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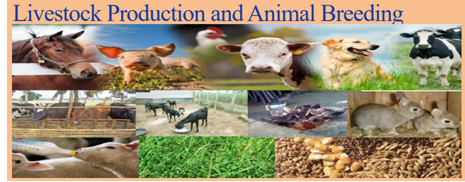

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The possible impact and prospect of animal biotechnology in Ethiopia: From the national SDG perspective

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ABSTRACT

Animal biotechnology contributes immensely to increasing livestock productivity. It involves assisted reproduction, molecular genetic analysis, and vaccine and therapeutics development to reduce the threats of diseases hence ensuring both animal and human welfare. Ethiopian economy is hugely agrarian that could have enormous benefit from ardent applications of biotechnology for increasing livestock product and productivity. The aim of this review paper is to inspect the impact of animal biotechnology research and development endeavors in the country. The country has a fairly long history in research and development activities of animal biotechnology particularly in the area of artificial cattle reproduction and vaccine development. Animal biotechnology applications in research and development arena include hormonal manipulation for estrus synchronization, artificial inseminations, molecular disease diagnostics, vaccine development and production, and molecular genetic analysis. Infrastructure and skills development in animal biotechnology sector such as assisted reproduction and genetic analysis tools are gaining momentum and need further effort to be more strengthened. Complementary assisted reproductive technologies such as the deployment of sexed semen is able to hasten the rate of replacement heifer's production and overall milk production capacity of the country. Ethiopia has recently given a due huge emphasis for capacity building in animal biotechnology extending from promoting research, development and education in various public institutions. The constraints holding back the progress of animal biotechnology are enormous ranging from inadequate physical and human infrastructure development to lack of appreciation of opportunities provided by animal biotechnology by both private and public sectors. Livestock is almost everything for the small holder farmers as a source of food, traction power, insurance and transportation. Hence, improving animal production through biotechnology highly contributes to the food and nutrition security of the country.

Keywords: Animal biotechnology, Artificial insemination, Estrus synchronization, Embryo transfer

INTRODUCTION

Global food security situation is deteriorated sharply, and it is on high development agenda for sustainable development goals. Currently, it is partly associated with an increase of conflict and violence in several parts of the world particularly in Eastern Europe. The ever increasing Food demand that arisen largely from fast population growth and urbanization is creating a concern for adequate production of animal origin proteins to meet the growing number of people in the Globe (FAO, 2017). Per capita milk consumption in Ethiopia, decreased from about 26 litersin mid-1980s to about 16 liters in 2001 (FAO, 2004). Very recent documents also indicated lower milk per capita consumption (19 liters/annum), which is by far lower than African and global averages (FAO, 2017). Livestock production and marketing of its products are essential to the livelihoods of more than one billion people in Africa and Asia (McDermott et al., 2010). Livestock contributes to nutrition and food security, poverty reduction, improved income and job creation, which are among the targets of the United Nations 'Sustainable Development Goals' (SDG) (Smith, 2015). Investment in livestock has a potential to create a multiplier effect. Hence, dairy production has the highest potential to sustainably contribute to the SDGs due to its extended value chain (Gebreyohanes et al., 2021).

Population growth, urbanization, and income growth, especially in developing countries, will result in huge demand for food of animal origin. Attempts to meeting this demand will place enormous pressure on the global food system particularly on mixed crop-livestock farming systems that currently producing most of the world's meat, milk, and staple crops. The only other path for either increased availability or decreased price is technological interventions in genetic improvement, individual/herd level productivity improvement, disease control and prevention, feed utilization efficiency and waste management (FAO, 2017).

The huge demand put high pressure to increase efficiency of livestock production and productivity: more milk, meat, and eggs with fewer inputs and lower greenhouse gas emissions per unit of production. Shifting to fewer, more productive animals of more productive breeds is one way to achieve this and definitely requires the application of animal biotechnology tools that address reproduction, breeding, animal health and nutrition (Tarawali et al., 2011).

