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A Review of Challenges to Genetic Improvement of Indigenous Livestock for Improved Food Production in Nigeria

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Abstract

Indigenous livestock production is intertwined with the life style of Nigerians. The Nigerian livestock industry employs the bulk of the rural work-force, and indigenous livestock breeds are abundant in the industry. These breeds are distributed across the diverse agro-ecological production systems, and are carriers of unique and responsive genotypes shaped by the needs of their managers. Despite their unique features, most indigenous livestock breeds are characteristically low in production and productivity. Improvement of these breeds represents a logical starting point for improving food security and agricultural productivity in Nigeria. To better understand natural genetic variation in these indigenous livestock breeds and strategies for improvement, better genetic characterization is required. Molecular assisted selection (MAS) will be valuable in the pursuit of selection for increased production, but the application of MAS to livestock improvement is constrained by a variety of limitations. The focus of this paper is to elucidate the potential of MAS as a tool for genetic improvement of indigenous livestock, to identify constraints and challenges in MAS implementation and propose solutions to increasing MAS feasibility in pursuit of improved food security and sustainability in Nigeria.

Key words: Food security, Genetic improvement, Genomic Selection, Indigenous livestock, Marker assisted selection, Nigeria

Introduction

Nigeria has a population of over 170 million (FDLPCS, 2007), making it the most populous country in Africa. Often referred to as "giant in the sun," or "big brother Africa," Nigeria is a leader in the export of many agricultural products including peanuts, rubber, oil palm, cocoa and livestock products. After the discovery of crude oil in the late 1960s, Nigeria's economy shifted from being predominantly agricultural and the country experienced an oil boom (Adenikinju, 2005). Many farmers migrated into the oil industry in search of better jobs. In the late 1960's, a Civil War broke out, which was a deadly blow to the agricultural sector and the economy overall; the country is still struggling to recover completely from the effects of the war.

Livestock have been intertwined with African societies for centuries (FAO, 2001). About 70% of Africa's rural poor keep livestock (Okpeku *et al*., 2011a) and an estimated 200 million people rely on livestock to support their livelihoods (Abdul-Aziz, 2010). In Nigeria, livestock plays an important role in the national economy, accounting for as much as one third of the country's agricultural gross domestic product (GDP) (Ekpo, 2012). Nigeria is home to a diversity of indigenous livestock breeds (Adebambo, 2003; Adebambo *et al*., 2004).

These, unlike most found in Europe and North America, have not been genetically manipulated for specific production functions (e.g. meat, milk or egg production), though they serve many purposes (Adedeji *et al*., 2011). Their role in the food production system is not just to meet dietary needs, they are also useful for generating income through animal by-products, powering transportation and farm machinery such as plows or carts, fertilizing crop systems with manure and playing import roles in socio-cultural activities of their owners (Adedeji *et al*., 2011; Adebambo *et al*., 2011; De los Campos *et al*., 2009; FAO, 1998).

In addition, livestock play important roles in religious ceremonies and festivals such as marriages, naming ceremonies and traditional worship activities (Adefenwa *et al*., 2013a).

Indigenous livestock breeds constitute the bulk of the Nigerian livestock industry, they vary across agro-ecological zones and are locally-adapted to specific regions of the country. Indigenous livestock are not only adapted to diverse agro-ecological production systems, they are also carriers of unique genotypes shaped by the needs of the people.

Despite their beneficial features, most of these indigenous breeds are characteristically low in productivity; for example, low number of eggs per generation in poultry, low volume of milk per lactation period and small body size in ruminants and non-ruminants with attending low carcass for meat. In the same way that the improvement of locally adapted European dairy and meat breeds paved the way for increased agricultural productivity in the Northern hemisphere, the livestock industry represents a critical area for improvement in working toward achieving food security in Nigeria.

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Experts worldwide agree that the demand for livestock products will increase with population growth, urbanization and changing consumer demands (FAO, 2017; Moyo and Swanepoe, 2010; Gouel and Guimbard, 2017). Nigerian livestock diversity represents valuable genetic resources and national heritage (Adebambo, 2004) that can be leveraged to pursue local and global food security because they constitute unique populations with unique genetic potential waiting to be tapped.

Many of the indigenous breeds are able to tolerate harsh climates (Yakubu *et al*., 2010), as well as pathogen, pest and disease pressure (Okpeku *et al*., 2011b), which improve their resilience in the challenging and changing ecological terrains of Africa. Suitability to traditional systems, short generation interval and ability to thrive on poor quality diets (Okpeku *et al*., 2016a) all combine to make these indigenous livestock breeds strategic (Yakubu *et al.*, 2010) for improved food production and productivity.

