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Assessment of Genetic Improvement Programs for Sheep Fertility in Iraq: An Analytical Study of Opportunities and Challenges

Ayman Hashem Essa[1]* , Safaa Salah Hussein[2] , Omar Khaled Attallah[3]
[1] College Of Law, University of Anbar , Iraq.
[2,3] College Of Agriculture, University of Anbar , Iraq.
1) aymaneng14@uoanbar.edu. 2) safaa.salah@uoanbar.edu.iq. 3) ag.omar.k.attalah@uoanbar.edu.iq.

Abstract:

The scientific analysis of the genetic and productive characteristics of Iraqi Awassi sheep that enhancing their reproductive performance relies fundamentally on integrating modern genomic tools with structured breeding programs. Although Awassi sheep exhibit remarkable adaptation to harsh environmental conditions and maintain stable productive traits, limitations in reproductive efficiency particularly the low rate of multiple births remain a major constraint to improving national flock productivity. Molecular studies have revealed that major-effective genes, such as FecB (Booroola) and FecX, represent strategic genetic markers that can be effectively utilized which help to increase reproductive potential through precise selection and early identification of animals with superior genetic merit. Complementary biotechnological approaches including multiple ovulation and embryo transfer (MOET), advanced artificial insemination, and gene-editing technologies such as CRISPR/Cas9 have opened new pathways for accelerating genetic gain and improving the dissemination of desirable traits within breeding populations. However, practical challenges in the Iraqi situation such as limited laboratory infrastructure, scarcity of comprehensive genetic databases, and the variable efficiency of reproductive biotechnologies continue to restrict the full deployment of these tools. Overall, the findings underscore the necessity of adopting a nationally integrated genetic improvement **strategy** that includes systematic breed characterization, the establishment of unified performance recording systems, and the incorporation of genomic data into decision-making within selected programs. Strengthening research capacities and enhancing breeder engagement are essential steps toward optimizing the reproductive and productive performance of Awassi sheep, thereby supporting food security and promoting sustainable genetic progress in Iraq's livestock sector.

Keywords: Awassi Sheep, Genetic Characteristics, Reproductive Performance, Productive Performance.

تقييم برامج التحسين الوراثي لخصوبة الأغنام في العراق: دراسة تحليلية للفرص والتحديات

ايمن هاشم عيسى [1] ، صفاء صلاح حسين [2] ، عمرخالد عطالله [3]
[1] كلية القانون ، جامعة الانبار ، العراق. [2،3] كلية الزراعة ، جامعة الانبار ، العراق.

مستخلص:

التحليل العلمي للخصائص الوراثية والإنتاجية للأغنام العواسي العراقية يعتمد على تحسين الأداء التناسلي للأغنام العواسي بشكل أساسي على دمج الأدوات الجينومية الحديثة مع برامج التربية المنظمة. على الرغم من أن الأغنام العواسي تظهر تكيفًا ملحوظًا مع الظروف البيئية القاسية وتحافظ على صفات إنتاجية مستقرة، إلا أن القيود المتعلقة بكفاءة التناسل وخاصة انخفاض معدل الولادات المتعددة تظل عائقًا رئيسيًا أمام تحسين إنتاجية القطيع الوطني. كشفت الدراسات الجزيئية أن الجينات الرئيسية الفعالة، مثل جين FecB (بوروولا) وجين FecX، تمثل علامات وراثية استراتيجية يمكن الاستفادة منها بفعالية لزيادة الإمكانيات التناسلية من خلال الاختيار الدقيق والتحديد المبكر للحيوانات ذات المزايا الوراثية العالية. لقد فتحت الأساليب البيوتكنولوجية المكملة بما في ذلك التبويض المتعدد ونقل الأجنة (MOET)، التلقيح الاصطناعي المتقدم، وتقنيات تحرير الجينات مثل CRISPR/Cas9 مسارات جديدة لتسريع المكاسب الوراثية وتحسين نشر الصفات المرغوبة داخل تجمعات التربية. ومع ذلك، لا تزال التحديات العملية في الوضع العراقي مثل محدودية البنية التحتية المخبرية، ندرة قواعد البيانات الجينية الشاملة، وكفاءة تقنيات التناسل المتغيرة تعيق الاستخدام الكامل لهذه الأدوات. بصفة عامة، تؤكد النتائج على ضرورة تبني استراتيجية وطنية متكاملة لتحسين الوراثة تشمل تصنيف سلالات منظم، إنشاء أنظمة تسجيل أداء موحدة، ودمج البيانات الجينومية في اتخاذ القرار ضمن البرامج المختارة. إن تعزيز قدرات البحث وزيادة تفاعل المربين هي خطوات أساسية نحو تحسين الأداء التناسلي والإنتاجي للأغنام العواسي، وبالتالي دعم الأمن الغذائي وتعزيز التقدم الوراثي المستدام في قطاع الثروة الحيوانية في العراق.

