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Influence of genotype and season on the sperm production of beef cattle-producing bulls in Kazakhstan

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Abstract In this paper, we aimed to study the influence of genotype and season on sperm production in beef cattle sires in Kazakhstan. Based on the results obtained over five years of using beef cattle sires, it can be considered that the spring and summer periods have a significant impact on Kazakh Whiteheaded sires; the winter and summer periods affect Aberdeen-Angus sires, and the spring period affects Hereford sires. Other seasons mainly had a positive influence on sperm production indicators, and if there were any changes, they were not significant. The highest concentration in the ejaculate was observed in Kazakh Whiteheaded sires during the winter-autumn period, amounting to 0.82 billion/ml; in Aberdeen-Angus sires during the spring-autumn period, it was 0.72-0.72 billion/ml; and in Hereford sires during the autumn period, it was 0.82 billion/ml. Autumn had a positive influence on all genotypes.

Keywords: genotype, beef cattle breeding, breeding bulls, season, sperm

1. Introduction

The reproductive capacity of breeding bulls largely depends on the interaction of genotype with the environment. Variations in ejaculate volume throughout the year are determined by the animals' response to seasonal changes in ecological/environmental conditions. In other words, sperm quality is influenced by the age, season, and breed characteristics of bulls (Chetvertakova 2012; Zenkov and Belousov 2009).

In this context, it can be stated that sperm formation is a complex and prolonged process that can be influenced to a greater or lesser extent by various factors in the external environment (Zenkov and Belousov 2009; Kostomaev 2007). The formation of viable sperm depends on both the innate functional capabilities of the bull's organism and a series of exogenous factors. One of the most important factors affecting spermatogenesis is the season of the year. Porfiriev I.A. observed that the minimum ejaculate volume was obtained during the winter period, highest in the spring, and maximum in the summer, while there was a decrease in autumn compared to summer months (Kostomaev 2007; Kazhgaliyev and Maygarin 2017).

Konov et al. (2009) indicated that sperm production in breeding bulls during the winter period had greater biological integrity compared to production obtained in the summer. From April to September, minimum ejaculate volumes were obtained, and maximum volumes were obtained between November and March (Konov and Chernykh 2009).

Many researchers who studied the impact of the season of the year on sperm production indicators in bulls observed that sperm activity was higher in the autumn-winter period and lower in the spring and summer. During the summer, with ambient temperatures above 25°C, the ejaculate volume decreased (Zenkov and Belousov 2009; Konov and Chernykh 2009; Kolosova 2009; Chenoweth 2005).

According to several studies, the external environment and animal genotype significantly influence sperm agglutination in beef cattle bull breeders (Kolosova 2009; Chenoweth 2005). A study on the impact of the season of the year and genotype on sperm agglutination was conducted on bull breeders of different beef cattle breeds (Hereford, Kazakh, Simmental) at the Animal Reproduction Experimental Center in the Orenburg Region. The results showed that the amount of agglutinated sperm in fresh ejaculates from the same bull in different seasons of the year was not the same. The highest quantity with a low percentage of agglutinated sperm (up to 10%) was obtained in winter and summer, while the lowest quantity was obtained in spring and autumn (Kolosova 2009).

When studying the influence of the season of the year on bull sperm production capacity, many scientists found that the highest level of sperm activity occurred during the autumn-winter period, while the lowest occurred during the spring and summer. In the summer months, with a temperature of 25 °C, the ejaculate volume decreased.

Bulls of different breeds may react differently to seasonal changes and consequently exhibit different-quality sperm production, hence the need to identify the breed and

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individual characteristics of bulls with stable sexual functions. Sperm quality is not strictly constant but varies depending on feeding conditions, management, use, producer health, ambient temperature, age, seasonality, and individual and breed characteristics (Petrov 2009).

Quantitative and qualitative analysis of semen from breeding bulls throughout the seasons showed that the lowest sperm production yield occurs during the summer, the hot season of the year. Sperm production yield is reduced by unfavorable housing conditions during confinement, reduced activity, and unbalanced feed. The total ejaculate volume of breeding bulls increases during the spring period. The highest concentration of sperm in the ejaculate is observed during the winter and spring periods (Fomichev 2007; Kolosova 2010). Therefore, sperm production indicators depend on breed, individual characteristics of breeding bulls, and the season of the year (Gavrikov et al 2010).