However, very little attention has been paid to the genetic characterization and possible improvement (Awobajo *et al*., 2015; Okpeku *et al*., 2016a) of these indigenous livestock breeds. In fact, the genetic architecture of most of these animal breeds has not been documented (Okpeku *et al.* 2016a,b).

Genetic improvement of indigenous breeds of livestock is very valuable for improved quality and quantity of protein production (Omitogun, 2007), for the ever-increasing population, now estimated at over 170 million (FDLPCS, 2007). Because of their high adaptability to harsh environmental conditions, poor nutritional regimes, climate and diseases compared with exotic breeds, indigenous breeds are more suitable to local agricultural systems (Adefenwa *et al*., 2013a,b).

Past efforts geared at improvement have been based on upgrading of available indigenous breeds with imported exotic breeds or complete replacement of indigenous stocks with such imported improved breeds. However, most imported improved exotic breeds from Europe and North America failed to perform true to their genetic potential, when raised in Nigeria (Adebambo, 2003) or some other tropical environments in Africa (Abdul-Aziz, 2010), different from the sanitized environments and temperate climates for which they were originally developed.

Genetic improvement of indigenous livestock will involve the introduction of exotic or improved genes. If not done properly, however, this introduction of genes could have negative results on the local livestock industry, such as loss of unique genes that have value for local-adaptation and survival under harsh tropical climates. In the past, the effect of such actions has in the worst cases led to extinction of many agriculturally valuable indigenous breeds of livestock, while many others became listed as endangered or threatened (FAO, 1998, 2001, 2004, 2005). The conservation of valuable genes in locally adapted breeds is genetic insurance for immediate use and future food security (Adebambo, 2003). Particularly in the face of global climate change, conservation of local gene pool diversity is a matter of great priority in planning genetic improvement of livestock breeds.

Approaches to genetic improvement of livestock cannot pursue only one objective, because a single breed or attractive trait cannot be suitable for all livestock and farmers' needs. Most of the traits considered in animal and plant genetic improvement programs are quantitative traits (Goddard and Hayes, 2007), and are controlled by many genes together with environmental factors. As such, the underlying genes have small effects on observed phenotypes. In classical genetic improvement programs, selection is carried out based on observable phenotypes of the candidates for selection and/or their relatives, but without knowing which genes are driving selection decisions (Ruane and Sonnino, 2003).

It has been reported that to better understand natural genetic variation in indigenous livestock breeds, and formulate appropriate conservation policies, finding balance between the competing needs of genetic improvement and genetic diversity is essential (FAO, 2005; Okpeku *et al.*, 2016b). The development of molecular DNA markers was therefore, greeted with great enthusiasm as it was a breakthrough, promising to overcome this key limitation (Choudhary *et al.*, 2008). Marker-assisted selection (MAS) that is based on genetic variation has proven to be very powerful and effective in traditional selection, especially for genetically improving economic traits for livestock such as overall growth, milk production, reproductive characteristics and meat quality traits (Zhang *et al.*, 2015).

Marker Assisted Selection, also generally referred to as genomic selection (Liu *et al.*, 2005), is a novel technology currently popular for genetic improvement in animals and plants. Over the past few years, MAS has become an important tool for livestock selection and improvement, and has been used extensively in dairy cattle breeding. Prior to the development of MAS tools, classical and statistical genetics tools were favored for breed evaluation, selection and genetic improvement (Ruane and Sonnino, 2003), though MAS quickly replaced these in popularity. Genomic evaluation with this tool is still progressing, despite the considerable resources invested in the field at large and the enormous results that have been achieved for breeding in developed countries, MAS is yet to reach its full potential for livestock improvement in developing countries, like Nigeria, where investments have been much more limited (Ruane and Sonnino, 2003).

Nigeria is endowed with a rich diversity of livestock species, from large and small ruminants like cattle, camel, sheep and goats, to poultry species such as chicken, turkey, duck and guinea fowl. The majority of these species have received little to no attention or investment in genetic improvement or conservation programs. Proper molecular characterization and MAS utilization will be valuable to increase indigenous livestock productivity. However, the use of this technology in Nigeria has been very challenging. This paper will elucidate a number of constraints to successful MAS implementation for genetic improvement of indigenous livestock in the drive for improved food security and sustainability.