In Ethiopia, improving the genetic potential of livestock has been a major concern to enhance production (milk and meat) that is limited by the poor growth and low reproductive performance in cattle kept under natural condition. The prevailing shortage of animal products in the country could be solved by divulging the potentials of cattle productivity through application of animal biotechnology tools such as molecular genetic analysis, Artificial Insemination (AI), Embryo Transfer (ET), Estrus Synchronization (ES) germplasm cryopreservation, molecular disease diagnostic and vaccine and therapeutic development.

Animal biotechnology as a tool is proven to speed up genetic progress, reduce the risk of disease transmission, and expand the number of off spring from the superior parent with immense opportunities of ensuring food security without destroying the environmental resource base. Therefore, breed improvement and conservation of genetic resources and the sustainable use, are vital to agriculture, food production, rural development and environment. Hence, enforcement of the application of modern animal biotechnological tools in research and development activities will be vital (EIAR SDG, 2019).

Therefore, the objective of this review paper is to assess the impact and prospect of animal biotechnology research and development endeavor from the national strategic development goal perspective in livestock sector in Ethiopia.

HISTORY OF ANIMAL BIOTECHNOLOGY IN ETHIOPIA

Animal biotechnology in Ethiopia was introduced in the form of assisted reproductive techniques and vaccine production. AI is the most commonly used reproductive biotechnology tool in the country, serving the dairy industry for more than five decades. It was adopted and practiced in Ethiopia soon after its commercialization in western countries. It was introduced to northern part of the country during the Italian invasion around 1940's and lately extended to central part of the country (Arsi and Walaita) through different development agents. Crossbreeding of indigenous local cattle dairy breeds with improved exotic bulls was introduced by the Italians in Asmara. It was interrupted later due to the Second World War (Yemane et al., 1993) and unaffordable expenses of importing semen, liquid nitrogen and other technical and logistical requirements. Large-scale dairy cattle crossbreeding activities were started later by the Institute of Agricultural Research (IAR) and Chilalo Agricultural Development Unit (CADU) using Holstein-Friesian, Jersey, and Simmental sires that were crossed with the local Horro, Boran and Arsi dams using artificial insemination technique (Brannang et al., 1980; EARO, 2001).

The National Artificial Insemination Center (NAIC) now restructured as Livestock Development Institute (LDI) established in Addis Ababa, Kaliti in 1981 as a national center for the production, cryopreservation and distribution of cattle semen mainly from selected exotic (Holstein Friesian) sires (NAIC, 1995). The institute also produces semen from selected sires of indigenous breeds and their crossbreeds with Holsteinn Freisians dairy cattle breed. Currently, it has an average capacity of producing one million doses of semen per year.

Estrus Synchronization (ES) is practiced to tackle some of AI's drawbacks such as rigorous heat detection requirement, in large farms and ranches (Pursley et al., 1995). Hormonal interventions for manipulation of bovine reproduction such as ovulation synchronization can even eliminate the necessity for estrous detection and allows anestrous cows to be inseminated, thus increase the reproductive efficiency of cows and heifers (Rhodes et al., 2003). The use of ES concentrates conception at the beginning of the breeding season increasing the reproductive and productive efficiency of farms (Sartori et al., 2016). Estrus synchronization in Ethiopia was first established for experiment purpose during Multiple Ovulation and Embryo Transfer (MOET) research activities in ILCA facility at Bishoftu in late 1990s. A mass scale estrus synchronization project has been launched in the country by the Ministry of Agriculture (MoA) and research centers at selected dairy villages since 2012 based on the recommendation given by ILRI and collaborative institutions. The mass ES project was aimed to improve dairy cattle breeds at small scale farmers' level. Though, the intervention was intended to boost the existing AI practices *via* quality semen delivery and bringing as many cyclic animals as possible for breeding at small scale farmers vicinity, a number of limiting factors hindered the anticipated success (Figure 1).

