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EVALUATION OF PRODUCTIVE, REPRODUCTIVE AND BIOLOGICAL TRAITS OF DIFFERENT DUCK CROSSES IN KAZAKHSTAN

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ABSTRACT

The aim of this study was to develop efficient approaches to waterfowl breeding based on selection and technological methods by comprehensively evaluating the productive, reproductive, and biological traits of different duck crosses. The Ansar, Bashkir Colored, Cherry Valley, and Kyzylzhar crosses were evaluated for feed composition, drake semen quality, egg morphology and incubation traits, egg production, growth performance, blood biochemical parameters, and carcass characteristics. Cereal feeds provided the main energy source, whereas soybean cake and soybean meal contained the highest crude protein concentrations (376.7 and 377.6 g/kg, respectively), confirming their importance for balancing dietary protein and essential amino acids. Ansar drakes had a significantly higher sperm concentration than Bashkir Colored drakes (2.23 ± 0.03 vs. 2.01 ± 0.05 × 10^9 spermatozoa/cm^3; $P<0.05$). Compared with Bashkir Colored, Ansar produced significantly heavier hatching eggs (86.2 ± 0.16 vs. 85.4 ± 0.19 g; $P<0.05$) and showed higher fertility (93.6% vs. 91.5%), hatchability (81.0% vs. 78.5%), and survival of young birds (99.0% vs. 98.0%). At 49 days of age, Ansar ducks had a significantly greater live body weight than Bashkir Colored ducks (3478.56 ± 9.47 vs. 3222.92 ± 10.25 g; $P<0.05$) and a lower feed conversion ratio (2.00 vs. 2.20 kg feed/kg live weight gain). Carcass evaluation showed that Ansar had the highest pre-slaughter live weight (3692.3 ± 30.2 g), eviscerated carcass weight (2409.2 ± 18.25 g), and eviscerated carcass yield (69.4%); its eviscerated carcass weight was significantly higher than that of the other studied crosses ($P<0.05$). The blood biochemical assessment indicated no overt adverse physiological responses. Overall, the Ansar cross demonstrated strong combined reproductive, growth, feed-efficiency, and meat-production performance, supporting its potential for commercial duck production under Kazakhstan conditions.

Keywords: Ansar cross, Productivity, Reproductive performance, Growth performance, Feed efficiency.

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1. INTRODUCTION

According to the FAO-OECD outlook, the global population is projected to increase by 729 million people by 2034, reaching approximately 8.8 billion, with an average annual growth rate of 0.8%. Long-term projections by the United Nations suggest that the world population will continue to grow, peaking at around 10.3-10.4 billion by the mid-2080s, after which a gradual decline is expected (OECD/FAO, 2025).

In this context, poultry production is becoming increasingly important as a major source of high-quality animal protein, which is key to human nutrition. In 2024, global meat production increased by 1.3% to 365 million tonnes, driven primarily by the expansion of poultry meat production (OECD/FAO, 2025).

Per capita meat consumption is projected to increase by 0.9 kg/year by 2034, expressed in retail weight equivalent. In high-income countries, consumers are paying increasing attention to animal welfare, environmental sustainability, and health considerations, which in some cases has led to stagnation in per capita meat consumption (Koshchaev et al., 2019; Satyukova et al., 2019; Nametov et al., 2023; ELDALA.KZ, 2025). At the same time, dietary preferences are shifting, with consumers reducing red meat intake, such as beef and pork, in favor of poultry (Dong et al., 2021; Sharipov & Kushchegulova, 2023).

Over the past decade, the growth in poultry meat consumption has been largely driven by increasing demand in Asia, particularly in China, India, Indonesia, Pakistan, and Vietnam (Neverov et al., 2026). This trend is expected to continue, with further growth projected in other regions, including Brazil, Egypt, Mexico, the Philippines, and the United States (Zhang et al., 2018; Han et al., 2025; Ye et al., 2025). The rising share of poultry protein in total meat protein consumption has been a defining feature of global dietary changes and is expected to persist. By 2034, poultry meat is projected to account for approximately 45% of total meat-derived protein intake (Zhang et al., 2022;

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Nassar, 2025).

Several factors support this trend, including the relatively low cost of poultry meat, which remains one of the most affordable animal protein sources, and its favorable nutritional profile, characterized by a higher protein-to-fat ratio than other types of meat. Environmental considerations also contribute to this shift, as red meat production is associated with higher resource use and increased greenhouse gas emissions. As a result, consumers concerned with sustainability increasingly prefer poultry meat (Bist et al., 2024; Sammani et al., 2025).

Waterfowl production, particularly duck and goose farming, plays an important role in meeting the growing demand for poultry meat. In Europe, duck and goose meat consumption increased by 3.2% in 2024, reaching 413 thousand tons. Hungary (2.9 kg), the Czech Republic (2.3 kg), and France (1.7 kg) recorded the highest per capita consumption levels. Between 2013 and 2024, the Czech Republic showed the most notable growth in consumption among major countries, with an average annual increase of 3.3% (Goluch et al., 2025).

France accounted for the largest share of consumption, reaching 119 thousand tons, or about 29% of the total. This level was more than twice that of Germany, the second-largest consumer, with 59 thousand tons. The United Kingdom ranked third, with a total consumption of 42 thousand tons, representing approximately 10% of the overall volume.

According to the Ministry of Agriculture of the Republic of Kazakhstan, the country aims to reduce its dependence on poultry meat imports and become a net exporter in the coming years. To achieve this goal, more than 30 poultry production projects are currently being implemented, along with ongoing research focused on breeding and genetic improvement (Neeteson et al., 2023; Bist et al., 2024).

Poultry production largely depends on effective breeding programs that improve productive and genetic traits, develop new breeds, lines, and crosses, ensure balanced nutrition, and adopt efficient production technologies (Ezhova et al., 2020). Industrial duck farming, in particular, allows for the production of high-quality products with efficient feed utilization (Abbas et al., 2024).

In certain years, the duck population in Kazakhstan exceeded one million birds. However, agricultural reforms negatively affected this level. Despite the recent recovery trend in poultry production, duck farming still receives insufficient attention. At the same time, the sector has strong economic potential, established traditions, and stable consumer demand.

One key constraint to the development of duck farming in Kazakhstan is limited progress in breeding and genetic improvement. Modern industrial production systems require continuous selection to enhance productivity, reproductive traits, and adaptability. Developing new crosses and improving existing ones are ongoing processes (Gržinić et al., 2023; Saginbayeva et al., 2023).

