CHAPTER 9

OPTIMISATION OF REPRODUCTIVE BIOTECHNOLOGIES IN GOATS: THE ROLE OF CRYOPRESERVATION

Bogdaniuk A. O., Yurchuk T. O., Petrushko M. P.
DOI https://doi.org/10.30525/978-9934-26-695-9-9

INTRODUCTION

According to the State Statistics Service of Ukraine, as of early 2023 the national goat population (*Capra aegagrus hircus*) comprised 422.8 thousand head, representing a 13.2% decrease compared to the previous year. The majority of animals belong to Ukrainian local, Saanen, and Alpine breeds. The military aggression of the Russian Federation against Ukraine has affected all sectors of society, rendering food security an issue of particular importance. Currently, approximately 14.2 thousand animals are maintained in breeding agricultural enterprises and may be most efficiently utilised for milk, fibre, and meat production. Dairy goat farming is especially prominent due to the recognised advantages of goat milk over bovine milk. Specifically, goat milk is considered less allergenic and more digestible[1, 2], largely owing to its lower lactose content, making it suitable for individuals with hypolactasia[3].

Ukraine has significant potential for goat breeding[4, 5]. However, maintaining purebred herds and increasing their numbers necessitates the application of modern assisted reproductive technologies (ART)[6].

---

[1] ALKaisy Q.H., Al-Saadi J.S., Al-Rikabi A.K.J., Altemimi A.B., Hesarinejad M.A., Abedelmaksoud T.G. Exploring the health benefits and functional properties of goat milk proteins. *Food Sci Nutr.* 2023. Vol. 11. № 10. P. 5641–5656. https://doi.org/10.1002/fsn3.3531

[2] Roy D., Ye A., Moughan P. J., Singh H. Composition, structure, and digestive dynamics of milk from different species – a review. *Frontiers in Nutrition*. 2020. Vol. 7. Article 577759. https://doi.org/10.3389/fnut.2020.577759

[3] Lad S. S., Aparnathi K. D., Mehta B., Velpula S. Goat milk in human nutrition and health – a review. International *Journal of Current Microbiology and Applied Sciences*. 2017. Vol. 6, No. 6. P. 1781–1792. https://doi.org/10.20546/ijcmas.2017.605.194

[4] Guziev Yu. V., Vinnichuk D. T. Goat farming – a promising sector of livestock production in Ukraine. *Tavriya Scientific Bulletin.* 2013. No. 83. P. 161–165. URL: https://www.tnv-agro.ksauniv.ks.ua/archives/83_2013/32

[5] Fedorovych Ye., Salyha Yu., Fedorovych V., Mazur N., Bodnar P. Development of goat farming in Ukraine. *Bulletin of Agricultural Science*. 2022. Vol. 100, No. 2. P. 42–49. https://doi.org/10.31073/agrovisnyk202202-06

[6] Paramio M. T., Izquierdo D. Assisted reproductive technologies in goats. *Small Ruminant Research*. 2014. Vol. 121, No. 1. P. 21–26. https://doi.org/10.1016/j.smallrumres.2014.01.002

Artificial insemination (AI) remains one of the most effective methods for goat breeding[7], enabling control over herd size, kidding seasonality, and genetic purity.

Due to the anatomical structure of the goat cervix, intrauterine AI is generally impractical; therefore, high sperm concentration and motility are required for successful cervical or vaginal insemination. Laparoscopic AI represents an alternative approach, albeit requiring specialised equipment and skilled personnel[8]. Given the preference for female offspring in dairy production, the use of sex-sorted semen is of particular relevance, although such procedures may adversely affect sperm morphological and functional parameters, as well as fertilisation capacity[9]. Goats inhabiting temperate regions exhibit pronounced reproductive seasonality, with breeding activity typically occurring in autumn[10]. Oestrus can be artificially induced through hormonal treatments (e.g., follicle-stimulating hormone (FSH), progesterone, gonadotropins), thereby allowing regulation of kidding periods[11]. Similarly, bucks demonstrate seasonal variation in semen quality. The high sperm concentration per ejaculate enables division into multiple insemination doses, reducing the need for maintaining numerous breeding males and improving farm economic efficiency. Contemporary advancements in ART in animal production are largely predicated upon the effective utilisation of cryopreserved gametes[12], facilitating optimisation of breeding programmes, conservation of genetic resources, and enhancement of reproductive performance. This is particularly critical for species with marked reproductive seasonality, such as goats, in which gamete quality is strongly influenced by physiological status during breeding and non-breeding periods.

