The Role of Molecular Genetics to Improve Dairy Cattle; Opportunities and Challenges in Case of Ethiopia: Review

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Abstract: The objective of this review was to characterize the role of molecular genetics, opportunities and challenges to improve the productivity of dairy cattle in Ethiopia. In Ethiopia, genetic improvement of the indigenous cattle for dairy production, focusing on crossbreeding, has been practiced for the last five decades, albeit with little success. Crossbreeding work in Ethiopia was initiated in the early 1950s. Genomic selection should be able to at least double the rate of genetic gain in the dairy industry, as it enables selection decisions to be based on genomic breeding values, which can ultimately be calculated from genetic marker information alone, rather than from pedigree and phenotypic information. There are opportunities for using molecular genetics to identify genes that influence milk production traits. The other major opportunities are indigenous livestock breeds in Ethiopia are a valuable source of genetic material because of their adaptation to harsh climatic conditions, their ability to better utilize the limited and poor quality feed resources and their tolerance to a range of diseases. The poor performance of the dairy sub-sector was attributed to socio-economic, infrastructure and technical constraints, inadequate research and extension activities and lack of policies relevant to the development of the dairy industry. Milk production was largely affected by a combination of factors namely; genetic make-up in terms of the use of improved breeds selected for milk production, a favorable nutritional environment and improved managerial practices. Therefore, establish operational strategy, evaluate applicability of technology, fulfill infrastructure, give training for farmers and experts should be the most important before implementing dairy cattle genetics improvements.

Key words: Challenge - Dairy - Improvement - Molecular - Opportunities Role

INTRODUCTION

Ethiopia was reported to be endowed with the largest livestock population in Africa. According to the Central Statistical Agency (CSA) [1] the report of the CSA estimated about 57.83 million head of cattle population. The indigenous breeds accounted for 98.59%, the remaining were hybrid and exotic breeds that accounted for about 1.22% and 0.19%, respectively [1].

In spite of such a substantial potential, the dairy sector is not developed to the expected level. The annual growth rate in milk production of 1.2% falls behind the annual human population growth estimated at three percent [2]. The traditional milk production system, which was dominated by indigenous breeds of low genetic potential for milk production, accounts for about 97 percent of the country’s total annual milk production [3].

The introduction of modern agriculture enforces to introduce modern breeding practices had targeted to improve livestock productivity [3]. The increase in productivity could be obtained through crossing of Bos Taurus and Bos indicus (local Zebu). Their aim was to combine adaptability, hardness, disease resistance and heat tolerance of local zebu with the high milk producing potential and faster growing rate of exotic breed. The genetic improvement of indigenous breeds was possible by way of selective breeding and/or strategic cross breeding some effort has been exerted to date to improve any of the indigenous breeds [4]. Genetic make-up of animals control their structural configuration and productive abilities either via single genes or by multiple genes situated in different loci. Genetic make-up of dairy animals plays a great role in the variation of milk yield and composition. Milk production is a factor of genotype-environment interactions. It is

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important to balance selection for both production (milk yield and composition) and functional (fertility, disease resistance, feed intake and body weight) trait. The first priority of every breeder is to breed his herd and to find a bull for this purpose. Genetics are available through modern methods of reproduction which will guarantee the quality of offspring. AI and ET are powerful means for propagating both genetic improvement and the breeds which are most advantageous at a given time.

The low productivity of the country’s livestock production system in general and the traditional sector in particular was mainly attributed to shortage of crossbred dairy cows, lack of capital by dairy producers, inadequate animal feed resources both in terms of quality and quantity, unimproved animal husbandry systems, inefficient and inadequate milk processing materials and methods, low milk production and supply to milk processing centers and poor marketing and market information systems. Milk production was largely affected by a combination of factors namely; genetic make-up in terms of the use of improved breeds selected for milk production, a favorable nutritional environment and improved managerial practices. The main objective of this review is to identify the role of molecular genetics to improve dairy cattle milk production, challenges and opportunities in case of Ethiopia.