Advancing industrial duck production requires further development of breeding programs, improved productive and consumer traits, and better adaptation of birds to production conditions. In recent years, research in this area has intensified. Within the framework of the scientific and technical program of the Ministry of Agriculture of the Republic of Kazakhstan "Development of technologies for effective management of breeding processes in poultry production" (2021–2023), the Ansar duck cross was developed. This cross has high genetic potential for productivity and good survivability.

This study aimed to develop effective approaches to waterfowl breeding using selection and technological methods. To achieve this objective, we conducted a comprehensive evaluation of productive, reproductive, and biological traits in different duck crosses. This included analyses of feed quality, parent-stock reproductive performance, egg incubation traits, growth and development of young birds, blood biochemical parameters, and meat productivity.

2. MATERIALS AND METHODS

The Local Ethics Committee on Bioethics of the Non-Commercial Joint-Stock Company Zhangir Khan West Kazakhstan Agrarian-Technical University (Ural'sk, Kazakhstan) approved the animal study protocol on 1 November 2023. All experimental procedures were conducted in accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes and complied with accepted bioethical standards.

The study was conducted at Bishkul Poultry Farm LLP (North Kazakhstan region, Kyzylzhar district, Beskol village) and at Zhangir Khan West Kazakhstan Agrarian and Technical University (Uralsk, West Kazakhstan region). The experimental work included duck crosses Ansar, Bashkir Colored, Cherry Valley, and Kyzylzhar, represented by both paternal and maternal lines.

Parent flocks were formed at a drake-to-duck ratio of 1:4. At Bishkul Poultry Farm LLP, the birds were maintained under an intensive indoor, non-range system in poultry houses designated for breeder flocks. Ducks were floor-housed on litter, and the poultry houses were equipped with mechanical supply-and-exhaust ventilation to maintain adequate air exchange and prevent the accumulation of moisture and harmful gases. Dry complete compound feed was supplied through raised trough feeders, while drinking water was continuously available in trough drinkers

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at a constant level. All crosses were maintained under identical sanitary, feeding, and management conditions and had ad libitum access to feed and water. The diets were formulated from locally available cereal, protein, fat, and mineral ingredients according to their analyzed energy, protein, amino acid, lipid, fiber, and mineral contents presented in Table 1 and 2. Diet composition was adjusted according to the age, productive stage, and physiological requirements of the birds using a phase-specific feeding approach previously described for waterfowl production in Kazakhstan (Nugmanova et al., 2024; 2026).

Table 1: Chemical composition of major feed ingredients in the Western region of Kazakhstan, g

Indicators	Feed types						
	Crushed corn	Rye	Barley	Crushed wheat	Soybean	Soybean cake	Soybean meal
Metabolizable energy, MJ	10.1	10.1	11.9	11.4	11.6	12.7	11.8
Dry matter, g/kg	850.7	855.3	896.8	843.5	853.8	898	896.8
Crude protein, g	94.3	112.2	146.7	128.0	243.6	376.7	377.6
Digestible protein, g	62.6	82.5	111.8	98.5	175.3	353.9	251.6
Lysine, g	2.6	4.1	5.7	4.1	43.6	22.6	24.7
Methionine + cystine, g	2.1	3.0	2.3	4.3	5.4	21.3	11
Tryptophan, g	1	0.9	1.2	1.1	3.4	3.7	3.5
Crude fat, g	31	21.2	17.4	18.9	39.6	76.3	26.6
Crude fiber, g	27.9	48.9	29.6	16.4	47.5	58.2	58.4
Nitrogen-free extractives (NFE), g	659	654.5	871.3	632	0.2	264.1	307.3
Sugars, g	20	14.1	13.1	13.6	0	76.2	88.4
Calcium, g	0.2	0.7	0.5	2.8	4.0	4.3	2.5
Phosphorus, g	3.4	2.5	2.9	3.7	6.9	6.4	7.8
Magnesium, g	2.9	0.9	2.0	1.4	2.3	2.4	3.0
Potassium, g	5.1	4.2	4.4	4.8	19.8	15.2	17.8
Sulfur, g	1.3	0.4	0	0.3	0.3	2.9	2.3
Iron, mg	7.1	62.1	0.9	45.9	114.1	210	210.2
Copper, mg	5	6.0	7.1	3.2	13.0	15.1	14.9
Zinc, mg	21.5	18.8	27.7	32.6	25.9	43.6	36.5
Manganese, mg	10.1	28.6	38.3	40.2	19.6	38	32.3
Cobalt, mg	1	0.04	0.1	0.2	0.01	0.05	0.10
Carotene, mg	2	0.8	0	5.6	0.3	2.7	0.09

Table 2: Chemical composition of feed in the Northern region of Kazakhstan,%

Indicators	Feed types						
	Wheat	Corn	Peas	Soybean	Meat-and-bone meal	Vegetable oil	Limestone
Metabolizable energy, MJ	10.1	9.4	10.1	11.9	11.4	11.6	12.7
Crude protein	94.3	107.1	112.2	146.7	128.0	243.6	376.7
Lysine	2.6	2.3	4.1	5.7	4.1	43.6	22.6
Methionine + cystine	2.1	4.1	3.0	2.3	4.3	5.4	21.3
Crude fat	31	28	21.2	17.4	18.9	39.6	76.3
Crude fiber	27.9	46	48.9	29.6	16.4	47.5	58.2
Crude ash	659	571	654.5	871.3	632	0.2	264.1
NFE	20	16	14.1	13.1	13.6	0	76.2
Available calcium	0.2	0.6	0.7	0.5	2.8	4.0	4.3
Phosphorus	3.4	5.5	2.5	2.9	3.7	6.9	6.4
Sodium	2.9	0.9	0.9	2.0	1.4	2.3	2.4
Linoleic acid	5.1	3.3	4.2	4.4	4.8	19.8	15.2

Day-old ducklings obtained from incubated eggs were assessed for general viability based on external appearance and activity. Non-viable birds were culled, whereas healthy ducklings were transferred to the rearing facility. The ducklings were reared on deep litter for 49 days under continuous lighting. Indoor temperature was maintained at 33°C during days 1–3, gradually reduced to approximately 25°C by day 14, and then maintained at 16–22°C until day 49. Feeders and drinkers provided approximately 3 cm of access per bird, and feed and water were offered ad libitum. All crosses were reared under identical environmental and management conditions. A total of 3101 ducklings were included in the growth-performance study. We recorded individual body weight at placement and then at 7-day intervals up to 49 days of age (Tonchabayev et al., 2023).