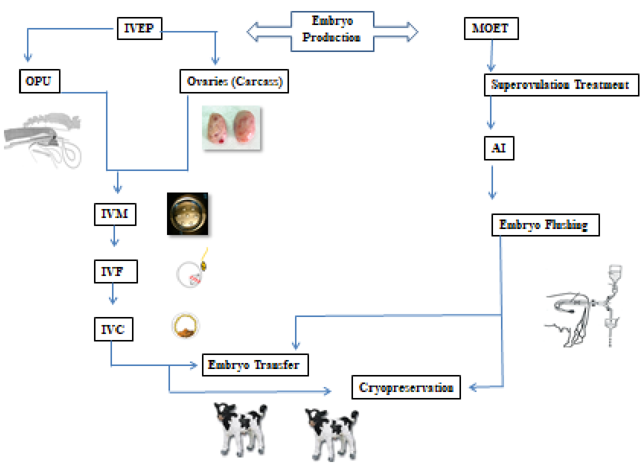

Figure 1: Schematic representation of embryo transfer technology. Note: AI- Artificial Insemination; IVC- *In-vitro* Culture; IVF- *In-Vitro* Fertilization; IVEP- *In-Vitro* Embryo Production; IVM- *In-Vitro* Maturation of oocytes; MOET- Multiple Ovulation and Embryo Transfer; OPU- Transvaginal Ultrasound-guided Ovum Pick-Up.

Embryo Transfer Technology (ETT) allows the dissemination of high value genetic material from both males and females. This technique increases the genetic gain of animal breeding programs as compared to AI. ETT has presented considerable growth in the last decades, mainly due to the scientific and technological development of innovative processes of embryo production. Globally, in the 2018, *in-vitro* embryo production represents 66% of the embryos produced (Viana et al., 2018). Embryo transfer technologies would have a major impact on cattle breeding especially as part of a nucleus breeding scheme in breed improvement effort in Ethiopia. The large livestock population, the favorable climate for improved, high-yielding animal breeds makes the country to have a significant potential for dairy development. Multiple ovulation and embryo transfer activities were long practiced in the country by ILRI, EIAR and international collaborative agents. The main goal for these efforts was to adopt the technique for elite dam multiplication and strengthen human and physical capacity building for research. ILRI initiated embryo transfer program at Debre Zeit Research Station in 1990, primarily on zebu cattle and the first calf was born in 1991 (Tegegne, 1991). Refinement of superovulatory regimes for Boran cattle has been undertaken and eight pairs of identical twins calves were produced using embryo-splitting technique (Tegegne et al., 1994). Recently, this technique is widely practiced at DZARC animal biotechnology research facility with a number of calves born using the technology. Efforts are currently underway to train practitioners to apply multiple ovulation and embryo transfer technology at various institutions (Research and Universities) (Table 1).

Table 1: Achievement of *in vivo* embryo production at DZ-ARC (EIAR) from 2010-2022.

In vivo embryo production trial	Results of *in vivo* produced	% Grand total
Unfertilized ovum	104	35.00%
Transferable quality embryo	154	51.90%
Poor quality embryo	39	13.13%
Fresh transfer	25	8.42%
Frozen transferred	32	10.77%
Pregnancy established	40	13.46%
Calf born	9	3.03%
Embryonic mortality	19	6.40%
Abortion	10	3.37%

Considering the important prospective for commercial and smallholder income generation and employment opportunities from the high value dairy products, the development of the dairy sector can contribute immensely to poverty alleviation and improved nutritional status of the community. The combination of Genomic Selection (GS), *in-vitro* Embryo Production (IVEP) and sexed semen in commercial dairy cattle production has proven success in several countries in improving the reproductive performance, reproductive efficiency and dairy cattle genetic gain (Ferré et al., 2020).

Biotechnological advances in the area of animal health in the country mainly involves in the development of vaccines and disease diagnostic tools. The National Veterinary Institute (NVI) based at Bishoftu is involved in large scale production of vaccines for major diseases of large and small ruminants and chicken (Yoseph, 1996). NVI was established at Bishoftu in 1964 under the Ministry of Agriculture, getting technical assistance from the French Government through the French Veterinary Mission in Ethiopia. Today, it is well-known veterinary vaccine producing institution in Africa with its multidisciplinary professional staff having long experience.

