reservoir of genetic resources because they are better adapted to the local climate conditions compared with their exotic counterparts, which is the basis for their genetic exploitations for efficient performances and productivity. Attempts made to exploit the breeds have led to different breeding and improvement programmes implemented in the country for close to a century, including both the documented and undocumented ones (Table 1). However, there is scarce information on the historical and socio-economic outcomes of some of the breeding programmes for the genetic transformation of the indigenous breeds. The few reports which could be regarded as near success and of little impactful ones were those implemented in the early years of the post - colonial era. Some of the breeding for genetic improvement during the period led to the early observation that upgrading of the genetics of indigenous breeds of cattle beyond 75% with the genetics of the high performing Holstein Freisian is not economically justified, leading to pegging of the use of the gene pool of the Holstein Friesian in crosses with the White Fulani at 50%; this report was obtained from a case study of 260 days lactation by Nuru & Buvanendran (1985).

Furthermore, Nigeria's indigenous cattle were identified to be highly responsive in growth and reproductive performances under improved husbandry system and this confirmed their suitability for improvement (Hill, 1964). The available documented records of cattle breeding and genetic improvement in Nigeria generally showed that cattle breeding programmes were unsuccessful; although during their heydays, the success, popularity, and vigour of some breeding programmes were exemplary (Table 1). For example, the successes of the Shika Stock Farms project could be attributed to the better understanding of husbandry practices and conservation of some Nigerian indigenous cattle breeds including the Bunaji, Sokoto and Adamawa Gudali, Kuri, and Shuwa cattle. Also, the Shika Stock Farms project could be cited for the existence of the National Animal Production Research Institute (NAPRI) today; having evolved from the Shika Grassland Research Station in 1962, to the National Animal Production Research Institute in 1976. These could be regarded as success of the Shika Stock Farm because since its establishment, NAPRI, despite its inability to live up to expectation in the recent decades, remained the only government-backed centre for animal breeding and reproduction biotechnology in Nigeria (Kolo, 2020; Nuru, 1984). In addition to the emergence of NAPRI, breeding activities at the Shika Stock Farms led to development of husbandry and livestock management practices resulting to the fattening of local zebu bulls (White Fulani) raised on improved pastures to attain market live weights at 18 months, which was better than the live weights of the same animal under local management conditions (Maule, 1961b,a).

The cattle breeding and improvement programmes of the then Western Region of Nigeria could perhaps be regarded as one of the most successful and impactful to date in their heydays. For example, from the 93 foundation stock imported to the Fashola Stock Farms for multiplication in 1947, a reported 4184 N'Dama calves were born at the farm between the year 1947 and 1984, before the political situation in the country up turned the activities of the farm from functional operations (Abanikannda, 1995). While inbreeding was reported at the farm, there were also reports of selection of stocks from the farm for commercial beef cattle production at the Upper Ogun Ranch which was a major source of beef in the country as of the period. In addition, apart from the breeding of cattle at the Fashola Stock Farm, Upper Ogun Ranch and the Livestock Investigation Centre, Ado-Ekiti all in the then Western Region of Nigeria; there was report of trypanotolerant cattle development in Nigeria which was bankrolled by the Western Nigeria regional government (Abanikannda, 1995; Hill, 1964; Lawal-Adebowale, 2012).

Unfortunately, apart from the successes reported above, cattle breeding and improvement programmes in Nigeria hardly see the light of the day. Starting from the Livestock Improvement Programme (LIP) anchored by different agricultural research institutes in the country in the '70s, to the recent breeding and improvement programmes such as the National Livestock Transformation Plan and National Livestock Breed Improvement Programme (NALBIP); they all suffered political backlashes. Meanwhile, in contrast across the West Africa sub-region, there are different breeding programmes implemented, completed and on-going between the '70s to date; for example, the breeding and improvement programme of N'Dama cattle in Senegal (1972 – on going as of 2021), Mali (1975 – on going as of 2021), Gambia (1994 – on going as of 2021), Azawak and Fulani Zebu in Burkina Faso (2000–2015; and 2005–2018); as reported by Ouédraogo et al. (2021).