**History of Dairy Cattle Genetic Improvement in Ethiopia:**

Cattle genetic improvement program in Ethiopia started with dairy cattle improvement to enhance milk production of local breeds. The program was launched by importing exotic dairy cattle breeds during Italy evasion. Later on, Dairy Development Agency (DDA) was launched (1958 to 1963) with the main duty of developing commercial dairy farms in Addis Ababa [5]. Following this, Chilalo Agricultural Development Project (CADU) was established jointly by the Ethiopian and Swedish Governments in Arsi region. This opened intensive small scale dairy development in Ethiopia in 1967/1968 [6]. Wolaita Agricultural Development Project (WADU) was established in 1971 By World Bank fund [7]. Production of deep-frozen semen started at CADU in 1973. CADU in Assela and WADU in Wolaita continued breeding and distributing crossbred dairy cows to farmers. In 1987, a FINNIDA funded project of the MOA started to improve dairy cattle productivity at the highlands of Ethiopia through the establishment of the Selale Peasant Dairy Development Pilot Project (SPDDPP). SPDDPP introduced crossbred dairy cattle and improved management skills with the objective of improving the living standard of smallholder farmers [8]. The focus of the program was on increasing the milk productivity of local breeds through crossbreeding and distribution of first generation (F1) heifers to farmers [9]. Furthermore, crossbred dairy cows and purebred Friesian and Jersey breeding bulls were distributed with introducing improved methods of fodder production in the project areas [10]. Despite all of these trials, the numbers of crossbred cattle made only 1% of the total cattle population of Ethiopia [11]. Then, the national artificial insemination center was established 1981, with the aim of country coverage in artificial insemination service (rural, peri-urban and urban areas) through the regional offices. To date, semen was collected from exotic, indigenous, as well as, crosses of these breeds, namely Friesian, Jersey, Brahman, Boran, Barca, Fogera, Horo, Sheko and crosses of 50, 62.5, 75 and 87.5% Holstein-Friesian indigenous bulls. NAIC at Kality served as the main semen collection and preservation center. Later, productions of semen from crossbred animals (Friesian × Fogera; Friesian × Boran; Friesian × Barca; Friesian × Arsi) and from indigenous breeds (Barca, Boran and Fogera) were undertaken and some doses distributed [7, 12]. The effectiveness of any dairy cattle genetic improvement program was measured by the genetic progress obtained [13, 14]. A standard way of measuring progresses in animal breeding was by regressing estimated annual environmental and breeding value on year of birth [15].

To meet the huge requirement of superior bulls of well-defined zebu cattle breeds and multiplication of their quality germplasm for enhancing the productivity of vast nondescript cattle as well as transforming non-descript to define purebreds, it is necessary to undertake large-scale genetic improvement programmes in different zebu cattle breeds in their respective breeding tracts through selective breeding. The animals with high producing ability belonging to well-defined indigenous dairy and dual-purpose cattle breeds were maintained under intensive production system at organized farms and under semi-intensive management system at farmers’ herds Anonymous, [16]. Annual Report 2011-2012.

Genetic gains resulted by crossbreeding Ethiopia’s local (generally hardy but low-yielding) animals with (high-yielding) exotic breeds and by improving local breeds through selection. Long-term research in tensed on developing within-breed selection programs for indigenous breeds; crossbreeding superior indigenous breeds; developing synthetic indigenous breeds; evaluating indigenous breed potential for economically important traits; and designing a genetic improvement strategy and program for each major livestock breed [17].
Genetic improvement of livestock depended on access to genetic variation and effective methods for exploiting this variation. Reproductive biotechnology provided means whereby reproductive performance may be modified at a number of points. The main objectives of using reproductive biotechnologies in livestock were to increase production, reproductive efficiency and rates of genetic improvement. From the various biotechnology methods were used in improving the breeding stock of animals the artificial insemination (AI), the embryo transfer (ET) and their associated technologies [18].