الكلمات المفتاحية : الأغنام العواسي ، الخصائص الوراثية ، الاداء التناسلي ، الأداء الإنتاجي .

Introduction

Genomic selection applications are a promising tool for enhancing the fertility of sheep, in accordance with regional breeding objectives and adaptation to environment. Sheep Breeding The capacity to add extra lambs to the sheep flock by two or three per year provides major advantages for breeders in that the time span which is available to increase flock size is no longer constrained by the time it takes to accumulate more ewes**1]**]. In Iraq, the lambing rate of two or more is an important trait in sheep production, particularly in the Awassi and Arabian local sheep breeds. Small lambing rates can be used to reduce the number of rams needed per breeding season due to the linear response by flock fertility to herd size [**2**]. Hence, breeding programs to increase fertility of Iraqi ewes to two or three lambs ovulating a year could be an efficient tool to overcome economic problems, enhance the sustainability of the local market, and improve the quality of life for pastoral producers.

1. Overview of Sheep Fertility

Reproductive performance is a major constraint to profitability of the commercial sheep industry. Fertility in animal populations is a complicated biological characteristic, a key point for population survival, highly affected by genetic and environmental factors [3]. It might contribute to 50% of sheep commercial farms with production decrease when underperforming and thus to farmer's income reduction. Fertility is a trait for which there is low to moderate heritability, fair repeatability, but is somewhat difficult to improve genetically without also having access to reproductive technologies [4].

Considering fecundity-genetics, researchers working on sheep have already been responsible for more than 40 years, ever since the discovery of the Booroola fecundity gene (FecB) [5 ,6]. focusing on the search and identification of genes, involved in various aspects of fertility. These genes play such important roles as the ovarian follicles development, ovarian follicles' maturation, menstrual cycles, ovulation, the refreshment of the cells in the sexual organs, the development of the uterus, and many other functions in connection with the female and/or male reproduction. Other genes have also been reported to be related to sheep fertility such as GDF9, BMP15, BMPR1B, B4GALNT2, CA5A, and HMGN1.

2. Genetic Enhancement Techniques

Advances in embryo technologies have been exploited to enhance genetic gain in small ruminants, especially in sheep embryos. The primary goals are to breed similar lines and support genomic selection. In this context, in sheep, the incorporation of embryo-based technologies can potentiate the efficiency of breeding programs focused on genetic improvement of sheep populations [7].

In addition, the possibility of manipulating the early sheep embryo is germane to the need of the animal industry for large animals for autoimmune clinical research as well as animals that specifically express proteins that confer resistance to pests from a wide variety of pathogens. Various methods are available to manipulate preimplantation embryos including separation of blastomeres, bisecting blastocysts and cloning.[8].

Cloning in sheep is a nuclear transfer technique that results in the reconstitution of host eggs that have had their genetic material removed. The birth of Dolly, the first cloned mammal in 1996, was a significant milestone in large animal cloning. Thereafter, numerous researches were carried out to enhance the in vitro embryo production and cloning rate. Such studies resulted in the identification of increasingly efficient methods for oocyte enucleation, as well as the potential to use in vitro-matured oocytes as recipient oocytes that could be successfully reconstructed with somatic donor cells. Nevertheless, the efficiency of cloned embryos is low due to uncompleted reprogramming of cells and/or subsequent abnormal gene expression [9].

The reprogramming of the donor nucleus is the major problem in cloning and it greatly affects the developmental capacity of reconstructed embryo. It has been proposed that the replacement of somatic histones by protamines prior to nuclear transfer might help reprogramming. Histone deacetylase inhibitors, including trichostatin A, valproic acid and several others, enhance cell reprogramming and developmental competence of cloned embryos leading to animal production that is generally similar to that produced using the nuclear transfer protocol alone. Additional methods to enhanced cloning efficiency include synchronizing the donor cell cycle with that of the recipient cytoplast ends [10]..Research has been undertaken to develop optimal biopsy techniques (the 'pull-apart', 'flicking' and 'laser cutting' methods) and to evaluate the effects of embryo biopsy on viability. This analysis is important in limiting the misuse of biopsy and in choosing what method is the best to obtain the highest post-transfer survival rate.In addition, genetically modified lambs were produced using new gene editing technology including CRISPR/Cas9 in recent years. The possibility exists that these methods can be optimized for the generation of transgenic lambs as required, carrying genes of choice and resistance to pathogens, and work in this direction continues [8].

