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Review on the Role of Crossbreeding in Improvement of Dairy Production in Ethiopia

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Abstract: Ethiopia is facing an increasing requirement of food of animal origin as the human population keeps increasing rapidly. Different livestock development projects and breeding strategies have been carried out with the aim of introducing crossbred animals to improve milk productivity and milk market involvement of subsistence farmers. Crossbreeding is one of the breeding strategies that is performed to increase the dairy cattle productivity and at the same time the profitability of the dairy production. Heterosis is an essential advantage of crossbreeding. It enhances the genetic level of the hybrid offspring more than the average of his/her parent breeds. Unsystematic crossbreeding due to lack of appropriate breeding strategy, poor infrastructure, lack of funding and qualified man power are some of the problems in implementation of crossbreeding in Ethiopia. To overcome the prevailing limitations, determination of the production system, enhancement of existing husbandry systems and selection of suitable breed is the most important points that must be considered during planning breeding program. It is suggested that in the future more effort should be directed to the development of crossbreeding programs for increasing the productivity of dairy cattle in the country.

Key words: Breeding Strategy · Crossbreeding · Heterosis · Productive Performance · Ethiopia

INTRODUCTION

Ethiopia is believed to have the largest livestock population in Africa and dairy production is an important component of livestock farming. The country's excessive and various cattle population, a relatively promising environment for improved, high-yielding dairy cattle breeds and regions with less animal disease-stress that make the country to have a considerable potential for dairy development. However, milking has not been fully exploited and promoted [1]. National milk production remains the lowest in the world, even by African standards [2, 3]. A total of 2940 million liters of milk were produced in 2010 from about 9.6 million cows at a national level [4].

Domestication and the practice of conventional livestock breeding techniques for genetic enhancement of dairy cattle to improve milk production of local breeds is over about six decades in Ethiopian history [5]. Genetic upgrading programs for improving dairy cattle to improve milk production of local breeds were started by importing pure temperate breed of cows during the Italian occupation, later crossbreeding using temperate breeds and indigenous breeds has been practiced by a number of governmental and non-governmental organizations. However, these efforts have been met with little success due to several technical, organizational and socioeconomic limitations [6].

Crossbreeding in tropical countries is practiced to combine superior hardiness, heat tolerance, disease resistance and environmental adaptability of indigenous cattle with superior high milk yield, faster growth rates and early maturity of exotic, temperate breeds [7,8]. Crossbreeding lead to a good improvement in production of milk, especially when accompanied with satisfactory management levels in terms of nutrition and disease control. Regardless of the existence of huge and diverse animal genetic resources, the potential for productivity performance of livestock remains low in many regions of the country. Therefore, crossbreeding with *B. Taurus* is suggested to certify better productive and reproductive performance of the hybrid [9-11].

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Artificial Insemination (AI) services in Ethiopia have been the most commonly practiced animal biotechnology all over the country for enhancing crossbreeding. Nevertheless, its activities have been unsatisfactory and restricted to the Capital city and some major cities owing to a number of technical, financial, infrastructural and managerial limitations that prevail in the developing countries [12]. The limitations associated with AI in Ethiopia include absence of breeding policy and herd recording system, insufficient resource in terms of inputs and facilities, poor structural association between AI center and service giving units, absence of partnership and consistent communication between national AI centers and stakeholders and absence of incentives and rewards to motivate AI technicians and this make crossbreeding processes hard [13, 14].

The cattle population in Ethiopia consists of 99.4% indigenous, 0.5% crossbreeds and 0.1% exotic breeds which are chiefly kept under smallholder subsistence farming. Precise assessment of the reproductive efficiency of indigenous cattle and their crossbred in different production systems is crucial for the development of suitable breeding strategies. However, there has been no tangible and binding breeding policy with regard to the choice of the exotic breed types to be crossed with the indigenous animals and the corresponding exotic blood level of the crosses [15]. Due to lack of a well-defined breeding aims and dependable performance recording system, breeding value estimation and selection for improved productivity would be challenging [16].

Therefore the aims of this review are to provide updated information on the role of crossbreeding programs in improving dairy cattle productivity and to indicate significant problems and prospects for sustainable breeding systems in Ethiopia.