However, in the reproductive centers of Kazakhstan, the factors affecting sperm production in beef cattle breeds of breeding bulls subject to the same use conditions are poorly studied and insufficiently identified. Only the adaptation indicators of imported cows have been studied. Therefore, improving the reproductive capacity of beef cattle breeding bulls used in Kazakhstan is a relevant issue, and in this context, we aim to study the influence of genotype and the season of the year on sperm production in beef cattle bulls in Kazakhstan (Shamshidin et al 2018).

2. Materials and Methods

This research was conducted at the facilities of the company "Asyltulik", within the Republican Center for Livestock Genetic Improvement, in the Cryopreservation and Transplantation Unit. Bulls of different genotypes of beef cattle were the subjects of this study.

In this study, bull semen and laboratory equipment from IMV Technologies were utilized for the cryopreservation of genetic material. The semen collection process involved the use of artificial vaginas and semen collectors, followed by the use of thermoregulators, autoclaves, water baths, microscopes, and photometers. Additionally, freezers, sperm production records, monthly and annual reports, and measuring instruments were employed.

The methods employed encompassed clinical, biochemical, laboratory, and other research techniques. Throughout the study, the effects of genotype and the season of the year on the reproductive capacities of the bulls were investigated.

The determination of genetic influence on the productivity of bulls with different genotypes was conducted during different seasons of the year: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November).

Semen was collected in the laboratory under standard conditions, adhering to all zootechnical and veterinary requirements. The utilization was carried out on an average regime (twice a week, with animals being inseminated twice). The process of collecting semen from the bulls was conducted following criteria for the evaluation of the collected material, and storage conditions were regulated by normative documents approved by the reproduction center. The manipulations for obtaining the ejaculate were performed only after prior preparation of the animal, equipment, and instruments.

Semen collection took place in a prepared location (courtyard) with an air temperature of 18 °C. The air in the courtyard was treated with fluorescent lamps or ultraviolet light for at least 10-15 minutes before semen collection.

For the mounting of the bulls, dummies on an adjustable angle support or animals placed on a stand were used.

Semen collection from the bulls was conducted twice a week during paired mating, excluding weekends (Saturday and Sunday). Additionally, before successful mating, up to 3 empty collections were performed for hormonal stimulation of the ejaculation process. Each day of semen collection, the bull underwent only two successful matings.

After collection, the semen underwent laboratory analysis, including assessment of color, odor, consistency, volume (measured in the semen collector), concentration via photometer, motility, and activity under the microscope.

The one-way ANOVA was determined by the following equation:

$$h^2_x = C_x / C_\Sigma$$

where C_x - factors to be considered and C_Σ - sum of all factors.

The results obtained and the data from zootechnical and reproductive records were processed using the biometric analysis method (Pokhinsky 1970, Merkureva 1977, Rebrova 2002) with the functionalities of Microsoft Excel 2010 and others (Kryuchkov 2011).

3. Results and Discussion

Significant differences in the manifestation of potency, sexual act characteristics, sexual reflexes, semen production, and quality are observed among animal species and even among their breeds. The reproductive capacity of bull sires is significantly influenced by their breed and lineage.

Artificial insemination technology involves a significant intensification in the use of bull sires. The sperm production characteristics of bull sires from different breeds can become a factor in determining the regimen and duration of their use in breeding centers. Therefore, the study of interracial differences in sperm production indicators throughout the entire period of use is considered important.

All studies on the seasons of the year were carried out under the following climatic conditions. The warm season lasts 4.0 months, from May 14 to September 13, with maximum average daily temperatures above 19 °C. The hottest month is July, with an average temperature maximum of 26 °C and minimum of 14 °C. The cold season lasts 3.8 months, from November 21 to March 14, with a minimum average daily temperature below -4 °C. The coldest month of the year is January, with an average temperature maximum of -20 °C and minimum of -11 °C.

Humidity varies depending on the month in the range from 50% to 83%. At the same time, the minimum humidity is observed in May, the maximum humidity occurs in December. The average hourly wind speed experiences significant seasonal variations throughout the year.

The windier part of the year lasts 7.0 months, from October 15 to May 13, with average wind speeds of more than 17.2 kilometers per hour. The windiest month of the year is January, with an average hourly wind speed of 19.9 kilometers per hour. The quieter time of year lasts 5.0 months, from May 13 to October 15. The calmest month of the year is July, with an average hourly wind speed of 14.4 kilometers per hour (Table 1).