1-2 Goals of Genetic Enhancement & Embryo Technologies

Table (1) framework of the primary objectives mentioned in the text and how they apply to local breeds.

Table (1) Goals of Genetic Enhancement & Embryo Technologies

Primary Goal	Explanation from Text	Application to Iraqi Breeds (Awassi, Arabi, Karadi)
Enhancing Genetic Gain	Exploiting embryo technologies to breed similar lines and support **Genomic Selection**.	Accelerating traits like **milk yield** in Awassi or **wool quality** in Karadi.
Disease Resistance	Developing animals that specifically express proteins conferring resistance to pests and pathogens.	Creating lines resistant to endemic pathogens found in the harsh Iraqi environment.
Clinical Research	Providing large animals for autoimmune clinical research.	Using local breeds as robust models for biomedical research due to their adaptability.

2-2 Embryo Manipulation & Cloning Methods

This table views the physical and biological techniques used on preimplantation embryos.

Table (2) Embryo Manipulation & Cloning Methods

Technique Categories	Available Methods	Details & Mechanism
Embryo Manipulation (Preimplantation)	1. **Separation of Blastomeres** 2. **Bisecting Blastocysts**	Aimed at multiplying embryos (twinning) to potentiate the efficiency of breeding programs.
Cloning	**Nuclear Transfer (SCNT)**	Reconstitution of host eggs by removing genetic material and replacing it with a somatic donor nucleus (e.g., Dolly the sheep).

3. Selective Breeding

Improvement strategies Through selection Selection is the primary tool for increasing the reproduction of Iraqi ewe flock [12,13,14].Challenges in keeping sufficient numbers to set up performance recording schemes for the major breeds in Iraq's large sheep industry, although other options exist.

Implementation of systems selecting men, with artificial insemination as a final step, provides a potential for utilizing large amounts of variation in individuals influencing characters that are possibly heritable and are important to fertility [13]. The response to selection occurs through both sexes, therefore if AI only benefits ram gene frequency, actual benefit will be heavily discounted from delivery via use of ewes, despite seasonality, libido and semen quality and oestrus behaviour issues [11].

3.1. Genetic Engineering in Animals

The use of reproduction techniques integrated with biotechnology for genetic identification and manipulation is a fast, efficient, and economic alternative to produce animals with genetically better phenotypic characteristics. It is necessary to explore ways to raise productivity of sheep by improving their potential for reproduction [9], and the acquisition of the reproductive ability of females is one of the most important factors in the genetic improvement of sheep [14]).Shortening the generation interval is a very important means of improving the reproductive capacity of sheep, and it has become increasingly important to increase the reproductive potential of each individual in a short period of time [5,11]. Genetically modified animals can be modelled to be those animals that one currently desires to create and grow up by reproducing next generations faster than is possible for the natural ones, and most likely, the most economical way to reach this particular genetic aims. Engineered farm animals are not only interesting in themselves as enhanced livestock or breeding animals, but derivatives thereof are useful in solving a wide range of agricultural problems, as well as in disease resistance, in the production of recombinant proteins, in transgenic research, and for regenerative medicine.

Embryo manipulation methods have been used for more than five decades to produce additional genetically identical sheep, from blastomere separation in the 1960s to blastocyst splitting and somatic cell nuclear transfer in the 1990s. Many NT (nuclear transfer) protocols have been developed, the transfer of a single nucleus into an enucleated zygote or and MII-staged oocyte being some of the most widely tested. Recent advances include injection of round spermatids, nuclear transfer from blastomeres and blastocysts, and cloning with fetal and adult somatic cells [15]. However, the efficiency of cloning is low in part because the transplanted nucleus is not fully reprogrammed in the recipient cytoplasm during early embryogenesis. Major advances in cloning efficiency attainable with sheep incl ude optimization of enucleation procedures for reducing cytoplasmic expul-sion, and c ytoplast–restoration treans fencti ons buffl er cytopl asmic complem en ation between cytoplast recipient and don or nucleus [16] Dolly represents the first successful cloning of an adult mammal, and demonstrates the feasibility of nuclear transplantation in an animal of agricultural importance such as sheep. Preparation of the donor cell is also key; for instance, fibroblasts depleted of histones associated with chromatin, and supplemented with protamines to emulate the extremely condensed nucleus of a sperm, support preimplantation development post-NT [17]. Embryo genotype or genetic defect screening ahead of ET has enabled geneticists to select against carrying forward of undesired alleles in both breeding using natural matings and ET programs. Nowadays research work is concentrated in trying to adjust biopsy methods to embryonic cells that, through polymerase chain reaction, are processed in order to choose embryos on the basis of the presence or absence of genetic markers [18]. Transgenic sheep Over the last three decades, considerable effort has gone into exploring the possibility of producing transgenic sheep for improved production and disease resistance (90 main high producing composite breeds have been produced). Although still in the developmental phase gene editing of sheep for improved production traits and resistance to disease remains a gold prospect area for transforming the sheep industry.

