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Application of reproductive biotechnologies for sustainable production of livestock in Turkey

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Abstract: Reproductive biotechnology encompasses powerful tools to enhance the efficiency and profitability of livestock reproduction, production, and product quality. These technologies include genomic selection, evaluation of semen (from bulls, bucks, and rams) using advanced cell and molecular technologies, semen cryopreservation and artificial insemination, estrus synchronization, superovulation of the females (cows, dams, and ewes), ovum pick-up, *in vitro* fertilization and embryo culture, embryo transfer, and pregnancy detection. The extent of applications of these modern technologies and their economic impacts for livestock production in Turkey are elusive. As a result, there is an urgent need for sound economic analyses, research and education, training of animal producers to facilitate technology transfer, and informing of the public of the benefits of animal biotechnology. The objective of this study was to provide a review of key reproductive technologies and economic analyses of them, followed by an outlook on the future production of cattle, goats, and sheep in Turkey. This review is an important resource for students, researchers, and producers for a better understanding and for the application of cutting-edge biotechnology in efficient, sustainable, and profitable livestock production.

Key words: Livestock production, reproductive biotechnologies, artificial insemination, superovulation, pregnancy detection, genomic selection

1. Introduction

1.1. The importance of livestock economy

The majority of farming households in Turkey still depend on low-input semisubsistence agriculture and livestock production. Despite a slow decline in recent years, agriculture and livestock production remain major employers in Turkey and are significant contributors to the country's gross domestic product (GDP) (1). Livestock production is an important and traditional sector in the agricultural economy of Turkey and is facing a decrease in herd numbers of cattle, sheep, and goats, and in meat production, despite growth in domestic demand. Animal production is vital for sufficient and balanced nutrition of the population. Sound evaluation of the critical factors of production, namely capital and labor, are necessary for establishing the baseline and advancing animal science and technology. The livestock industry is also valuable for enabling strategic investments and placements of labor to develop within the sector. The livestock industry is linked with crop production and agricultural economy.

The employment rate in animal agriculture is much higher in Turkey than in the USA and EU. The livestock industry helps to reduce unemployment year-round. According to TurkStat, the agriculture sector constituted 7.4% of the total GDP in Turkey (1). However, agriculture is only 1.7% and 1.9% of the total GDP in the USA and EU, respectively (1). In its contribution to the economy, the Turkish agricultural sector consists of three million agricultural farms, most of which typically have mixed farming in which crops and animal production occur together. According to typological classification, about two-thirds of farms specialize in field crop production and livestock production. Only 2%–3% of the total are specialized in livestock production alone (2,3). Although this percentage is low, in recent years there has been intensive investments in livestock by means of low interest rate loans and government subsidies. Livestock production is important, especially milk production, for which Turkey ranks about 15th in the world.

Despite the fluctuations in milk and meat prices, the livestock industry has a significant role in preventing

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immigration of rural populations. In Turkey, the livestock industry constitutes a significant portion of agriculture and the contribution to the general economy is imperative, not only for capital contributions but also in decreasing unemployment year-round. However, animal farms have generally been small-scale family farms with low efficiency. Over the last decade, efforts have been made to adapt modern technologies to make animal farming more profitable. However, the use of land, animal genetics, reproduction, and water resources is not yet managed properly. Thus, there are urgent needs in developing modern farming and improving genetics and efficiency of the livestock. Turkey has a number of large-scale commercial farms, including feedlots and several government and university experimental establishments, in contrast to small holder subsistence farming (4). These advantages provide good opportunities for reproductive biotechnologies in livestock agriculture.

1.2. Development of livestock production in Turkey

Livestock products are an important source of household income for many farmers and households in rural areas. Small farmers generate income and make a living from the sale of livestock and livestock products from cattle, sheep, and goat (5). Turkey produces 618,584 tons of meat and 15 million tons of milk annually. It has been reported that the average carcass weight of cattle is 176 kg and milk production per lactation in cattle is 1699 kg (6). There are 15 million cattle and 42.3 million sheep and goats (7).