**Dairy Cattle Traits:** An efficient, systematic and operational breeding strategy is necessary to bring about improvement in the dairy sector. Such a strategy needs to take into account selection within the local cows and crossbreeding local cows of good production potential with sires of known exotic dairy breeds. The breeding strategy should also take into consideration the agro-climatic and production system as well as socio-economic conditions of the country [19, 20]. The productivity of dairy cattle breeds depended mainly on their reproductive performance and efficiency of service per conception [21]. Among reproductive performance traits: age at first service, number of service per-conception, calving interval, age at first calving, days open, first service per conception, gestation length, calving rate, non returning and returning rate of service were the bases of profitable production for dairy farm [22]. The choice among the different foreign breeds to be used for crossbreeding was made based on available information on the limited experience of crossbreeding work in Ethiopia and/or experiences of other tropical developing countries [23].

**Production of Milk in Ethiopia:** Total milk production in Ethiopia increased during the 1961 to 2000 period at an average annual rate of 1.55%. Additionally, during the last decade, milk production was grown at even higher rate (3.0%). This might be as a result of increased coverage of extension services (such as better management skills) and increased use of improved inputs (improved breeds and feed) and technology and policy changes promoting dairy production [24]. Similarly, Central statistical authority data on milk production also showed an increment to 3.33 billion liters in 2012 [25] from 2.4 billion liters in 2004 [26]. Therefore, crossbreeding program has been contributing its impact on alleviating the ever increasing demand of milk and its product in the country.

**Milk Production Traits Genetic Determinants:** The phenotypic expression of milk production traits (milk yield and composition) are controlled by genes, which may or may not be transferred to the offspring. The genetic value of a trait indicates the likelihood that the genes responsible for that trait will be transferred to any offspring. Consequently, when dairy producers were selecting animals for breeding stock, they were typically more concerned with an animal’s genetic value rather than its phenotypic value of a particular trait. The difference was that while the phenotypic value refers to the presence or absence of particular traits, the genetic value indicated the potential (or probability) that this animal, if bred, will give birth to calves with certain desired traits. Two main reasons for the decline in fitness traits of cows associated with increased genetic merit for milk yield were: (i) fitness traits are ignored in the construction of selection indices because they were considered to have lower heritability or are not easy to record and (ii) use of inappropriate breeding programmes while the underlying genetic process (selection and inbreeding depression) was not well understood [27]. However, the low heritability of some fitness traits does not imply negligible genetic variance; often heritability was low because the phenotypic variance was rather larger than the genetic variance as evidenced by as high genetic coefficient of variation for fitness traits as for some production traits [27].

**Role of Molecular Genetics and Technologies:** Molecular genetics is the study of the genetic makeup of individuals at the DNA level; it is the identification and mapping of genes and genetic polymorphisms. There are opportunities for using molecular genetics to identify genes that influence milk production traits. Armed with this information, it would be possible to select improved livestock on the basis of their genetic makeup [28]. The use of molecular genetics technologies potentially offer a way to select breeding animals at an early age (even embryos); to select for a wide range of traits and to enhance reliability in predicting the mature phenotype of the individual. The broad categories of existing gene technologies based options include; molecular analysis of genetic diversity, animal identification and traceability, reproductive enhancement; transgenic livestock; germ line manipulation and; marker/ gene based trait selection; animal health: diagnosis, protection and treatment; ruminant and non-ruminant nutrition and metabolism [28].
**Genetic Markers:** Recent developments in molecular biology and statistics had opened the possibility of identifying and using genomic variation and major genes for the genetic improvement of livestock. Molecular techniques allow detection of the existence of variation or polymorphisms among individuals in the population for specific regions of the DNA. These polymorphisms can be used to build up genetic maps and to evaluate differences between markers in the expression of particular traits in a family that might indicate a direct effect of these differences in terms of genetic determination on the trait [29]. Application of molecular genetics for genetic improvement relies on the ability to genotype individuals for specific genetic loci. Genetic markers were used to identify specific regions of chromosomes where genes affecting quantitative traits are located, i.e., QTL [30].

