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Integrated assessment of the reproductive performance of ewes of different genetic origins considering animal welfare indicators

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The article investigates the peculiarities of reproductive performance formation in ewes of different genetic origins under modern intensive sheep production systems. The relevance of the study is determined by the need to improve flock reproductive efficiency through the combination of genetic resources, the enhancement of breeding strategies, and the consideration of animal welfare indicators. It was established that genetic origin significantly affects fertility, prolificacy, and lamb output. Crossbred genotypes Dorper × Romanov and Merinoland × Romanov outperformed purebred Dorper sheep in most reproductive traits, demonstrating the manifestation of heterosis effects. The highest fertility rate (92.3 %) was recorded in the Dorper × Romanov group, whereas the greatest prolificacy (161.1 %) was observed in Merinoland × Romanov ewes. The results showed that crossbred animals were characterized by higher milk production (5.7–9.6 % increase), lower incidence of diseases and stress load, and better behavioral activity indicators, suggesting a higher level of animal welfare. At the same time, the highest lamb survival rate was observed in purebred Dorper ewes (90.9 %), whereas a slight decrease was recorded in crossbred groups due to their increased prolificacy. The Integrated Reproductive Ability Index (RAI) in the experimental groups ranged from 0.73 to 0.91 conventional units. The highest values were obtained in the Merinoland × Romanov group (+24.7 % compared with Dorper), indicating the most complete realization of genetic complementarity and an optimal balance between productivity and adaptability. The scientific novelty of the study lies in substantiating a systematic approach to evaluating reproductive performance based on the integration of genetic, productive, and animal welfare indicators. Therefore, the proposed Integrated Reproductive Ability Index (RAI) provides a comprehensive evaluation by combining fertility, prolificacy, lamb survival, milk production, and animal welfare indicators into a single integrated criterion. It can be recommended as an additional selection criterion for identifying breeding ewes with high reproductive efficiency and adaptive potential. The practical application of the Integrated Reproductive Ability Index (RAI) enhances the objectivity of breeding genotype selection, optimizes breeding programmes and flock reproduction, and contributes to the implementation of sustainable sheep production in accordance with the principles of the Animal Welfare, One Welfare, and One Health concepts.

Keywords: Dorper, Merinoland, Romanov sheep, crossbreeds, reproduction, prolificacy, animal welfare.

Інтегрована оцінка відтворювальної здатності вівцематок різного генетичного походження з урахуванням показників благополуччя

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У статті досліджено особливості формування відтворювальної здатності вівцематок різного генетичного походження в умовах сучасного інтенсивного вівчарства. Актуальність роботи зумовлена необхідністю підвищення ефективності відтворення стада шляхом поєднання генетичних ресурсів, удосконалення селекційних підходів та врахування рівня благополуччя тварин. Встановлено, що генетичне походження істотно впливає на рівень запліднюваності, багатоплідності та вихід ягнят. Помісні генотипи Dorper × Romanov і Merinoland × Romanov перевищували чистопородних Dorper за більшістю репродуктивних показників, демонструючи прояв гетерозисного ефекту. Найвищу запліднюваність (92,3 %) виявлено у Dorper × Romanov, а максимальну багатоплідність (161,1 %) – у Merinoland × Romanov. Показано, що помісні тварини характеризуються вищою молочністю (на 5,7–9,6 %), зниженим рівнем захворюваності та стресового навантаження, а також кращими показниками поведінкової активності, що свідчить про більш високий рівень благополуччя. Водночас встановлено, що найвища збереженість ягнят спостерігалася у чистопородних Dorper (90,9 %), тоді як у помісей вона дещо знижувалась унаслідок підвищеної багатоплідності. Інтегральний індекс відтворювальної здатності (ІВЗ) у дослідних групах коливався в межах 0,73–0,91 ум. од. Найвищі значення встановлено у Merinoland × Romanov (+24,7 % до дорпер), що свідчить про найповнішу реалізацію генетичної комплементарності та оптимальний баланс між продуктивністю й адаптивністю. Наукова новизна полягає в обґрунтуванні системного підходу до оцінювання відтворювальної здатності на основі інтеграції генетичних, продуктивних і показників благополуччя тварин. Отже, запропонований інтегральний індекс відтворювальної здатності (ІВЗ) забезпечує комплексне оцінювання шляхом поєднання показників запліднюваності, багатоплідності, збереженості ягнят, молочності та благополуччя тварин в єдиний інтегральний критерій. Його можна рекомендувати як додатковий селекційний критерій для відбору племінних вівцематок із високою відтворювальною ефективністю та адаптивним потенціалом. Практичне використання інтегрального індексу відтворювальної здатності (ІВЗ) дозволяє підвищити об'єктивність добору племінних генотипів, оптимізувати селекційні програми й відтворення стада, а також сприяє реалізації принципів сталого розвитку вівчарства відповідно до концепцій Animal Welfare, One Welfare та One Health.