Representative samples of the major feed ingredients used in the Western and Northern regions of Kazakhstan were collected before diet formulation and analyzed at the Testing Center of Zhangir Khan West Kazakhstan Agrarian and Technical University using standard laboratory procedures. The analyzed ingredients included cereal grains, legumes, soybean products, meat-and-bone meal, vegetable oil, and limestone. The determined variables included, as applicable, metabolizable energy, dry matter, crude and digestible protein, lysine, methionine + cystine, tryptophan, crude fat, crude fiber, nitrogen-free extractives, sugars, and macro- and trace-element concentrations. The analytical results for the feed ingredients used in the Western and Northern regions are presented in Table 1 and 2, respectively. We used these results to formulate age-specific complete diets with balanced levels of metabolizable energy, protein, essential amino acids, fat, fiber, calcium, and phosphorus. Separate diets were developed for the starter and grower stages according to the physiological requirements of the birds, following previously published approaches to formulating waterfowl diets from locally available feed resources (Nugmanova et al., 2024; Nugmanova et al., 2026).

Reproductive performance of drakes was assessed by semen collection and analysis using procedures previously described for ducks (Giri et al., 2016; Abadjieva et al., 2023; Agustin et al., 2025). The parameters evaluated included ejaculate volume, sperm concentration, and motility. A total of 10 drakes per cross were examined. Artificial insemination was performed according to established procedures for ducks (Chen et al., 2016; Giri et al., 2016), with 40 females per group.

Eggs were collected from parent flocks and evaluated for morphological and physical characteristics, including egg weight, shell thickness, air cell height, and proportions of albumen, yolk, and shell. We analyzed 50 eggs per group. For incubation studies, 2000 eggs per cross were set under controlled conditions. Fertility, hatchability, and duckling survival were recorded. We also determined average egg weight.

Growth performance was assessed based on live body weight and average daily gain. At 7 weeks of age, a carcass evaluation was conducted on 5 birds per cross. The following parameters were recorded: pre-slaughter weight, carcass weight, eviscerated carcass yield, weight of edible and non-edible parts, and muscle distribution.

Blood samples were collected from the wing vein of 42-day-old ducks in the morning before feeding. We analyzed 18 samples (3 per cross). We measured total protein, albumin, glucose, cholesterol, AST, ALT, urea, creatinine, calcium, phosphorus, and chloride. We processed all data using standard statistical methods. Results are presented as mean ± standard error (mean ± SE). We evaluated differences between groups using appropriate statistical tests, and considered significance at $P<0.05$.

3. RESULTS

The study was conducted at Bishkul Poultry Farm LLP (North Kazakhstan region, Kyzylzhar district, Beskol village) and at Zhangir Khan West Kazakhstan Agrarian and Technical University (West Kazakhstan region, Uralsk). The research used parental lines from the following duck crosses: Ansar, Bashkir Colored, Cherry Valley, and Kyzylzhar.

3.1. Chemical Composition of Major Feed Ingredients

The chemical composition of the main feed ingredients used on farms in the Western and Northern regions of Kazakhstan was analyzed for both paternal and maternal lines of the duck crosses Ansar, Bashkir Colored, Cherry Valley, and Kyzylzhar (Tables 1 and 2). Samples of major feed components from the West Kazakhstan region, including barley, crushed corn, rye, wheat, soybeans, soybean cake, and soybean meal, were collected. The Testing Center laboratory at Zhangir Khan West Kazakhstan Agrarian and Technical University determined the nutritional value of these feeds (Table 1).

Analysis of the feed ingredients revealed noticeable differences in nutritional value. In terms of metabolizable energy, soybean cake (12.7 MJ) and crushed wheat (11.4 MJ) showed the highest values, making them effective energy sources in poultry diets.

Regarding protein content, soybean cake (376.7 g/kg) and soybean meal (377.6 g/kg) were the richest sources (Table 1). At the same time, soybean meal had a high level of digestible protein (251.6 g/kg), which increases its biological value.

The amino acid profile clearly demonstrated the advantage of soybean-derived products. Lysine (22.6-43.6 g), methionine+cystine (11.0-21.3 g), and tryptophan (3.5-3.7 g) were present at substantially higher levels compared to cereal grains (Table 1). This confirms their essential role in balancing poultry diets.

Soybean cake also contained the highest level of crude fat (76.3 g/kg), providing an additional source of energy (Table 1). In contrast, cereal feeds had higher levels of nitrogen-free extractives (up to 871.3 g/kg in barley), contributing to energy supply but with lower protein content.

Overall, cereal feeds (corn, rye, barley, and wheat) serve primarily as energy sources but are relatively poor in protein and essential amino acids (Table 1). In contrast, soybean-based feeds and their by-products contain high levels of digestible protein, amino acids, and minerals, making them key components in balanced diet formulation. The optimal combination of cereal and protein-rich feeds ensures proper nutrition and supports high productivity in poultry.

The chemical composition of feeds used in the Northern region of Kazakhstan also showed considerable variation in terms of metabolizable energy, protein, amino acids, and mineral contents (Table 2). Soybeans (243.6 g/kg) and meat-and-bone meal (376.7 g/kg) were identified as the main protein sources, while corn (107.1 g/kg) and wheat (94.3 g/kg) had lower protein content but remained important due to their high energy value.

Amino acid composition varied substantially across feed types. Soybeans (43.6 g/kg) and meat-and-bone meal (22.6 g/kg) contained the highest levels of lysine, whereas wheat and corn showed relatively low values (2.3-2.6

g/kg). The highest levels of methionine + cystine were found in meat-and-bone meal (21.3 g/kg) and soybeans (5.4 g/kg), highlighting their importance in achieving a balanced amino acid profile. Thus, soybean, meat-and-bone meal, and vegetable oil serve as the main concentrated sources of protein, amino acids, fat, and minerals, whereas wheat and corn primarily provide energy and carbohydrates. The combination of these feed ingredients provides the balanced nutrient supply required for high-performance poultry.

3.2. Breeding Work and Evaluation of Reproductive Traits of Drakes of Different Crosses

Replacement stock of the studied crosses was selected, and the parent flock was formed at a ratio of 1:4 (one drake to four females), taking into account the target breeding parameters.

The breeding program included an individual assessment of productive and genetic traits in the base lines, parental forms, and final hybrids. We focused on improving reproductive performance by incorporating additional fertility-related traits into the selection scheme. Birds were selected from the best families that combined high reproductive capacity with rapid early growth.

We applied a combined selection approach, integrating family-based selection with individual evaluation of breeding males based on the performance of both line and hybrid offspring. Mating was carried out without inbreeding. Lines were selected for key economically important traits, with clear differentiation between paternal and maternal lines. Selection methods and parameters were developed based on genetic analysis of line performance data.

In the paternal line, the main selection traits included body weight at 7 weeks of age, meat conformation, feathering quality, feed conversion per unit of body weight gain, and survival rate from 1 to 7 weeks. We also considered reproductive traits of the parent stock, such as egg production, fertility, and hatchability. At 7 weeks of age, the heaviest birds with typical conformation were selected (Table 6, 8–10, and 12).