Cryopreservation of spermatozoa is known to induce a range of structural, functional, and molecular alterations, including plasma membrane disruption,

---

7 Baldassarre H., Karatzas C. N. Advanced assisted reproductive technologies in goats. *Animal Reproduction Science*. 2004. Vol. 82. P. 255–266. https://doi.org/10.1016/j.anireprosci.2004.04.027

8 Gangwar C., Ranjan R., Kharche S. D., Pourouchottamane R., Rai B. Success of artificial insemination in goats: an overview. *Indian Journal of Small Ruminants*. 2023. Vol. 29, No. 1. P. 1–10. https://doi.org/10.5958/0973-9718.2023.00017.X

9 Bathgate R., Mace N., Heasman K., Evans G., Maxwell W. M. C., De Graaf S. P. Birth of kids after artificial insemination with sex-sorted frozen-thawed goat spermatozoa. *Reproduction in Domestic Animals*. 2013. Vol. 48, No. 6. P. 893–898. https://doi.org/10.1111/rda.12182

10 Koshevoy V. P., Sklyarov P. M., Naumenko S. V. Characteristics of reproductive function in sheep and goats. In: *Reproductive problems and ways of solving them*. Kharkiv: Kharkiv State Zooveterinary Academy, 2011. P. 136–461. URL: http://dspace.dsau.dp.ua/jspui/handle/123456789/778

11 Hashemi M., Safdarian M., Kafi M. Estrous response to synchronisation outside the natural breeding season in ewes. *Small Ruminant Research*. 2006. Vol. 65, No. 3. P. 279–283. https://doi.org/10.1016/j.smallrumres.2005.07.051

12 Kopeika E. F., Petrushko M. P., Piniaiev V. I. et al. Cryopreservation of reproductive cells and embryos of animals. *Problems of Cryobiology and Cryomedicine*. 2019. Vol. 29. P. 3–18. https://doi.org/10.15407/cryo29.01.003

reduced motility, oxidative stress, and DNA damage[13]. The extent of these changes depends not only on freezing protocols but also on initial sperm quality, which is itself influenced by the season of collection. Sperm obtained during the non-breeding season generally exhibits lower cryoresistance, potentially compromising fertilisation capacity[14]. Importantly, fertilisation success and subsequent embryonic development depend not only on sperm quality but also on oocyte functional competence. Oocytes possess the ability to repair sperm DNA damage post-fertilisation, partially mitigating the detrimental effects of cryopreservation[15]. However, this reparative capacity may vary with the season of oocyte retrieval, a factor that remains insufficiently investigated. Despite existing studies addressing seasonal effects on either sperm or oocyte quality, the combined interaction within the "oocyte–spermatozoa" system using fresh and cryopreserved gametes remains inadequately understood. In particular, the influence of season combined with sperm cryopreservation on early embryogenesis, as well as the compensatory potential of oocytes, warrants further investigation.

Thus, the relevance of the present study lies in elucidating the role of seasonality in gamete quality formation, assessing the effects of sperm cryopreservation across different seasons, investigating oocyte–sperm interactions under varying biological conditions, determining the contribution of oocyte repair mechanisms to normal embryogenesis, and optimising ART protocols with consideration of seasonal factors.

1. Methodological and laboratory approaches to goat reproduction using ART

Research in goat reproduction employing ART is conducted in accordance with contemporary bioethical standards and international guidelines for animal welfare. All procedures involving biological material comply with national legislation and European conventions on the protection of vertebrate animals used for scientific purposes. Adherence to bioethical principles is essential not only from a regulatory perspective but also for ensuring reproducibility and scientific validity, as animal physiological status directly influences gamete and embryo quality[16].

