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Original Article

The effect of different protein levels in the diet of beef cattle on growth and development, as well as on reproductive ability

O efeito de diferentes níveis de proteína na dieta de bovinos de corte sobre o crescimento e o desenvolvimento, bem como na capacidade reprodutiva

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Abstract

The purpose of this study was to study the effect of different levels of crude protein (CP) in the diet of Kazakh white-headed bull calves on their growth, development, feed efficiency and reproductive qualities using the digital Intergado system. The study involved 21 animals aged 7-8 months, divided into three groups: control (CP 11%), experimental 1 (CP 13%) and experimental 2 (CP 14.5%). The results showed that in the experimental groups, the consumption of metabolic energy increased significantly (up to 2.61±0.01 Mcal/lb) and crude protein (up to 0.92±0.03 kg; p = 0.006), as well as protein decomposed in the rumen (RDP up to 0.70±0.02 kg). This led to an improvement in the nitrogen balance, which became positive in experimental group 2 (0.01±0.01 kg d^{-1}; p < 0.001). The most significant effect was observed on the productivity of animals. The experimental groups showed significantly higher average daily gains: 1.20±0.08 kg (CP 13%) and 1.26±0.07 kg (CP 14.5%) versus 0.87±0.14 kg in the control (p < 0.05). The absolute weight gain was 53.00±2.98 kg (experimental 2) and 50.43±3.36 kg (experimental 1), significantly exceeding the control group (36.57±5.79 kg; p < 0.05). The feeding efficiency improved significantly: the feed conversion rate in the group of CP 14.5% was 5.17 versus 8.54 in the control. Meat quality indicators included an increase in the area of the muscular eye in Experimental group 1 (39.81±1.59 cm2; p < 0.05). It is important to note that the studied protein levels did not negatively affect the indicators of reproductive function, where the scrotum circumference ranged from 28.14±1.32 cm in the control to 30.14±0.80 cm in the experimental group 1, and the ejaculate score ranged from 7.66±0.51 points in the control to 7.79±0.61 points in the experimental group 1, without statistically significant There were no significant differences (p = 0.388 and p = 0.693, respectively). However, an increase in methane emissions was recorded in the experimental groups (up to 14.75±0.01 g/kg DM; p < 0.001). Thus, the level of 13-14.5% crude protein in the diet provides a significant improvement in the growth, digestibility and bioavailability of nutrients without impairing reproductive functions, and can be recommended for intensive fattening of bull calves using digital feeding control technologies.

Keywords: digital technologies, protein nutrition, automated feeding, Intergado, feed conversion.

Resumo

O objetivo deste estudo foi avaliar o efeito de diferentes níveis de proteína bruta (PB) na dieta de bezerros machos da raça Kazakh Whiteheaded sobre seu crescimento, seu desenvolvimento, sua eficiência alimentar e suas qualidades reprodutivas, utilizando o sistema digital Intergado. O estudo envolveu 21 animais com idade entre 7 e 8 meses, divididos em três grupos: controle (PB 11%), experimental 1 (PB 13%) e experimental 2 (PB 14,5%). Os resultados mostraram que, nos grupos experimentais, o consumo de energia metabólica aumentou significativamente (até 2,61±0,01 Mcal/lb) e de proteína bruta (até 0,92±0,03 kg; p = 0,006), assim como a proteína decomposta no rúmen (PDR até 0,70±0,02 kg). Isso levou a uma melhora no balanço de nitrogênio, que se tornou positivo no grupo experimental 2 (0,01±0,01 kg d^{-1}; p < 0,001). O efeito mais significativo foi observado na produtividade dos animais. Os grupos experimentais apresentaram ganhos médios diários significativamente maiores: 1,20±0,08 kg (PB 13%) e 1,26±0,07 kg (PB 14,5%) versus 0,87±0,14 kg no grupo controle (p < 0,05). O ganho de peso absoluto foi de 53,00±2,98 kg (experimental 2) e 50,43±3,36 kg (experimental 1), superando significativamente o grupo controle (36,57±5,79 kg; p < 0,05). A eficiência alimentar melhorou significativamente: a taxa de conversão alimentar no grupo com PB 14,5% foi de 5,17 versus 8,54 no grupo controle. Os indicadores de qualidade da carne incluíram um aumento na área do lombo muscular no grupo experimental 1 (39,81±1,59 cm^2; p < 0,05). É importante notar que os níveis de proteína estudados não afetaram negativamente os indicadores da função reprodutiva, em que a circunferência do escroto variou de 28,14±1,32 cm no grupo controle a 30,14±0,80 cm no grupo experimental 1, e a pontuação do ejaculado variou de 7,66±0,51 pontos no grupo controle a 7,79±0,61 pontos no grupo experimental 1, sem diferenças estatisticamente significativas (p = 0,388 e p = 0,693, respectivamente). No entanto, foi registrado um aumento nas emissões de metano nos grupos experimentais (até 14,75±0,01 g/kg MS; p < 0,001). Assim, o nível de 13-14,5% de proteína bruta na dieta proporciona uma melhoria significativa no crescimento, na digestibilidade e na biodisponibilidade de nutrientes sem prejudicar as funções reprodutivas, podendo ser recomendado para engorda intensiva de bezerros touros utilizando tecnologias digitais de controle alimentar.

Palavras-chave: tecnologias digitais, nutrição proteica, alimentação automatizada, Intergado, conversão alimentar.