Since 1920, animal agriculture has been supported by the government in different ways. In spite of incentives and development of regulations, the livestock industry has not yet been improved to the level seen in developed countries (8). Government incentives and supports have positive impacts on animal agriculture. Genetic improvement programs in the dairy industry have helped to increase production of milk and milk products. However, the dairy industry still seems vulnerable and has not yet become sustainable due to high production costs. Therefore, government incentives are key to maintaining farmers in animal agriculture. However, the gap between meat production and demand is still high, which results in high prices of meat and meat products in the market. This shows that in Turkey there is an urgent need to establish efficient beef cattle production programs to increase meat supply and make it competitive.

The dairy sector is prominent in Turkey; thus, a majority of cattle are dairy. However, there is a significant amount of beef cattle and improvements are needed in international trade agreements in order to enhance the beef industry in Turkey (9). Animal breeding projects through collaborations with researchers in Turkey, Germany, and Italy started in the mid-1990s and resulted in establishment of the Cattle Breeders' Association, which then partnered with the Ministry of Food, Agriculture, and Livestock and developed record-keeping systems. These are important for sustainable, efficient, and profitable livestock production to achieve productivity of animals through breeding. There was a dramatic reduction in the number of livestock between 1990 and 2011 in Turkey. The presence of sheep, goat, and buffalo declined by 38%, 34%, and 74%, respectively, although a 9% increase was seen in cattle number. On the other hand, overall milk production increased by almost half during this period, where the highest growth in milk production was in dairy cattle (92%) (10). The ovine sector is also an important part of Turkey's economy in terms of wool, hair, and mohair production in addition to meat and milk yield. The excess of demand cannot be matched by the supply in Turkey. Moreover, the number of ovine animals decreased gradually by 40% from 1994 to 2009. Following the development of organization systems, ovine numbers climbed again in the following years. However, this increase has not represented the direct proportion between meat and milk productivity in ovine breeding (11).

Factors that prevent initiatives in reproductive biotechnologies include the high cost of research and insufficient funding for translational research, challenges in technology transfer such as increased cost of the technology, lack of well-trained farm technicians, and lack of public understanding and appreciation of animal biotechnologies. In order to provide high quality meat and dairy products, the enhancement of domestic production is the most permanent method. Thus, the implementation of advanced animal improvement programs is essential to make animal agriculture sustainable and more profitable. Overall, advanced animal biotechnologies are essential tools to accelerate the improvement of genetics and allow the selection of high-producing, fertile, and healthy animals in Turkey.

2. Reproductive biotechnologies and their current applications in livestock production in Turkey

The applied reproductive biotechnologies include artificial insemination (AI), semen technologies and evaluation, embryo transfer, in vitro fertilization (IVF), ovum pick-up and combination with IVF, estrus synchronization, superovulation, and pregnancy detection and monitoring. In cattle, the most recent biotechnology is the use of DNA technologies in genomic selection of elite males and females. Implementation of these technologies has made significant improvement in animal reproduction and genetic progress in cattle industry.

2.1. Semen cryopreservation and AI

The first scientific experiment in AI was conducted in dogs by Italian scientist Spallanzani in 1780. In 1922, the Russian scientist Ivanoff started serious studies to develop

AI in horses. The Russians began using the technique widely in the 1930s to inseminate millions of sheep and cattle. Then the technique began to spread worldwide rapidly, and a number of organizations were formed, such as cooperatives and breeding organizations (12).

The major commercial applications of AI in the animal breeding industry began after World War II. The successful freezing of semen by Polge in 1949 led the industry to develop and spread globally. The widespread use of AI has led to the establishment of improved breeding methods and animal recording systems to better select next-generation superior sires to enhance and monitor genetic progress over time. Superior sires were selected through progeny testing programs that that include evaluation of production performance of the progeny. The system always allows to provide semen to producers from superior genetic sires to make continuous improvement in cattle genetic. Over 70 years, with widespread use of AI and continuous selection, today's dairy cattle produce 346% more milk than the ones in 1945 (13).