Ключові слова: дорпер, мериноландшаф, романівська, помісі, відтворення, багатоплідність, благополуччя.

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Introduction

In modern conditions, increasing the efficiency of sheep production based on the rational use of genetic resources, the improvement of breeding programs, and the implementation of sustainable development principles has become of particular importance. The economic performance of the sector is largely determined by the reproductive capacity of the ewe flock, since reproductive traits directly shape flock replacement rate and overall production output.

Reproductive performance in ewes is one of the most complex economically important traits, characterized by polygenic inheritance and strong environmental dependence. According to numerous studies, even a slight improvement in fertility and lamb survival rates leads to a substantial increase in production output and overall economic efficiency. Modern breeding programs increasingly consider not only productivity traits but also adaptive capacity, resistance to stress factors, and animal welfare levels [1–4].

The current development of animal science is characterized by a shift from the analysis of single economically important traits to integrated approaches that allow for a comprehensive evaluation of productivity, adaptability, and animal welfare. In sheep production, such approaches involve combining reproductive indicators with physiological, behavioral, and technological parameters, providing a more complete understanding of the mechanisms underlying productivity formation and the adaptive potential of different genotypes [5–7].

However, existing evaluation systems for reproductive performance are mainly based on individual indicators such as conception rate, prolificacy, or lamb survival, which do not provide an integrated assessment of reproductive potential. The lack of a unified integral criterion complicates comparative evaluation of ewes of different genetic backgrounds and reduces the efficiency of selection decisions [8–10].

Therefore, the development and implementation of integrated index-based approaches that combine key reproductive traits into a single composite indicator is highly relevant. Such approaches improve the objectivity of evaluation, simplify selection procedures, and create a foundation for the application of digital technologies and artificial intelligence in sheep management systems [6, 7, 9].

Recent studies emphasize that selection focused exclusively on increasing growth intensity and production traits may be accompanied by unfavorable genetic correlations with reproductive traits [10–12]. This phenomenon is known as antagonism between production and reproductive characteristics, which necessitates a revision of traditional breeding strategies.

Genetic background is one of the key factors determining the reproductive potential of animals. Different breed groups exhibit distinct biological reproductive strategies: some genotypes are oriented toward high fertility and maternal ability, while others are selected for intensive growth rate and feed conversion efficiency [1, 2, 8].

Scientific literature indicates that specialized meat breeds (e.g., Suffolk, Texel, Charollais, Dorper, etc.) demonstrate high growth performance and desirable carcass traits; however, maternal breeds, particularly Romanov sheep, are characterized by superior prolificacy and enhanced reproductive performance. This contrast provides a strong basis for the widespread use of crossbreeding as a tool to improve reproductive efficiency [11, 13].

The heterosis effect resulting from the crossing of genetically distant breeds is expressed through improved conception rates, lamb survival, and adaptive resilience. However, the magnitude of heterosis depends on the specific genetic combination, flock structure, and management conditions, which is confirmed by previous research findings [8, 10, 11].

Sejian et al. [14] demonstrated that heat stress induces hormonal imbalance, reduces oocyte quality, and increases embryonic mortality, which directly affects fertility levels in livestock.

In contemporary research, the concept of animal welfare has gained increasing importance as an integral component of efficient livestock production systems. The main welfare indicators influencing reproductive function include stress levels (cortisol concentration), behavioral responses, health status, lameness, feed quality, and postpartum recovery [5, 15, 16].