**Genetic Marker Technologies Applied in Animal Breeding:** Recent developments in molecular biology and statistical methodologies for QTL mapping have made it possible to identify genetic factors affecting economically important traits. Such developments had the potential to significantly increase the rate of genetic improvement of livestock species, through MAS of specific loci, genome-wide selection, gene introgression and positional cloning [31]. Instead of conventional animal breeding programs solely relying on phenotype and pedigree information, the incorporation of detected QTL into genetic evaluation provides a great potential to enhance selection accuracies, which expedites the genetic improvement of animal productivity [32]. Highly saturated genetic maps are now available for cattle provided the genetic framework for developing MAS programs [30].

**Marker-assisted Selections (MAS):** Genetic improvement involves selection of outstanding individuals from a population to produce better yields in future generations. For a long time, dairy breeders had used genetic evaluations to identify superior animals. Selective use of these animals improved phenotypic measures for milk production and milk components. However, there were some limitations to selecting on predicted breeding values. This selection approach has limited ability to improve lowly heritable traits without adversely affecting production. Low heritable traits often included those associated with disease resistance, reproduction, duration of productive life and some conformation traits correlated with fitness [33].

Marker-assisted introgression programs depended on tandem selection in a multigenerational backcrossing program, in which a marker selection (MS) based on the presence of donor breed alleles at or around the target gene was used in the first selection step (foreground selection), followed by background selection on a MS based on presence or absence of recipient alleles at markers spread over the genome, on phenotype, or an index of the two [34].

Animals breeding programmes depended on selection programs based on phenotypic selection where traits were measured directly and animals with superior performance in the traits were used as breeding stock where the trait was limited, like milk production, progeny test schemes had allowed the genetic merit of the sex and did not display the trait to be estimated. Several problems were associated with the phenotypic selection included (i) the narrowing the genetic base of a population; (ii) the approach can only be applied to traits that were easily measured; and (iii) the high costs [28].

**Artificial Insemination (AI):** Artificial insemination (AI) is the manual placement of semen in the reproductive tract of the female by a method other than natural mating. It is one of a group of technologies commonly known as “assisted reproduction technologies” (ART), whereby offspring were generated by facilitating the meeting of gametes (spermatozoa and oocytes). ART involve the transfer of the products of conception to a female, for instance if fertilization has taken place in vitro or in another female. In Ethiopia, mainly crosses of zebu with Holstein-Friesian cattle had been used for milk production for decades [35].

One of the earliest perfected technologies was the artificial insemination (AI) where new breeds of animals are produced through the introduction of the male sperm from one superior male to the female reproductive tract without mating. AI reduced transmission of venereal disease, lessened the need of farms to maintain breeding males, facilitated more accurate recording of pedigrees and minimized the cost of introducing improved genetics [18].

**Embryo Transfer (ET):** Embryo transfer is one step in the process of removing one or more embryos from the reproductive tract of a donor female and transferring them to one or more recipient females. Embryos are produced in the laboratory via techniques such as in vitro fertilization or the somatic cell cloning. But the actual transfer of an
embryo is only one step in a series of processes included some or all of the following: super ovulation and insemination of donors, collection of embryos, isolation, evaluation and short-term storage of embryos, micromanipulation and genetic testing of embryos, freezing of embryos and embryo transfer. Proper recipient herd management was critical to embryo transfer success. Cows that were reproductively sound, that exhibit calving ease and that have good milking and mothering ability were recipient prospects.

The principal benefit of embryo transfer is the possibility to produce several progeny from a female, just as AI can produce many offspring from one male. For example the average lifetime production of a cow could be increased from 4 to 25 calves. Increasing the reproductive rate of selected females had the following benefits: genetically outstanding animals could contribute more to the breeding program, particularly if their sons were being selected for use in AI; the rate of genetic change has been enhanced with specially designed breeding schemes which took the advantage of increased intensity of female selection combined with increased generation turnover; transport of embryos was much cheaper than that of live animals; risk of importing diseases was avoided; facilitates rapid expansion of rare but economically important genetic stocks; and the stress to exotic genotypes could be avoided by having them born to dams of local breeds rather than importing them as live animals.