This technology has revolutionized livestock production and reproduction because sperm from sires can be collected, cryopreserved, and used in insemination of thousands of cows around the world and also used in IVF. Ejaculated sperm are filtered to remove any debris and then centrifuged to remove seminal plasma. The cells are then resuspended in different extenders and concentrations (usually ranging from 8–20 million cells in 250–500 µL in extender). The mixture is then cryopreserved in liquid nitrogen, with temperatures reaching down to −196 °C. While the cryopreservation methods are well-established for bull sperm, techniques for ram and buck sperm still need to be improved. In AI, cryopreserved semen is deposited in natural heat or hormonally synchronized cows that are in heat. In Turkey, Minister of Agriculture Mehmet Sabri Toprak visited Russia to transfer AI technology in 1926. In the same year, Professor Michailov from Russia was invited to Turkey to train Tevfik Bulak and Nazım Bulak and start AI on the Karacabey and Çifteler farms. Similar to other countries, after 1950, semen preservation and the use of extended semen in AI were started on government farms (14).

Although the AI technology was transferred at the same time as in other countries, breeding methods and animal recording systems were not established to select superior sires to use in AI in Turkey. The cryopreservation method is widely used for bull sperm and minimally or not at all for ram and buck sperm. In addition to domestic semen production, cryopreserved bull sperm is imported from abroad, such as from the United States and Europe (Table) (15). Similarly, AI is most commonly used in cattle breeding and to a much lesser extent for sheep and goats. There are no reported records of the use of AI in sheep and goats in Turkey.

2.2. Evaluation of semen from bulls, bucks, and rams using advanced cellular and molecular technologies

Bulls, bucks, and rams are evaluated to determine their overall prominence in sperm production and fertility. For example, the Bull Breeding Soundness Exam provides vital information on physical soundness important for a bull's ability to breed cows and the quality and quantity of semen production (16,17). Once ejaculated sperm are collected, the cells are examined using different methods to assess their anatomy and function (18). These

Table. Number of frozen bull semen units produced domestically and imported from abroad, and reported insemination numbers (15).

Year	Amount of sperm produced in Turkey (straws)	Amount of imported sperm (straws)	Total sperm used (straws)
2016	2,340,635	6,073,893	8,414,528
2015	1,644,595	5,171,353	6,815,948
2014	1,056,710	4,061,925	5,118,635
2013	1,300,065	3,194,213	4,494,278
2012	1,336,710	3,995,843	5,332,553
2011	1,806,093	4,689,256	6,495,349
2010	1,321,983	3,734,092	5,056,075
2009	1,976,494	3,427,608	5,404,102
2008	2,237,764	2,228,765	4,466,529
2007	2,300,659	3,451,557	5,752,216

analyses help measure morphological and physiological capabilities of spermatozoa. For example, sperm motility can be analyzed by computer-assisted sperm analyses, integrity of membranes and DNA by flow cytometry, functional genome (transcripts and proteins) as well as epigenome (DNA methylation and chromatin dynamics) by techniques in molecular and cell biology, oxidation by biochemical assays, and chromatin by chromatin structure assay (19,20). Currently, applied techniques in Turkey include traditional semen evaluation methods in rams (21,22), bulls (23), and goats (24). These techniques can be used in combination with the genomics/single-nucleotide polymorphism (SNP) marker-assisted selection methods to evaluate semen quality and predict bull fertility, which will increase the efficiency of livestock reproduction.

2.3. Genomic selection

Economically important traits have been traditionally estimated based on phenotypic records of individual animals and their parents and relatives. The entire process is time-consuming and expensive. The genomic selection or whole-genome selection approach has been proposed to explain genetic variation in important traits using dense marker arrays (25). The advanced DNA-genomic technologies have resulted in discoveries of a large number of SNPs in cattle and other species. This is a powerful tool to determine the genetic merit of a genotyped animal based on the model derived from pedigreed animals with phenotype and genotype using statistical tools (26,27). In order to apply genomic selection in livestock production, there are two major needs: phenotypic data and genetic markers such as SNPs associated with the phenotypes of interest on a DNA chip. Phenotypic data on economically important traits such as fertility, growth and development, disease resistance, longevity, and milk production are foundations for animal selection. Animal producers and breeding associations diligently collect data on each of these traits for many generations and breeds of animals. The quality of phenotypic data is extremely important for reliability and for animal selection.