In the maternal line, the key selection traits were egg production, hatchability, feed efficiency, growth rate of both line and hybrid offspring, and survival up to 7 weeks of age. Selection in the maternal line aimed to improve reproductive performance and reduce feed costs per unit of production while maintaining standard body weight at 7 weeks. This selection approach increases reproductive performance, reduces feed costs, and maintains or improves live body weight at 7 weeks of age. As a result, it contributes to higher productivity per breeding female and lower production costs (Table 6–10). When breeding values differed between within-line mating and cross-line crossing, we prioritized evaluation based on hybrid offspring performance.

We compared semen characteristics of the studied crosses at base farms in the Western and Northern regions of Kazakhstan (Table 3). Table 3 shows that average ejaculate volume was similar across crosses, ranging from 0.87 ± 0.03 mL (Bashkir Colored) to 0.92 ± 0.04 mL (Ansar). Ejaculate volume is of practical importance, as it determines the number of semen doses obtained from a single drake, directly affecting the efficiency of breeding stock utilization (Table 3).

Table 3: Comparative evaluation of semen characteristics of drakes of different crosses (n = 10, mean ± SE)

Indicator	Crosses			
	Kyzylzhar	Cherry Valley	Bashkir Colored	Ansar
Drakes evaluated, head	10	10	10	10
Drakes providing semen, head	9	8	9	9
Average ejaculate volume per drake, mL	0.88 ± 0.05	0.90 ± 0.02	0.87 ± 0.03	0.92 ± 0.04
Sperm concentration, billion/cm³	2.12 ± 0.04	2.09 ± 0.06	2.01 ± 0.05	2.23 ± 0.03
Motility score, points	8.8 ± 0.3	9.0 ± 0.4	8.9 ± 0.2	9.1 ± 0.3
Ducks inseminated, head	40	40	40	40
Eggs incubated, number	150	150	150	150

Sperm concentration was higher in drakes of the Ansar cross (2.23 ± 0.03 × 10^9/cm³) and the Kyzylzhar cross (2.12 ± 0.04 × 10^9/cm³), whereas slightly lower values were recorded in Cherry Valley (2.09 ± 0.06 × 10^9/cm³) and Bashkir Colored (2.01 ± 0.05 × 10^9/cm³). Sperm concentration is a key indicator of semen quality in poultry, as higher sperm density increases the number of viable spermatozoa per dose and improves the likelihood of successful fertilization (Table 3).

Sperm motility ranged from 8.8 to 9.1 points, indicating good viability across all crosses. Ansar (9.1 ± 0.3) and Cherry Valley (9.0 ± 0.4) showed the highest values, while Kyzylzhar (8.8 ± 0.3) and Bashkir Colored (8.9 ± 0.2) showed slightly lower results. High motility is essential, as only active sperm cells can reach and fertilize the ovum (Table 3). The number of inseminated ducks (40 per group) and the number of incubated eggs (150 per group) were the same for all crosses, confirming uniform experimental conditions and allowing a reliable comparison of reproductive performance (Table 3).

Overall, all studied crosses demonstrated good semen quality. However, based on the combined assessment of sperm concentration and motility, the Ansar cross showed a certain advantage, suggesting its greater potential for use in artificial insemination programs. The Kyzylzhar cross also exhibited relatively high sperm concentration,

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supporting its value in breeding programs (Table 3).

3.3. Egg Incubation and Evaluation of Incubation Performance in Different Duck Crosses

Incubation is a critical stage in poultry reproduction, as it determines hatchability and the survival of young birds. The success of this process largely depends on egg quality, storage conditions, and incubation parameters. This study focused on the organization and efficiency of egg incubation at Bishkul Poultry Farm LLP (North Kazakhstan region) and Zhangir Khan West Kazakhstan Agrarian and Technical University (West Kazakhstan region).

Fertile eggs were collected, and the average egg weight for the Northern and Western regions was determined to be 86.65 g (Table 4). According to the data presented in Table 4, the weight of hatching eggs across different duck crosses ranged from 85.4 to 88.0 g. The Kyzylzhar cross had the highest value (88.0 ± 0.01 g), exceeding the overall average of 86.65 g. Slightly lower egg weight was recorded in the Cherry Valley cross (87.0 ± 0.02 g), while Bashkir Colored and Ansar showed values of 85.4 ± 0.19 g and 86.2 ± 0.16 g, respectively. Overall, the results indicate that the Kyzylzhar and Cherry Valley crosses produced heavier eggs with greater uniformity. This is an important factor for successful incubation and producing viable offspring.

Table 4: Weight of hatching eggs (mean ± SE)

Cross	Number of eggs	Egg weight, g	SD (σ)	CV,%
Kyzylzhar	2000	88.0 ± 0.01	0.007	8.26
Cherry Valley	2000	87.0 ± 0.02	0.008	9.45
Bashkir Colored	2000	85.4 ± 0.19	1.355	1.58
Ansar	2000	86.2 ± 0.16	1.160	1.34
Average egg weight	86.65g			

Table 5: Quality characteristics of hatching eggs in different duck crosses (n = 50, mean ± SE)

Indicator	Crosses	
	Bashkir Colored	Ansar
Egg weight, g	85.4 ± 0.19	86.2 ± 0.16
Air cell height, mm	2.71 ± 0.003	2.78 ± 0.002
Shape index,%	71.24 ± 0.24	71.86 ± 0.26
Shell thickness, μm	397.14 ± 5.16	402.51 ± 34.12
Mass of egg components, g:		
Albumen	47.83 ± 0.80	49.51 ± 0.51
Yolk	28.05 ± 0.30	27.09 ± 0.28
Shell	9.62 ± 0.03	9.71 ± 0.05
Albumen-to-yolk ratio	1.70	1.82

The study of morphological and physical characteristics of hatching eggs from Bashkir Colored and Ansar duck crosses (n = 50) in the West Kazakhstan region showed that the main parameters were within physiological limits, although some differences between groups were observed (Table 5). The average egg weight in the Ansar group was 86.2 ± 0.16 g, which was slightly higher than that of the Bashkir Colored cross (85.4 ± 0.19 g). Egg weight is considered one of the key factors influencing embryonic development and viability, as both insufficient and excessive values may negatively affect incubation outcomes.

The air cell height in both crosses ranged from 2.71 to 2.78 mm, indicating good freshness of the hatching eggs and their suitability for incubation. This parameter is of diagnostic importance, as an increase in air cell size reflects dehydration processes and deterioration of storage conditions.