PREVIOUS STUDIES

Various studies were undertaken commissioning animal biotechnology tools to improve the product and reproductive performance of dairy cattle throughout the country. Bovine AI is a relatively old and well-known Assisted Reproductive Technology (ART) technique. It has got a wide commercial acceptance in the US dairy industry around 1950s (CRS, 2011) and it is the most widely used reproductive biotechnology tool in dairy and beef farms around the world. No other technology in agriculture except hybrid seed and fertilizer use has been so widely adopted at a global scale as AI (Rege, 1999). Its application brought great benefits to the dairy industry compared to bulls' natural mating services (Baruselli et al., 2018). In Ethiopia, almost all activities were related to evaluating the breeding works so far are from government ranches or research stations. Besides, there were few field studies made to evaluate the efficiency of AI service (Abate, 2008). Nevertheless, they are not representative of the farming condition in the country (Haile Mariam, 1994). Studies conducted at ranches and on stations were from controlled environment, it is difficult to figure out the problems and device possible solutions on AI service efficiency and constraints of AI service at farmers' level.

The prominent research intervention was mass insemination in targeted dairy production areas using hormonal interventions to regulate the estrus cycle as alternative animal biotechnology option in different milk sheds of the country. The result reported by ILRI, (2011) on efficiency of AI indicated that there was no AI service provider in the rural areas in which the large milk and butter value chains were found. An AI technician covers large area mostly urban and peri-urban dairy farmers with low pregnancy rate (27%) of first insemination. This brought no or negligible dairy cattle breed genetic improvement in the rural areas. The ILRI report further indicated that the mass AI interventions (comprises of technological, organizational and institutional changes) improved the effectiveness of the insemination process increasing pregnancy rate per first insemination from 27% to 62% (ILRI, 2011).

The use of hormones to regulate the estrus cycles of animals is known and ILCA (among others) conducted research on this technology in the late 1980s and early 1990s. Some of the most common uses for the hormones in the Ethiopian context were to match calving rates with feed availability and to avoid high milk production during fasting periods. Another was to control heat period and allow more accurate AI services (ILRI, 2011). A mass scale estrus synchronization project has been launched by the MoA) and research centers at selected dairy villages since 2012. The mass ES project was aimed to improve dairy cattle breeds at small scale farmers' level. Though the technique was intended to boost the existing AI practice by minimizing infrastructure gap; a number of factors hindered the success of the project instead. Estrus synchronization technique is not recommended for scattered village settlement and small scale dairy producers with small number of cows. However, intensive and semi-intensive production systems can employ the tool to synchronize with the market and milk production pick, feed resource availability and calves management particularly in local context.

PROGRESS

Recent advances in molecular biology, ART and information and communication technologies, present unprecedented opportunities for livestock improvement in developing countries (Rege et al., 2011). Molecular biology is facilitating the emergence of more reliable point-of-care and point-of-transaction diagnostic tools, which would improve veterinary clinical practice and facilitate certification of traded animals and animal products. In livestock breeding, the application of genomic tools offers potential advances in the genetic characterization and improvement of animal breeds, and in developing improved animal feeds and more effective vaccines (Marshall et al., 2011). These technologies can also facilitate the development of traceability tools that can be applied in smallholder livestock systems. While these suites of technologies offer new tools for tackling old and emerging problems, there are also significant opportunities to innovatively use the existing knowledge and tools to address these problems (Rege et al., 2011).

Now a days, vaccine production infrastructure at NVI is well developed and playing an important role in the attraction of international institution such as the Pan African Veterinary Vaccine Control Center (PANVAC), which is under the African Union. NVI has been given the responsibility to produce and supply vaccines for PTA (Preferential Trade Area) countries of Eastern, Western and Southern Africa. The institute has reached the level of using state of the art techniques and technologies for biological production and vaccine related researches. Million doses of different vaccines have been produced and dispatched to protect millions of animals from various infectious diseases (NVI, 2021). The institute produces vaccines for about 17 types of viral and bacterial diseases. At present, the institute fully satisfies the national demand for livestock vaccines and also exports to some African and Middle East countries. Recombinant DNA-based vaccines have also been produced in collaboration with oversee laboratories and used against rinderpest (Yilma et al., 1988) while dual recombinant vaccine for capripoxvirus and peste des petits ruminants virus in small ruminants is under evaluation (Berhe et al., 2003) in collaboration with foreign institutions. ELISA, cDNA probes and PCR-based methods have been used at Animal Health Research Laboratory, Sebeta in livestock disease diagnosis (Abraham et al., 2005). Molecular characterization and phylogenetic studies of Ethiopian isolates of many animal viruses has been done among others for peste-des-petits virus (Abraham, 2005) and foot and mouth disease virus (Sahle et al., 2007) by reverse transcriptase PCR analysis and sequencing parts of the viral genome. The National Veterinary Institute (NVI) is mainly engaged in research on veterinary vaccines, diagnostic kit development and other products and services. The research and development work at NVI is being carried out with local and international collaboration and with qualified research staffs. It has well equipped research laboratories including virology, serology, bacteriology, molecular biology and nutrition. New laboratories of proteomics and cellular immunology, cloning, bacterial zoonoses, diagnostic kit development, mycology, fish diseases and sequencing/bioinformatics are being established and expected to become functional soon (NVI,2021).