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1. Introduction

Digital technologies play an increasingly important role in modern animal husbandry by enabling accurate monitoring, nutrition analysis, and automation of management processes. The use of sensors and data-driven systems allows the collection of large volumes of information on animal behavior, health, and welfare, which can be analyzed to support informed management decisions and improve production efficiency (Džermeikaitė et al., 2023). Intelligent agriculture contributes to the sustainability of livestock systems by optimizing resource use, reducing environmental emissions, and improving animal performance.

Digital monitoring technologies are widely applied across livestock sectors. Bolus-based systems such as smaXtec are used in dairy cattle to monitor health and reproductive status (Uskenov et al., 2024b), while wearable trackers are applied in horse breeding to assess movement and physiological condition (Akimbekov et al., 2023). In beef cattle production, automated systems such as GrowSafe and Intergado enable continuous monitoring of feed intake, feed efficiency, and growth performance, including stress-free live weight assessment under pasture and feedlot conditions (Tilepova et al., 2024; Uskenov et al., 2023).

One of the leading digital platforms is Intergado, which allows you to track feed consumption in detail, calculate protein balance and adapt the diet depending on the physiological needs of animals. Validation of the system has shown high accuracy and sensitivity in measuring feeding and drinking behavior, which makes it an effective tool for managing the nutrition of young cattle (Oliveira Junior et al., 2017).

In addition, the work of Chizzotti et al. (2015) highlighted the importance of creating large databases on cattle feed consumption to improve breeding programs and develop precision animal husbandry. These studies show that monitoring systems such as Intergado play a key role in improving the efficiency of fattening and feeding management (Chizzotti et al., 2015). Intergado can be used to optimize breeding selection by identifying animals with better feed conversion and growth efficiency (Uskenov et al., 2024a). One of the key nutritional parameters in the diet of ruminants is crude protein (CP) and its ability to decompose is critically important, since they regulate the supply of nitrogen to ruminant microbes, regulating microbial protein synthesis, digestive efficiency, and animal productivity (Ali et al., 2022).

In the production of beef cattle, it is very important to feed a sufficient amount of crude protein (CP), given its impact on productivity. Protein deficiency in the diet of beef cattle can negatively affect weight gain, feed intake, and carcass quality (NRC, 2001). Young animals aged 9 to 12 months demonstrate effective deposition of tissues in the body and a high need for nutrients, especially protein (Schwab and Broderick, 2017).

Protein feeding is an important factor in the growth and development of cattle, affecting the growth of muscle mass and meat quality . Studies have shown that the level of crude protein in the diet significantly affects the average daily gain (ADG), feed conversion rate (FCR), and rumen function in cattle, while a diet with a higher protein content leads to improved growth rates, rumen function, and microbiological activity. In addition, the interaction between protein and other dietary components such as energy and minerals is crucial to achieve optimal growth results and meat quality (NASEM, 2021)

Increasing the concentration of CP usually improves the performance during cultivation. When fattening beef cattle, the reaction of animals to an increased content of CP varies depending on the source of CP (i.e., the level of decomposition in the rumen). It is for this reason that the most modern systems of rational nutrition of beef cattle take into account both the quantity and quality of dietary protein (NASEM, 2016). Research shows that the type, quantity, and quality of protein consumed can significantly affect growth rates, with a direct correlation between adequate protein levels and increased muscle mass. For a more accurate diet, it is necessary to take into account not only the total CP, but also the profile of amino acid decomposition in order to avoid a lack of RUP and insufficient intake of essential amino acids into the intestine (Uskenov et al., 2023). Understanding the exact nutrient and protein needs of bull calves at different growth phases is important both for optimizing productivity and improving animal health.

Studies by Dung et al. have shown that elevated CP levels (10%, 13%, 16%, and 19%) led to an increase in the digestibility of CP, but did not significantly affect the digestibility of DM, OM and NDF (Dung et al., 2013). The introduction of high-protein additives into the feed increases the synthesis of microbial protein, which plays an important role in the digestive process in ruminants (Kim et al., 2022).The purpose of this article is to explore the importance of digital technologies in the analysis and management of protein nutrition for the growth of Kazakh white–headed meat bulls and to provide an idea of optimal diet compositions and management methods that can improve the growth rate and quality of meat.

2. Materials and Methods

Scientific research was carried out on Kazakh white-headed bull calves in Novobratskoye & K LLP, Akmola region, Republic of Kazakhstan. The study period is August 11, 2023 - January 6, 2024. During the period of scientific research, feeding standards corresponded to the breed, live weight and physiological condition of the bulls.

The research work was carried out by measuring every 28 days during the first day of assessment, and then in the morning before feeding for 112 days. The results formed the basis for determining the average daily increase in body weight.

Breeding bulls of the Kazakh white-headed breed aged from 7 to 8 months in the amount of 21 heads were selected for the research. At the end of the experiment, the bulls were about 11-12 months old. Taking into account age and live weight, three groups of bull calves (7 heads in each group), one control group and two experimental groups were formed according to the principle of paired analogues.

The rations were made up of feed produced on the farm, and during the growing period from 7 to 12 months, the average daily increase was calculated at the level of 900-1200 g. The main diet consisted of hay, hayloft, barley and premixes.

Fodder peas were added as protein to the diet of the experimental group of steers. During the experiment, 11% of crude protein was included in the diet of bulls in group I, 1.5 kg of peas were added to the main diet in group II and the amount of crude protein was increased to 13%, in group III 2.5 kg of peas were consumed and the crude protein content was 14.5%. The chemical analysis of the feed was carried out in the laboratory of BKN Nova LLP, and it was also studied in the laboratory of zootechnical analysis of feed and milk of NAO KATU. S.Seifullina" on the FOSS NIRS DS2500F analyzer and in the laboratory of chemical analysis of feed at the University of Erciyes, Republic of Turkey.