Table 1 Climatic data by season.

Seasons of the year	Air temperature, °C		Relative humidity, %		Wind speed, m/s	
	Seasonal average	deviation	Seasonal average	deviation	Seasonal average	deviation
Winter	-13,4	1,1	81,3	1,1	4,6	0,1
Spring	5,2	6,9	64,6	10,8	4,7	0,2
Summer	19,5	0,4	56,3	2,2	3,9	0,1
Autumn	3,0	6,5	71,6	6,8	4,4	0,4

While studying the dynamics of quantitative and qualitative indicators of sperm production in bulls, a small seasonal variation was observed (Table 2; Figures 1, 2, and 3).

From Table 2, it can be observed that the highest percentage of defects was observed in Kazakh Whiteheaded and Hereford bulls during the spring and summer periods, while Aberdeen-Angus bulls showed a high percentage of defects in all periods.

The study of the dynamics of quantitative and qualitative indicators of sperm production in bulls showed a small seasonal variation. The lowest number of ejaculates was obtained in Kazakh Whiteheaded and Aberdeen-Angus bulls during the spring period and in Hereford bulls during the summer period. This indicator was higher for the Kazakh Whiteheaded and Aberdeen-Angus breeds in autumn and spring, while for the Hereford bulls, it was higher in autumn. Our results are confirmed by similar studies by Chetvertakova (2012), Kazhalieva and Margarina (2017), Isimov et al (2020) and Bisembayev et al (2022).

Table 2 Sperm production indicators of breeding bulls by season.

Season	Average number of ejaculations/bull	Ejaculated volume, ml	Sperm concentration, billions/ml	Marriage of ejaculates, %	Average amount of semen to be used, doses
Kazakh Whiteheaded (n=10)					
Winter	80.75	3.19±0.03	0.82±0.01	44.6	5025.1
Spring	68.93	3.23±0.04	0.76±0.02	50.5	3554.8
Summer	98.5	3.44±0.03	0.77±0.01	49.6	5589.5
Autumn	98	3.41±0.04	0.82±0.02	45.3	5573
Aberdeen Angus (n=10)					
Winter	60.2	3.73±0.06	0.69±0.01	64	2532.8
Spring	49	4.09±0.05	0.72±0.02	54.6	2865
Summer	66.1	4.25±0.06	0.69±0.01	61	3618.8
Autumn	70.6	3.86±0.05	0.73±0.02	58.4	3675.6
Hereford (n=10)					
Winter	92.6	3.92±0.05	0.80±0.02	38.7	9112.3
Spring	91.4	4.15±0.06	0.75±0.01	46.1	6042
Summer	85.6	4.05±0.05	0.80±0.02	42.2	7517.1
Autumn	100.5	4.08±0.06	0.83±0.01	39.6	9824.6

According to the ejaculate volume, the Kazakh Whiteheaded bulls showed the highest value in the autumn period and the lowest in the winter period, while the other periods had intermediate values. For the Aberdeen-Angus bulls, the favorable period was summer, and the worst period was winter. For the Hereford bulls, the worst period was winter.

The highest concentration in the ejaculate was observed in Kazakh Whiteheaded bulls during the winter-autumn period, with a quantity of 0.82 billion/ml; in Aberdeen-Angus bulls during the spring-autumn periods, with 0.72 - 0.72 billion/ml; and in Hereford bulls during the autumn period, with 0.82 billion/ml.

The periods with negative effects on concentration for Aberdeen-Angus bulls were considered winter and summer due to low temperatures in winter and high temperatures in summer, which influenced the high percentage of defects in these periods.

The quantity of semen for use mainly depends on the concentration of sperm in the ejaculate. In the spring period, the minimum number of semen doses was obtained from Kazakh Whiteheaded and Hereford bulls, per bull, and in the winter-spring period, from Aberdeen-Angus bulls. The maximum values of this indicator were in the summer-autumn period for Kazakh Whiteheaded bulls, in the spring period for Aberdeen-Angus bulls, and in the autumn period for Hereford bulls. In other periods, this indicator had intermediate values. The results are consistent with the data of other studies (Kolosova 2010; Chindalieva et al 2023; Seisenov et al 2023).