Molecular Markers Selection for Indigenous Livestock Improvement
As in most developing countries, animal improvement efforts in Nigeria have relied heavily on biometric evaluation of breeding values from animal's own performance

(Adebambo, 2003; Omitogun, 2007) and performance of parents, siblings and progenies (Adedeji *et al*., 2011). Molecular genetic markers (DNA markers) are one of the most powerful means for genomic analysis and connection of hereditary traits with genomic variation (Gibson and Bishop, 2005; Yadav *et al*., 2017).

They have proved to be more reliable than other types of genetic markers (Ebegbulem and Ozung, 2013) and designated makers of choice because of their properties of abundance, hyper variability and Mendelian inheritance that make them very informative in genome analysis (Yadav *et al.,* 2017). They have been used for a variety of purposes, including gene tagging, physical mapping, genome mapping, estimation of genetic diversity (Troy *et al*., 2001; Hanotte *et al*., 2002; Gibson and Bishop, 2005), phylogenetic and conservation (Reist-Marti *et al*., 2002; Eding and Meuwissen, 2002; Simianer *et al*., 2003) genetic purposes in farm animal breeding and utilization decisions (Lopez-Fanjul and Hill 1973; Hanotte *et al*., 2003) with a good degree of success.

According to Bishop *et al*. (2002) they are particularly useful for genetic studies in low input livestock production systems in the developing world like Nigeria; which are prone to high environmental risk, disease prevalence, climatic pressures and characterized by poor management practices. Uses, merits and drawbacks of the different molecular markers have been extensively reviewed (Yadav *et al*., 2017). However, recent genetic markers of choice are single nucleotide polymorphisms (SNPs) and copy number variations (CNVs).

Single nucleotide polymorphisms (SNPs)
Single nucleotide polymorphisms (SNPs) are generally defined as a DNA base pair location at which the frequency of the most common base pair is lower than 99%. Unlike microsatellites, which usually have multiple alleles, SNPs are generally biallelic, but are much more prevalent throughout the genome, with an estimated frequency of one SNP per 300–500 base pairs. In human populations differences in the base pair sequence of any two randomly chosen individuals occur at a frequency of approximately one per 1000 kb (Weller, 2016).

Thus, SNPs can be found in genomic regions that are microsatellite poor. They are genetically stable and amenable to high-throughput automated analysis (Vignal *et al*., 2002), with lower frequencies of mutation. Genotyping error rates are relatively low too, they are marker of choice when exploring with technologies developed for high (throughput SNP) analysis.

Copy number variations (CNVs)
In copy number variation (CNVs) sections of the genome are repeated and the number of repeats in the genome varies between individuals in a population (Naskar *et al*., 2015). These CNVs could be deletions or insertions of genomic sequence between two individuals of a species. Substantial progress has been made in understanding their impacts on both normal phenotypic variability and disease susceptibility in both humans and animals (Naskar *et al*., 2015).

Majority of previous studies of CNVs in domesticated animals have been based on array comparative genomic hybridization (CGH) experiments or single-nucleotide polymorphism (SNP) arrays. However, sequence-based approaches are becoming more and more popular for the study of CNVs in domesticated animals. The CNV distribution within and among species seems to be shaped by mutation, selection, and demographic history (Naskar *et al.*, 2015).

Whole genome sequencing (WGS)
Whole genome sequencing (WGS) is a laboratory process that determines the complete DNA sequence of an organism's genome at a single time. This entails sequencing all of an organism's chromosomal DNA as well as DNA contained in the mitochondria and, for plants, in the chloroplast. Whole genome sequencing is not the same as DNA profiling, which only determines the likelihood that genetic material came from an individual or group, and does not contain additional information on genetic relationships, origin or susceptibility to specific diseases.

High-throughput genome sequencing technologies have largely been used as a research tool. Several public and private companies are competing to develop an improved full genome sequencing platform (Naskar *et al.*, 2015), known as next generation sequencing (NGS) technology that is commercially robust for both research and practical uses. This technology promises to greatly reduce the cost of sequencing and genotyping and make available the entire genomic profile of an organism; a fundamental requirement for fishing for genetic markers and application of MAS in breed improvement programs (Wong *et al.*, 2008).

Genomic Selection (GS)
Traditional breeding programs rely mainly on phenotypes evaluated in different environments (Naqvi, 2007); selection and recombination are based solely on data generated and pedigree information, when available. On the other hand, MAS uses molecular markers in linkage disequilibrium with quantitative trait loci (QTL) (Pandey *et al.*, 2006; Habier *et al.*, 2009), this is the core of genomic selection.