Genomic markers such as SNPs are identified through analyses of animal genomes for heritable mutations that are associated with the traits of interest. Once the markers are identified and validated, then DNA molecules including the SNPs are attached to a solid surface, known as DNA chips. Development of reliable phenotypic data as well as DNA SNP microarrays in the United States and Canada were described by Wiggans et al. (28) and VanRaden et al. (26). To determine the genetic merits of an animal, first the genomic DNA is isolated from a variety of tissues including hair, sperm, or blood. Then the DNA is hybridized to DNA chips containing SNPs, followed by data analyses between thousands of SNP markers and the phenotypic data of the profiled animals. As such, a recommendation is provided to the animal producer about the genetic merits of the cows and the bulls to breed. While Turkey has a wealth of natural resources including fertile lands and many unique breeds of livestock, genomic selection is not yet applied in animal agriculture. Thus, there is an urgent need for capitalizing on our native genetic resources and developing genomic selection programs for sustainable and efficient production of cattle with higher product quantity and quality.

2.4. IVF and embryo culture (IVC)

IVF and IVC are important biotechnologies in evaluating sperm and bull fertility in vitro as well as production of embryos both for research and embryo transfer (29). For IVF, immature oocytes aspirated from abattoir ovaries are matured in maturation medium at 37 °C overnight and fertilized with motile sperm isolated from cryopreserved semen using a Percoll gradient in fertilization medium. The next day, for IVC, cumulus cells are removed from the presumptive zygotes and the embryos are cultured in embryo culture medium at 37 °C. Embryo development to blastocyst usually occurs on days 7 or 8 post insemination. Blastocysts can be used to determine the quality including total cell numbers or macromolecules such as RNAs and proteins. Blastocysts can also be cryopreserved for embryo transfer. The advancement in the in vitro oocyte maturation techniques and the discovery of the use of heparin to increase the success of fertilization ability of frozen-thawed bull semen has resulted in the current commercial application of embryos produced in vitro . Parrish et al. (30) demonstrated that the addition of heparin to fertilization medium increased the capacitation of bull semen, resulting in a higher normal fertilization rate. This work was the milestone leading to commercial application of in vitro-produced bovine embryos. Wiltbank et al. (31) reported that globally 443,533 embryos were produced through IVF in 2012. About 80% (355,205 embryos) were produced in Brazil and 17% were produced in North America (USA and Canada). While the use of IVF has been increasing greatly around the world, especially in countries such as the United States, Brazil, and Argentina, it is still in the research phase, which is only gradually increasing in Turkey (24,32). Birler et al. (33) demonstrated the first IVF-produced healthy live-born lambs at İstanbul University in 2000. Later, from the research conducted at the Lalahan Livestock Institute, two pregnancies were achieved, and one live calf was born from IVF-produced embryos (34). Much work needs to be done to implement this technology for producers in Turkey. Although there have been recent advances in small ruminant reproductive technologies, there are still major barriers in in vitro embryo transfer. Laparoscopic ovum pick-up (OPU) is a suitable technique for follicular aspiration to obtain oocytes, although in vivo-maturated oocytes have greater competency than in vitro-matured (IVM) ones obtained by follicular aspiration. Synthetic oviductal fluid is supplemented with heparin, hypotaurine, and estrous sheep serum for in vitro culture of the embryos (35).