Literature Review

Crossbreeding Strategy for Improvement of Dairy Production: Crossbreeding is a method that is used to increase the health and efficiency of animals by introducing favorable genes from other breeds, removing inbreeding depression and by maintaining the gene interactions that result in heterosis [17]. Heterosis is a principal factor in crossbreeding strategies [18]. It is defined as the improvement in genetic level and the benefit expressed for traits in a hybrid offspring above the average of the parent breeds [19, 20]. Any crossbreeding selection needs purebred populations [21]. To be effective, selection in the contributing pure breeds or the resulting synthetics is vital [22, 23]. Moreover, a crossbreeding program should be relatively simple and in harmony with other aspects of the production system [24]. Results of crossbreeding can be affected by the Climate, temperature, region-specific breeds, on farm conditions, nutrition and breeding and management practices [25, 26].

Dairy production systems in most developed countries exclusively consisted of pure breeds of Holstein [27]. This domination was caused by its high production and good conformation traits [25, 28]. Today the interest in crossbreeding increases due to changes in the dairy market towards broader breeding goals including functional traits and milk components, along with an increased level of inbreeding among purebred Holstein [29]. Unfortunately, crossbreeding can also pose a risk of adverse effects and one of them is recombination loss [30]. It is caused by separation of favorable gene combinations that are accumulated in the parental breeds. Recombination loss can be challenging to estimate although it has been seen to decrease the level of heterosis [31]. The functional traits seem to have no recombination loss and instead sometimes even have a recombination gain [32].

Inbreeding refers to mating of individuals with one or several ancestors in common [33], the closer relationship, the larger the quantity of identical genes and the higher the risk of inbreeding. Inbreeding can lead to a decline in performance of dairy cattle and it is known as inbreeding depression [34]. It is the reverse of heterosis and is caused by a too high rate of homozygosity in loci with genes which have a negative effect on traits connected with survival and overall fitness, e.g. reproductive rate, health and disease resistance [33].

The genetic superiority of Holstein-Friesian cows compared with crossbred animals and other breeds has encouraged its adoption in most countries where dairy cattle breeding has covered an important role on livestock production and where milk volume has been of great importance in determining income for the dairy farm [35]. In comparison of milk production and reproduction performances, Frisian crossbred dairy cows were more productive than Jersey crosses in central highlands of Ethiopia [36]. However, Jersey crossbred dairy cows have shorter lactation lengths and calving interval than Frisian crossbred dairy cows that reflects better reproduction efficiencies in Jersey crosses. However, continuous decline in the milk production traits over time accompanied by substantial improvements in

reproduction traits showed gradual deterioration in the genetic components of the breeding programs. It generally reflects the lack of efficient selection program, absence of periodic monitoring of the genetic progresses attained and use of sires with low breeding value [37].

Historical Development of Crossbreeding in Ethiopia: Crossbreeding in Ethiopia has been started by the Institute of Agricultural Research, through the establishment of on-station dairy cattle crossbreeding program, using Friesian, Jersey and Simmental sires that were crossed with the local Horro, Boran and Barka dams with the goal of trying the productivity of crossbred dairy cows with different levels of exotic blood [38]. Ethiopia received its first exotic cattle (Holstein Friesian and Brown Swiss) in the 1950's from the UN Relief and Rehabilitation Administration and since then started commercial liquid milk production on government stations [16].

Crossbreeding did not start until 1967 when the Chilalo Agricultural Development Unit (CADU) was established at Asela station. This project, founded cooperatively by the Ethiopian and Swedish Governments, made the first steps in introducing crossbreeding at smallholder farm level [39]. After recognizing the genetic improvement possibilities, similar dairy development programs were implemented in Ethiopia with assistances from international agencies [40]. The Wolaita Agricultural Development Project (WADU) that was established in 1971 and funded by the World Bank, applied the CADU program, followed this, Production of deep-frozen semen started at CADU in 1973 [41].

Systems of Crossbreeding: There are three different systems of crossbreeding. These are Grading up, Composite breeding and Rotational crossing. There are numerous characteristics that should be considered when selecting the most competitive breed and crossbreeding system [42]. Grading up is a crossbreeding system common in the tropics due to its relatively easy implementation. Regularly, indigenous female animals are mated with exotic males through AI [42]. Continuous grading up with exotic animals leads to replacement of more than 90% of the local genotype. In many occasions grading up to a certain percentage of exotic blood is desirable taking prevailing local conditions and requirements into account [43]. The composite breeding aims to develop a new, composite breed made up of two or more component breeds and to take advantage from combined favorable characteristics of the different breeds [24]. A synthetic population can be designed either by continuous inter se mating of F1 individuals or via backcrossing to the superior breed. The synthetic breed is always poorer compared to the original cross from which it was formed, that is why successful composite breeding requires stable selection within the crossbred population [44, 45]. After a certain number of generations, the performance level of the population is balanced and the animals can be considered as purebred [24].