---

[13] Bogdaniuk A. O., Yurchuk T. O., Petrushko M. P. Seasonal differences in sperm characteristics. Cytology and Genetics. 2022. Vol. 56, No. 5. P. 410–416. https://doi.org/10.3103/S009545272205003

[14] Bogdaniuk A., Garkavii V., Petrushko M. Seasonal variability in cryoresistance of spermatozoa. *Problems of Cryobiology and Cryomedicine.* 2022. Vol. 32, No. 1. P. 34–43. https://doi.org/10.15407/cryo32.01.034

[15] Musson R., Gąsior Ł., Bisogno S., Ptak G. E. DNA damage in embryos and gametes. *Human Reproduction Update.* 2022. Vol. 28, No. 3. P. 376–399. https://doi.org/10.1093/humupd/dmab046

[16] Landi M., Everitt J., Berridge B. Bioethical, reproducibility, and translational challenges of animal models. ILAR Journal. 2021. Vol. 62, No. 1–2. P. 60–65. https://doi.org/10.1093/ilar/ilaa027

Semen collection from bucks is typically performed using an artificial vagina in the presence of an oestrous female as a stimulus[17]. This approach yields high-quality ejaculates while minimising stress and preserving natural ejaculation mechanisms. Semen collection is conducted regularly, taking into account seasonal variations in reproductive activity. Sperm quality assessment includes evaluation of concentration, total and progressive motility, morphological characteristics, membrane integrity, and, where necessary, functional characteristics. Standardised analytical methods ensure comparability across studies and laboratories (Fig. 1).

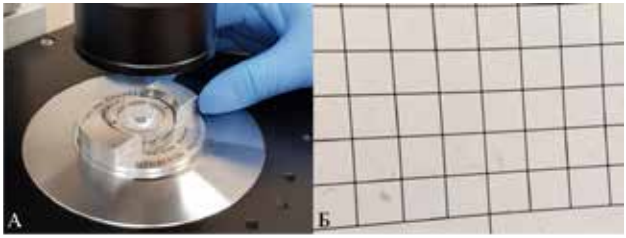

Fig. 1. External view of the Makler chamber (A) and appearance of goat spermatozoa under a microscope at ×400 magnification

Goat oocytes are obtained via follicular aspiration, commonly from ovaries collected post-mortem from animals without reproductive pathology. This method enables efficient utilisation of biological material and recovery of large numbers of oocytes at various maturation stages. Retrieved cumulus–oocyte complexes (COCs) are morphologically evaluated based on cumulus cell layers and cytoplasmic homogeneity. Subsequent washing in buffered media removes follicular fluid residues and potential contaminants. Random allocation of oocytes into experimental groups minimises biological variability and enhances data reliability.

In vitro fertilisation (IVF) is performed following *in vitro* maturation (IVM) of oocytes, a critical step for achieving nuclear and cytoplasmic competence[18]. Maturation is conducted in specialised media containing hormonal and metabolic components until the metaphase II stage is reached. Mature oocytes

[17] Lv C., Larbi A, Liang J., Li C., Bouabid B., Wu G., Quan G. Effects of semen collection methods on sperm quality and metabolite profile in goat seminal plasma: Comparing between artificial vagina and electro-ejaculator techniques. Animal Reproduction Science. 2025. Vol. 279. Article 107885. http://doi:10.1016/j.anireprosci.2025.107885.

[18] Widjiati W., Darsini N., Hendrawan VF., Taqwa SF., Shabira Z., Kurniawati DY. Post-warming quality of goat oocytes under heat shock stress: A study of the maturation rate, heat shock protein-70, adenosine triphosphate, and glutathione levels. Veterinary World. 2025. Vol. 18, No 7. P. 2127–2135. https://doi.org/10.14202/vetworld.2025.2127-2135

are co-incubated with capacitated spermatozoa, which undergo biochemical and structural modifications necessary for fertilisation. The process is conducted under controlled environmental conditions.