The major pitfalls of the successful execution of breeding and improvement programmes in Nigeria, are shortcomings in planning and execution of the programmes. For example, the Shika Stock Farm focused on the selection of indigenous bulls which were actually known as natural poor performers; apart from this, the end users including pastoralists, farmers, agro-pastoralists, and nomads were not engaged; so, the objectives of the programme even after the transformation of the programme were not achieved. Although, the breeding programmes in the then Western Nigeria Region was somewhat more successful, the programmes also suffered similar problems to the extent that thousands of multiplied stock could not be transferred to commercial farms or ranches for production; not forgetting the high rate of inbreeding reported from the records of the farm (Abanikannda, 1995).

However, the biggest blow against recent breeding and improvement programmes in Nigeria vis-a-viz the National Livestock Transformation Plan (NLTP), National Livestock Breed Improvement Programme (NLBIP), Rural Grazing Area (RUGA), Livestock Productivity and

Table 1. Analyses of previous breeding and genetic improvement of Nigeria indigenous cattle: the success and pitfalls.

S/N	Year	Programme	Programme objectives	Breeding scheme	Locations and nucleus type	Genetic evaluation	Stakeholders participation	Success and pitfalls	References
1	1928	Shika Cattle Stud Farm	Selection of bulls of the indigenous breeds of cattle for breeding native herds	Multiplication and population improvement	Samaru, closed nucleus; 500 indigenous White Fulani cattle	Daughter-dam pairs	British Colonial Office, Northern Nigeria	Development of improved husbandry of White Fulani cattle, but there was poor engagement of the smallholders and the programme was discontinued too early	Hill, 1964; Nuru, 1984; Nuru & Buvanendran, 1985
2	1947	Fashola Stock Farm	To multiply N'Dama cattle for distribution to local farmers; to develop beef cattle that can thrive under production system of the heavy tse-tse fly challenge areas of Southern Nigeria; multiplication centre for other local breeds especially Keteku and Muturu cattle	Multiplication and population improvement using herd sire and dam selection	Fashola, Oyo state. Closed nucleus; 93 heads of N'Dama cattle imported from Republic of Guinea (73 cows and 20 bulls)	Daughter-dam pairs; progeny testing, and production performances assessment	Extension agents of the then Western Nigeria region, Western Nigeria Development Corporation and the Upper Ogun ranch of the then Western Nigeria region	Production of 4184 cattle from the initial foundation stock of 93 cattle between 1947–1984. The pitfalls of the programme include prevalent inbreeding and sudden programme discontinuation	Abanikannda, 1995; Hill, 1964
3	1951	Agege Dairy Farm Project	Pilot scheme for the crossbreeding of imported Friesian bulls with indigenous White Fulani and imported Montbelliard cows for milk production	Crossbreeding using exotic bulls imported from abroad	Agege, Lagos; Closed nucleus	Milk yield per lactation period of 305-days	The government of the then Western Nigeria region, Western Nigeria Development Corporation and Upper Ogun Ranch, and the then Government Livestock Investigation Centre, Ado Ekiti	No documented record of success and there was poor programme implementation	Hill, 1964
4	1954	Sown Pastures and Range management	Introduction, selection, propagation and utilization of natural and sown pastures for livestock production	Integration of forage legumes into cropping system and establishment of fodder banks	Sub humid zone of Northern Nigeria	N/A	Shika Stock Farms	Development of intensive forage and pasture production, but there was no transmission of the developed technologies to smallholders.	Nuru, 1984
5	1956	Breeding of Muturu steer for beef production	Breeding, improvement and multiplication of Muturu steers for supply of beef and development of trypanotolerant cattle for	Crossbreeding of Muturu and N'Dama bulls and cows	Government Livestock Investigation Centre, Ado Ekiti; and Upper Ogun ranch; Open nucleus	Performance evaluation and time take to reach mature weight of 200kg	The government of the then Western Nigeria, Western Nigeria Development Corporation and Upper Ogun ranch, and Government Livestock	Development of trypanotolerant beef breed of cattle, but there was no records of progeny testing and the	Hill, 1964

(continued)

Table 1. Continued.