The rotational crossing system rotates purebred sires from each breed used in the crossbreeding system to inseminate female animals. The sires allow genetic gain in a population [24]. Ideally, tropical sires should come from an improved local breed under selection and temperate sires should be selected from a herd bred in the local environment. Such systems allow continuous replacement heifers on farm, which keeps replacement costs in rural areas low. Downsides of rotational crossing are less exploitation of heterosis and additive effects as well as has wide fluctuations in breed characteristics between generations [43]. Rotational crossing leads to better dairy performance compared to synthetics, chiefly due to more heterozygosity [42].

Dairy Production Systems in Ethiopia: There are four main dairy production systems in Ethiopia. These are lowland pastoral dairy production systems, highland small-holder dairy production system, urban and peri-urban small scale dairy production system and Intensive dairy farming system [46].

Lowland Pastoralist Dairy Farming: In Ethiopia, pastoralists have about 30% of the indigenous livestock population. The herd is dominating with animals of unimproved Zebu and milk production is of subsistent type [47]. Pastoralism is the chief system of dairy production in the lowland areas [48]. It is mainly operating in the range lands and livestock does not deliver inputs for crop production but support their owners offering all of the consumable and marketable yields and viewed as insurance against difficulty time. Milk production is reliant on a season owing to the rainfall pattern that effects feed accessibility [46].

Highland Small-holder Dairy Farming: It is found in the central parts of Ethiopia where dairying is almost part of the subsistence smallholder mixed crop and livestock farming [47]. This production system is mostly present in

the highland agro-ecological zone [48]. Two systems are identified in the highland. The traditional system which is founded up on indigenous breeds and the market-oriented system that is founded up on crossbred dairy cattle. The smallholder farmers chiefly raise indigenous cattle breeds. However, some farmers found near city areas and that have access to milk markets for marketing excess milk have crossbred cattle in this farming system, all the feed requirement is derived from native pasture and a balance comes from crop residues and sub grazing [49]. The surplus is primarily processed by means of traditional technologies and the processed milk products such as butter, ghee, ayib and sour milk are regularly marketed via the informal market after the households satisfy their needs [50].

Urban and Peri-Urban Small Scale Dairy Farming: It helps vastly towards satisfying in the large demand-supply gap for milk and milk production urban center [51]. This production system mainly concentrates on production and sale of milk by means of the accessible human and capital resources [52, 4]. This dairy production system is established in and around main cities and towns situated chiefly in the highlands of Ethiopia. The key feed resources are agro-industrial derivatives and bought roughages. The system consists of small and medium-sized dairy farms that have crossbreed dairy cows. Land is used for forage production by Farmers. The chief purpose of milk production is generating further income of money to the household [46].

Intensive Dairy Farming: The herd is dominated with improved/cross breed dairy cattle and the production system is market oriented and milk production is for sale (surplus production) [16]. Applied by the state sector and few private commercial farms [53]. It is a market-oriented dairy procedure, which is a specialized operation. Most of the farms are situated near Addis Ababa and fundamentally possess exotic dairy stock [46]. In this system, dairy animals do not offer draft, but their manure is used as fertilizer on crops [54].

The Role of the Dairy Sector in Ethiopian Economy: Dairy plays a vigorous role in the Ethiopian agricultural sector and the national economy [53]. The Dairy sector is a foundation of livelihoods for an enormous majority of the rural population in terms of consumption, income and job opportunities [48]. Dairying is critical at household level in one way or another in all the farming systems of Ethiopia [55].

Milk is the greatest important source of protein in pastoralist farming system and the crop farming areas [56]. In the mixed farming systems, milk is important principally as food to the household and to a slighter extent as a source of income [57]. In the urban and peri-urban areas, dairy production is chiefly implemented as a source of income [55].

There is no satisfactory information to evaluate the portion of the dairy sector in the GDP of the country [48]. Nevertheless, the description of Tegegne and Alemu [51] showed that 800, 000 metric tons of milk were produced per year. The low per capita consumption of milk, which is 20 kg per annum, is inferior than the average of other east African countries and this showed that the real level of dairy efficiency is enormously low [58].

Genetic Improvement Activities of Dairy Cattle in Ethiopia: Plans for genetic breed improvement for dairy production in Ethiopia was started by introducing pure temperate breed of cows and meanwhile crossbreeding using temperate breeds and indigenous breeds have been undertaken by a few governmental and non-governmental organizations [55, 58]. Nevertheless, these hard works have been encountered with slight achievement owing to the numerous technical, organizational and socioeconomic limits. Far along, the First Livestock Development Project (1958-1963) established the Dairy Development Agency (DDA) that was chiefly aims with the advance of commercial dairy farms in Addis Ababa [59].