The first group with a content of 11% crude protein in the diet was formed according to the protein needs according to the norms of "Norms and rations for feeding farm animals" by Kalashnikov et al. (2003). The second and third groups with 13% and 14.5% crude protein content were formed according to NASEM 2016 standards. RUP, RDP, N Balance, and Methane indicators were also calculated at the NASEM 2016 Beef program.

Scientific research was conducted using the Brazilian Internado system. The Intergado monitoring system (Intergado Ltd., Contagem, Minas Gerais, Brazil) determines individual feeding behavior and consumption of animal feed. To study the effectiveness of feeding calves in terms of protein content in the diet, we studied and obtained results in terms of body weight at the time of testing, body weight at the end of the test, and absolute and average daily gains using the Intergado system (Figure 1).

The EXAGO scanner, developed using the latest technologies and adapted for use in the field of animal science, was used in the research work, designed to determine the lifetime quality of meat using high-frequency ultrasonic waves (from 2 to 10 MHz). Lifetime assessment of meat productivity of farm animals by ultrasound scanning is successfully used in animal husbandry in the USA, Canada, Australia and in a number of other countries. In Kazakhstan, this method is at the initial stage of study and practical application.

The measurement of the "scrotum girth" in one-year-old bull calves is performed at the widest point of the scrotum at the age of 300 to 400 days using a centimeter measuring tape and entered into the database.

The parameters of the ejaculate were assessed by volume (ml), sperm concentration (million/ml) using light microscopy and a hemocytometer, sperm motility (%) visually at 400× magnification in a fresh preparation, sperm morphology by the number of abnormal forms, and viability.

Statistical processing was carried out in the IBM SPSS Statistics 25.0 program. Descriptive statistics (mean, standard deviation, minimum, maximum) were calculated.

3. Results

To study the effect of protein levels on the growth and development of calves, the following key indicators were calculated based on data obtained from Intergado, such as average daily feed intake, average daily intake of dry matter, metabolic energy, and crude fat.

The Table 1 shows the average values, standard deviation, minimum and maximum daily intake of feed and its nutritional components in the control and two experimental groups. The statistical significance of the differences between the groups (p-value) is indicated in the last column.

Daily feed intake: There were no statistically significant differences between the groups ($p = 0.978$), which indicates a similar level of feed intake. The experimental groups (1 and 2) showed slightly higher average values (10.57 and 10.65 kg d^{-1}) compared to the control group (10.44 kg d^{-1}).

The differences in dry matter between the groups are statistically insignificant ($p = 0.769$).

Experimental group 2 showed the highest intake of dry matter (6.43 kg d^{-1}), which may indicate better digestibility of feed.

Figure 1. Using the Intergado system to evaluate protein feeding of calves.

Table 1. Indicators of feed consumption and nutritional value in various groups.

Indicators	Groups	M±m	δ	min	max	P-value
Daily feed intake,kg	CP 11	10.44±0.72	1.91	6.91	12.89	0.978
	CP 13	10.57±0.65	1.73	7.25	12.62	
	CP 14.5	10.65±0.73	1.93	7.52	13.78	
Dry Matter (kg/d^{-1})	CP 11	6.00±0.41	1.10	3.97	7.41	0.769
	CP 13	6.26±0.38	1.02	4.30	7.47	
	CP 14.5	6.43±0.44	1.17	4.54	8.32	
ME (Mcal/lb)	CP 11	2.50±0.00	0.00	2.50	2.51	0.000
	CP 13	2.57±0.00	0.00	2.57	2.58	
	CP 14.5	2.61±0.00	0.01	2.60	2.62	
CP kg	CP 11	0.64±0.04	0.11690	0.42	0.79	0.006
	CP 13	0.81±0.05	0.13129	0.56	0.96	
	CP 14.5	0.92±0.06	0.16620	0.65	1.19	
Fat kg	CP 11	0.16±0.01	0.02994	0.11	0.20	0.155
	CP 13	0.18±0.01	0.02998	0.13	0.22	
	CP 14.5	0.20±0.01	0.03601	0.14	0.26	
Ash	CP 11	0.47±0.03	0.08612	0.31	0.58	0.999
	CP 13	0.47±0.03	0.07642	0.32	0.56	
	CP 14.5	0.47±0.03	0.08578	0.33	0.61	
Sugar	CP 11	0.33±0.02	0.05977	0.22	0.40	0.507
	CP 13	0.31±0.02	0.04945	0.21	0.36	
	CP 14.5	0.29±0.02	0.05315	0.21	0.38	
Strach	CP 11	1.57±0.11	0.28733	1.04	1.94	0.592
	CP 13	1.68±0.10	0.27334	1.16	2.01	
	CP 14.5	1.73±0.12	0.31375	1.22	2.24	
NDF	CP 11	2.54±0.18	0.46351	1.68	3.13	0.977
	CP 13	2.50±0.15	0.40514	1.72	2.98	
	CP 14.5	2.49±0.17	0.45151	1.76	3.22	
Lignin	CP 11	0.22±0.02	0.04058	0.15	0.27	0.943
	CP 13	0.22±0.01	0.03526	0.15	0.26	
	CP 14.5	0.22±0.01	0.03904	0.15	0.28	

There are highly significant differences ($p < 0.001$) between the groups in terms of metabolic energy. The experimental groups received more energy (2.57 and 2.61 Mcal/lb) compared to the control group (2.50 Mcal/lb), which may be due to the changed composition of the diet.