ACHIEVEMENTS

Estrus Synchronization and Artificial Insemination

Dairy cattle genetic improvement through crossbreeding in Ethiopia has been practiced through development and research projects for more than six decades. The provision of artificial insemination service, setting up of bull service stations and distribution of crossbred heifers were major components of the development projects. As indicated by (Ahmed et al., 2003), Ethiopia has built up a herd of more than 120 thousand dairy cattle breed with exotic inheritance through the effort of these projects. Today AI is recognized as the primary tool for genetic improvement in cattle breeding. Therefore, a series of studies are needed to determine the coverage and performance of AI at national, provincial and district levels (NAIC, 1995).

The use of sexed semen may offer benefits both for small scale and intensive dairy production systems. In urban and semi urban non-expanding herds, the use of sexed semen enables the number of replacement heifers required to maintain herd size to be produced from a smaller proportion of the herd. Sexed semen technology has entered a new era with advanced biochemical techniques and high throughput machinery. It is accessible in local market with the performance of the product improving continually. The use of sexed semen, combined with estrus synchronization has the potential to rapidly accelerate genetic gain in dairy cattle in different production systems of the country.

Using every available uterus for productive animals in the farm efficiently should be the goal of the farmer. To use all available pregnancies to generate productive animals (females) and also targeted sex skew to produce high-value heifers from a certain sire/dam combination will maximize the use of these animal resources for dairy genetic improvement (Vishwanath et al.,2018). AI augmented with sexed semen technology already had a major impact on dairy industry in developed countries (Holden et al., 2018). AI with sexed semen brought about great advantages in terms of reduction of cost of acquiring replacement breeding stock, mitigate the effects of high involuntary culling and poor reproductive efficiency by a preferential use of female and sexed semen (Sá Filho, et al., 2013; Yousuke et al., 2018).

Multiple Ovulation and Embryo Transfer (MOET and IVEP)

MOET research was launched in 1994 in the then called International Livestock Center for Africa-ILCA by the late Dr Azage Tegegne with the first eye opening success ended up with the delivery of the first embryo transfer calf named “RAS” shown in Fig.2 below. Further implementation effort was discontinued with unknown reason. The second trial was launched in 2002 in Ethiopia by the then Ethiopian Agricultural Research Organization (EARO) with preparation of Agricultural Biotechnology Research Guideline, establishment of National Biotechnology Research Center at Holeta and employment of expatriate expert, Professor Luis Alba Gomez from Cuba in Bovine embryo production and capacity building 2006/2007 (Figure 2).

Figure 2: The first embryo transfer calf (RAS) in Ethiopia (Tegegne, 1994).

Another subsequent effort was re-started in 2009 by Morel Agro-industry Plc at Adami Tullu Research Center with the objective of establishing breeding stock for their dairy farm at Kokossa, Bale. Imported frozen embryos were transferred to Boran heifers as recipient and six calves were born in 2010. The EIAR teams from DZARC and HARC working in collaboration with Morell Agro-industry Plc have managed to produce three ET calves at DZARC and two ET calves born at HARC in 2010, respectively. The effort was continued at DZARC and additional 7 ET calves in the research center and two ET calves in dairy producer farm were born (three in 2012 and 6 in 2015). As a PhD research project additional embryos were produced for experimental purpose in 2015/2016 and more 150 embryo/ unfertilized ovum produced with the research planned to optimize the super ovulatory protocol for Boran and Boran HF cross breeds.