Embryos are subsequently cultured *in vitro* to the morula and blastocyst stages. Optimal culture conditions, including osmolarity, pH, and redox balance, are maintained. Media composition is adjusted according to embryonic metabolic requirements, with pyruvate and lactate predominating in early stages and glucose in later stages. Minimisation of oxidative stress is essential for embryo quality and implantation potential. Embryo development is assessed according to international standards, including those of the International Embryo Transfer Society (IETS)[19], considering cleavage rate, blastomere symmetry, fragmentation, and blastocoel formation. Embryogenesis efficiency is determined by blastocyst yield relative to fertilised oocytes. Embryo transfer to recipients is performed following oestrus synchronisation using hormonal protocols to ensure synchrony between donor and recipient reproductive cycles[20]. Transfer is conducted surgically or via minimally invasive techniques. Typically, a single embryo is transferred to avoid multiple pregnancies and associated complications (Fig. 2).

Fig. 2. Laparotomic transfer of a donor goat embryo into the uterine horn of a recipient goat

[19] Wright J. M. Photographic illustrations of embryo developmental stages. In: Manual of the International Embryo Transfer Society. 4th ed. 2010. P. 141–144

[20] Luo J., Wang W., Sun S. Recent advances in dairy goat reproduction. *Asian-Australasian Journal of Animal Sciences*. 2019. Vol. 32, No. 8. P. 1284–1295. https://doi.org/10.5713/ajas.19.0486

The veterinarian exteriorizes the uterine horn from the abdominal cavity, creates an opening using an 18G needle, and inserts the tip of a catheter containing the embryo. The embryologist then depresses the syringe plunger to release the embryo into the lumen of the uterine horn.

Pregnancy diagnosis is performed using ultrasonography, followed by monitoring until delivery. This integrated approach enables objective evaluation of ART efficiency.

Overall, in vitro maturation and fertilisation, followed by controlled embryo culture and transfer, provide a reliable framework for evaluating reproductive potential in goats. While these assisted reproductive techniques are well-established, factors such as seasonal variation and the use of fresh versus cryopreserved gametes can influence early embryonic development, highlighting the need to assess their practical impact under different experimental conditions. The following section presents the results of our study, examining how these variables affect oocyte fertilisation, embryo development, and reproductive outcomes.

2. Biotechnological aspects of goat embryo collection and development: our experience

Male reproductive function is largely dependent on seasonal changes, which affect not only sperm quality but also fertilisation efficiency and subsequent embryo development. In this context, it is important to use appropriate models to assess the fertilising capacity of sperm, in particular by utilising oocytes obtained during different periods of reproductive activity. Assessing the maturation potential of oocytes *in vitro* is a key step for further analysis of fertilisation, as the degree of their cytoplasmic and nuclear maturity determines the success of viable embryo formation. One of the morphological criteria for maturity is the expansion of cumulus cells, which reflects the functional state of the oocyte-cumulus complex and its readiness for fertilisation.

During the breeding season, we obtained 356 immature oocyte-cumulus complexes (Fig. 3A), which were placed in a medium for IVM and, after 24 hours, their maturity was assessed by the expanded layer of cumulus cells (Fig. 3B). During the non-breeding season, 182 oocyte-cumulus complexes were obtained.

Each season, the oocyte-cumulus complexes were randomly divided into three groups for the *in vitro* fertilisation with freshly collected and cryopreserved spermatozoa. Thus, during the breeding season, 120 oocytes were fertilised with freshly collected sperm, 120 with sperm cryopreserved during the breeding season, and 116 with sperm cryopreserved during the non-breeding season. Oocytes aspirated during the non-breeding season were grouped similarly: 61 oocytes were fertilised with freshly collected sperm,

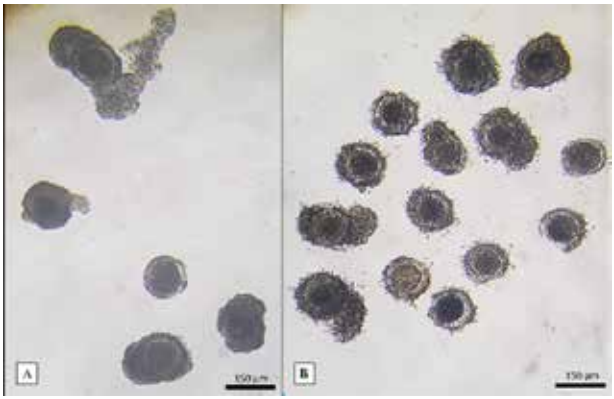

Fig. 3. Microscopic photographs of oocyte-cumulus complexes from goats obtained during the breeding season: immature (A) and mature (B)

61 with sperm cryopreserved during the breeding season, and 60 with sperm cryopreserved during the non-breeding season.