Statistically significant differences ($p < 0.05$) in crude protein were revealed.

The experimental groups consumed more protein (0.81 and 0.92 kg) than the control group (0.64 kg), which is important for assessing the effectiveness of feeding.

Fats (Fat, kg), ash (Ash), Sugar (Sugar), Starch (Starch), NDF and Lignin (Lignin)

No significant differences were found in these indicators ($p > 0.05$), except for the tendency to increase fat in the experimental groups.

The content of fiber Neutral Detergent Fiber (NDF) and lignin remained stable in all groups, indicating a balanced diet of structural carbohydrates.

The results show that changes in the diet of the experimental groups led to a significant increase in the consumption of crude protein and metabolic energy, while other parameters remained at a comparable level. This may indicate a higher nutritional value of the feed in the experimental groups without adversely affecting overall consumption.

To assess the degree of consistency of the results obtained using different dry matter consumption calculation systems, a correlation analysis was performed between the data obtained using the Intergado and NASEM models (Figure 2).

The calculated Pearson correlation coefficient was r = 1.00 at p < 0.001, indicating an absolute linear relationship between the two datasets. All observation points lie on the line of coincidence y=xy = xy=x, which confirms the complete coincidence of the results obtained by both methods.

Thus, we can conclude that the values calculated using the Intergado and NASEM programs are completely identical in this case. This may indicate that the calculation algorithms are synchronized correctly or that the same source data set is being used.

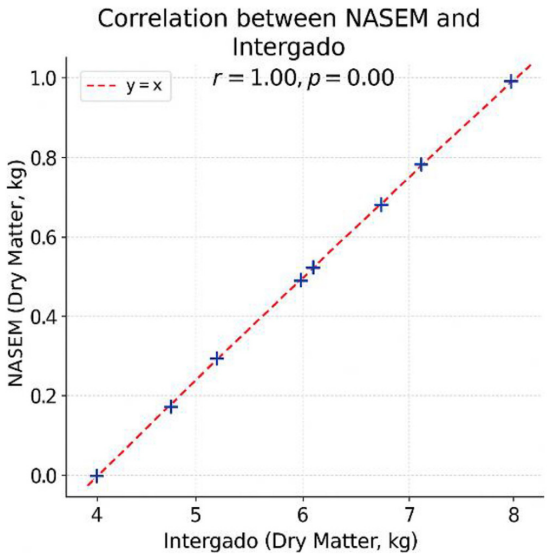

Figure 2. Correlation analysis of dry matter between Intergado and NASEM models.

The indicators of protein nutrition were also calculated with the actual consumption of feed at different levels of crude protein in the diet.

Analysis (Table 2) of nitrogen metabolism indicators revealed significant differences between the groups in terms of Rumen degradable protein (RDP) consumption (p<0.005) and nitrogen balance (p<0.001). In the experimental groups, there was a significant increase in RDP consumption by 29.4% and 49.0% in Experimental 1 and 2, respectively, compared with the control. At the same time, the Rumen undegradable protein (RUP) content remained stable in all groups (p=0.485).

Of particular interest is the dynamics of the nitrogen balance:(N Balance) in the control group there was a negative balance (-0.02 kg /day), whereas in Experimental 1 it reached zero, and in Experimental 2 it became positive (0.01 kg /day). These changes indicate a significant improvement in nitrogen absorption when using modified diets.

The experimental results show (Table 3) that the level of methane emissions (g/kg of dry matter, DM) varied significantly between the groups. In the control group, the average value was 13.24 ± 0.04 g/kg DM with a standard deviation of 0.10, with a range of values from 13.15 to 13.47. In experimental group 1, the methane level was higher — 14.18 ± 0.01 g/kg DM, the standard deviation was 0.02, the minimum and maximum values were 14.15 and 14.23, respectively. In experimental group 2, the highest level of methane emissions was recorded — 14.75 ± 0.01 g/kg DM, with a standard deviation of 0.03, ranging from 14.70 to 14.81.

Table 2. Indicators of protein nutrition with actual feed intake of different levels of crude protein in the diet.

Indicators	Groups	M±m	δ	min	max	P-value
RDP (kg/d)	CP 11	0.51±0.03	0.09	0.34	0.62	0.002
	CP 13	0.66±0.04	0.11	0.46	0.79	
	CP 14.5	0.76±0.05	0.14	0.54	0.99	
RUP (kg/d)	CP 11	0.13±0.01	0.03	0.09	0.17	0.485
	CP 13	0.14±0.01	0.02	0.10	0.17	
	CP 14.5	0.15±0.01	0.03	0.10	0.20	
N balance (kg N/d)	CP 11	-0.02±0.00	0.00	-0.03	-0.01	0.000
	CP 13	0.00±0.00	0.00	0.00	0.00	
	CP 14.5	0.01±0.00	0.00	0.01	0.02	

Table 3. The level of methane emissions (g/kg of dry matter) in groups with different protein levels.

Indicators	Groups	M±m	δ	min	max	P-value
Methane (g/kg DM)	CP 11	13.24±0.04	0.10	13.15	13.47	0.000
	CP 13	14.18±0.01	0.02	14.15	14.23	
	CP 14.5	14.75±0.01	0.03	14.70	14.81	

The initial live weight of animals in all groups was statistically homogeneous (p=0.925), which confirms the correctness of the formation of groups (Table 4). The average initial weight ranged from 233.14 kg (Experimental 2) to 237.43 kg (Experimental 1). Despite the absence of statistically significant differences in final weight (p=0.492), there was a clear trend towards an increase in body weight in the experimental groups.