In 1987, a FINNIDA funded project of the MOA started to enhance dairy cattle efficiency at the highlands of Ethiopia the establishment of the Selale Peasant Dairy Development Pilot Project. SPDDPP presented crossbred dairy cattle and enhanced supervision skills with the goal to improve the living standard of small-holder farmers. Nevertheless, the genetic enhancement events for dairy production in Ethiopia were embarrassed by a number of issues.

Climatic pressure in the form of erratic and insufficient rainfall; low feed yield ability and maximum price for concentrate and exposure to a wide variety of grave diseases adversely distress the productivity of genetically upgraded dairy cattle especially the upgraded ones [55, 60].

Table 1: Milk Production Performance of Indigenous, Crossbred and Exotic cows in Ethiopia.

Breed	Milk yield (Kg)	Length (days)	Location	Source
Indigenous				
Boran	494	155	On station	[61]
Horro	559	285	On station	[61]
Arsi	809	272	On station	[39]
Barka	552a	128a	On station	[62]
Fogera	613	353a	On station	[62]
Crossbred				
Friesian X Boran	1554	350	On farm	[63]
Friesian X Arsi	1040	350	On farm	[40]
Friesian X Arsi	1977	356	On station	[39]
Friesian X Arsi (25-62.5%)	1547	366	On farm	[64]
Friesian X Arsi (≥75%)	2924	361	On farm	[64]
Friesian X Barka	1488	301	On farm	[65]
Jersey X Barka	970	257	On farm	[65]
Jersey X Arsi	1741	334	On station	[39]
Exotic				
Friesian	3796	323	On station	[66]
Jersey	1619	273	-	[63]

a= first lactation.

Source: Desta, 2002.

Dairy Cattle Breeding Policy in Ethiopia: In the face of the number of hard work in the past years to advance the genetic potential of the local dairy cows, there has been no tangible and compulsory breeding policy with respect to the selection of the exotic breed sorts to be crossed with the indigenous animals and the finest exotic blood level of the crosses to be achieved in different production systems [63, 48]. Although it has not been applied, there was a policy proposal, set by the Ministry of Agriculture in 1985. A draft proposal for a new livestock breeding policy has been arranged by the Ethiopian Agricultural Research Organization. Accomplishment of self-adequacy in milk and milk products in both quality and quantity is one of the definite aims of the draft policy [63, 48].

According to the proposal, the national cattle breeding program intend to have the following three components:

- Achievement of Cattle breed zoning is based on aims of livestock keeping, the recent distribution of breeds, the physical environment, socio-economic conditions; predominant farming system and accessibility of infrastructure cattle breeds are thus situated to zones that suit their biology.
- Four alternatives of breeds are mentioned to be used: indigenous, exotic, crossbred and synthetic. It is planned that the indigenous cattle shall be left to prosper to preserve the indigenous gene pool.
- Pure-breeding is suggested to enhance desirable traits as to the breeding methods.

Pure-breeding and development of exotic breeds using more capable and enhanced tropical breeds are suggested for all intensive dairy areas. The second choice stated in the draft policy are crossbreeding of indigenous breeds with exotic breeds, combined with performance recording and selection program within the local cattle, rotational crossbreeding: using exotic and local breeds in alternate generations to take benefit of shifting market demands is the third choice in the draft policy [63].

Consequence of Crossbreeding on Maintaining Genetic Diversity: The presence of genetic polymorphism or diversity in a population is the foundation of genetic enhancement by selection and desires to be appropriately evaluated [67]. Scheming of a breeding program also consider a mechanism that ensures maintenance of animal genetic resources [4]. Nevertheless, crossbreeding was and still is regarded as the method to forward to enhance efficiency of indigenous livestock under smallholder situations and development policies has largely disregarded adapted farm animal genetic resources [36]. Crossbreeding with exotic breeds is a chief issue supporting the erosion of locally adapted AnGR [37, 3].

Main Challenges of Crossbreeding in Ethiopia

Environment and Genotype Mismatch and Market Value Chain: For the development of smallholder dairy system, there would be an excessive ability if the government proposes appropriate praise, access to market and services, in peri-urban and urban areas [68]. Recent suggestions pointed that, the financial benefits of crossbreeding might have been overrated as non-market effects and environmental standards have not been comprised in breed evaluation studies. The development of market infrastructure and market institution is also vital for inducing efficiency and incentives for market participants in the value chain [69]. The level of management attainable under most smallholder conditions in Ethiopia which has been rather unfavorable to higher exotic inheritance levels [55].