Shell thickness varied from 397.14 ± 5.16 µm in the Bashkir Colored cross to 402.51 ± 34.12 µm in the Ansar cross. Shell strength plays a crucial role in embryo protection by providing mechanical resistance and regulating gas exchange. Reduced shell thickness may increase the risk of contamination and embryo mortality, whereas excessive thickness can hinder hatching.

Evaluation of egg component weights showed that the albumen weight was higher in the Ansar cross (49.51 ± 0.51 g) compared to the Bashkir Colored cross (47.83 ± 0.80 g). In contrast, the yolk weight was slightly higher in the Bashkir Colored cross (28.05 ± 0.30 g) than in the Ansar cross (27.09 ± 0.28 g). Shell weight was similar in both groups, ranging from 9.62 to 9.71 g.

The main stages of incubation preparation and evaluation included placing hatching eggs into trays, preparing eggs for incubation, monitoring the incubation process, and assessing egg fertilization (Fig. 1–4).

The albumen-to-yolk ratio in the Ansar cross reached 1.82, which was higher than that of the Bashkir Colored cross (1.70). This balance is essential for proper embryonic development, as an optimal ratio ensures adequate nutrient supply and supports normal embryo growth. The obtained results indicate that hatching eggs from both crosses were of high quality and met the required morphological standards. At the same time, eggs of the Ansar cross showed several advantages, including higher weight, greater albumen content, and a more favorable albumen-to-yolk ratio. These characteristics suggest a higher biological value and better suitability for incubation.

3.4. Egg Production and Evaluation of Incubation Traits in Different Duck Crosses

Egg production and incubation characteristics are among the most important criteria for assessing the breeding value and productive potential of duck crosses. Egg production and incubation characteristics are among the most important criteria for assessing the breeding value and productive potential of duck crosses.

It is well known that both egg production and incubation performance depend on genetic factors as well as feeding

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conditions, housing systems, and overall management. Comparing these traits across crosses helps identify the most promising lines for breeding programs and commercial production. A comparative analysis of productivity in Bashkir Colored and Ansar duck crosses (n = 40) showed that the Ansar cross had an advantage in most key parameters (Table 6).

Fig. 1: Placement of hatching eggs into trays.

Fig. 2: Preparation of eggs for incubation.

Fig. 3: Monitoring of the incubation process.

Fig. 4: Egg fertilization.

Table 6: Productivity parameters of ducks of different crosses (n = 40)

Indicator	Crosses	
	Bashkir Colored	Ansar
Egg production per initial hen, number	189.8	201.5
Eggs set for incubation, number	2000	2000
Average egg weight, g	85.4	86.2
Hatchable eggs,%	85.51	86.53
Fertility,%	91.5	93.6
Number of eggs obtained, number	1830	1872
Hatchability,%	78.5	81
Adult survival,%	100	100
Ducklings per hen, head	1608	1692
Feed intake per bird, kg	5.72	5.18
Feed conversion ratio (kg feed per 1 kg live weight gain)	2.20	2.00
Survival of young birds,%	98.0	99.0

Egg production per initial hen in the Ansar cross reached 201.5 eggs, which was higher compared to the Bashkir Colored cross (189.8 eggs). This parameter reflects the genetic potential of the birds and directly affects their efficiency in breeding programs.

The average egg weight in the Ansar cross was slightly higher (86.2 g vs. 85.4 g). The proportion of eggs suitable for incubation was 86.53% in Ansar and 85.51% in Bashkir Colored. Fertility was also higher in the Ansar cross (93.6% compared to 91.5%). Of the total number of eggs set for incubation (2000), 1872 were suitable for hatching in Ansar and 1830 in Bashkir Colored.

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Hatchability was higher in the Ansar cross (81%) compared to Bashkir Colored (78.5%). As a result, the number of ducklings obtained per hen reached 1692 in Ansar and 1608 in Bashkir Colored. Thus, the advantage of the Ansar cross is reflected in a higher output of young birds under identical incubation conditions.

Adult survival was 100% in both groups, indicating high adaptability and resistance to management conditions. Young-bird survival was also high, though slightly higher in Ansar (99% vs. 98%).

Feed consumption per bird was lower in the Ansar cross (5.18 kg vs. 5.72 kg), and the feed conversion ratio was 2.00 kg per kg of live weight gain, compared to 2.20 kg in Bashkir Colored. This indicates more efficient feed utilization in the Ansar cross, which is important from an economic perspective.

Overall, based on the evaluated parameters, the Ansar cross showed higher productivity than the Bashkir Colored cross. This advantage was reflected in higher egg production, improved incubation characteristics, better hatchability and survival of young birds, and lower feed costs per unit of production.

Egg production per initial hen in the studied duck crosses from the Northern and Western regions ranged from 200 to 226.9 eggs, while egg production per average hen ranged from 189.8 to 239.1 eggs. The mean egg production of the studied crosses was 207.35 eggs per initial hen and 214.3 eggs per average hen (Table 7).

Table 7: Egg production of the studied duck crosses in the Northern and Western regions of Kazakhstan, number of eggs

Crosses	Indicators	
	Per initial hen	Per average hen
Kyzylzhar	202.5	226.8
Cherry Valley	226.9	239.1
Bashkir Colored	186.4	189.8
Ansar	195.8	201.5

At Bishkul Poultry Farm LLP (North Kazakhstan region, Kyzylzhar district, Beskol village), egg samples were collected for morphological analysis (30 eggs in total, including 10 eggs from each of the following groups: Kyzylzhar, Cherry Valley, and Kyzylzhar × Cherry Valley).

The results of the morphological analysis showed the following values: shell weight ranged from 6.5 to 7.1 g, albumen weight from 32.2 to 34.3 g, and yolk weight from 13.5 to 13.8 g. Shell thickness averaged 0.25 mm. The albumen index ranged from 0.06 to 0.08. Haugh units were 75.3 in the Kyzylzhar cross, 77.1 in Cherry Valley, and 78.1 in the Kyzylzhar × Cherry Valley cross.

3.5. Productive Performance of Ducklings of Different Crosses

Day-old ducklings were evaluated based on external appearance. Survival during the first days of rearing was satisfactory, and non-viable chicks were culled. A total of 3101 birds were transferred to the rearing facility of Bishkul Poultry Farm LLP.

An important indicator of growth and development is the change in live body weight. We monitored live weight every 7 days. Body weight was determined by individual weighing of the ducklings (Table 8). The dynamics of live body weight of ducklings during the 7-week rearing period showed that the Kyzylzhar cross had a growth advantage over the Cherry Valley cross up to three weeks of age. However, from the fourth week until slaughter age (49–50 days), it lagged behind in body weight by 155 g (2.702 kg vs. 2.857 kg, respectively).