Based on the data on the defect rate obtained from the breeding bulls at the reproduction center from 2016 to 2022, it was found that, on average, 49.6% of the semen was considered defective. This included 47.5% for the Kazakh Whiteheaded bulls, 59.9% for the Aberdeen-Angus bulls, and 41.6% for the Hereford bulls. This high defect rate is primarily a result of insufficient nutrients in the feed, especially the lack of carotene, and second, it is influenced by the genetic characteristics and adaptation of the imported bulls. The majority of the defects occurred due to low sperm concentration and low sperm activity.

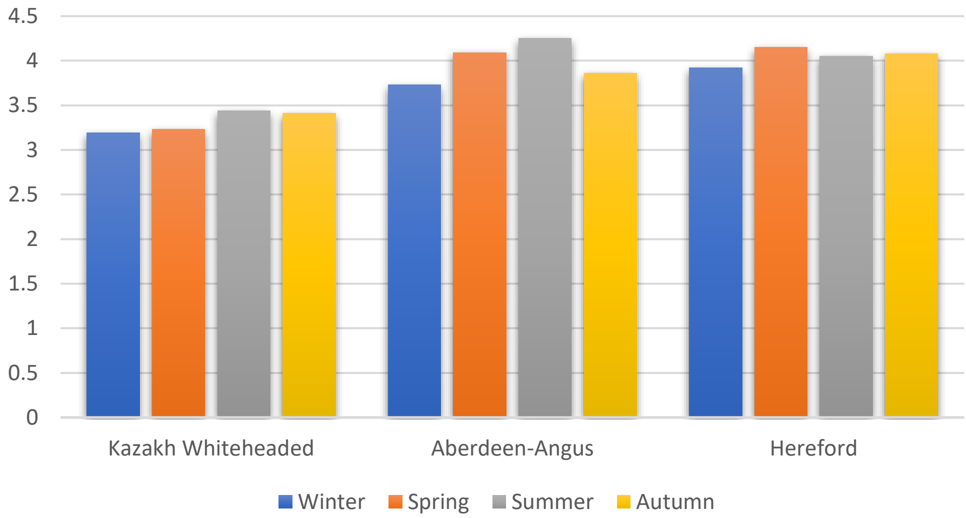

Figure 1 Ejaculate volume in relation to the season.

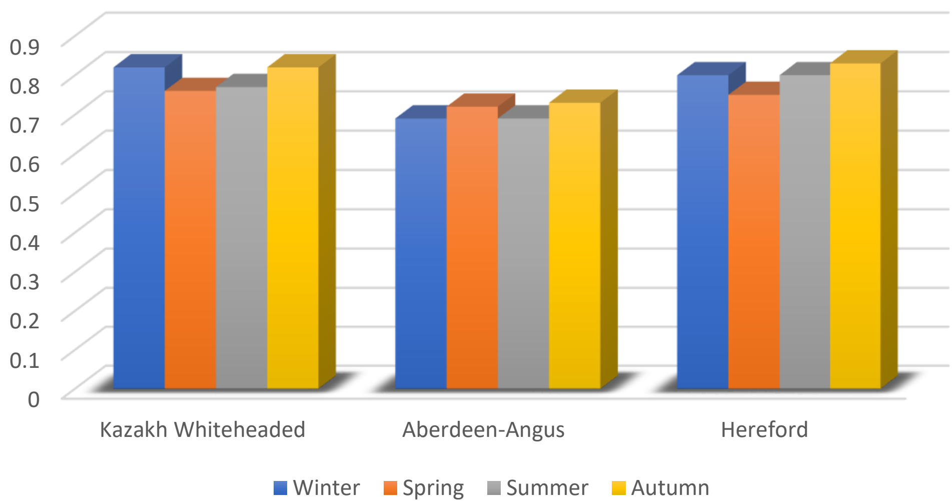

Figure 2 Sperm concentration in relation to the season.

Genetic characteristics related to the level of defects in sperm production were associated with the adaptation period of imported bulls, such as those of the Hereford and Aberdeen-Angus breeds, and were also linked to nervous activity, health status, and, primarily, the level of nutrition. Seasonal variability revealed that the highest number of defects was observed in the Kazakh Whiteheaded and Hereford bulls during the spring and in the Aberdeen-Angus bulls during the winter.

It should be noted that many scientist studies also confirm that the favorite periods for sperm quality were in the winter and autumn for the Kazakh Whiteheaded and Hereford bulls and in the autumn for the Aberdeen-Angus bulls (Zenkov and Belousov 2009; Islamova 2007; Volkova et al 2008; Sisenov et al 2023).