Modern scientific development is characterized by a shift toward integrated evaluation models that combine genetic parameters (estimated breeding values, EBVs), reproductive performance indicators, adaptive traits, and animal welfare metrics. Such approaches improve the accuracy of selection decisions and enhance the sustainability and resilience of production systems [7, 9, 17].

The analysis of scientific literature confirms the feasibility of transitioning from traditional breeding evaluations to integrated models that combine genetic, physiological, and animal welfare indicators. This represents a key prerequisite for improving reproductive efficiency, ensuring sustainable development of sheep production, and implementing the “One Health” concept in livestock systems. The study of modern meat genotypes and their crossbreeds is particularly relevant under conditions of climate change, transformation of production technologies, and increasing requirements for animal welfare [13, 18].

In this context, conducting a comprehensive assessment of the reproductive performance of ewes of different genetic backgrounds, taking into account welfare indicators, is an important scientific and practical task. Its implementation will contribute to improving the efficiency of breeding programs, enhancing flock reproductive performance, and ensuring the sustainable development of meat sheep production systems.

The aim of the study

The aim of this study was to investigate the patterns of reproductive ability formation in ewes of different genetic origins (Dorper, Romanov, Merinolandschaf, and their crossbreeds) and to assess animal welfare levels.

Additionally, the study aimed to evaluate the applicability of an integrated reproductive ability index for the objective assessment of ewe reproductive efficiency.

Materials and methods

The study was conducted under farm conditions at the family farm "Sheiko" in Kyiv region, Ukraine, using Dorper ewes (D) and crossbred ewes – Dorper × Romanov (½D × ½R) and Merinolandschaf × Romanov (½Ml × ½R).

During the mating and gestation periods, all ewes were maintained under identical management and environmental conditions. Reproductive performance was evaluated based on conception rate, prolificacy, and the number of live-born and stillborn lambs. Regardless of genetic origin, lambs were reared with their dams until weaning at 3 months of age.

Ewe milk production was estimated indirectly using lamb average daily gain during the first 20 days of the postnatal period, multiplied by a coefficient of 5.

Animal welfare was assessed using a comprehensive system of indicators, including body condition score (BCS), disease incidence rate, behavioral activity level, and a stress load index. These parameters reflect energy balance, immune stability, and the degree of adaptation to technological housing conditions.

To integrate the obtained data, an aggregated approach was applied. It involved the construction of a composite reproductive ability index based on normalized productive and welfare indicators using weighted coefficients.

The Integrated Reproductive Ability Index (IRAI) was calculated as a weighted sum of normalized indicators of conception rate (F), prolificacy (P), lamb survival rate (S), milk production (M), animal welfare (B), and lamb output (L). The weighting coefficients reflect the relative contribution of each trait to the overall reproductive efficiency of the flock.

The integrated index was calculated using the following formula:

$$IRAI = (F_n \times 0.20) + (P_n \times 0.20) + (S_n \times 0.20) + (M_n \times 0.15) + (B_n \times 0.15) + (L_n \times 0.10)$$

Biometric data processing was performed using Microsoft Excel software with the application of statistical functions.

Results and discussion

The reproductive performance of ewes is one of the most important economically valuable traits in sheep production, as it determines the intensity of flock reproduction, the level of output, and the overall economic efficiency of the industry. Crossbreeding between breeds provides the most rapid improvement in reproductive efficiency due to the heterosis effect, which is particularly expressed in fertility, prolificacy, and lamb survival rates.

To assess the characteristics of reproductive potential realization, a comparative analysis was conducted on purebred Dorper ewes (D) and crossbred genotypes Dorper × Romanov (D × R) and Merinoland × Romanov (Ml × R) (***Table 1***).