The animals of the experimental groups exceeded the control in final weight by 15-16 kg (5.6–5.9%).

The average daily weight gain (ADG) significantly (p<0.05) differed between the groups. The experimental groups showed an increase of 37.9–44.8% compared with the control (1.20–1.26 kg d^{-1} versus 0.87 kg d^{-1}).

The absolute weight gain was significantly higher (p<0.05) in the experimental groups: +50.43-53.00 kg versus +36.57 kg in the control (difference 38-45%).

The relative increase also showed significant differences (p<0.05), exceeding the control values by 36.8–46.1%.

These data confirm the effectiveness of using experimental diets to increase animal productivity. The observed increase in average daily weight gain by 0.33-0.39 kg d^{-1} may have significant economic significance when scaling the technology.

The study used data from the Intergado system. The graphs show the dynamics of feed intake (Intake, kg) and changes in body weight (Weight, kg) depending on the number of days of testing. The data make it possible to assess changes in nutrition and weight gain of animals under various conditions of detention.

With the Intergado system, we can monitor feed consumption and animal weight dynamics on a daily basis. This allows you to track changes in feeding and growth in detail, detect fluctuations and respond promptly to possible deviations. Such data helps to optimize diets and housing conditions to achieve better results (Figure 3).

The area of the muscular eye (cm2) (Table 5)

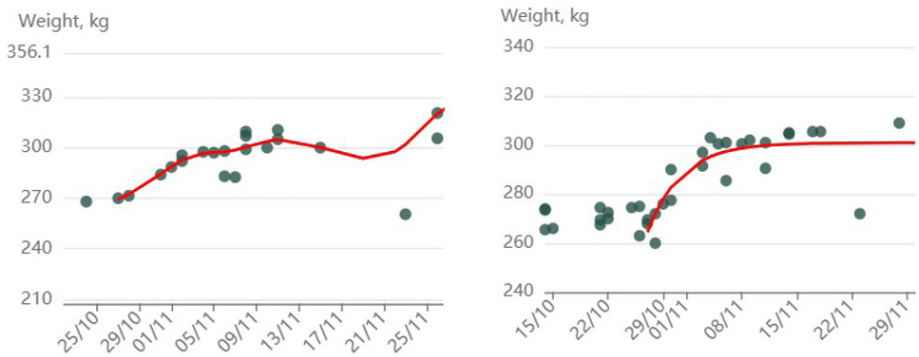

Figure 3. Dynamics of weight changes in Kazakh white-headed bull calves according to the Intergado system.

Table 4. Weight indicators for the growth of Kazakh white-headed bull calves.

Indicators	Groups	M±m	δ	min	max	P-value
Initial live weight of animals	CP 11	235.29±8.29	21.92	207.00	270.00	0.925
	CP 13	237.43±7.60	20.12	220.00	280.00	
	CP 14.5	233.14±7.11	18.80	210.00	270.00	
Final live weight of animals	CP 11	271.86±11.22	29.70	224.00	314.00	0.492
	CP 13	287.86±9.68	25.61	254.00	336.00	
	CP 14.5	286.14±9.70	25.66	260.00	336.00	
ADG	CP 11	0.87±0.14	0.37	0.40	1.40	0.029
	CP 13	1.20±0.08	0.21	0.81	1.48	
	CP 14.5	1.26±0.07	0.19	1.07	1.57	
Absolute weight gain	CP 11	36.57±5.79	15.31	17.00	59.00	0.028
	CP 13	50.43±3.36	8.89	34.00	62.00	
	CP 14.5	53.00±2.98	7.90	45.00	66.00	
relative weight gain	CP 11	15.52±2.50	6.63	7.08	26.82	0.019
	CP 13	21.23±1.29	3.41	15.45	26.38	
	CP 14.5	22.68±0.81	2.15	19.74	25.42	

The control group showed an average value of 34.04 ± 2.30 cm2, whereas in experimental group 1 this indicator was significantly higher (39.81 ± 1.59 cm2), and in experimental group 2 – lower (27.84 ± 2.97 cm2). The range of values ranged from 20.6 to 44.9 cm2, with the lowest minimum values observed in experimental group 2.

P-value = 0.006 indicates statistically significant differences between the groups. It can be assumed that the factors used in experimental group 1 contributed to an increase in the area of the muscular eye, whereas in experimental group 2 the opposite effect was observed.

The thickness of back fat in the control group had an average fat thickness of 2.17 ± 0.21 mm, in experimental group 1 this indicator was higher (2.86 ± 0.30 mm), and in experimental group 2 it was lower (1.88 ± 0.16 mm). The range of values ranged from 1.67 to 4.14 mm, with maximum values observed in experimental group 1.

P = 0.04 confirms the presence of statistically significant differences between the groups. This suggests that the factors used in the experimental groups had an effect on subcutaneous fat deposition: an increase was observed in group 1, and a decrease in group 2.

The average circumference of the scrotum in the control group was 28.14 ± 1.32 cm, in the experimental group 1 – 30.14 ± 0.80 cm, and in the experimental group 2 – 29.29 ± 0.81 cm (Table 6). The range of values ranged from 24 to 33 cm in all groups. The standard deviation was highest in the control group (3.48), which indicates a higher variability of the trait compared to the experimental groups (2.12–2.14).

Statistical analysis (P = 0.388) did not reveal significant differences between the groups, which allows us to conclude that there is no significant influence of experimental factors on this indicator.