After 16–18 hours of incubation of the oocytes with sperm, the oocytes were stripped of the cumulus cells and the result of *in vitro* fertilisation was assessed, which was determined by the presence of two polar bodies in the perivitelline space (Fig. 4).

Fig. 4. Microphotograph of oocytes from goats during the breeding season, stripped of cumulus cells, following in vitro fertilisation with sperm cryopreserved during the breeding season. The arrows indicate the bodies polar

Embryos were cultured continuously *in vitro* for one week; embryos at the 7th day of development were analysed and classified, and the blastulation rate was calculated (Table 1).

Table 1

Blastulation rate following *in vitro* fertilisation of goat oocytes in different breeding seasons using freshly collected and cryopreserved spermatozoa

Season in which oocytes were collected	Blastulation rate, %		
	Sperm		
	Freshly collected	Cryopreserved during the breeding season	Cryopreserved during the non-breeding season
Breeding	82.6±3.7 a	71.9±9.2 a,b	57.9±9.7 b,c
Non-breeding	69.6±9.6 b,c	68.2±11.2 b,c	53.5±6.5 c

Note: Columns marked with the same letter (a–b) do not differ significantly, $p \geq 0.05$.

The results obtained showed that the highest blastocyst development rate was observed for oocytes collected during the breeding season, when fertilised with freshly collected sperm from the same season (Fig. 5A). This indicator differs insignificantly from the blastulation rate when sperm cryopreserved during the breeding season were used for fertilisation. Fertilisation of oocytes from the breeding season with sperm cryopreserved during the non-breeding season yields sufficiently high embryo development rates (Fig. 5B).

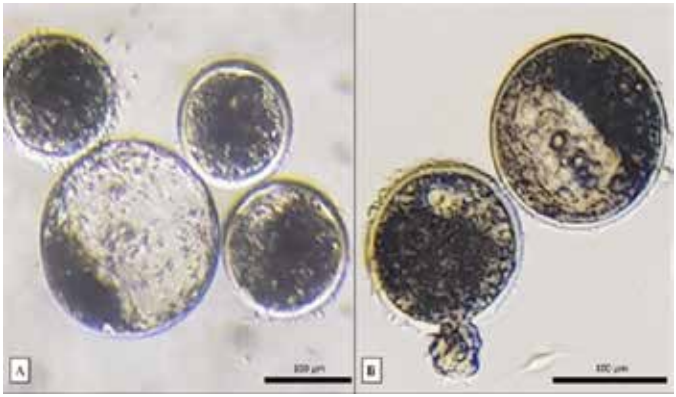

Fig. 5. Microphotographs of blastocysts obtained following in vitro fertilisation of goat oocytes collected during the breeding season with freshly obtained (A) and sperm (cryopreserved during the non-breeding season) (B)

Analysis of the blastulation rate following fertilisation of oocytes collected during the non-breeding season revealed that the groups fertilised with fresh and cryopreserved sperm collected during the breeding season exhibited the same level of blastocyst development. These values did not differ from those of the breeding season, for which cryopreserved spermatozoa were used. The lowest level of embryo development on the 7th day of *in vitro* culture was observed in the fertilisation of oocytes obtained during the non-breeding season with spermatozoa cryopreserved during the non-breeding season. This may indicate that the reparative abilities of oocytes from the non-breeding season are insufficient to repair all damage to sperm cryopreserved during the non-breeding season, particularly to DNA molecules. Ultrasound diagnosis of pregnancies on the 50th day after embryo transfer to recipient goats of the Ukrainian local breed revealed that there was no significant difference in embryo implantation rates between the study groups (Table 2). Around 30% of the goats in each group were diagnosed as pregnant, indicating that the season of oocyte collection and sperm ation does not affect the embryos' ability to implant; moreover, embryos obtained following oocyte fertilisation with cryopreserved sperm are capable of implanting at the same rate as those obtained using freshly collected cells.