3.2. CRISPR Technology

CRISPR (clustered regularly interspaced short palindromic repeats) technology embodied the third generation of restriction endonuclease, also enjoying rapid popularity because of greater efficacy and easier operation compared to pre-existing methods [19]. The CRISPR system consists of a complex of CRISPR RNA (crRNA), tracrRNA, and Cas9 nuclease, which binds to precise DNA targets and generates double-strand breaks (DSBs). Cell repair systems then mend these breaks, often adding or deleting nucleotides or integrating transgenes. In ruminants, CRISPR utilities have focused on the enhancement of meat, wool, and milk traits, the production of disease-resistant and tolerant livestock, and the establishment of animal models for human diseases. Some major features of the method are its high mutagenesis efficiency, simplicity of zygote microinjection, and low molecular complexity. Gene-edited progeny have been obtained in goat and sheep and into cattle, allowing development of farm animal models. Global models continue to be developed using a growing list of models including knockouts and knock-ins. Future progress seeks to address off-target effects, increase homologous recombination rates, and improve the delivery approaches based on techniques such as electroporation that would confer overall improved accuracy and flexibility [13,20]. Table (3) explain summarizes the features, uses in ruminants, and future goals mentioned in the text.

Table (3) Applications & Future Directions Table

Category	Details from Text
Why CRISPR? (Features)	• **Higher Efficacy & Simplicity:** Compared to pre-existing methods. • **High Mutagenesis Efficiency.** • **Simple Microinjection:** Easy to inject into zygotes. • **Low Molecular Complexity.**
Applications in Ruminants	• **Trait Enhancement:** Improving meat, wool, and milk qualities. • **Disease Control:** Producing disease-resistant and tolerant livestock. • **Biomedicine:** Establishing animal models for human diseases. • **Successes:** Gene-edited progeny obtained in **Goats, Sheep, and Cattle**.
Mechanism Summary	Consists of **crRNA**, **tracrRNA**, and **Cas9**. It creates Double-Strand Breaks (DSBs) which are repaired by the cell, leading to insertions, deletions, or transgene integration.
Future Directions	• **Accuracy:** Addressing and reducing **off-target effects**. • **Efficiency:** Increasing homologous recombination rates. • **Delivery:** Improving delivery approaches using techniques like **electroporation** for better flexibility.

4. Indigenous Sheep Breeds in Iraq and the Imperative for Genetic Improvement

History of Sheep Farming in Iraq Sheep farming in Iraq has deep roots, and the country has a significant flock of local sheep. They are animals adapted to the peculiar environment of Iraq where native feed is available in abundance on mountainous terrain. A number of SRP sheep breeds, such as Awassi, Karadi, Shami and Chiroptera (Baluchi), are recorded in the Ministry of Agriculture, Iraq. The Karadi type, in particular, is also the most popular, the most distributed and is more adapted to the north of Iraq. Nevertheless, sheep farmers are confronted with challenges of genetic dilution, inadequacy in number and good quality of rams. Due to suboptimal levels of production and reproductive performance, genetic development of the sheep industry must rely heavily on reproductive technologies [21]. The embryo transfer technique has recently become popular and remains a future trend for small ruminants with superior genetic value in addition to a program of priority in Iraq. [13].