S/N	Year	Programme	Programme objectives	Breeding scheme	Locations and nucleus type	Genetic evaluation	Stakeholders participation	Success and pitfalls	References
			the high forest zone of Western Nigeria				Investigation Centre, Ado Ekiti	distribution of the breed to smallholders	
6	1964	Crossbreeding of N'Dama cattle with American breeds initiated by USAID	Crossbreeding research to develop dual purpose cattle for dairy and beef industry suitable for the climatic conditions of Western Nigeria.	Crossbreeding of N'Dama cows selected at Upper Ogun Ranch with bulls of exotic breeds imported from the United States of America	Fashola, Oyo state; and Upper Ogun ranch, Oyo state; Open nucleus	N/A	The government of the then Western Nigeria, Western Nigeria Development Corporation and Upper Ogun ranch, and United States Agency for International Development	Development of trypanotolerant beef breed of cattle, but there was no records of progeny testing and the distribution of the breed to smallholders	Abanikannda, 1995; Blench, 1999
7	1976	Livestock Improvement Programme (LIP) anchored by the Institute of Agricultural Research and Training, Ibadan	Development of efficient management systems for livestock that are adapted to Southern agro-ecologies	Breeding and husbandry activities for improved productivity of cattle and other livestock	Institute of Agricultural Research and Training, Moor Plantation, Ibadan Nigeria; Closed nucleus	N/A	Institute of Agricultural Research and Training, Ibadan, Obafemi Awolowo University, Ile-Ife	No reported records of success due to poor programme implementation	Greenland, 1997
8	2019	National Livestock Transformation Plan	To curtail the movement of cattle for grazing, boost livestock production and elimination of herder-farmer conflict through development of public grazing reserves	There is no specific breeding component, but there is a plan for the establishment of breeder ranches and semen banks for commercial artificial insemination	Pilot locations: Adamawa, Benue, Kaduna, Nassarawa, Plateau, Taraba and Zamfara states of Nigeria	N/A	National Economic Council, Nigeria; Federal Ministry of Agriculture, and Rural Development, Federal Ministry of Interior, Nigeria, The Presidency, Abuja; State Governments in Nigeria; Northern States Governors Forum, Nigeria	The programme is still in progress, but there is no report on successes and there are many ethno-religious cynicism against the programme coupled with poor implementation	ICG, 2021
9	2021	National Livestock Breed Improvement Programme (NALBIP)	To improve the genetic makeup of certain indigenous breed of animals, especially dairy cattle, in order to achieve increased milk and meat yields from the nation's herds	Crossbreeding of Nigeria, indigenous dairy cattle using exotic genetics via artificial insemination	Planned for implementation across the country, but the launching took place at Dawanau, Dawakin Tofa Local Government Area, Kano State	Assessment of performance traits of the hybrid progeny filial generations	Federal Ministry of Agriculture and Rural Development, Abuja	The programme is still in progress, but there is no report on successes and there are many ethno-religious cynicism against the programme coupled with poor implementation	Gabriel, 2021

Table 2. List of recommended specific actions for exploiting the genomic and post genomic era technologies for promoting national dairy development in Nigeria.