Genomic selection is an approach for improving quantitative traits in breeding populations (Heffner *et al.*, 2009) and relies more on whole genome molecular markers (high density markers) and high throughput genotyping. This technique combines genomic prediction and marker data with phenotypic and pedigree data, when available, in an attempt to increase the accuracy of the prediction of breeding and genotypic values (Gonzalez-Recio *et al.*, 2008).

Genomic selection has become popular and widely adopted in livestock and crops research and improvement programs. Garrick *et al.* (2009) found that, when variances estimated using SNPs (single nucleotide polymorphisms) are simultaneously used in selection, most of the missing heritability in complex traits could be accounted for, thus making this technique the best approach to prosecute improvement studies, policies and breeding programs for indigenous livestock species.

Selection based solely on marker effects is becoming a focal point in breeding not only in the developed countries of the world but also in some parts of Africa, Asia, and Latin America (Bernardo and Yu, 2007). The implementation of GS in breeding programs are expected to help speed up genetic gains and, as a result, improved, higher yielding, broadly adapted, and stable genotypes will be delivered at a much faster rate (Wong and Bernardo, 2008).

Africa and other resource poor countries can develop improved varieties, lines, and hybrids in indigenous livestock and crops to improve food production and increase diversity for food security (Gianola and Van Kaam, 2008).

However, the state of research and development in this field in Nigeria and most of Africa, is still very much at the infantile stage and implementation is frost with a host of challenges, which if properly addressed will boost food production in Nigeria and other African States that support GS for indigenous livestock and crops improvement. This in turn will promote improved food production and ensure food security now and in the future.

Current limitations of MAS application
Absence of an established livestock records and evaluation system
Records are essential in any management operation. A good record keeping system provides means for monitoring and evaluation of performance of production systems. It helps to identity problems, make plans, and effect necessary corrective measures where and when appropriate. The absence of functional national herd records and baseline characterization information of indigenous livestock gene pool in Nigeria is an extreme obstacle to genetic improvement.

Establishment of national heard book and genetic characterization of available indigenous livestock is a necessary precursor to expanding national breeding efforts. Application of molecular tools in this characterization effort, is a fast and cost effective measure to ensure comprehensive evaluation and construction of the genetic architecture of Nigerian indigenous livestock, before any meaningful improvement program can be established.

Genetic structure and compelling environmental pressures
The large number of different livestock breeds and varieties in an array of production indicates that animal diversity has developed over time and in response to the ecosystem (Bickhart *et al*., 2016). Nigeria is particularly well endowed with livestock diversity, and most breeds have been reared under low-input, extensive systems with very little reproductive control. Uncontrolled mating on pasture or free ranging is the common practice, much in contrast to the highly structured breeding programs and intensive selection used in the developed world.

In the rare cases where selection is controlled, the resulting livestock are product of a few key selection criteria. Their parents were picked for their resilience to harsh environments, disease resistance or reproductive potential. Limiting breed selection to

only a few traits risks erosion of genetic diversity (Bickhart *et al.*, 2016) so special effort must be taken to conserve diversity through breeding for a variety of traits.

Both direct and indirect effects of climate change, including mitigation measures are also believed to strongly influence the loss of genetic diversity (Bickhart *et al.*, 2016), which is viewed as threat to livestock sector sustainability (Hanotte *et al.*, 2003). The presence of varied livestock species and breeds with widely variable performances offers the opportunity for genetic improvement. In the absence of variation, we risk progress in the sector. Natural stratification of species and breeds of livestock should be an important guide in the design of successful livestock genetic improvement programs (Reist-Marti *et al.*, 2002; Eding and Meuwissen, 2002; Simianer *et al.*, 2003). An appropriate policy framework and large-scale cooperation to increase knowledge and awareness of resources is of crucial importance to overcome these challenges (Ebegbulem and Ozung, 2013).

Government attitude to policy formulation and execution

Policy formulation, implementation and monitoring process (Aminu *et al.*, 2012) is a sequential pattern of action involving several overlapping categories of activities (Egonmwan, 1991). However, the Nigerian government is highly bureaucratic and requires significant reform efforts to overcome problems of disorganization, corruption, favoritism and poor execution (Emeh and Eden, 2007).

The prevalence of these issues is severely detrimental to the execution of policy. In turn, these conditions also discourage capital investment, particularly long-term investments, like those required for supporting MAS for livestock improvement. Improving the enabling environment for policy formulation and implementation in collaboration with private investors will ultimately promote capital investment in research and development (R and D) supporting livestock genetic improvement.