Table 8: Dynamics of live body weight of ducks up to 7 weeks of age at Bishkul Poultry Farm LLP in the Northern region of Kazakhstan (mean ± SE)

Age	Indicators/ crosses					
	Kyzylzhar			Cherry Valley		
	X ± SE	δ	Cv	X ± SE	δ	Cv
Day-old	0.078 ± 0.0005	0.008	10.7	0.077 ± 0.004	0.007	10.1
1 week	0.216 ± 0.0021	0.037	17.3	0.196 ± 0.0021	0.036	18.3
2 week	0.507 ± 0.115	0.663	12.5	0.472 ± 0.002	0.039	8.4
3 week	0.875 ± 0.075	0.130	14.9	0.808 ± 0.009	0.147	18.3
4 week	1.393 ± 0.009	0.193	10.7	1.427 ± 0.011	0.193	13.5
5 week	1.797 ± 0.011	0.193	10.7	1.822 ± 0.013	0.228	12.5
6 week	2.378 ± 0.024	0.422	17.7	2.403 ± 0.026	0.457	19.0
7 week	2.702 ± 0.016	0.274	10.1	2.857 ± 0.012	0.214	7.5

Table 9: Dynamics of live body weight of ducks of different crosses up to 7 weeks of age in the Western region of Kazakhstan (mean ± SE)

Age (day)	Crosses					
	"Bashkir Colored"			"Ansar"		
	X ± SE	σ	Cv	X ± SE	σ	Cv
1	50.97 ± 0.28	1.9	3.9	51.41 ± 0.36	2.5	5.0
7	179.59 ± 1.15	8.1	4.5	185.19 ± 2.01	14.2	7.7
14	355.17 ± 3.25	22.9	6.5	363.42 ± 3.87	27.3	7.5
21	887.94 ± 4.06	28.7	3.2	918.37 ± 5.08	35.9	3.9
28	1443.87 ± 7.12	50.3	3.5	1547.15 ± 8.41	59.4	3.8
35	2144.36 ± 8.19	57.9	2.7	2296.06 ± 7.12	50.3	2.2
42	2752.10 ± 9.36	66.2	2.4	2939.87 ± 8.56	60.5	2.1
49	3222.92 ± 10.25	72.4	2.3	3478.56 ± 9.47	66.9	1.9

The study also demonstrated that the live body weight of ducks of the Ansar cross remained higher throughout the entire rearing period from 1 to 49 days compared to the Bashkir Colored cross (Table 9). These differences were already noticeable during the first week and reached 255.6 g by the end of the experiment. The most pronounced advantage of the Ansar cross was observed between 28 and 49 days of age, when growth rates were more intensive. At the same time, the coefficient of variation in the Ansar group remained lower, indicating better uniformity and stability of the flock.

Thus, ducks of the Ansar cross are characterized by faster growth and greater uniformity in live body weight, making them promising for use in meat production. The data in Fig. 5 indicate that live body weight increased with

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age in all studied crosses; however, growth rates differed between groups. The Ansar cross showed the highest values, reaching the greatest live body weight by 7 weeks of age, indicating strong genetic potential for meat production.

The Bashkir Colored cross recorded slightly lower values but still showed stable, consistent growth. Ducks of the Cherry Valley cross showed intermediate results, with lower weight gain than the two aforementioned crosses. The Kyzylzhar cross showed the lowest values, indicating relatively lower productivity. The results suggest that under conditions in the Western region of Kazakhstan, the Ansar cross appears most promising for industrial production because of its faster growth rate and higher final live body weight.

The analysis of average daily gain in ducks of different crosses (Table 10) shows that growth dynamics varied with age, with peak values observed between 28 and 35 days. Throughout the entire experimental period, ducks of the Ansar cross demonstrated higher growth rates compared to the Bashkir Colored cross. The most pronounced differences occurred during the 21-28 and 28-35 day intervals, where the advantage reached 74.04 and 43.26 g, respectively. Over the whole rearing period (0-49 days), the cumulative gain in the Ansar cross was higher by 245.94 g, indicating a more intensive accumulation of live body weight.

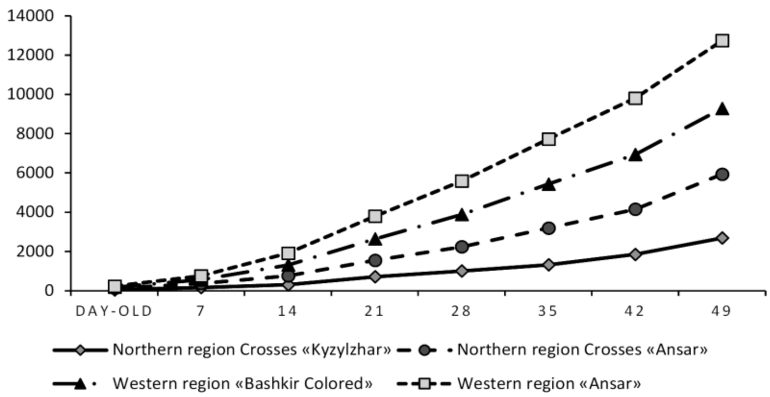

Fig. 5: Dynamics of live body weight of young stock by region.

Table 10: Dynamics of average daily gain in ducks of different crosses (mean ± SE)

Indicators	Crosses	
	Bashkir Colored	Ansar
	X ± SE	X ± SE
0-7	128.68 ± 1.09	134.96 ± 1.50
07-14	175.4 ± 2.41	177.84 ± 2.53
14-21	532.76 ± 4.84	554.3 ± 7.04
21-28	555.38 ± 9.05	629.42 ± 11.70
28-35	702.76 ± 13.93	746.02 ± 15.32
35-42	606.26 ± 19.68	660.7 ± 20.75
42-49	470.24 ± 18.25	514.18 ± 20.83
0-49	3171.48 ± 15.21	3417.42 ± 14.40

On average, across the entire experimental cycle (0-49 days), the mean absolute gain in the Ansar cross reached 69.74 g, compared to 64.72 g in the Bashkir Colored cross, resulting in a difference of 5.02 g. These results confirm the higher growth intensity and productivity of the Ansar cross, suggesting its greater potential for commercial meat production.

3.6. Blood Biochemical Parameters and Evaluation of Physiological Status in Ducks of Different Crosses

Enzymes are produced by cells of various organs, and each bird species has a characteristic baseline level of enzymatic activity under normal physiological conditions. When cellular damage occurs, certain enzymes are released into the bloodstream. Therefore, changes in enzyme activity, trace elements, and other blood parameters are key indicators used to assess the functional state of internal organs.