Cloning: Using cloning in animal genetic improvement for milk production aimed to increase the rates of selection progress in certain cases, particularly in situations where artificial insemination was not possible, like in pastoral systems with ruminants. Cloning is another technique that raised concerns both from the ethical and practical point of view. In animals, besides the very low success rates, some abnormalities suggested that more information was required on the consequences of such practices in humans and animals, before its routine application [29].

Selection of Bulls: Methods of selection should be based on clear breeding goals, aimed at increased milk and improved productivity. The selection of sires used in artificial insemination (AI) based on the estimated breeding values (EBVs) of the sire’s parents or, in the case of beef breeds, his own EBVs for different traits. The availability of EBVs in a population depended on an internationally approved pedigree registering and recording system. The basis for selection and ranking of bulls with respect to their genetic value for different attributes was the EBV. The EBV for a characteristic such as milk production of daughters was Heritability x Phenotypic Superiority [36].

The four factors determined genetic progress were the accuracy of selection, the selection intensity, the generation interval and the genetic variation. Genetic improvement per generation from selection depended on the variability of the traits considered, their heritability (i.e. the proportion of total variation which can be ascribed to genetic differences) and the intensity of selection [37-39].

Opportunities and Challenges

Opportunities: The development of market infrastructure and market institution was also very important for inducing efficiency and incentives for market participants on the value chain. The marketing system should operate efficiently to ensure that the consumer gets their demands and the producer gets the reforms needed to continue production [40]. The tools of molecular genetics were likely to have considerable impact in the future. For example, DNA-based tests for genes or markers affecting traits that were difficult to measure currently, such as meat quality and disease resistance, will be particularly useful. Genomic selection should be able to at least double the rate of genetic gain in the dairy industry [41], as it enables selection decisions to be based on genomic breeding values, which can ultimately be calculated from genetic marker information alone, rather than from pedigree and phenotypic information.

Furthermore, the large national livestock populations that offer significant potential for genetic improvements in productivity, these in turn would greatly increase total production rapidly rising world-wide demand for cattle products, government well disposed to sector and willing to improve policies and increase budgetary allocations for livestock sub-sector, increase supply of improved local and exotic genotypes through private and community based animal genetic improvement program for targeted interventions [23, 40, 42]

The growing demands for reliable services and quality semen, in most cases, users of the AI service were willing to pay even higher fees per service provided that they get quality semen and reliable services, the possibilities of getting alternative semen sources from private organizations, Nationally established system and organization to coordinate crossbreeding efforts, efforts
being made by partner GOs and NGOs to improve the service were some important opportunities to implement and improve efficiency and effectiveness of AI service.

Diversified genetic resource permits traditional selection practices of breeding animals within and between populations are also one potential that could lead to gradual genetic differentiation and breed divergence. Adaptation of animals to cope up specific environmental stresses was another force responsible for genetic variations between cattle populations. Genetic variation wa as key issue for adaptation and selective breeding as result; it was basic tool for future genetic improvement [43].

Ethiopia holds large potential for dairy development due to its large livestock population, the indigenous animals had resistance for harsh climate, ability to convert roughage feeds, there is excess labor, the presence of land resources were the opportunities. Artificial Insemination (AI) technology had also led to one of the most successful smallholder dairy systems in the developing world [44].

**Challenges:** In Ethiopia, the livestock sector in general and the dairy sub-sector in particular do not make a substantial contribution to the national income, despite their large size, due to numerous socio-environmental factors. The poor performance of the dairy sub-sector was attributed to socio-economic, infrastructure and technical constraints, inadequate research and extension activities and lack of policies relevant to the development of the dairy industry [45, 46].