Poor Agricultural biotechnology base economy

Nigeria is a dominant economic player in the region and an emerging market on the African continent. Currently ranked 21st in the world in terms of GDP ($600 billion) by the IMF, it is the largest economy in Africa with rapidly growing contributors to GDP in telecommunications, banking, and the film industry. The country's re-emergent, though currently underperforming, the manufacturing sector makes her the third-largest country on the continent of Africa (NPC, 2014); however, biotechnology has been slower to develop.

In the last few years, agricultural biotechnology has been gaining ground and several institution-based initiatives have sprang up with active research and development programs in arable crops, root and tubers, tree crops and forestry as well as livestock (Banziger and Diallo 2002; Alhassan, 2003).

The performance of these actors has been constrained by various challenges including: poor access to modern biotech reagents and supplies, lack of technical knowledge about lab equipment maintenance, poorly equipped laboratories, poor electricity supply (Akanji, 2016) and insufficient technical expertise in biotechnology research.

Investment in the sector and implementation of a functional biotechnology agenda will go a long way to enhance agricultural production and move the nation closer to being self-reliant in food production.

Cost of implementing MAS for livestock improvement

Application of molecular techniques in enhancing improved livestock production can be expensive. In the words of Dekkers and Hospital (2002), "economics is the key determinant for the application of molecular genetics in genetic improvement programs." The cost of importing tools and equipment from developed countries can be so high that the benefit derived (Ebegbulem and Ozung, 2013) is insufficient.

Current development in next generation sequencing (NGS) techniques, offer cheaper alternatives that make MAS research more achievable. Furthermore, investment in training of trainers who in turn can develop increase workers' skills and knowledge through local training organizations will go a long way to improve MAS technology implementation. Where funds are scare for formal training, collaborative efforts between local researchers with researchers at private institutions abroad can upgrade skills more affordably.

Poor Research and Development (R and D) policy and priorities

Presently, functional biotechnological and genomic centers for R and D are not common in Nigeria and most parts of Africa. The two main research hubs are the International Livestock Research Institute (ILRI) in Nairobi, Kenya, with a mandate for animal R and D, and the International Institute for Tropical agriculture (IITA), in Nigeria with mandate for crop and crop related R and D.

Furthermore, both federal and state governments provide little incentive to expand agriculturally relevant R and D. Government research institutions are plagued with inadequate funding, poor management and politicization of employment. Many tertiary institutions and agricultural universities are also ill equipped for training and R and D in the use of MAS technology.

In developed countries, most of the plant and animal breed improvements achieved with MAS can be credited to local non-governmental institutions and collaborative ventures between the public and private sectors (FAO, 2015). These types of collaboration are largely absent in Nigeria, and much of the developing world. Encouragement of open market policies that allow public-private partnership in organized MAS application to indigenous animals and plant germplasm, could go a long way to drive genetic improvement and development of highly productive novel breeds.

Poor Funding for R and D

Research involving molecular technologies is often thwarted in Nigeria due to inability of researchers to access grants and funds (Ebegbulem and Ozung, 2013). Attracting quality investors to Nigeria for MAS technology-based R and D, has proven to be very challenging because most institutions could not provide the basic equipment/facilities

required to effectively carry out basic MAS related research. The issue is further exacerbated by the dearth of local grant awarding institutions.

The few available ones have their priorities directed away from long term agricultural projects. However, if the political and economic environment is made conducive to private investment in agricultural R and D, researchers may be able to slowly build their capacity to take on grants and meet minimum requirements. The establishment of local granting institutions and farmers' societies to fund agricultural research with the mandate to improve productivity in local species would go a long way to move R and D forward with consequential improvement in food production and productivity.

Instability of Electricity
In Nigeria, electricity supply is very erratic and research is often forcefully terminated as a result of irregular power supply (Ebegbulem and Ozung, 2013). Some experts have argued that this erratic power supply appears to be the most challenging factor impeding human activities in developing countries (Olowofeso, 2011; Olaseni and Alade, 2012; Akanji, 2016a; Akanji, 2016b). The problem of irregular electricity supply has also been described as being more political than technical (Adenikinju, 2005; Iwayemi, 2008; Ise-Olorunkanmi, 2014). The major electrical power generators (hydroelectric) are government institutions that are ill managed and dysfunctional (Ekpo, 2012). Alternative energy sources such as gas turbine are also not very effective with irregular gas production from dysfunctional petroleum company that is run by the government (Adenikinju, 2005). Disengagement of politics from electric power generation and appropriation of workable policies for electric power generation, with the involvement of private local and foreign investment in this sector will see a dramatically impacted R and D potential, as well as the overall development of the nation. More so, Nigeria, like most African countries, has great potential for solar energy. If this natural energy source is harnessed as a result of investment in solar energy alternatives, this could ease some of the problems with erratic power supply.