The average ejaculate score in the control group was 7.66 ± 0.51 points, in the experimental group 1 – 7.79 ± 0.61, and in the experimental group 2 – 7.71 ± 0.29. The minimum and maximum values ranged from 4 to 9 points in all groups. P-value = 0.693 indicates the absence of statistically significant differences between the groups, which allows us to conclude that the experimental effects did not significantly affect the quality of the ejaculate.

The Table 7 shows the results of calculations on feed conversion rate, conversion rate and residual feed consumption (RFI) in Kazakh white-headed bulls that received different levels of crude protein in the diet.

Table 5. Lifetime indicators of meat productivity.

Indicators	Groups	M±m	δ	min	max	P-value
The area of the muscular eye (cm2)	CP 11	34.04±2.30	5.13	28.1	41.6	0.006
	CP 13	39.81±1.59	4.22	32.7	44.9	
	CP 14.5	37.84±2.97	6.63	31.6	43.9	
The thickness of back fat (mm)	CP 11	2.17±0.21	0.46	1.67	2.51	0.04
	CP 13	2.86±0.30	0.8	1.67	4.14	
	CP 14.5	2.88±0.16	0.36	1.67	3.67	

Table 6. Indicators of reproductive function by groups with different protein levels.

Indicators	Groups	M±m	δ	min	max	P-value
Scrotal girth (cm)	CP 11	28.14±1.32	3.48	24	33	0.388
	CP 13	30.14±0.80	2.12	26	33	
	CP 14.5	29.29±0.81	2.14	26	33	
Ejaculate evaluation (score)	CP 11	7.66±0.51	1.35	5	9	0.693
	CP 13	7.79±0.61	1.6	4	9	
	CP 14.5	7.71±0.29	0.76	7	9	

Table 7. Data on feeding efficiency.

Indicators	Groups	M±m	δ	min	max	P value
Feed Conversion Ratio	CP 11	8.54±1.95	5.16	4.30	16.24	0.094
	CP 13	5.27±0.28	0.74	3.99	6.15	
	CP 14.5	5.17±0.47	1.25	3.96	7.75	
Feed Conversion Efficiency	CP 11	0.15±0.03	0.07	0.06	0.23	0.123
	CP 13	0.19±0.01	0.03	0.16	0.25	
	CP 14.5	0.20±0.02	0.04	0.13	0.25	
RFI	CP 11	2.05±0.77	2.04	-0.07	4.36	0.019
	CP 13	-0.84±0.61	1.62	-2.67	1.75	
	CP 14.5	-0.35±0.69	1.83	-2.66	2.70	

It was found that the feed conversion rate was higher in the control group (8.54±1.95), compared with the experimental groups: 5.27±0.28 (experimental 1) and 5.17±0.47 (experimental 2). Despite the fact that there were no statistically significant differences in this indicator ($p = 0.094$), there is a clear tendency to improve feed efficiency in bulls fed a diet with a high protein content. This may indicate a more rational use of nutrients in animals of the experimental groups.

The feed conversion rate, reflecting the efficiency of converting feed into weight gain, also turned out to be higher in the bulls of the experimental groups (0.19±0.01 and 0.20±0.02, respectively), compared with the control group (0.15±0.03), but the differences did not reach statistical significance ($p = 0.123$).

The most pronounced differences were found in the indicator of residual feed consumption (RFI) — it was positive in the control group (2.05±0.77), indicating less efficient feed use, and negative in the experimental groups: -0.84±0.61 and -0.35±0.69. This suggests that the bulls that received an increased amount of protein consumed less feed than expected based on their weight gain, which is a positive sign in terms of breeding and feed efficiency. The differences in RFI turned out to be statistically significant ($p<0.05$), which confirms the effectiveness of protein nutrition in optimizing feed consumption.

4. Discussion

During the experiment, it was found that an increase in the crude protein content to 15-16% contributed to a significant improvement in body weight gain. The average daily increase in the experimental groups exceeded the control by 38-45%, which is consistent with the data presented in Xia et al. (2018) and Gleghorn et al. (2004), where an increase in protein levels was associated with improved productivity and growth efficiency.

The indicators of protein nutrition, in particular, the consumption of protein decomposed in the rumen (RDP) and nitrogen balance, also improved significantly in the experimental groups, indicating a more efficient use of nitrogen and an increased level of protein metabolism. This is consistent with the findings of Morales et al. (2024), which emphasize the importance of a balanced amino acid composition and protein shape in the diet.

An additional confirmation of the effectiveness of diets with a high protein content is the data on the reduction of residual feed intake (RFI) in bulls of the experimental groups. Negative RFI values in these groups indicate a more rational use of feed, which is important in selective breeding and in the framework of sustainable animal husbandry.

The Intergado system plays a key role in the digitalization of animal husbandry, providing continuous data collection on feed consumption and body weight dynamics of animals.

Comparing these data with the results of studies by Beretta et al. (2020), it can be noted that the authors conclude that protein levels have a positive effect on calf growth. In their experiment, conducted on 24 Hereford calves, diets with protein levels of 12%, 15%, 17% and 21% were tested. The maximum increase in body weight was observed with 17.5% crude protein, reaching 1.36 kg d^{-1}, which confirms the need for an accurate protein balance for the growth of young animals.

At the same time, in the study Amaral et al. (2023), an increase in ammonia nitrogen (NH3-N) in the rumen was observed with an increase in crude protein levels, which is consistent with our results on nitrogen balance. In their work, the NH3-N level reached 18.5 mg/dl with 16% protein, whereas in our study, the nitrogen balance in the rumen ranged from 0.12 ± 0.01 kg to 0.24 ± 0.02 kg ($P<0.000$), which also indicates an increase in nitrogen losses with high-protein diets .