Table 2

Pregnancy rates diagnosed on day 50 after the transfer of Zaanen breed embryos to recipient goats of the Ukrainian local breed, obtained during different breeding seasons

Season in which oocytes were collected	Pregnancy rate, %		
	Sperm		
	Freshly collected	Cryopreserved during the breeding season	Cryopreserved during the non-breeding season
Breeding	33.3	29	23.8
Non-breeding	30	24.4	28.1

Approximately 100 days after pregnancy diagnosis, the kidding period began. Six females were found to be pseudopregnant. No significant difference in kidding frequency was observed between the study groups (Table 3).

More than 20% of recipient goats gave birth to kids (Fig. 6). The absence of a significant difference in the frequency of kidding between the study groups suggests that the use of cryopreserved sperm in any breeding season allows for the birth of kids at the same rate as when using freshly collected sperm.

Thus, a synthesis of the results of *in vitro* fertilisation of oocytes obtained in different seasons, in combination with both freshly collected and cryopreserved spermatozoa at various times of the year, indicates the presence of seasonally

Table 3

Frequency of kidding following the transplantation of Saanen breed embryos, obtained in different breeding seasons, into recipient goats of the Ukrainian local breed

Season in which oocytes were obtained	Kidding rate, %		
	Sperm		
	Freshly collected	Cryopreserved during the breeding season	Cryopreserved during the non-breeding season
Breeding	33.3	26.7	23.1
Non-breeding	30.9	22.2	21.8

determined differences in the course of early embryogenesis. In particular, it has been established that both the breeding season and the effect of sperm cryopreservation are associated with changes in the rate of embryo development to pre-implantation stages.

At the same time, these factors do not have a significant effect on subsequent reproductive indicators, in particular the pregnancy rate and the rate of lambing. This may indicate the presence of compensatory mechanisms at the implantation

Fig. 6. Recipient goats with their newborn kids, resulting from the transplantation of embryos created by *in vitro* fertilisation of oocytes from the breeding season using freshly collected (A) and cryopreserved (B) sperm during the non-breeding season

and gestation stages, which ensure the realisation of the reproductive potential of embryos that have reached the transfer stage, regardless of the conditions under which they were obtained.

Overall, the obtained results demonstrate that, despite detectable seasonal fluctuations in early embryonic development, the practical reproductive outcome remains stable. The comparable kidding rates across all experimental groups confirm that the use of cryopreserved spermatozoa does not compromise the final efficiency of assisted reproductive technologies in goats. From an applied perspective, this indicates that cryopreservation can be reliably implemented throughout the year without a loss in reproductive performance, thereby expanding the flexibility of breeding programs. Taken together, these findings suggest that seasonal factors and sperm cryopreservation primarily influence the kinetics of early embryo development rather than its ultimate viability. The lack of significant differences in pregnancy and kidding rates points to the existence of intrinsic compensatory mechanisms operating at later stages of reproduction, including implantation and gestation. This highlights the biological resilience of caprine embryos and supports the feasibility of integrating cryobiological approaches into routine reproductive management, irrespective of seasonal constraints.

CONCLUSIONS

A summary of the data obtained indicates that the efficiency of *in vitro* embryogenesis in goats is largely determined by seasonal characteristics of the functional state of gametes. The highest rates of embryo development were observed when using oocytes obtained during the breeding season, in combination with both freshly collected (82.6±3.7%) and cryopreserved (71.9±9.2%) spermatozoa from the same period.

It has been shown that the use of cryopreserved sperm obtained during the non-breeding season to fertilise oocytes from the breeding season is associated with a lower rate of embryo development to the blastocyst stage (57.9±9.7%) compared with freshly collected sperm. At the same time, this rate is comparable to the figures obtained when using sperm cryopreserved during the breeding season, indicating the dominant role of the factor cryopreservation in determining the functional integrity of sperm.