Table 1

Reproductive performance of ewes of different genetic origins

Genotype ♀	Mated, head	Lambed, head	Fertility, %	Lambs obtained, head			Prolificacy, %
				rams	ewes	total lambs	
D	37	31	83.8	23	21	44	141.9
D × R	52	48	92.3	36	38	74	154.2
Ml × R	41	36	87.8	28	30	58	161.1
Total	130	115	88.5	87	89	176	153.0

The analysis of the obtained data showed that the highest fertility rate was observed in crossbred Dorper × Romanov ewes (92.3 %), which exceeded purebred Dorper ewes by 8.5 percentage points. This pattern can be explained both by the manifestation of individual heterosis and by the positive influence of the Romanov breed's genetic characteristics on the functioning of the reproductive system. It is well known that the Romanov breed is characterized by increased polyestricity, a shortened service period, and high ovulatory activity, which ensure consistently high conception rates regardless of the season.

A more important integral indicator is prolificacy, as it determines the number of lambs obtained per ewe. In the present study, the highest prolificacy level was recorded in Merinoland × Romanov crossbred ewes (161.1 %), which exceeded purebred Dorper ewes by 19.2 percentage points. The obtained results indicate a pronounced additive genetic effect of the Romanov breed on fertility and its ability to promote multiple births.

From the perspective of modern breeding science, the obtained results confirm the concept of genetic complementarity. The Dorper breed contributes high viability, adaptability, and good maternal abilities, the Romanov breed provides high fertility and prolificacy, while the Merinoland breed is characterized by a satisfactory level of milk production and the capacity to rear multiple offspring. The combination of these genetic resources makes it possible to form new genotypes with more efficient realization of reproductive potential.

From an economic standpoint, the observed differences are of considerable practical importance. An increase in prolificacy by only 10–15 % can significantly enhance the output of marketable young stock without additional costs for maintaining the breeding flock. In the present study, the superiority of crossbred genotypes in terms of the number of lambs obtained ranged from

31.8 to 68.2 %, which ensures a substantial increase in lamb production profitability and shortens the payback period of breeding programs.

In modern sheep breeding, the level of milk production is considered one of the key criteria for assessing maternal traits, adaptive capacity, and animal welfare. Milk yield determines the intensity of lamb growth during the first weeks of life, when maternal milk is virtually the sole source of energy, protein, immunoglobulins, minerals, and biologically active compounds.

According to current scientific understanding, approximately 70–85 % of the variation in lamb live weight during the first 3–4 weeks of life is determined by the milk production level of the ewe. Studies have shown that the correlation between ewe milk yield and average daily gain of lambs during the suckling period may reach r=0.70–0.92, indicating an extremely strong biological relationship between these traits [8, 19–21].

Overall, it was established that the crossbred Dorper × Romanov and Merinoland × Romanov genotypes exceeded purebred Dorper ewes in daily milk yield by 5.7–9.6 %, and in total milk yield over 21 days of lactation by 5.7–9.4 % (***Table 2***). Such a consistent advantage indicates a pronounced heterosis effect, which in this case is manifested through increased secretory activity of the mammary gland and more efficient utilization of dietary metabolic energy.

Table 2

Milk production of ewes of different genetic origins, M±SE

Genotype ♀	n	Average daily lamb weight gain, kg	Milk yield of ewes, kg	Milk yield over 21 days of lactation, kg
D	31	0.298±0.06	1.527±0.07	32.08±0.92
D × R	48	0.281±0.04	1.614±0.08	33.91±1.07
Ml × R	36	0.289±0.06	1.673±0.07	35.09±1.35
Total	115	0.288±0.02	1.609±0.04	33.87±0.83

A particularly notable finding is that the highest milk yield values were obtained in the Merinoland × Romanov genotype. This indicates not only the presence of heterosis but also a genetic complementarity effect. Merinoland sheep are characterized by a relatively well-developed lactation ability and the capacity to rear multiple offspring, whereas Romanov sheep provide high ovulatory activity. Their combination forms a biologically balanced system in which high prolificacy is not accompanied by a functional "deficit" in milk production.

It should also be taken into account that the increased milk yield in crossbred ewes occurred against the background of previously established higher prolificacy. This is particularly important, since in multiple births competition between lambs for milk intake and a reduction in individual weight gains are usually observed. However, in the present study, lamb growth intensity remained stable (0.281–0.298 kg), indicating sufficient milk supply even under increased physiological load on the maternal organism. The Merinoland × Romanov genotype is especially valuable, as it demonstrates the highest milk productivity, which is crucial for rearing multiple lambs without additional costs for artificial feeding.