2.5. Estrus synchronization

The highest success is achieved when cows are inseminated during standing heat. However, poor estrus detection in cows can result in low conception rates, which can create significant economic loss for most dairy and beef producers. In an effort to increase reproduction efficiency, estrus synchronization protocols have been developed using PGF2α. The synchronization of cows with PGF2α allows producers to increase detection of estrus and to better manage artificial insemination. The challenge in these protocols is that the cows are coming into estrus over a period of several days due to the fact that PGF2α does not synchronize follicular growth; it can only regulate the lifespan of the corpus luteum. Therefore, estrus detection is still needed after two doses of PGF2α administered at an 11- to 14-day interval. Consequently, the pregnancy rates following fixed-time AI at 72 and 80 h after the second injection of PGF2α are lower than those in cows inseminated at a detected estrus (36). Thus, in order to achieve success in fertilization of the ovulated egg in vivo, it is critical to synchronize the timing of ovulation and AI.

In 1995, Pursley et al. (37) developed a new protocol, called Ovsynch, using gonadotropin-releasing hormone (GnRH) and PGF2α to synchronize ovulation in lactating dairy cows. Briefly, the protocol starts with injection of GnRH at any stage of estrus to cause ovulation of the dominant follicle, followed with PGF2α administration after 7 days to regress any corpus luteum present in the ovaries. Forty-eight hours later, the cows are administered a second GnRH injection to ovulate the new dominant follicle. The cows undergo AI 24 h after the second GnRH injection. This Ovsynch protocol allows ovulation within an 8-h period from 24 to 32 h after the second GnRH injection.

Following the development of the Ovsynch protocol, the same research group or others have developed several kinds of Ovsynch protocols by changing the time of GnRH and PGF2α injections and insemination time (38,39). In Turkey, many groups have conducted research on estrus and ovulation synchronizations, and the protocols were successfully implemented in the field (40).

2.6. Embryo transfer

In vivo or conventional embryo transfer technology involves specific hormonal treatment (FSH, eCG) of donor cows and heifers to increase the number of mature oocytes to be ovulated. Following superovulation, the donors are bred using AI when they are in estrus (standing heat) or bred at a fixed time. Fertilization and embryo development occurs in vivo and typically 7 days after insemination embryos are nonsurgically collected or "flushed" from the donor's uterus. The embryos are either transferred fresh or frozen to be transferred later into synchronous recipients who carry the transferred embryos to term. Conventional embryo transfer allows to increase reproductive efficiency of the cows by producing over 100 calves compare to 5–7 calves in a lifetime.

In cattle, after the first calf from embryo transfer was reported in 1951 (41), significant research was conducted to generate knowledge to improve technology, and the commercial application of embryo transfer in the cattle industry began in the early 1970s. Cryopreserved or fresh blastocysts are transferred into the uteri of cows hormonally prepared using FSH, pregnant mare's serum gonadotrophin (PMSG), progesterone, PGF, or GnRH hormones depending on the superstimulation protocol and the cow's physiology. Twin births cause complications in pregnancy and dystocia; thus, only one blastocyst-stage embryo is transferred per cow. Pregnancy rates for embryo transfer when transferring fresh embryos range from 60% to 70% (42); when they are frozen the pregnancy rates range from 50% to 60%. This technology has not been offered to producers in Turkey, where there is no record of embryos being commercially transferred. Molecular approaches to ascertain function or physiological state of embryos in conjunction with monitoring morphological features by semiautomated set-ups are necessary for a better understanding of the quality of embryos. For example, the proteome, transcriptome, and metabolome of the spent embryo culture medium can be analyzed to evaluate embryo quality and predict developmental competency (43).

2.7. Superovulation of the females and embryo flushing

To produce maximum numbers of eggs from valuable females, the hormones FSH, LH, anti-Müllerian hormone, and PRID are administered for synchronization (44). Typically, in each superovulation, 8–30 oocytes can be produced and ovulated per cow. These oocytes can then be fertilized in vivo using AI and the resultant embryos can be flushed, used in embryo transfer as fresh embryos, or cryopreserved. The International Embryo Transfer Society (IETS) publishes the number of flushes and embryos produced every year. North America (USA and Canada) has been flushing half of the embryos and producing half of the embryos in the world. The IETS reported that the number of flushes has been constant, ranging from 100,000 to 130,000 flushes per year between 2004 and 2012 in the world. During the same period, the average number of embryos per flush ranged from 5.91 to 7.0 embryos (average: 6.08 embryos/flushing) (31). In Turkey, nonsurgical embryo transfer was successfully demonstrated by İleri and Sayın (45) in İstanbul. Since then, it is still in the research phase, and there is no record of commercial usage.