The lowest efficiency of *in vitro* embryogenesis was observed when using gametes obtained during the non-breeding season: in particular, when oocytes from this period were fertilised with sperm cryopreserved under similar seasonal conditions, the rate of embryo development on the 7th day of culture was 53.5±6.5%.

It was established that, despite the observed differences in the course of early embryonic development, subsequent reproductive parameters remain

stable: the pregnancy rate and the rate of lambing following embryo transfer do not depend on the season of sperm collection or its physiological state (fresh or cryopreserved).

SUMMARY

Seasonal variability in reproductive function remains a major challenge in goat breeding, affecting gamete quality, fertilisation efficiency, and embryo development, and thereby limiting the consistency of assisted reproductive technologies. This study investigated the effects of seasonal factors and sperm cryopreservation on in vitro fertilisation and embryo development in goats. Oocytes obtained during breeding and non-breeding seasons were fertilised using both freshly collected and cryopreserved spermatozoa collected at different times of the year. The results demonstrated that the highest blastocyst development rates were achieved when both oocytes and sperm were obtained during the breeding season. In contrast, the lowest embryo development rates were observed when gametes from the non-breeding season were used, particularly in combination with cryopreserved sperm. Despite significant seasonal differences in early embryogenesis, no differences were found in pregnancy and kidding rates following embryo transfer. More than 20% of recipient goats successfully gave birth across all experimental groups. These findings indicate that seasonal factors and cryopreservation influence early embryo development dynamics but do not affect the final reproductive outcome, likely due to compensatory mechanisms at later stages of gestation. The study supports the effective use of cryopreserved sperm in goat reproduction throughout the year.

Bibliography

1. ALKaisy Q.H., Al-Saadi J.S., Al-Rikabi A.K.J., Altemimi A.B., Hesarinejad M.A., Abedelmaksoud T.G. Exploring the health benefits and functional properties of goat milk proteins. Food Sci Nutr. 2023. Vol. 11. № 10. P. 5641–5656. https://doi.org/10.1002/fsn3.3531

2. Roy D., Ye A., Moughan P. J., Singh H. Composition, structure, and digestive dynamics of milk from different species – a review. Frontiers in Nutrition. 2020. Vol. 7. Article 577759. https://doi.org/10.3389/fnut.2020.577759

3. Lad S. S., Aparnathi K. D., Mehta B., Velpula S. Goat milk in human nutrition and health – a review. International Journal of Current Microbiology and Applied Sciences. 2017. Vol. 6, No. 6. P. 1781–1792. https://doi.org/10.20546/ijcmas.2017.605.194

4. Guziev Yu. V., Vinnichuk D. T. Goat farming – a promising sector of livestock production in Ukraine. Tavriya Scientific Bulletin. 2013. No. 83. P. 161–165. URL: https://www.tnv-agro.ksauniv.ks.ua/archives/83_2013/32

5. Fedorovych Ye., Salyha Yu., Fedorovych V., Mazur N., Bodnar P. Development of goat farming in Ukraine. Bulletin of Agricultural Science. 2022. Vol. 100, No. 2. P. 42–49. https://doi.org/10.31073/agrovisnyk202202-06

6. Paramio M. T., Izquierdo D. Assisted reproductive technologies in goats. Small Ruminant Research. 2014. Vol. 121, No. 1. P. 21–26. https://doi.org/10.1016/j.smallrumres.2014.01.002

7. Baldassarre H., Karatzas C. N. Advanced assisted reproductive technologies in goats. Animal Reproduction Science. 2004. Vol. 82. P. 255–266. https://doi.org/10.1016/j.anireprosci.2004.04.027

8. Gangwar C., Ranjan R., Kharche S. D., Pourouchottamane R., Rai B. Success of artificial insemination in goats: an overview. Indian Journal of Small Ruminants. 2023. Vol. 29, No. 1. P. 1–10. https://doi.org/10.5958/0973-9718.2023.00017.X

9. Bathgate R., Mace N., Heasman K., Evans G., Maxwell W. M. C., De Graaf S. P. Birth of kids after artificial insemination with sex-sorted frozen-thawed goat spermatozoa. Reproduction in Domestic Animals. 2013. Vol. 48, No. 6. P. 893–898. https://doi.org/10.1111/rda.12182