Biochemical analysis provides insight into the condition of internal systems and their functional efficiency. Deviations in multiple parameters may indicate specific physiological disturbances, whereas changes in a single parameter may be associated with several conditions. Identifying a consistent pattern of altered indicators allows for a more accurate interpretation of physiological status.

Given the importance of blood composition, samples were collected from the wing vein of 42-day-old ducks in the morning, one hour before feeding. For biochemical analysis, we collected blood samples from 18 birds (three per cross). The evaluated parameters included albumin (6-18 g/L), glucose (9.36-24.63 mmol/L), uric acid (117-347 mmol/L), cholesterol (2.17-5.89 mmol/L), AST (37-107 U/L), and ALT (6-48 U/L) (Table 11).

Blood represents the internal environment of the organism, where vital physiological processes take place. It reflects metabolic activity and is considered one of the most sensitive indicators of changes occurring within the body. One of its key characteristics is the maintenance of homeostasis, which supports the stability of species- and breed-specific traits. At the same time, blood composition is dynamic and may vary depending on environmental conditions. Therefore, the study of blood composition and its physicochemical properties provides valuable information about metabolic processes and the bird's capacity for intensive growth.

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Table 11: Blood biochemical parameters of ducks in the Northern and Western regions of Kazakhstan (mean ± SE)

Indicator	Unit	Crosses			
		Kyzylzhar	Cherry Valley	Bashkir Colored	Ansar
Total protein	g/L	35.0 ± 0.14	38.0 ± 0.23	35.1 ± 0.15	33.8 ± 0.30
Albumin	g/L	18.0 ± 0.39	19.0 ± 0.22	19.1 ± 0.36	24.2 ± 0.12
Glucose	mmol/L	9.9 ± 0.62	10.1 ± 0.56	8.9 ± 0.60	10.99 ± 0.84
Cholesterol	mmol/L	3.1 ± 0.14	3.8 ± 0.34	2.9 ± 0.12	3.9 ± 0.19
Alkaline phosphatase	U/L	102.2 ± 0.69	98.7 ± 0.23	100.2 ± 0.59	99.9 ± 0.34
Total bilirubin	mmol/L	0.98 ± 0.27	0.87 ± 0.11	0.95 ± 0.24	0.92 ± 0.34
AST	U/L	28.0 ± 0.41	32.0 ± 0.34	26.0 ± 0.39	24.5 ± 0.51
ALT	U/L	15.0 ± 0.48	14.0 ± 0.36	14.0 ± 0.44	13.9 ± 0.31
Urea	mmol/L	2.9 ± 0.27	2.7 ± 0.63	2.7 ± 0.25	2.5 ± 0.33
Creatinine	mmol/L	0.28 ± 0.23	0.25 ± 0.57	0.25 ± 0.19	0.20 ± 0.66
Calcium (Ca)	mmol/L	3.1 ± 0.23	3.2 ± 0.43	2.9 ± 0.19	2.4 ± 0.81
Chlorides	mmol/L	101.0 ± 0.65	105.0 ± 0.37	99.0 ± 0.61	109.3 ± 0.76
Phosphorus (P)	mmol/L	2.1 ± 0.48	1.9 ± 0.39	1.9 ± 0.45	1.9 ± 0.52

The results of the morphological analysis of eggs and the biochemical analysis of blood in ducks were within the normal range in the breeding flocks of the base farms in the Northern and Western regions. This indicates that the level of protein nutrition met the biological requirements of the birds. Variation between crosses was minimal, suggesting stable physiological condition, normal liver and kidney function, balanced water-electrolyte status, and adequate protein supply supporting proper growth and development.

3.7. Meat Characteristics of Ducklings of Different Crosses

Carcass evaluation is a key method for assessing meat productivity in poultry. It allows determination of live body weight, carcass weight, the proportion of edible parts, and the ratio of muscle to non-edible components. These indicators are essential for evaluating production efficiency and the meat value of different crosses. Their analysis allows comparison of duck cross productivity and identification of the most promising crosses for commercial production. In this study, we evaluated carcasses in 7-week-old ducks, with five birds examined per cross. These data are important for breeders when characterizing lines, crosses, and breeding combinations (Table 12).

Table 12: Results of carcass evaluation of ducks at 7 weeks of age (n = 5)

Indicator	Crosses			
	Bashkir Colored	Ansar	Kyzylzhar	Cherry Valley
Pre-slaughter live weight, g	3358.1 ± 25.98	3692.3 ± 30.2	2937.0 ± 18.56	3055.0 ± 22.47
Carcass after bleeding, g	3156.7 ± 30.29	3471.6 ± 32.2	2895.9 ± 23.45	2870.3 ± 19.85
Eviscerated carcass weight, g	2124.4 ± 20.20	2409.2 ± 18.25	1791.6 ± 13.48	1851.3 ± 16.33
Eviscerated carcass yield,%	67.3	69.4	61	60.6
Edible parts weight, g	1925 ± 22.23	2117.5 ± 24.0	1709.0 ± 21.73	1776.5 ± 18.92
Muscle mass, g	979.8 ± 18.8	1077.8 ± 19.2	1077.9 ± 15.65	115.1 ± 16.51
- including breast muscles, g	302.2 ± 3.85	332.4 ± 4.5	343.6 ± 4.18	357.4 ± 4.56
- leg muscles, g	365.7 ± 4.45	402.3 ± 5.2	334.8 ± 4.62	339.1 ± 5.49
Non-edible parts weight, g	1420.4 ± 19.2	1562.3 ± 21.3	769.3 ± 15.11	800.2 ± 17.63
Ratio of edible to non-edible parts	1.35	1.36	2.22	2.22

Anatomical dissection of carcasses revealed the morphological distribution of different body parts. The breast region had the highest proportion of muscle tissue (87.22-87.98%). The largest proportion of bone tissue was observed in the wings (31.37-35.35%) and in the carcass frame (22.97-23.81%).

Pre-slaughter live weight varied across the studied crosses. The lowest values were recorded in Kyzylzhar (2937 g) and Cherry Valley (3055 g), whereas the highest were observed in Ansar (3692 g) and Bashkir Colored (3358 g). These differences reflect the growth characteristics and genetic potential of the crosses. Ansar and Bashkir Colored showed higher growth rates and larger body size.

Carcass weight after slaughter ranged from 2870.3 g (Cherry Valley) to 3471.6 g (Ansar). Overall, carcass weight was closely associated with pre-slaughter live weight, indicating consistent meat productivity and feeding efficiency across groups.