Insufficient trained personnel
The application of molecular markers to the improvement of animal species in Nigeria is also constrained by the insufficient supply of adequately trained personnel with the requisite practical experience in MAS technology application. University curriculum is devoid of comprehensive training in this field and MAS technology can only be imported from countries where the sector is highly developed. Those Nigerians that do go abroad to receive additional education or training do not have the enabling environment to practice, resulting in massive out-migration of trained personnel. Systems need to be established to successfully train faculty or educators abroad, who can return to help prepare a cohort of qualified personnel through locally organized training. University curricula should be reviewed to include training relevant to MAS related R and D as well as commercialized livestock production. These efforts along with the provision of a positive enabling environment, would go a long way in not only promoting improving indigenous livestock, but also in putting the nation at the forefront of MAS technology implementation in Africa.

Intellectual Property Rights Issues

Ebegbulem and Ozung (2013) identified intellectual property rights as a key factor in improved and sustainable food production in developing countries. They argued that poor regulation of patents and poor dissemination of innovative ideas, generally negate the quality of agricultural research. Intellectual property rights can also strain the relationships between collaborators in both the public and private sectors, as well as between developing and developed countries. The pursuit of policies that protect R and D in the field of agriculture and any resulting products or breeds may serve as an incentive that will encourage investment in MAS applications and ultimately improvement in sustainable food production.

Discussion

Nigeria and most of Africa are blessed with a rich diversity of indigenous livestock genetic resources which have received little improvement. Characterization efforts of existing indigenous livestock breeds (Yakubu *et al*., 2009; Okpeku *et al*., 2011a,b; Agaviezor *et al*., 2012a,b; Yakubu *et al*., 2013) have been useful to describing the genetic diversity and population structure (Reist-Marti *et al*., 2002; Eding and Meuwissen, 2002; Simianer *et al*., 2003). Efforts to identify the unique traits associated with improved productivity, adaptability and disease resistance are ongoing (Adefenwa *et al*., 2013a,b; Ajayi *et al*., 2013; Ebegbulem and Ozung, 2013; Okpeku *et al*., 2016a,b; Yakubu *et al*., 2016; Yakubu *et al*., 2017a,b). Development of improved livestock breeds, strains and hybrids from these indigenous livestock can potentially improve food production quantity and quality. Advanced biotechnology tools such as marker assisted selection, and genomic selection particularly hold potential for the introgression of favorable genes in resource-poor livestock production systems. They have the ability to increase the rate of genetic improvement with positive influence on improved protein production from meat and other livestock products. Although MAS is not the only useful technique for livestock improvement, it is popular for the following reasons: (1) the technique leans favorably toward genetic evaluation of indigenous biological systems with low input production systems (Yadav *et al*., 2017), typical of the Nigerian livestock industry, (2) continued improvement of the NGS technique has made MAS more affordable (Naskar *et al*., 2015), and (3) MAS has been successfully implemented in genetic improvement of animals and plants (Lopez-Fanjul and Hill, 1973; Hanotte *et al*., 2003) in other parts of the world. Promotion of MAS should be encouraged for those Nigerian indigenous livestock in which it can be easily used to enhance rapid turnover in genetic improvement for sustainable food production.

Constraints associated with breeding improved indigenous livestock are both genetic and environmental, including management, disease prevalence, climatic conditions and more. Further, absence of an established livestock record and evaluation system, as well as barriers to accessing advanced biotechnology tools have a detrimental impact on the sector. This myriad of challenges is further compounded by excessive government bureaucracy and challenges to policy formulation and execution. These factors combined, have limited the progress of indigenous livestock improvement and conservation. Appropriate interventions, such as government's increased role in establishing a positive enabling environment for research, implementing policies for livestock breed improvement programs, and funding indigenous livestock conservation

efforts will go a long way to promoting improved livestock productivity and can make real contributions to food security and economic growth in Nigeria.

Conclusion

Molecular assisted selection is a cost-effective and promising technique for driving genetic improvement in the livestock industry not only in Nigeria, but all over the developing countries of the world. Support for public and private investment in molecular technology can improve agricultural production, productivity and sustainable growth in the livestock sector in pursuit of food security.

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