In addition, automated systems such as Intergado have not only production but also environmental advantages. Optimizing feeding helps reduce nitrogen emissions into the environment, as a more accurate protein dosage reduces nitrogen excretion in urine and feces (Himu and Raihan, 2024).

Digital feeding systems can reduce feed costs by increasing the feed conversion rate (FCR). During the experiment, it was found that the level of exchange energy (OE) in the first group was the highest (140.22 ± 9.40 MJ), while in the second and third groups this indicator was 103.08 ± 5.98 MJ and 109.02 ± 7.47 MJ, respectively ($P<0.007$). In a study by Beretta et al. (2020) also noted that the maximum level of digestible protein (94.6%) was achieved with 17% of crude protein, which confirms the need for precise selection of protein levels to improve feed conversion .

Overall, the use of the Intergado system demonstrates significant advantages in managing protein feeding of calves. Accurate data on feed consumption, the ability to quickly change the diet and improve the bioavailability of nutrients make this technology an important tool for increasing productivity and sustainability of livestock production.

5. Conclusion

The conducted studies have shown that an increase in the level of crude protein in the diet of Kazakh white-headed bull calves has a positive effect on growth rates, feed efficiency and some parameters of reproductive ability. The use of the Intergado digital system made it possible to accurately track individual changes in weight and feed consumption, providing a reliable basis for analysis.

The results showed that the modification of the diet led to significant changes in nutrient intake. Although the total intake of feed and dry matter did not differ statistically, the consumption of metabolic energy (up to 2.61±0.01 Mcal/lb) and crude protein (up to 0.92±0.03 kg; $p = 0.006$) significantly increased in the experimental groups. The analysis of protein nutrition revealed a significant increase in the consumption of protein decomposed in the rumen (RDP up to 0.70±0.02 kg) and a noticeable improvement in the nitrogen balance, which became positive in experimental group 2 (0.01±0.01 kg d^{-1}; $p < 0.001$).

The most pronounced positive effect of increased protein levels was observed on animal productivity. In the experimental groups, a significantly higher average daily increase was recorded: 1.20±0.08 kg (SP 13%) and 1.26±0.07 kg (SP 14.5%) versus 0.87±0.14 kg in the control ($p = 0.029$). The absolute weight gain was 53.00±2.98 kg

(experimental 2) and 50.43±3.36 kg (experimental 1), significantly exceeding the control group (36.57±5.79 kg; $p<0.05$). The feeding efficiency also improved: the feed conversion rate in the JV group of 14.5% was 5.17 versus 8.54 in the control.

Meat quality indicators demonstrated an increase in the area of the muscle eye in Experimental group 1 (39.81±1.59 cm2; $p<0.01$), as well as a tendency to increase the thickness of fat in the back ($p = 0.04$).

It is important to note that the studied protein levels did not negatively affect the indicators of reproductive function, where the scrotum circumference ranged from 28.14±1.32 cm in the control to 30.14±0.80 cm in the experimental group 1, and the ejaculate score ranged from 7.66±0.51 points in the control to 7.79±0.61 points in the experimental group 1, without statistically significant There were no significant differences ($p = 0.388$ and $p = 0.693$, respectively).

However, an increase in methane emissions was recorded in the experimental groups (up to 14.75±0.01 g/kg CB; $p < 0.001$), which must be taken into account when developing diets.

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Data Availability Statement

The entire data set that supports the results of this study was published in the article itself.

References

AKIMBEKOV, A.R., USKENOV, R.B., ISKHAN, K.Z., ASSANBAYEV, T.S., SHARAPATOV, T.S., BAIMUKANOV, D.A. and BAIMUKANOV, D.A., 2023. Creation of smart farms in the herd horse breeding of Kazakhstan (Results of using Trackers). *Online Journal of Biological Sciences*, vol. 23, no. 1, pp. 44-49. https://doi.org/10.3844/ojbsci.2023.44.49.

ALI, A.S., JACINTO, J.G.P., MŸNCHEMYER, W., WALTE, A., GENTILE, A., FORMIGONI, A., MAMMI, L.M.E., CSABA BAJCSY, Á., ABDU, M.S., KAMEL, M.M. and GHALLAB, A.R.M., 2022. Estrus detection in a dairy herd using an electronic nose by direct sampling on the perineal region. *Veterinary Sciences*, vol. 9, no. 12, pp. 688. https://doi.org/10.3390/vetsci9120688. PMid:36548849.

AMARAL, P.M., MARIZ, L.D.S., BENEDETI, P.D.B., SILVA, L.G., PAULA, E.M., MONTEIRO, H.F., SHENKORU, T., SANTOS, S.A., POULSON, S.R. and FACIOLA, A., 2023. Effects of static or oscillating dietary crude protein levels on fermentation dynamics of beef cattle diets. *Journal of Animal Nutrition Metabolism: Clinical and Experimental*, vol. 10, no. 2, pp. 87-102.

BERETTA, V., SIMEONE, A., MORTEIRO, I. and YOUNG, I., 2020. Effect of crude protein level in high grain diets on calf growth, feed utilization. *Agrociencia Uruguay*, vol. 24, no. 2, pp. 111.

CHIZZOTTI, M.L., MACHADO, F.S., VALENTE, E.E.L., PEREIRA, L.G.R., CAMPOS, M.M., TOMICH, T.R., COELHO, S.G., RIBAS, M.N., 2015. Validation of a system for monitoring individual feeding behavior, individual feed intake in cattle. *Journal of Dairy Science*, vol. 98, no. 5, pp. 3438-3442. https://doi.org/10.3168/jds.2014-8925. PMid:25771061.