5. Opportunities for Genetic Enhancement

Fertility preservation is a critical issue for animal scientists around the world. Although the fertility potential of the sheep is ignored in many cases, the Iraqi sheep still have multiple possibilities for being improved genetically in terms of fertility by focusing on body weight, scrotal circumference, plasma testosterone level, and number of the accessory glands in the present study [22**].**

AI and MOET provide avenues to predict genetic gain and to broaden the genetic lives of outstanding sires. To estimate genetic progress, frozen semen inseminations of reference sires may be performed at regular intervals, these representing a constant portion of the genetic base across time. Management of these types of matings in commercial flocks, along with elite and commercial matings in the current generation, makes it possible to estimate not only genetic gain but also genetic discrepancy between nucleus and commercial **levels [23].** Especially when applied in sheep and goat herds, MOET can be used in breeding programs and can provide early selection relative to sibs, because litter sizes form oestrus induction are increased compared with young beef and dairy cows. Negative effects of reduced accuracy of selection could be partially compensated by reduced generation interval.

Embryo biotechnologies result in fluctuating success which greatly still restrains their commercial use. In vitro embryo production from pre-pubertal and adult animal oocytes should be further optimized, mainly in terms of refinement and standardization of in vitro embryo production (IVEP) protocols [**13**]. More and more sophisticated methods of producing embryo genetic cryobanks have been developed, but titles as advanced reproductive techniques for cloning, embryo gene editing or ICSI are still experimental. Application of the assisted reproductive technologies (ARTs) would help the regions with sheep production by increasing the production of domestic breeds and supporting the conservation of biodiversity.

More detailed studies are needed to obtain clear strategies for genetic improvement of sheep reproductive performance in the whole Iraqi flocks. Continued studies into the characterisation of local breeds will form the basis for the development of improvement programmes and the introduction of the breed into commercial flocks. The genetic manipulation of reproductive traits is hence a tempting challenge.

5.1. Increased Lamb Production

Two primary genetic objectives can be identified for increased lamb output: increased rate of lambing by facilitated multiple births, and increased rate of fresh lamb production by either reducing gestation length or promoting early rapid lamb growth. A breeding flock in the United States usually has a 180 percent lamb crop born, and a 148 percent crop weaned without help [24,25]. Stated research data The 275 percent lamb crop is expected to be achievable from selection on a once-a-year-lambing basis. Lambing percentage of over 200 percent is made possible due to the development of methods of rearing surplus or orphan dams on milk replacers with high growth factor and early weaning [**26**]. For example, more than 100,000 lambs were raised on milk replacers in the United States during 1973. Grower and confinement performer Although the National Pork Producers Council(1998) indicated that early weaning and confinement feeding will improve the growth efficiency (daily gain averages 0.8-1.0 pounds and feed efficiency averages 3.0-4.5 pounds of feed per pound of gain). Expanding national lambing through these new breeds and their associated management systems could be realized through continued or greater litter sizes together with accelerated lambing programs and well-designed mating systems. More studies are needed to understand the suitability of breeds for long-term accelerated production, the refining of accelerated lambing systems and the related nutritional and management applications. This broader attitude shift across industry is required to effectively bring these advances to scale at a national level **[27].**

5.2. Improved Disease Resistance

Genetic resistance to parasites hold good potential as it provides additional avenues to control parasites in relation to other control options on sheep **[24].** In another heavy nematode infected area "Iraq" the nematode infection losses in sheep are an approximate 27 million USD annually and in order to select sheep for resistance or to discover genetic markers associated with resistance, no more success has been made to date [**28**]. A number of loci have been associated with nematode resistance in sheep, where the major histocompatibility complex (MHC) has been demonstrated to be significantly associated with resistance. Polymorphism of the MHC-DRB1 gene was found to be linked to FEC for gastrointestinal nematode parasites in the Iranian Ghezel sheep breed [**29**]. Resistant breeding represents a potential solution for the livestock industry, particularly in the era of high prevalence of anthelmintic resistance, projected environmentally mediated increase in parasite transmission and the need for environmentally friendly production. FEC is the most commonly used resistance trait, as it is simple, inexpensive to measure, moderately to highly heritable, has a ubiquitous distribution, and is strongly genetically correlated with nematode burden and production traits. Carriers become more prolific egg shedders during the peri-parturient period (PPR), which is when infective larvae are placed onto the pasture and it is believed that carriers contribute to the decline in chemotherapy efficacies; if selection for resistance were to progress in the PPR this could have additional benefits to the livestock industry. Estimated breeding values (EBVs) for trait performance recorded on other flock mates are commonly employed to make genetic selection decisions, but it has not been tested if selecting on these values will decrease PPR and the resultant infection pressure. Predictive epidemiological models are employed to estimate any potential gain from the selection of ewe lambs for low FEC at the PPR under both present and future climate conditions [**30 , 31].**