Trans-vaginal follicular aspiration and *in-vitro* embryo production activity was started in 2019 at Holeta National Agricultural Biotechnology Research Center (NABRAC) and DZARC. *In-vitro* embryo production protocols for oocyte aspiration, maturation and fertilization were optimized. IVEP infrastructure in EIAR centers (NABRC and DZARC) was established and skilled man power was trained at both centers.

Contribution of ABT in Food/Nutrition Security

Consumption of even small amounts of animal origin foods has been shown to substantially contribute to dietary adequacy, preventing under-nutrition and nutritional deficiencies. It has positive impacts on growth, cognitive function, and physical activity of children and better pregnancy outcomes (Neumann et al., 2002). Dairy cattle genetic improvement and availability of replacement heifers has great potential to boost the national milk production, reduce poverty, and contribute to food security, and increase households and national income generation (Agajie et al., 2018).

In spite of the great effort made on dairy cattle genetic improvement in Ethiopia which fully based on crossing indigenous breeds with highly productive exotic breeds through AI since its inception in 1947, there only trivial impact and yet inefficient (Hunde, 2018; Desalegn et al., 2009). The available information indicates that improved dairy cattle with exotic blood inheritance constitute about 1.2% of the national cattle population (CSA, 2019/20). Although the total national dairy cows used for milk production is estimated to be around 7.15 million including those milking cows in the hands of pastoralists. The production and productivity of these animals doesn't commensurate with their number. Local breeds (98%) producing less than two liters of milk per day. In consequence, besides the deficit in nationwide milk supply currently there is a high demand for improved dairy cows on the market and the exorbitant prices became unaffordable for smallholder farmers. Importation of live cow/heifer from other country is also unlikely.

As human population increases, so does the demand for food, particularly animal origin protein like milk and meat. In Ethiopia meeting the alarmingly increasing demand for milk is possible only by increasing the efficiency of an individual/herd productivity and increasing the number of dairy cows producing milk. However, there are three big challenges hindering the effort. The first is low availability of improved germplasm of dairy breed to replace the available local breeds currently producing 98% of the national milk yield (CSA 2019/20). The second challenge is shrinking of the grazing area by the continuously expanding cropland and the traditional production systems that come under increasing pressure due to competition for land resources (Schmidt and Timothy, 2018). Policy interventions, such as land redistribution and urbanization have also aggravated the situation. The Green House Gas (GHG) emission with the high number of cattle owned by the farmers for milk, meat and draft power is another threat to the increasing herd size for milk production. To meet the challenges, improving the productivity of the herds, reducing headcount, and establishing mechanisms to monetize the abatement potential in livestock with the help of development partners has been suggested. Therefore, adoption and application of potential modern reproductive technologies would be the best solution to enhance the genetic improvement and multiplication of improved dairy heifers to increase milk yield and household's income.

The indirect effect of livestock on food and nutrient security comes from generating cash incomes from the sales of animals, their products, or services, or through employment along animal source food value chains in poor countries. MoA has launched estrus synchronization and artificial insemination program with sexed semen through the logistical support of the LFSDP project, in selected districts and ranches of the three regions (Amhara, Oromia and SNNPR).The regional agricultural offices, research institutes and some universities collaborated in this project to produce replacement crossbred heifers with 90% accuracy of getting desired heifers.

Major Challenges

The major constraints on intensification of livestock in general and dairy are unavailability of adaptable high-yielding improved genetics, lack of feed, animal diseases and poor animal health care, extension and market services. In Ethiopia, genetic improvement of indigenous breeds through crossbreeding and upgrading and Artificial Insemination (AI) started more than 40 years ago following the establishment of the NAIC. However, the number of improved breeds in the country is still too small to transform the current subsistence-based smallholder dairy system to market oriented commercial dairy production and boost milk production to meet current and predicted future domestic demands (CSA, 2019). The efficiency and impact of AI operation has not been well-documented (Himanen et al., 1998). Reproductive problems related to crossbreed dairy cows under farmers' conditions are still immense (Tadesse, 2005). Even though, Ethiopia's dairy value chains have been assessed (Yilma et al. (2011), there is a need to have periodic assessments of these value chains to provide up-to-date information for informed evidence based interventions by policymakers. The other major challenge in modern livestock breeding scheme is unbalanced attention given by the policy with the contribution of livestock and low management practices and awareness by small holder farmers, which constitutes the majority of animal population in the country.