Differences between seasons of the year may exist for some breeds, although in our case, they have not been proven and are influenced by individual characteristics and other significant factors.

As shown by the analysis of variance of a single factor, it was observed that the influence of the bull's genotype on the sperm count varies throughout the year and depends on the age of the bulls (Table 3).

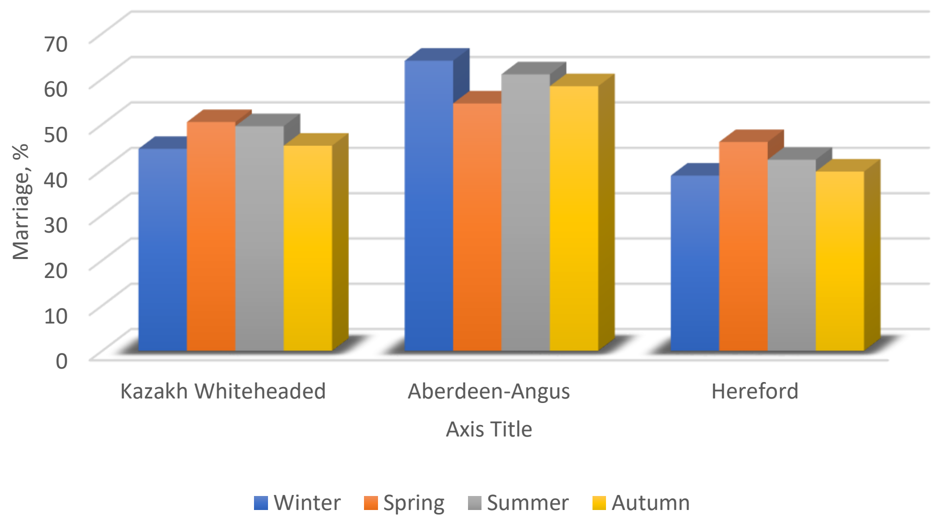

Figure 3 Marriage concerning the season.

The bulls with different genotypes were observed to be most affected during the summer, with a 65.46% (P > 0.001) impact observed in 5-year-old bulls and a 68.32% (P > 0.001) impact observed among young bulls. In sexually mature bulls, the analyzed semen parameters showed a higher dependence on genotype during different seasons of the year. Among young bulls, the impact of this factor was small, but a greater genotype effect could be observed during winter and summer, with 60.67% and 68.32%, respectively (P > 0.001). Other factors influencing the phenotype were the different ejaculate volumes, with 34.54-67.24% and 45.63-68.32%, respectively. The results of the evaluations, just with the data of the repeaters of others and the investigation how Islamova (2007), Volkova and Alifanov (2008), Kazhgalyev and Maigarin (201) and Chindaliev et al (2023).

Table 3 Influence of genotype on sperm count throughout the year (%).

Season	3 years		5 years	
	η^2_x	P_x	η^2_x	P_x
Winter	60.67	$P > 0.05$	67.24	$P > 0.001$
Spring	57.41	$P > 0.05$	59.33	$P > 0.05$
Summer	68.32	$P > 0.001$	34.54	$P > 0.05$
Autumn	45.63	$P < 0.05$	65.46	$P > 0.001$
Average	55.50		58.66	

4. Conclusions

Based on the results obtained over five years of using breeding bulls, it can be concluded that the seasons of the year affect Kazakh Whiteheaded bulls from spring to summer, Aberdeen Angus bulls from winter to summer, and

Hereford bulls during spring. Other seasons mainly positively influence semen production parameters, and when changes occur, they are not significant.

In sexually mature bulls, semen parameters show a greater dependence on genotype in different seasons of the year. In young bulls, the impact of this factor was small, but a stronger genotype effect was observed during winter and summer.

The highest concentration of spermatozoa was observed in Kazakh Whiteheaded bulls during the winter-autumn period (0.82 million/ml), in Aberdeen Angus bulls during the spring-autumn period (0.72 million/ml), and in Hereford bulls during autumn (0.82 million/ml). Autumn had a positive impact on all breeds.

When assessing the genetic influence on the reproductive capacity of beef breeding bulls, their genotype and breed should be taken into consideration.

Ethical considerations

According to ethical norms, the animals were not subjected to any form of inhumane treatment.

Conflict of Interest

The authors have stated that they do not have any conflicts of interest.

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