The results of carcass evaluation show that the Ansar and Bashkir Colored crosses had higher live weight, greater carcass weight, and a higher yield of edible parts. In contrast, Kyzylzhar and Cherry Valley had lower live weight and reduced edible meat yield, although the ratio of edible to non-edible parts was higher in these crosses. These findings provide a comparative assessment of meat productivity and the suitability of the studied crosses for commercial production.

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4. DISCUSSION

The results indicate that the productive and reproductive traits of different duck crosses are shaped by a combination of genetic factors and nutritional balance, consistent with current concepts in poultry science and nutrigenomics. Recent genomic studies have confirmed heritable variation and identified candidate loci for egg production and egg-quality traits in ducks (Kroger et al., 2024; Sun et al., 2024; Han et al., 2025; Yang et al., 2025).

The analysis of feed composition showed that cereal components of the diet (wheat, corn, and barley) provide high metabolizable energy but are deficient in crude and digestible protein, as well as in essential amino acids such as lysine, methionine, and tryptophan. Including soybean-based ingredients helps compensate for this deficiency and contributes to a more balanced amino acid profile. Recent duck nutrition studies similarly show that performance depends on balanced energy, protein, and amino acid supply (Lim et al., 2024; Wu et al., 2026). Replacing soybean meal must preserve amino acid balance and digestibility (Quan et al., 2026), while improved feed efficiency can reduce intake without impairing growth (Li et al., 2023).

Evaluation of the reproductive traits of drakes demonstrated that all studied crosses exhibited good semen quality, reflecting a favorable physiological condition. At the same time, the Ansar cross's advantage in sperm concentration and motility suggests higher spermatogenic activity and potentially greater fertilizing capacity. Recent studies support these indicators but recommend combining them with kinematic, membrane, metabolic, and oxidative-stress assessments (Abadjieva et al., 2023; Bongalhardo, 2025; Wang et al., 2025). Genetic variation in drake sperm motility has also been demonstrated (Zhu et al., 2026).

The morphological and physicochemical characteristics of hatching eggs were within normal physiological ranges; however, differences between crosses were evident. The higher egg weight and increased albumen content in the Ansar cross indicate a better nutrient supply to the embryo, which may positively influence embryonic development and hatchability. Comparable studies show that albumen, yolk, shell, water loss, storage temperature, and albumen viscosity influence duck hatching-egg quality (Biesek et al., 2023; Wlaźlak et al., 2024a). Egg weight and albumen weight also show measurable heritability and positive genetic relationships (Kroger et al., 2024; Yang et al., 2025).

In the direct comparison with Bashkir Colored, the Ansar cross had higher egg production, fertility, and hatchability. These results may reflect both genetic characteristics and more efficient nutrient utilization. Improved feed conversion in this cross indicates more efficient metabolism and better conversion of nutrients into production output, which aligns with modern approaches in poultry breeding aimed at improving feed efficiency. Genomic studies support the selectable, polygenic nature of egg number, laying rate, and egg weight (Sun et al., 2024; Han et al., 2025), whereas feed-efficiency phenotyping can identify ducks with lower intake and rapid growth (Li et al., 2023).

Growth analysis revealed that Ansar cross ducks showed higher growth intensity and reached greater live body weight by 7 weeks of age. The most pronounced differences were observed during key growth periods (28–35 days), suggesting differences in metabolic activity and growth regulation between crosses. The lower coefficient of variation indicates better uniformity and greater stability of the trait, which is an important advantage in breeding. Similar genotype-dependent differences in growth and carcass traits have been reported among Cherry Valley crossbreeds (Zhang et al., 2023), while nutrition can modify growth and feed utilization (Wlaźlak et al., 2024b; Wlaźlak et al., 2025).

The relatively narrow between-cross variation in most blood biochemical parameters did not indicate overt metabolic disturbances. This suggests that the applied feeding strategies supported protein, carbohydrate, and mineral metabolism under the study conditions. However, duck biochemical values can vary with genotype and management, and some are genetically associated with economically important traits (Hefnawy et al., 2024; Hu et al., 2025).

Carcass evaluation results showed that the Ansar cross had higher meat productivity, including greater pre-slaughter weight, eviscerated carcass weight, and carcass yield. This reflects more efficient tissue deposition and confirms its strong genetic potential for meat production. Similar genotype- and sex-related differences in carcass composition have been reported (Zhang et al., 2023; Wegner et al., 2024), while diet can also affect carcass characteristics (Wlaźlak et al., 2024a; Wlaźlak et al., 2025).

Overall, the findings suggest that the Ansar cross demonstrates a consistent advantage in reproductive, productive, and meat-related traits, making it a promising option for commercial duck production under the conditions of the Northern and Western regions of Kazakhstan.

5. CONCLUSION

1. Cereal components of the diet provide the main energy supply but require proper balancing in terms of protein and essential amino acids through the inclusion of high-protein feed ingredients, particularly soybean-based products.
2. All studied duck crosses showed generally high reproductive performance; however, the Ansar cross

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demonstrated a clear advantage in sperm concentration and motility.
3. The morphological characteristics of hatching eggs were within physiological norms, although the Ansar cross exhibited higher biological quality.
4. The Ansar cross outperformed the other crosses in egg production, fertility, hatchability, and survival rate of young birds.
5. Ducks of the Ansar cross showed higher growth intensity and better flock uniformity, indicating a strong genetic potential.
6. Blood biochemical parameters remained within normal ranges, confirming the adequacy of feeding and management conditions.
7. The Ansar cross showed better meat productivity, including a higher yield of edible parts and improved feed utilization efficiency.
Overall, the results suggest that the Ansar cross is the most promising for industrial production due to its combination of high productivity, reproductive performance, and economic efficiency.

Declarations

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Conflicts of Interest: The authors declare no conflict of interest.

Data Availability: The datasets generated and analyzed during the present study are stored by the author and are available for review upon a reasoned request, subject to compliance with the conditions of scientific use.

Ethics Statement: The Local Ethics Committee on Bioethics of the Non-Commercial Joint-Stock Company Zhangir Khan West Kazakhstan Agrarian-Technical University (Ural'sk, Kazakhstan) approved the animal study protocol on 01 November 2023. All experimental procedures were conducted in accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes and complied with accepted bioethical standards.

Author's Contribution: Conceptualization: A.N. and A.Nu.; Methodology: A.N., A.S., and A.Nu.; Investigation and data collection: A.N., A.S., A.Nu., A.Sa., Z.M., and N.B.; Laboratory analysis: A.S. and A.Nu.; Formal analysis: A.Nu. and Z.M.; Writing – original draft preparation: A.N. and A.Nu.; Writing – review and editing: all authors; Visualization: A.Nu. and N.B.; Supervision: A.N.; Project administration: A.N.; Funding acquisition: A.N. All authors have read and agreed to the published version of the manuscript.

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