Prospect of Animal Biotechnology R&D

The potential benefits of animal biotechnology to the sustainable development goals are enormous. It is evident that there are real prospects for the benefit of animal biotechnology tools and products in Ethiopia. Enhanced nutritional content of food for the increasing population, more abundant, cheaper and varied food supply are the core uses of the subsector. Agricultural land-use savings, decrease in the number of animals needed for the food supply, improved health of animals and humans, development of new, low-cost disease treatments for humans, and increased understanding of human disease are among the benefits that are assisted by the animal biotechnology tools (EIAR; SDG, 2019) (Figure 3).

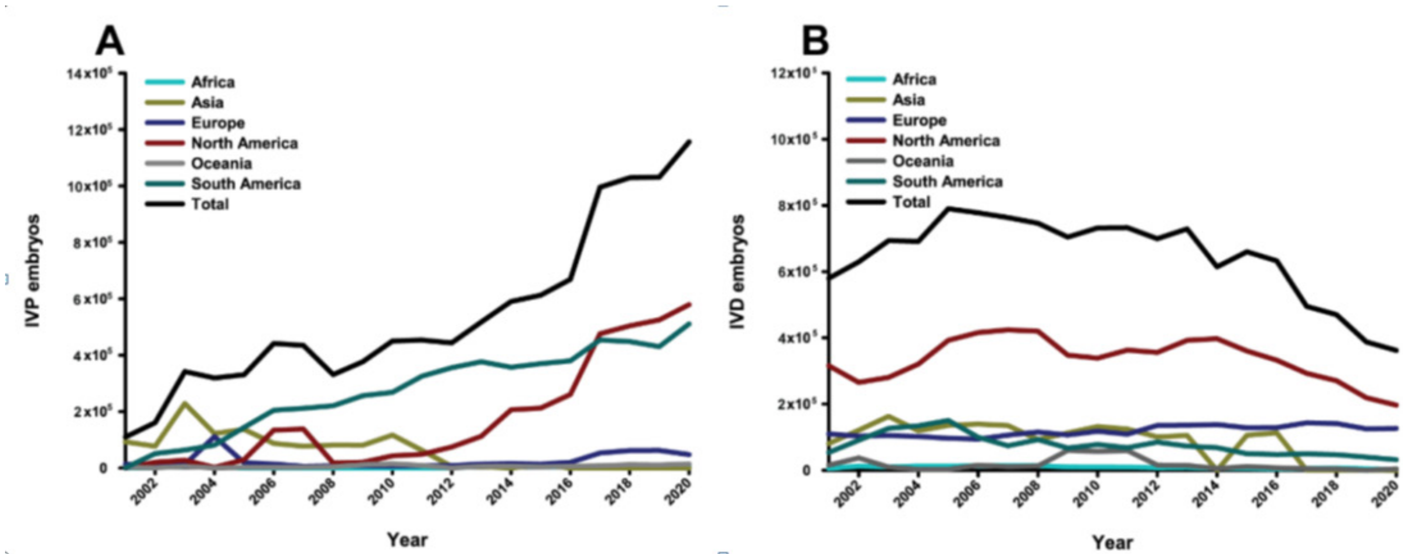

Figure 3: A-B Number of embryos produced or collected in cattle in the period of 2001-2022 by continent. A) *In vitro* Produced (IVP) embryos B) *In- vivo* Derived (IVD), (Viana, 2021).

Table 2: Total production (transferrable embryos) of IVD and IVP embryos in 2020 in cattle, sheep, goats, and horses, by region (Viana, 2021).

Region	Cattle		Horses		Sheep		Goats	
	IVD[1]	IVP[2]	IVD	IVP	IVD	IVP	IVD	IVP
Africa	2763	4977	0	0	0	0	0	0
Asia	0	0	0	0	0	0	0	0
Europe	1,26,491	47,470	2,248	5,359	966	0	346	0
North America	1,96,704	5,78,995	851	1,126	9,204	141	10,757	2,275
Oceania	4,211	14,345	0	0	12,427	0	1,890	0
South America	31,559	5,00,397	22,120	2,156	7,222	0	184	0
Total 2020	3,61,728	11,56,422	25,219	8,641	29,819	141	13,177	2275

Note: IVD[1]: *in vivo* derived; IVP[2]: *in vitro* produced.