The climatic conditions in Ethiopia vary from humid tropical in the western lowlands through mild subtropical in the highlands to the arid tropical conditions of the eastern lowlands [23]. Lack of establish a national database system, monitor genetic improvement and progress through monthly genetic evaluations and develop a feedback system for farmers, enabling selection of superior bulls [17]. Lack of record keeping and reporting by AI service providers and farmers had adversely affected national data analysis and decision making on progress and it was also highly believed to have increased the incidence of inbreeding in the country. The challenge of the dairy breeder was, therefore, to determine which cows and bulls to breed in order to obtain progeny with high quality milk production traits, as well as any other desirable attributes. The following were the major challenges of genetic improvement for dairy cattle.

**Genetic Limitation:** The main problem of milk production in the country was that of the poor genetic potential of the indigenous cattle, which gave rise to low milk output. Milk production was as low as 0.5 to 2 liters per day over a lactation period of 160 to 200 days. Improving the feeding, water availability and health care of the indigenous cattle did not increase the quantity of milk per day to allow the animals to be used for commercial market-oriented milk production. The current specialized dairy breeds were a result of a long period of selection program. If improvement of the local Ethiopian breeds for milk production had targeted, then it was important to have a well designed selection program in place for a few selected promising breeds. Exotic animals used in crossbreeding were not naturally adapted to local conditions, so large scale (beyond optimal exotic blood level) crossbreeding should be carried out with caution [46].

**Limited Access and High Cost of Dairy Heifers/cows:**
The improved crossbreed, upgrade and pure exotic dairy cattle were usually in short supply and when available, the high cost was a major problem. The few government crossbreed heifer multiplication centers that used to distribute in calf crossbreed heifers to producers at reasonable prices had been sold after the introduction of the privatization policy. Prices of crossbreed cows and heifers were now unaffordable by the poor and the average smallholder farmers that would have liked to engage in the dairy business.

**Absence of an Operational Breeding Strategy and Policy:**
The absence of effective breeding programs was a major constraint to the dairy development. The AI service has been inefficient for different reasons in rural areas where smallholder farmers predominate. As reported by FAO/IAEA [47], some of these reasons include: inappropriate infrastructure, managerial and financial constraints, inefficient heat detection and improper timing of insemination, embryonic death and very small number of AI technicians compared with the number of cows in a given area. As [48] indicated that the Ministry of Agriculture assigns one AI technician to serve farmers of one district.

Dairy cattle genetic improvement program started in Ethiopia in the early 1970s has never been subjected to periodic evaluation for the genetic and environmental trends. Thus, the effectiveness of this program is not clearly known. Moreover, no information was available on
the status of the national dairy cattle genetic improvement program that guide policy makers, development planners and breeders to redesign appropriate breeding programs that respond to the current scenarios in Ethiopia [49].

Inadequate Veterinary Service Provision: The prevalence of various animal diseases, tick borne diseases, internal parasites and infectious diseases affected dairy development programs in varying scales, depended on ecological zones and management levels. The animal health services provided were inadequate; the cost of drugs and ascaricides was very high, while the diagnostic services were not readily available to the dairy farmer. This was partly attributed to the insufficient budget allocated to veterinary services [49].

CONCLUSION AND RECOMMENDATION

Based on this review concluded that molecular genetics is the best important way to improve the dairy cattle milk production. Genetic improvement program for livestock can be increased by the use of molecular genetic information in introgression, genotype building and recurrent selection program. Ethiopia holds large potential for dairy development due to its large livestock population, the animals have resistance for harsh climate, animals have ability to convert roughage feeds, there is excess labor, the presence of land resources are the opportunities. The challenges of dairy cattle’s were prevalence of various animal diseases, market infrastructure, absence of an operational breeding strategy and policy, lack of reliable services and quality semen, lack of trained technician, lack of improved crossbreed and pure exotic dairy cattle. Generally the role of molecular genetics to improve dairy cattle breeds and milk production in Ethiopia are still very poor because of different challenges even some opportunities are present. Therefore, establish operational strategy, evaluate applicability of technology, fulfill infrastructure, give training for farmers and experts should be the most important before implementing dairy cattle genetics improvements.

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