6. Challenges Faced

As well as these numerous small research/genetic-improvement projects, it is hoped that a well-organized, ongoing genetic-improvement program would be initiated as the 'skeleton' of operations within which the various on-going small projects would function. Collaborative sire and/or dam recording schemes on two or more flocks, and, preferably, two or more breeds, of sheep and goats are confronted by problems that are broadly based on objectives, the way in which the benefit of gain will be shared and who are the genetic decision makers [23]. Development of a performance-recording system, a system of breeding from the sires of tomorrow, and a system of transmitting genetic advance to all its breeders, necessarily derive from the evolution of the particular situation in which improvement is mediated. The other strategies that deserve investigation as potential alternative or complementary methods of evaluating breeding programs and assessing genetic gain are monitoring and comparing progeny performance through time and options such as artificial insemination (AI) [10]. multiple ovulation and embryo transfer and the sophisticated advanced mixed-modeling method BLUP [25]. Reliability of data, sample procedures, industry genetic progress per flock, genetic correlations across flocks, generation interval, and inbreeding within flocks were the factors that determined the value of comparing flocks as an indicator of industry genetic progress [24].

6.1. Regulatory and Technical Challenges in Ovine Genetic Engineering

Full GM in sheep as regulated by the directive 2001/18/CE needs tight control **[34].** Blastomere early-stage blastomeres, one of the most frequently used One of the most frequent drawbacks to ovine genetic manipulaprojection) tion techniques is the derivation of early-stage blastomeres, which lead to mosaicism initiation (an incidence rate that is by large higher than instance, the 98% in mosaic germinal **[35, 36]**. the morula stage due to the high embryonic lethality of all. IVF-derived embryos can be targeted more easily than SCNT-derived ones (since there is an epigenetic reprogramming window), with the generation of clonal flocks only being feasible in the case of the later. Single blastomere is the only cell from which single cell culture is conveniently performed [**37**]. When TGE Vectors are used in ovine, the limited chromosomal recombination prevents sheep genome due to their size. The transgenic vectors may not be inherited by the offsprings or too many copies integrated in the hostâ ™ D/S DNA in the process of nuclear transfer. Sheep/lamb embryo derived embryonic cells are not available yet and therefore cloning or embryo based modifications are required. As cell totipotency is preserved until the 8-cell or 16- cell stage in sheep [**38**], the corresponding blastomeres can be employed for genetic manipulation.

At present, the desired recipient of transgene DNA is the late morula or the early blastocyst, wherein the inner cell mass (the origin of ES cells) makes up a quarter of the cell number [**13**]. The isolation of blastomeres or microinjection into the perivitelline space or cytoplasm are performed withholding / piezo-drive pipettes and polypropylene micro-capillaries used for micro-manipulation stage. Vectors can be micro-injected into the whole embryo (ZP), through small perforations around the equator **[39].**

Transgenic DNA is distributed throughout the embryo, or in the whole embryo, when the vector is diluted in polyvinyl-pyrrolidone at the time of micro-injection; the transfection efficiency is low, however with spermatozoids, as implied by data**[40].** A micro-injection of a few picolitres could deliver to the entire sheep embryo several million copies of vector, possibly to nearly all of the cells in the 8–16-cell embryo. It is necessary to excise and purify TGE vectors from BACs or plasmids, which complicates the procedure and reduces efficiency **[13**]. In order to avoid this, transgenic lentivirus production is optimally performed. Upon the removal of sequence specificity and replication origin, you can raise vector concentration to 1mg/ml or so, whereas permissive lentivirus is orders of magnitude lower. Loss of sequence-specificity also presumably allows for less sequence restricted (lacZ or GFP) expression from the reporter gene. In this work, when filtering the vector solution with a 0.2-µm filter, a particle and viral loss of 40% was observed, passes of ZP are almost nil [**41].**

6.2. Technical Barriers to Assisted Reproductive Technologies in Sheep

However, technical barriers still exist which reduce the efficacy of ARTs. Pregnancy derived from the delivery of in vitro fertilized (IVF) embryos produced from the oocytes of both pre-pubertal and adult animals must still be further improved with the settling of IVEP methodologies **[13]**. Procedures like ICSI, cloning and embryonic genetic engineering remain in the theoretical/experimental realm and need to be developed further before they are applicable.

Frozen semen has traditionally been restricted in the sheep industry owing to low conception rates, however laparoscopic intrauterine insemination has been significantly increasing the application of frozen semen in sheep, especially in the Merion breed [23]. There has been relatively less focus on MOET programs in sheep than in beef and dairy cattle. Higher litter sizes from MOET might result in faster selection of replacements due to sib comparison, but any decrease in accuracy due to sib comparison could be compensated by a reduction in generation interval.