2.8. Ovum pick-up

OPU or the transvaginal ovum retrieval technique is the process of collecting immature unfertilized oocytes directly from the ovaries of a donor cow or heifer by using a specially designed probe equipped with an ultrasound transducer to visualize the ovary during oocyte aspiration (46). Then the harvested oocytes are treated by IVM/IVF procedures to produce transferrable embryos in laboratory conditions such as media and temperature that mimic the cow's reproductive system. Briefly, the recovered oocytes are cultured to mature the same day of aspiration and fertilized 1 day after aspiration. Then presumptive zygotes are transferred to development media for 7 days. Then the in vitro-grown embryos are transferred into recipient cows or frozen for later transfer, similar to conventional embryo transfer. In OPU, similar to conventional embryo transfer programs, the donor cows can be stimulated with hormones to mature multiple oocytes in vivo or all immature oocytes in the 2–8 mm follicles are can be aspirated to mature in vitro.

Following the release of genomic evaluation of bulls by the USDA in 2009 (28), the technology has allowed producers to predict the genetic potential of their potential males (bulls) and females (embryo donors) for economically important traits such as production, health, longevity, and physical fitness. Recently, the use of genomic technology has shortened the generation interval and resulted in faster genetic progress for cattle producers and breeders. The genomic evaluation has simultaneously increased the use of OPU due to many advantages over conventional embryo transfer in the cattle industry. The advantages of OPU include the use of pregnant cows as well as nonpregnant ones; females can be aspirated once a week instead of the 45–60 days waiting period in conventional embryo transfer; the OPU/IVF combination maximizes the use of sexed semen; and OPU allows the use of elite cows that are not producing embryos through conventional embryo transfer. OPU allows to use females at early ages. In OPU, the number of oocytes per procedure can vary from 12 to 30 oocytes depending on operator, breed, age, health, and nutritional status of female. After IVF, the rate of transferrable embryos can be 30% or more (47). In Turkey, Akyol et al. (1) at the Lalahan Livestock Institute successfully harvested an average of 1.9 ± 0.2 oocytes per OPU procedure, which is low compared to countries that successfully implemented OPU/IVM/IVF. Although this method is widely used abroad, its applications have not yet taken off in Turkey.

2.9. Pregnancy detection and monitoring

For profitability, livestock producers need to maximize the pregnancy of the females in their herds. The cows are generally considered pregnant if they are not showing estrus around 3 weeks following insemination. However, even if the estrus detection method is perfect, all of the cows that show estrus around 3 weeks after insemination may not be pregnant due to the fact that some of the cows might be showing estrus during pregnancy. Insemination of the cows by relying on only estrus symptoms around 3 weeks may cause embryonic loss.

In cattle, reliable methods to diagnose early pregnancy include rectal palpation, hormone measurements, early pregnancy-associated protein, and ultrasonography examination. Following the development of ultrasound technology, rectal palpation has been replaced with ultrasound to diagnose early pregnancy and fetal sexing. Moreover, with the use of noninvasive ultrasound, not only can early pregnancy be diagnosed but also uterine infections and ovarian dysfunctions can be easily monitored.

The detection of embryos, fetal development, and maintenance of pregnancy can be visualized using ultrasonography or Doppler radar starting at day 20 through pregnancy (48). Pieterse et al. (49) reported that the accuracy of pregnancy detection from day 21 to day 25 was 65% using ultrasound. The detection accuracy was found as high as 93%–100% from day 26 to day 33 using B-mode real-time ultrasonography (49,50,51). Even though these methods are used in Turkey and they are reliable, they are yet to become fully common in cattle production due to initial costs of equipment and lack of professional training. Early pregnancy losses hinder the accuracy of early pregnancy diagnosis, so better technologies coupled with direct and indirect detection of pregnancy would enable more precision in agriculture (52). As such, there is a need to determine pregnancy much earlier using innovative approaches such as biomolecular markers for pregnancy.