Recommended specific actions	Description
Establishment of the "Federal Dairy Development Board (FDDB)" and "Federal Dairy Research Institutes (FDRIs)"	The FDDB is recommended to be established as a department of the Federal Government Nigeria under the supervision of the Federal Ministry of Agriculture with statutory task of financing and supporting dairy producers-owned and controlled organisations, establishment and financing of FDRIs for provision of high quality education, research and development in all field of dairying. The FDDB is also recommended to be in charge of policies on import and export of goods necessary for production and promotion of milk and milk products including animal feeds, and acceleration of private sector participation in the Nigeria dairy sector.
Breeds and breeding management	These are recommended actions covering research on the identification and management of indigenous breeds with milk production potential. The focus of breeding management could be applied strategies of heterosis maintenance in cattle herds. Whole genome sequencing and marker-assisted selection may also be implemented to accelerate the selection for climate-adapted cattle for dairy production without compromising the animal productivity. This will also involve the screening of exotic dairy cattle breeds using different genomic tools on high performing exotic breed to develop cross-breeding decisions on commercial dairy production herds.
Genomic selection of breeds and linking of genotype to phenotypes associated with milk production	Presently, the indigenous cattle are poor milk producing animals; this necessitate crossbreeding of exotic and indigenous breed to produce heifers and bulls with desirable phenotypes of milk production and linking of the genotypes the phenotypes. This can be implemented through molecular breeding values (MBVs) estimation because the use of MBVs and relevant use of reproductive technologies such as artificial insemination can both reduce the generation interval and increase genetic progress towards the selection of cattle with superior performance capabilities. For example, different studies on understanding the genetic potential Nigeria cattle have shown that the indigenous Zebu cattle (White Fulani) are a potential dairy candidate; hence, the use of genomic and post genomic era tools could aid better results of crossbreeding this breed with superior exotic genetics. The area research need could be linking of genotype to phenotypes traits, including reproductive, productive, visual, body conformation scores, milk, fat and protein yields, age at first calving, age of heifer rebreeding, age at first calving, early pregnancy occurrence and the understanding of the genomic regulations and control of productivity and resilience. The action of linking genotype to phenotype is expected to generate information that can be used to develop a genomic tool for screening exotic bulls with superior adaptable performance in Nigeria, which could be used for designing a strategic improvement indigenous cows using artificial insemination.
Establishment of nucleous breeding cattle population and collaborative networking	The application of genomic and post genomic tools required access to animal population large enough to accommodate genomic selection, data collection for reliability. Hence, it is recommended that there is a need to establish nucleous populations of indigenous cattle breeds of interest for milk production. This population could be used for collection of data needed for the successful use of different genomic tools which could used for gathering, storing, and retrieval of data for future reference. Therefore, there is a need to form collaborative networks among scientists working in the domain of cattle breeding, genetics, reproduction and production at agricultural research institutes, public and private universities, dairy companies, cattle breeders associations, and biotechnology companies (such as African Biosciences®, Inqaba WA and others). This is because, incorporation of genomic information into the selection of cattle for improved production is complex and requires sophisticated multidisciplinary efforts of stakeholders.

Resilience Support (LPRES) and numerous other programmes, are faces with different politico-religious and ethnic cynicisms at one or all stages from conception, planning and execution. The situations are complex because of intertwined bureaucratic, technical and professional failures putting Nigeria at the crossroad of food insecurity (Ochim & Joseph, 2020; Sikiru, 2020). Furthermore, it is difficult to control breeding under these programmes because of the predominant extensive grazing production system practice in Nigeria which has in the recent time transformed into cankerworm promoted by the transhumance protocol permitting herdsmen unquestionably roaming across West Africa (Gini, 2011; Padgham *et al*., 2016; Sikiru, 2020; Vanvanhossou et al., 2021).

Potential application of post genomic era technologies for cattle improvement and promotion of the national dairy development in Nigeria

To be specific, cattle breeding and improvement in Nigeria lacks the establishment or availability of a close nucleus population, this is critical for the promotion of the national dairy development in the country, and it is the basis justifying the need for application of the post genomic era technologies for cattle improvement. Another shortcoming that could cripple the achievement of the national dairy development with regards to lack of applicable post genomic era technologies is the evaluation of genetic potential of indigenous breeds of cattle to better understand their suitability for exploitation. Furthermore, lack of database on established phenotypic traits of production, which are of interest to farmers and consumers that could be used for selection of cattle for breeding and improvement, and poor involvement of research and training centres in the planning and execution of breeding programmes are factors limiting the application of the post genomic era technologies in Nigeria. For example, the most recent livestock breeding and improvement programme (NALBIP) was rolled out entirely by bureaucrats without visible involvement of scientists working in either public or private research organizations such as universities, colleges and agricultural research centres (ARC). Apart from the exclusion of these categories, the need to involve farmers (pastoralists and agro-pastoralists), non-government organization and community-based organizations can not be overemphasized as they could be critical in the successful rolling out of future breeding programmes in Nigeria; this is because, they could contribute immensely in the areas of selection and determination of selection criteria, breeding, reproduction and dissemination (Ouédraogo et al., 2021).