7. Economic Implications

Methods of applying selection criteria are explained, including multiple-trait selection, independent culling levels, tandem selection and economic selection indices. Behavioral traits of sheep and goats and associated genetic traits are presented, focusing on the observed components of reproduction **[25].** The problems and constraints of measuring fitness and economic traits, obtaining data organized at the right level of measurement and using it to get evidence of genetic advancement are detailed. Different alternatives for mating systems are discussed, and the importance and difficulty of molecular genetic application are stressed. Methods are described for estimating genetic parameters and weighting values for classes of traits [42]. The economic importance of traits is discussed relative to shifting marketing situations, alternate feeding and management regimens, and the effects of breed composition and heterosis [23].

7.1. Successful Genetic Enhancement Programs

The existence of a commercial flock as the sink for the 'dissemination' of genetic improvement to other flocks is widespread in the more established sheep producing countries. Farmers in most countries already practice some form of extensive controlled breeding, so the commercial flocks are selected to produce improvement in a suite of traits. Nucleus schemes such as those based solely on highly selected breeds however do not permit such an exclusive approach to individual character improvement. Probably two or three highly selected breeds are not going to be able to cover all production contexts. In the selection of the base seed stock or inbred more subtle social and cultural considerations may also be brought into play, and while a commercial multiplier may still exert a greater control over future technical developments in genetics it is more distant [43]. Table (4) explains the commercial flocks which represent the fundamental pillar, or the 'sink,' for the dissemination of genetic improvement, where controlled breeding is applied to enhance a comprehensive suite of traits. Furthermore, the success of future improvement programs requires not only a technical focus but also the integration of social and cultural considerations when selecting base seed stock, while acknowledging the escalating role that Commercial Multipliers will play in steering the course of future genetic technical developments.

Table (4)
Structure of Genetic Improvement Dissemination & Influencing Factors

Entity / Factor	Role in the Structure	Characteristics, Challenges & Impact
Commercial Flocks	Act as the **"Sink"** for the dissemination of genetic improvement to other flocks.	• Farmers practice some form of **extensive controlled breeding**. • Flocks are selected to produce improvement in a **suite of traits** rather than a single character.
Nucleus Schemes	Schemes based on highly selected breeds (the top of the pyramid).	• **Limitation:** They typically rely on only **two or three breeds**. • **Impact:** They are unable to cover all distinct **production contexts** or individual character improvements exclusively.
Commercial Multiplier	An intermediary entity in the breeding chain, described as being "more distant".	• Despite being distant, it may exert **greater control** over future technical developments in genetics.
Selection Considerations	Criteria applied when selecting the **base seed stock** or inbred lines.	• Decisions are not purely biological; **subtle social and cultural considerations** are also brought into play during the selection process.

7.2. Failures and Lessons Learned

The MOET protocol can therefore be considered as an important alternative for enhanced offspring from genetically elite females in sheep. Several methods to synchronize donors and recipients have been developed to circumvent the problems resulting from the naturally irregular ovulatory pattern and the short persistence of ovulation induced by a single FGA sponge [**44, 45**]. In MOET programs requiring the standard one or two splits of the follicular wave, this low efficiency and costly doses of hormones can be disadvantage. Consequently, alternative strategies are needed, like lowering the number of recipients per donor, to 6 or even less **[38]**. Since [13] embryo biotechnologies have been developed for sheep genetic improvement going from in vivo/in vitro embryo production to cloning and genetic screening.

The major drawback of these biotechnologies is their poor efficiency, since, up to now, the production rate of lambs per oocyte has not exceeded 8–10% [**13**]. The best currently achieved pregnancy rate in embryo transfer is reduced from 75–80% to 35–40% when the embryos produced in vitro rather than in vivo are used [**44**]. Likewise, the cloning technique suffers serious losses in viability, and significant phenotypic malformations that render long-term production of genetically modified sheep currently [46]. There are several possible explanations for this decreased efficiency including a decreasing quality of the gametes, damage to the embryo during handling. In vitro embryos are frequently poor quality and limited in quantity and require freezing for future use [47]. The feasibility of freezing embryos marks a further constraining step within the entire procedure, as only 25T30% of embryos survive the cryopreservation [48]. The efficiency of cloning is significantly influenced by the waiting time for nuclear reprogramming, which confines production of the early embryo, until the bulk level of reprogramming has occurred During this waiting time, DNA may be affected by deleterious agents, triggering early apoptosis and blastocyst embryo death. Learning from the mistakes of biotechnological failures may be very helpful to design more successful advanced reproductive techniques [32,49].