Lack of Continuous Evaluation and Input Supply: Lack of Evaluation and input supply has been lead to problems toward the implementation of crossbreeding in Ethiopia. Costs for breeding such as labour, feeds and vaccinations are high, such that on-farm cross breeding might not bid any economic aids to the farmers [70]. As a result, farmers

are favoring local breeds limiting acceptance of improved breeds. Therefore, it might be of bigger support to integrate indigenous breeds into selection programs to advance adoption rates of improved crossbreeds [71].

Lack of Designing Appropriate Breeding Program: Well-designed crossbreeding programs might lead to achieve needed characteristics of the breeds or strains involved and to take gain of heterosis for traits of economic importance [35]. The problem, however, is how to design maintainable breeding schemes for indigenous breeds under inherent tropical circumstances [72] where resources are inadequate, feed accessibility and quality varies critically dependent on the type, geographical location and season and the demand in animals that are better able to adapt to the ever-changing environment owing climate change is increasing. During designing of a breeding program, conservation of animal genetic resources needs to be considered [73].

Lack of Crossbreeding Policy and Recording: Information is not accessible on the status of the national dairy cattle genetic improvement program that lead policy makers, development planners and breeders to redesign fitting breeding programs that respond to the contemporary situations in Ethiopia [36]. Lack of fitting livestock policies has been recognized as one of the increasing vital aspects triggering threats to Farm Animals Genetic Resource (FAnGR) in the developing world [55]. Absence of record keeping and reporting by AI service providers and farmers has adversely affected national data analysis and decision making on progress and it is also believed to have increased the occurrence of inbreeding in the country [74]. The recent crossbreeding work in Ethiopia, was not unfortunately based on a clearly defined breeding policy with regard to the level of exotic inheritance and the breed type to be used. In general, in Ethiopia, crossbreeding is not-systematic [4].

Future Prospects of Crossbreeding in Ethiopia: Research, development and use of improved techniques for animal breeding during the past few decades have given good outcomes [53]. However, finest rates of enhancement in production traits are not yet being accomplished. New technology and systems would be investigated and established for increasing the genetic improvement in dairy cattle [3]. Crossbreeding is one of the methods that might contribute to the future improvement of dairy cattle [75]. However, crossbreeding in Ethiopia is on the road that requires future effort. Contemporary researches demonstrated that crossbreeding might have bigger benefits to the Ethiopian dairy industry as a whole. So, crossbreeding must be considered wisely and planned. The use of sexed semen can quicken the improvement of dairy cattle's, since sexed semen enables breeding schemes with F1 crossbred cows in production [67, 76]. Nowadays, numerous dairy farmers have documented the significance of crossbreeding and a rise in the use of different crossbreeding systems to improve dairy cattle productivity can consequently be expected in the future [3].

Generally, continuous hard work will be required in the future to gain further improvement in milk production through crossbreeding. In particular, there is a need to increase the number of traits for which dairy animals will be evaluated and means by which to quantify correlated responses to selection for milk production and other economically vital traits [1, 77].

CONCLUSIONS

Ethiopia has a huge number of dairy cattle and great potential for dairy development. However, dairying has not been fully exploited and promoted due to different reasons including lack of appropriate breeding policy, lack of governments attention towards implementation of productivity improvement techniques, lack of infrastructure, lack of skilled personnel, poor education and management skill of farmers, misunderstanding of production systems, lack of extension works to transfer new technologies and knowledge obtained via researches to farmers and different challenges that makes the country unable to take the benefit gained from dairy sector. The dairy sector aids the livelihood of most of small holder farmers but these farmers need to improve their production by undertaking proper management practices and selecting the appropriate breeding methods such as crossbreeding. Crossbreeding in Ethiopia is on the road that needs future hard work. Recently, the interest in crossbreeding aspects has been growing among dairy producers in the country and this practice is important to remove inbreeding depression kept in the major dairy breeds, to improve some economically important traits such as fertility, health, longevity and calving ease and to increase financial gains in the country. Unsystematic cross breeding, absence of appropriate breeding policy and recording system, poor infrastructure, absence of funding and skilled manpower are some of the obstacles in implementation of crossbreeding in Ethiopia. So, the dairy cattle genetic improvement programs of Ethiopia

need to be subjected to national assessments to redesign suitable policies that would be more responsive to the presently varying scenarios in the country.

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