Thus, the obtained data confirm that ewe milk yield is an integral trait formed under the influence of complex interactions between genotype and physiological adaptation mechanisms, while its increase in crossbred animals represents a direct manifestation of heterosis and genetic complementarity of the parental breeds.

The assessment of lamb survival to weaning is an important stage in the comprehensive analysis of reproductive efficiency in sheep production, as it allows for determining the actual realization of ewe reproductive potential in relation to their genetic origin. This indicator integrates the effects of prolificacy, milk production, maternal abilities, and the level of lamb adaptation to early postnatal development conditions.

Table 3 presents data on the number of lambs at birth and at weaning, as well as the calculated survival rate in ewes of different genotypes. The obtained results indicate a high overall level of lamb survival in all experimental groups (86.5–90.9 %), which reflects adequate feeding levels, appropriate housing conditions, and a sufficient degree of maternal behavior in ewes.

Table 3

Survival of experimental lambs

Indicator	Genotype		
	D	D × R	Ml × R
Number of lambs at birth, head	44	74	58
Number of lambs at weaning, head	40	64	51
Including ram lambs	21	31	25
Including ewe lambs	19	33	26
Survival rate, %	90.9	86.5	87.9

The highest lamb survival rate was observed in purebred Dorper ewes (90.9 %). This may be explained by their strong constitutional robustness, stable adaptation to various environmental conditions, and relatively lower intra-litter competition among lambs.

In the Dorper × Romanov and Merinoland × Romanov crossbreds, lamb survival decreased to 86.5–87.9 %. This phenomenon has a clear biological explanation and is associated with a "resource allocation" effect under conditions of multiple births: an increased number of lambs per litter leads to higher competition for colostrum intake during the first hours of life, which directly affects the survival of weaker individuals.

In modern animal production, the assessment of animal welfare is a key component in interpreting both productive and reproductive traits, as the physiological state of the organism determines the level of expression of genetic potential. According to the One Welfare concept, productivity, health, and behavioural status of animals are considered as an integrated system in which any disruption of homeostasis manifests as reduced reproductive efficiency, milk yield, and offspring viability.

The obtained results demonstrate a clear systemic pattern: improvement of the genetic structure through crossbreeding is accompanied by simultaneous optimization of welfare indicators, indicating a deep physiological integration of productive and adaptive traits (***Table 4***).

Table 4
Welfare indicators of ewes of different genetic origins, M±SE

Genotype ♀	BCS (points)	Disease incidence, %	Activity (arbitrary units)	Stress indicator (relative level)
D	3.2±0.1	16.8±1.3	6.4±0.3	0.60±0.03
D × R	3.4±0.1	11.2±1.0	7.3±0.2	0.52±0.02
Ml × R	3.5±0.1	8.9±0.8	7.7±0.2	0.47±0.02

The highest BCS values were recorded in the Merinoland × Romanov genotype (3.5 points), indicating an optimal energy balance and efficient conversion of nutrients into productive functions. In the Dorper × Romanov group, this indicator was 3.4 points, while in purebred Dorper ewes it was 3.2 points. From a physiological perspective, stable BCS values within the range of 3.2–3.5 are considered optimal for reproductive ewes; however, the higher values observed in crossbred animals indicate more efficient regulation of energy metabolism, reduced catabolic load during lactation and the postpartum period, and better adaptation to energy-demanding phases of the reproductive cycle.

The incidence of clinical disease was markedly reduced in crossbred genotypes, decreasing from 16.8 % in Dorper to 11.2 % in Dorper × Romanov and 8.9 % in Merinoland × Romanov. This reflects enhanced immunological stability in crossbred animals, which is a typical manifestation of heterosis.

Behavioral activity increased from purebred Dorper ewes (6.4 arbitrary units) to Merinoland × Romanov (7.7 arbitrary units). An increase in locomotor activity in the absence of elevated stress responses is considered a positive indicator of physiological welfare, normal neuroendocrine status, and the absence of chronic discomfort.