7.3.Future Prospects

And the future vision for future challenges is also studied to provide sustainable solutions to the aforementioned challenges. Embarking on new biotechnological trends, including embryo biotechnologies, cloning, genetic screening and gene editing, show promise [13]. The priority areas of development include the establishment of centers of excellence in advanced reproductive biotechnologies, the development of cost-effective methods for genetic improvement in natural and artificial mating management systems, the production of genetically improved sheep stock for early puberty and high prolificacy, the increased use of frozen semen in artificial insemination, the development of breeding programs to boost prolificacy, and the development of controlled mating selection programs for prolific breeds based on set criteria [6,13].

8. Research Directions

Genetic enhancement of reproduction involves identification, and estimation of factors that influence reproductive performances such as ovulation rate and fecundity[5,50]. Regarding third birth, in the tropical and in most developing countries like Iraq, we have a few good data for reproduction that would allow estimation as it should. Since these characteristics are economically important, studies on the candidate genes and their duplication have become topics of great interest in animal biotechnology and breeding. Mutation screening in candidate genes involved in follicle growth and JY=McDonald=246 ovulation rate traits in Iraqi sheep population and to identify gene expression difference in Gorki sheep and prolific breed using ovarian tissue collected during follicular and luteal phase would provide better understanding of reproductive mechanisms and extent of genetic variation **[51].**

Both the GDF9 gene and the BMPR1B gene, which belong to the transforming growth factor β family they have consistent role in follicular development, ovulation, and female reproduction [1,2]. Mutations of these genes are known to be associated with ovulation rate and litter size. G1 point mutation in BMPR1B gene reduces litter size in Sudanese desert sheep. These loci could be potential biomarkers for litter size increase by genotypic, allele or gene introgression. Detecting G1 themselves point mutation in Iraqi sheep breeds may help to incorporate it into the selection strategies to increase fecundity. Screening and verification of these candidate genes in the local population are necessary for genetic improvement [52].

Previous studies emphasize the possibilities of using crossbreeding towards increasing the numbers of piglets born. Native Iraqi breeds, acclimatized and with steady fertility but small litter sizes, had a better lamb output after crosses with Finnsheep, at different inheritance levels. Nevertheless, the cost and performance of these crosses need to be carefully evaluated before broad adoption. Crossing indigenous sheep with prolific exotic sheep breeds, like Romanov, is a potential approach to increase the number of lambs born and preserve environmental adaptation [53].

Iraqi indigenous breeds are highly adapted, breed-round and fertile yet bear low litter size. Adding a Finnsheep influence would potentially increase lamb production at all levels of inheritance but cost-effectiveness and performance should be evaluated before adoption becomes widespread. Crossbreeding indigenous sheep with the highly prolific exotic breeds (e.g., the Romanov) could present possibilities for increasing lambing rate without jeopardizing adaptation to the local environment[9,54].

Conclusion

The results show that the sustainability and economic viability of the ovine sector, particularly within the challenging environmental context of Iraq, pivot fundamentally upon the strategic integration of genetic enhancement technologies. While traditional phenotypic selection remains foundational, it is no longer sufficient to meet the escalating demands for food security and production efficiency. This review highlights that a paradigm shift towards advanced biotechnologies—ranging from Assisted Reproductive Technologies (ARTs) like MOET and IVF to cutting-edge genomic editing tools such as CRISPR/Cas9 and somatic cell nuclear transfer (SCNT)—is imperative for transcending current physiological limits. Although the theoretical potential of these technologies to engineer disease-resistant and high-fecundity flocks is immense, their practical application is currently constrained by technical barriers, primarily the incomplete epigenetic reprogramming in cloned embryos and the low efficiency of gene transfer. Therefore, future research must prioritize optimizing in vitro culture conditions and refining molecular screening protocols to identify fecundity alleles (e.g., FecB, BMP15) within indigenous breeds like Awassi and Karadi. Ultimately, the success of genetic enhancement programs does not rest solely on laboratory breakthroughs but on the effective dissemination of superior germplasm to commercial flocks—the vital "sink" of the industry. Thus, a holistic approach that bridges the gap between molecular innovation, regulatory compliance, and socio-economic feasibility is essential to secure the genetic progress of the sheep industry.

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