The post genomic era is the period after the successful sequencing of human and other organisms genomes, and it is characterized by a paradigm shift opening the way into the better understanding of how genes influence phenotypes (Perbal, 2015). In order to overcome some of the challenges associated with failures of the previous cattle breeding and improvement programmes in Nigeria, to salvage current and future breeding programmes, there is a need to exploit the potentials of the post genomic era technologies, especially for the promotion of national dairy development. This is because, dairy production is one of the least developed livestock activities in Nigeria and despite the huge markets, the indigenous breeds of cattle in Nigeria cannot fill the vacuum based on their present state. Hence, exploiting these technologies has the potential to improve and boost science for dairy growth in Nigeria. While one of the strongest approaches of genetic improvement is the crossbreeding of indigenous cattle with the exotic breeds, the use of genomic tools could hasten the process, protect and conserve the desirable genetic of the indigenous breeds. This is because, compared with the pre genomic era, the selection of animals for economic traits of interest is less accurate and time consuming because of limited knowledge about genes which could be used to select more profitable animals. While cattle breeding during the pre-genomic era was not very successful in Nigeria, it is crucial that breeding programmes take advantage of the genomic and post-genomic technologies which are now available to advance animal production and productivity. Even in countries where breeding were successful during the pre-genomic era, they have taken and still are taking advantages of the post genomic era technologies to advance animal production and health. For instance, in the United States of America, after the "Blueprint for the United States Department of Agriculture (USDA) efforts in Agricultural Animal Genomics" was implemented between 2008 and 2017, another "Blueprint for Animal Genome Research" has been rolled out for implementation between 2018 and 2027; these blueprints were aimed at increasing livestock production ability to meet the demands for animal product using genomic methods (Rexroad et al., 2019). Having analysed previous breeding and improvement programmes on cattle in Nigeria and their outcomes, specific actions are recommended on the application of genomic and post genomic era technologies that could be used for driving the national dairy development programme (Table 2).

Conclusion

There is a great possibility of improving the genetics of Nigeria's indigenous cattle breeds for meat and milk production. For this to happen, however, all the pitfalls identified must be taken into consideration. The era of making policies just for the sake of it by government is over. If Nigeria is to become a provider of meat and milk to its people from its cattle breeds, then the current cattle production system must be jettisoned and confined to history. There must be a purposeful shift to ranching where improved cattle (indigenous and exotic) will be reared using modern scientific tools, coupled with the provision of improved feeding and healthcare. This means that the psyche of the pastoralists and agro pastoralists must of necessity be changed to embrace a modern system of animal agriculture. Governmental input must come into play in the form of provision of basic infrastructure like water, irrigation, roads, electricity, extension services,

training and subsidies to the pastoralists and young agriculture graduates interested in going into this area. Government policy could also guarantee the provision of tax holidays to industrialists who may be interested in going into commercial production of cattle for the supply of milk for the populace. The use of post genomic era technologies in achieving national dairy development will enhance the early selection and improvement of indigenous cattle breeds. There will be a need for the provision of modern genomic tools and equipment to facilitate this. Breeders and scientists in the field will need training and the establishment of nucleous populations of animals in various centres of the country linked to the different cattle breeds is also an essentiality. When put together, these achievable variable will not only hasten the genetic improvement of the indigenous cattle breeds, but ensure that they play their part in the achievement of food security at least, in beef and milk production.

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