2.10. Other tools and emerging technologies

Advancements in the knowledge base and technologies to study biomolecules lead to development of new biotechnologies in livestock production and uses of animals for various different purposes. For example, the production of transgenic animals can benefit both biomedical sciences through developing animal models for the study of humans and xenotransplantation for organ donor animals for humans. Somatic nuclear transfer (SCNT or cloning) has been used to produce transgenic livestock. This method has been used to produce transgenic goats whose recombinant protein has already been marketed for human medicine (50). Although the efficiency of cloning is higher in goats and cattle as compared to other mammals, overall it still remains a less efficient method for production of transgenic livestock.

Following the successful production of Dolly, the lamb (53), SCNT has been extensively applied to clone and conserve native Anatolian Turkish livestock breeds. A consortium project called TÜRKHAYGEN-1 (http://www.turkhaygen.gov.tr) was funded by the Turkish Ministry of Agriculture and a number of scientists from different institutions (İstanbul University, Uludağ University, and Marmara Research Center) conducted research on cloning. The outcome was the production of livestock using the cloning technology, which provided a training opportunity for the students and researchers. TÜRKHAYGEN-1 was an opportunity to preserve native species.

Birler et al. (54) transferred 69 cleaved SCNT early embryos into the oviduct of eight recipient ewes. Five pregnancies were achieved, two of which continued to term, resulting in two live cloned lambs born in Turkey. A year after the first cloned lambs were born, Arat et al. (55) cloned Anatolian Grey cattle using different somatic cell types as the donor nuclei (fibroblast, cartilage, and granulosa cells) under the National Conservation Program of the Turkish Government. This research suggested that the combination of somatic cell banking and nuclear transfer technologies can be used as a tool to conserve endangered breeds of Turkey.

Production of transgenic livestock is important for mass production recombinant proteins. In Turkey, Bagis et al. (56) generated transgenic mice carrying human interferon-c (hIFN-c). The study showed that hIFN-c was expressed in the mammary glands of transgenic mice and secreted into milk. A more recent method, clustered regularly interspaced short palindromic repeats (CRISPR/Cas), has the potential to help edit the genome to produce transgenic animals and animals with desired genotypes both for agriculture and biomedicine (57).

3. Conclusions

The contribution of animal production to the Turkish economy can be seen in terms of economics, rural development, human nutrition, employment, and migration. The continuity of all applications and sustainability of the production system in animal livestock farms depends on the profitability. The current and emerging biotechnologies are essential for improving efficiency and profitability of the livestock industry. Livestock producers aim at having the best animals with economically important traits including milk or meat quantity and quality, disease resistance, thermotolerance, feed efficiency, and longevity. Therefore, reproduction is the key area of animal science to produce livestock with the desired traits.

For widespread applications of reproductive biotechnologies, proven technologies need to be transferred to the livestock producers in a cost-effective way. In addition, producers should be trained in the technology and its application. Furthermore, the public should be empowered with knowledge about animal biotechnology. Advancements in both basic and applied science provide significant opportunities in enhancing reproductive biotechnologies. Transfer of these new technologies positively impacts livestock agriculture. To achieve this goal, continuous support is critical for high quality fundamental and applied research projects as well as training the next generation of scientists and animal producers. The government, private sector, research institutions, and producers should work together to contribute to biodiversity and sustainable livestock production.

Recording systems for economically important traits will help build up data systems for analysis to generate a knowledge base that will lead to the implementation of genomic selection. Genomic selection can be achievable with an increase in productivity, and business structures in the continuity of the systems and decision-making processes are important. Dynamic changes in market conditions are important and they influence production decisions. Production and marketing of the assessed products are key factors in profitability. In addition, producer behavior, input, and climate changes affecting supply, price, and demand dynamics affecting consumers should be considered.

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