10. Koshevoy V. P., Sklyarov P. M., Naumenko S. V. Characteristics of reproductive function in sheep and goats. In: Reproductive problems and ways of solving them. Kharkiv: Kharkiv State Zooveterinary Academy, 2011. P. 136–461. http://dspace.dsau.dp.ua/jspui/handle/123456789/778

11. Hashemi M., Safdarian M., Kafi M. Estrous response to synchronisation outside the natural breeding season in ewes. Small Ruminant Research. 2006. Vol. 65, No. 3. P. 279–283. https://doi.org/10.1016/j.smallrumres.2005.07.051

12. Kopeika E. F., Petrushko M. P., Piniaiev V. I. et al. Cryopreservation of reproductive cells and embryos of animals. Problems of Cryobiology and Cryomedicine. 2019. Vol. 29. P. 3–18. https://doi.org/10.15407/cryo29.01.003

13. Bogdaniuk A. O., Yurchuk T. O., Petrushko M. P. Seasonal differences in sperm characteristics. Cytology and Genetics. 2022. Vol. 56, No. 5. P. 410–416. https://doi.org/10.3103/S009545272205003

14. Bogdaniuk A., Garkavii V., Petrushko M. Seasonal variability in cryoresistance of spermatozoa. Problems of Cryobiology and Cryomedicine. 2022. Vol. 32, No. 1. P. 34–43. https://doi.org/10.15407/cryo32.01.034

15. Musson R., Gąsior Ł., Bisogno S., Ptak G. E. DNA damage in embryos and gametes. Human Reproduction Update. 2022. Vol. 28, No. 3. P. 376–399. https://doi.org/10.1093/humupd/dmab046

16. Landi M., Everitt J., Berridge B. Bioethical, reproducibility, and translational challenges of animal models. ILAR Journal. 2021. Vol. 62, No. 1–2. P. 60–65. https://doi.org/10.1093/ilar/ilaa027

17. Lv C., Larbi A, Liang J., Li C., Bouabid B., Wu G., Quan G. Effects of semen collection methods on sperm quality and metabolite profile in goat seminal plasma: Comparing between artificial vagina and electro-ejaculator techniques. Animal Reproduction Science. 2025. Vol. 279. Article 107885. http://doi:10.1016/j.anireprosci.2025.107885.

18. Widjiati W., Darsini N., Hendrawan VF., Taqwa SF., Shabira Z., Kurniawati DY. Post-warming quality of goat oocytes under heat shock stress: A study of the maturation rate, heat shock protein-70, adenosine triphosphate, and glutathione levels. Veterinary World. 2025. Vol. 18, No 7. P. 2127–2135. https://doi.org/10.14202/vetworld.2025.2127-2135

19. Wright J. M. Photographic illustrations of embryo developmental stages. In: Manual of the International Embryo Transfer Society. 4th ed. 2010. P. 141–144.

20. Luo J., Wang W., Sun S. Recent advances in dairy goat reproduction. Asian-Australasian Journal of Animal Sciences. 2019. Vol. 32, No. 8. P. 1284–1295. https://doi.org/10.5713/ajas.19.0486

Information about the authors:
Bogdaniuk Anastasiia Oleksandrivna,
Doctor of Philosophy, Director
LLC "Institute of Contemporary Veterinary Technologies"
27, Shevchenka street, Cherevky, Kyiv Oblast, Ukraine

Yurchuk Taiisia Oleksandrivna,
Candidate of Biological Sciences,
Head of the Laboratory for Gamete and Embryo Cryopreservation,
Department of Cryobiology of Reproductive Systems,
Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine
23, Pereyaslavska street, Kharkiv, Ukraine;
Associate Professor,
InLife – Institute of Animal Reproduction and Food Research
Polish Academy of Sciences
Władysława Trylińskiego 18, 10-683 Olsztyn, Poland

Petrushko Maryna Pavlivna,
Doctor of Biological Sciences, Professor,
Head of the Department of Cryobiology of Reproductive Systems
Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine
23, Pereyaslavska street, Kharkiv, Ukraine