DUNG, D.V., BA, N.X., VAN, N.H., PHUNG, D., NGOAN, D., CUONG, V.C. and YAO, W., 2013. Practice on improving fatten ing local cattle production in Vietnam by increasing crude protein level in concentrate, concentrate level. *Tropical Animal Health and Production*, vol. 45, no. 7, pp. 1619-1626. https://doi.org/10.1007/s11250-013-0407-2. PMid:23619780.

DŽERMEIKAITĖ, K., BAČENINAITĖ, D. and ANTANAITIS, R., 2023. Innovations in cattle farming: application of innovative technologies, sensors in the diagnosis of diseases. *Animals*, vol. 13, no. 5, pp. 780. PMid:36899637.

GLEGHORN, J.F., ELAM, N.A., GALYEAN, M.L., DUFF, G.C., COLE, N.A. and RIVERA, J.D., 2004. Effects of crude protein concentration, degradability on performance, carcass characteristics, serum urea nitrogen concentrations in finishing beef steers. *Journal of Animal Science*, vol. 82, no. 9, pp. 2705. https://doi.org/10.2527/2004.8292705x. PMid:15446487.

HIMU, H.A. and RAIHAN, A., 2024. An overview of precision livestock farming (PLF) technologies for digitalizing animal husbandry toward sustainability. *Global Sustainability Research*, vol. 3, no. 3, pp. 1-14. https://doi.org/10.56556/gssr.v3i3.954.

KALASHNIKOV, A.P., FISININ, V.I., SHCHEGLOV, V.V. and KLEYMENOV, N.I., 2003. *Norms and Rations of Feeding Farm Animals*. Moscow: Agropromizdat.

KIM, W.S., NEJAD, J.G., PENG, D.Q., JO, Y.H., KIM, J. and LEE, H.G., 2022. Effects of different protein levels on growth performance, stress parameters in beef calves under heat stress. *Scientific Reports*, vol. 12, no. 1, pp. 8113. https://doi.org/10.1038/s41598-022-09982-4. PMid:35581285.

MORALES, Á.G., NAVARRO, Á.R., PULIDO, R.G. and HANIGAN, M.D., 2024. Characterization of in situ ruminal degradation of crude protein, individual amino acids from ryegrass. *Agriculture*, vol. 14, no. 12, pp. 2283. https://doi.org/10.3390/agriculture14122283.

NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE – NASEM, 2021. *Nutrient requirements of dairy cattle*. 8th ed. Washington: The National Academies Press. 502 p. https://doi.org/10.17226/25806

NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE – NASEM, 2016. *Nutrient requirements of beef cattle*. 8th ed. Washington: The National Academies Press. 494 p. https://doi.org/10.17226/19014

NRC, 2001. *Nutrient requirements of beef cattle*. 7th ed. Washington: National Academy Press.

OLIVEIRA JUNIOR, B.R., RIBAS, M.N., MACHADO, F.S., LIMA, J.A.M., CAVALCANTI, L.F.L., CHIZZOTTI, M.L. and COELHO, S.G., 2017. Validation of a system for monitoring individual feeding, drinking behaviour, intake in young cattle. *Animal*, vol. 12, no. 3, pp. 634-639. https://doi.org/10.1017/S1751731117002002. PMid:28820079.

SCHWAB, C.G. and BRODERICK, G.A.A., 2017. 100-Year Review: protein and amino acid nutrition in dairy cows. *Journal of Dairy Science*, vol. 100, no. 12, pp. 10094-10112. https://doi.org/10.3168/jds.2017-13320. PMid:29153157.

TILEPOVA, A., ARNEY, D.R., BOSTANOVA, S. and USKENOV, R., 2024. Evaluation of Qazaq Aqbas bulls’ feed efficiency traits for breeding goals: A case study. *Smart Agricultural Technology*, vol. 9, pp. 100554. https://doi.org/10.1016/j.atech.2024.100554.

USKENOV, R., AKKAIR, B., BOSTANOVA, S., KONCA, Y. and STRELETS, A., 2024b. The relationships between the types of temperament on residual feed intake, the productivity of Kazakh White-Headed bulls. *Journal of Animal Behaviour and Biometeorology*, vol. 12, no. 2, pp. e2024015. https://doi.org/10.31893/jabb.2024015.

USKENOV, R., MIRMANOV, A., TRETYAKOV, I. and BOSTANOVA, S., 2023. Automatic cattle weighing on pastures with behavioral analysis during drinking. *Journal of Animal Behaviour and Biometeorology*, vol. 11, no. 3, pp. e2023020. https://doi.org/10.31893/jabb.23020.

USKENOV, R.B., YENGSEBEK, T.D. and KONCA, Y., 2024a. The effect of protein content in the diet of Kazakh white-headed bulls on their growth and development. *Scientific Journal Bulletin of Science of S.Seifullin Kazakh Agro Technical Research University*, vol. 2, no. 121, pp. 71-81.

XIA, C., RAHMAN, M.A.U., YANG, H., SHAO, T., QIU, Q., SU, H., CAO, B., 2018. Effect of increased dietary crude protein levels on production performance, nitrogen utilisation, blood metabolites, ruminal fermentation of Holstein bulls. *Asian-Australasian Journal of Animal Sciences*, vol. 31, no. 10, pp. 1643-1653. https://doi.org/10.5713/ajas.18.0125. PMid:29879836.