Globally, as the International embryo transfer society data indicated (2020) the number of countries reporting embryo transfer data and the level of adoption for the technology is increasing (Table 2).

Animal biotechnology has several potential uses, through genetic engineering, animals have been created with increased growth rates, humanized milk production, enhanced institutions (Research and Universities) muscle mass, enhanced resistance to disease or improved use of dietary phosphorous to lessen the environmental impacts of animal manure. Poultry, goats and cattle that generate large quantities of human proteins in eggs, milk, blood or urine also have been produced, with the goal of using these products as human pharmaceuticals though these modern techniques. Human pharmaceutical proteins include enzymes, clotting factors, albumin and antibodies. The major factor limiting the widespread use of transgenic animals in agricultural production systems is their relatively inefficient production rate (a success rate of less than 10 percent) (EIAR; SDG, 2019).

EIAR has established at National Agricultural Biotechnology Research Center (NABRC) that comprises animal, plant and microbial biotechnology research programs. It also reinforces animal biotechnology capacity building effort to other research center such as Debre Zeit Agricultural Research Center (DZARC) renovating reproductive biotechnology laboratory with animal maintenance facility. These facilities would be a national center of excellence for animal biotechnology research, technology generation and human resource development. The laboratories will have facilities for germplasm (semen and embryo) storage and analysis, *in-vitro* embryo production, molecular animal breeding research and animal transgenes studies.

The biotechnology teaching and research capacity of Addis Ababa University has been strengthened through training of individuals, acquisition of equipment by the government and foreign funded projects sponsored by countries like Sweden (Abreham,2009). Other public higher learning institutions including Addis Ababa University College of Veterinary Medicine and Agriculture, Addis Ababa Science and Technology University, Haramaya and Jimma Universities are also strengthening their capacity in animal biotechnology teaching and research. Therefore, this sector one of the most promising R & D area in research institutes and public universities. It is highly probable that animal biotech will receive attention by the government because of its dependable applications and potential in livestock improvement.

CONCLUSION AND RECOMMENDATION

Animal farming requires a strategic use of new biotechnologies to tackle and address production bottlenecks. Strategic implementation of animal biotechnology techniques should not only focus on genetic improvement per se rather it should be emphasized in improving food security, income and overall livelihoods of the poor. Reproductive techniques should focus on availing appropriate genotypes (semen and embryo) and to support genetic material delivery structures to make the genotype work for the poor (small scale farmers) in the local context. The current state of information strongly suggests that for small holders, highest priority has to be given on the provision of appropriate genotypes *via* ES and AI in a sustainable manner from the range of global breed resources already available.

The application of reproductive biotechnologies to dairy cattle improvement in Ethiopia is a much needed and long-overdue technological advancement that will transform the lives of smallholder farmers. These modern technologies concisely support the achievement of the national and global SDG of zero hunger and nutritional secure citizen by 2030. The following steps are recommended to strengthen the animal biotechnology interventions in the country and realize its benefits.

Introduction of exotic germplasm may be a risky undertaking and could be uneasy to smallholder livelihoods in certain situations (crossbreeding at remote small scale farmers level), it may present a golden opportunity in others (urban and semi urban dairy producers) if well designed and supported. Efforts are required to understand what breeds exist that have demonstrated potential, where else they could be used, and how they would be delivered in sustainable manner.

Current large scale applications of estrus synchronization and AI with sexed semen, molecular disease diagnostic kits, vaccine production and research should be expanded. Utilization of the country's biodiversity for potential breed selection and crossbreeding through molecular breed characterization and elite individual multiplication using ART should be promoted.

Establishing and sustaining institutional linkage within the country as well as strengthening collaboration among Ethiopian and foreign institutions should be improved. Policies and incentive mechanisms should be developed to encourage private sector investment and their participation in animal biotechnology R & D (AI service delivery). The engagement of the private sectors in identifying livestock improvement opportunities is critical to ensure demand and ownership from the beginning.

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