A systematic analysis of welfare indicators reveals an important pattern: genotypes with better welfare parameters simultaneously exhibit higher reproductive and milk productivity, which confirms the concept of biological integration between productive and adaptive systems of the organism.

Overall, the crossbred Dorper × Romanov and Merinoland × Romanov genotypes are characterized by improved energy balance (higher BCS), reduced disease incidence (by 5.6–7.9 %), increased behavioral activity, and lower stress load (by up to 21.7 % compared with Dorper). These changes create a favorable physiological background that directly contributes to improved fertility, prolificacy, and milk yield, as described above.

Of particular importance is the fact that the Merinoland × Romanov genotype demonstrates the best balance between productivity and welfare, which allows it to be considered a promising model for the development of highly efficient maternal flocks under intensive sheep production systems.

The integrated reproductive ability index (IRA) is a generalized multifactorial indicator that allows for a comprehensive assessment of the efficiency of reproductive potential realization in ewes, taking into account the main components of reproduction. Its structure typically includes fertility, prolificacy, lamb survival, and indirectly milk production and animal welfare level.

The obtained results indicate a significant influence of genetic origin on the integrated reproductive efficiency of ewes. The lowest IRA value was recorded in purebred Dorper sheep (0.73 a.u.), which was taken as the baseline reference level (***Table 5***).

Table 5
Integrated reproductive ability index (IRA) of ewes of different genetic origins

Genotype ♀	IRA (arbitrary units)	Deviation from Dorper, %
D	0.73	–
D × R	0.86	+17.8
Ml × R	0.91	+24.7

Crossbred genotypes demonstrate a pronounced increase in the integrated reproductive ability index. In the Dorper × Romanov sheep group, the IRA reached 0.86 a.u., which is 17.8 % higher than the baseline level. This indicates effective realization of the heterosis effect, manifested in improved fertility and overall reproductive activity.

The highest IRA value was recorded in the Merinoland × Romanov genotype (0.91 a.u.), exceeding the purebred Dorper by 24.7 %. This reflects the most complete expression of genetic complementarity between the parental breeds, where the combination of high milk production and reproductive activity ensures optimal integration of all components of the reproductive system.

The IRA does not represent an isolated trait but rather a systemic property of the organism that integrates reproductive, productive, and adaptive characteristics. It was established that Dorper × Romanov crossbreds provide a substantial increase in reproductive performance, while Merinoland × Romanov exhibits the maximum IRA value and the best balance between the quantity and quality of offspring.

Conclusions

The conducted study demonstrates the superiority of crossbred genotypes over purebred Dorper sheep in most reproductive performance traits. The highest fertility rate was recorded in Dorper × Romanov ewes (92.3 %), whereas the highest prolificacy was observed in Merinoland × Romanov crossbreds (161.1 %). Particular attention should be given to Dorper × Romanov crossbred ewes, which combine high fertility, considerable prolificacy, and an increased number of lambs per ewe, making them promising for use in breeding and selection programs. The highest level of lactation performance was identified in Merinoland × Romanov crossbreds, indicating the appropriateness of this genotype for the formation of highly productive maternal flocks. An improvement in welfare indicators was also observed in crossbred animals, including a reduction in disease incidence to 8.9 % and a decrease in the stress index to 0.47. The integrated reproductive ability index (IRA) in the studied ewes ranged from 0.73 to 0.91 a.u. The Merinoland × Romanov genotype was identified as the most promising, combining an optimal balance between productivity and offspring viability. It was established that the maximum realization

of the genetic potential of ewes is possible only under optimal welfare conditions, and the use of crossbred genotypes represents an effective tool for improving reproductive performance in sheep production.

DECLARATIONS

Ethical Statement

The author confirms that the study was conducted in accordance with the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, 1986), national ethical regulations, and international standards (NIH, ARRIVE guidelines).

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Conflict of Interest

The author states that there is no conflict of interest.

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Declaration of AI and AI-assisted technologies

During the preparation of this work, the author used ChatGPT (OpenAI) for language polishing, improving readability, and translating text segments. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the final manuscript.

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