International Journal of Agriculture and Biosciences 2025 14(6): 1231-1239.
https://doi.org/10.47278/journal.ijab/2025.108

RESEARCH ARTICLE
eISSN: 2306-3599; pISSN: 2305-6622

Novel Feed Mixture from Non-Traditional Forage Plants for Young Farm Animals

Sholpan Bakhtiyarova [1], Unzira Kapysheva [1], Yerbulat Makashev [1], Bolatbek Zhaksymov [1,*], Yerlan Makashev [1], Askar Kalekeshov [1], Ainur Junussova [1] and Zhanat Bimenova [2]

[1]Institute of Genetics and Physiology, 93 Al-Farabi Ave., Almaty, 050040, Kazakhstan
[2]Kazakh National Agrarian Research University, 8 Abay Ave., Almaty, 050010, Kazakhstan
*Corresponding author: bolat_kaz@inbox.ru

ABSTRACT

Nowadays, the production of feed mixtures from non-traditional perennial forage plants has become a promising area in Kazakhstan and worldwide. The current study evaluates the effects of the Topirum feed mixture, composed of local montmorillonite and green biomass of *Rumex* K-1 and Jerusalem artichoke, on the growth and metabolic health of sheep, to assess its ability to compensate for the deficiency in the daily diet of farm animals in arid regions. The experimental group, supplemented with 200g of Topirum daily, showed a significant improvement in average daily weight gain (220-280g) compared to the control group (140-170g), leading to a 24.1% weight increase over 30 days. Hematological analysis revealed substantial increases in red blood cell (RBC) count (33.9%) and hemoglobin (HGB) levels (18.5%) in the experimental group, indicating enhanced oxygen transport. Biochemical analysis indicated improved protein metabolism and nutritional status, with significant rises in protein (17.1%), albumin (26.2%), glucose (39.6%), and creatinine (70.0%). The activity of alkaline phosphatase also increased by 93.2%, confirming active musculoskeletal growth. These results suggest that Topirum effectively enhances growth and metabolic health in sheep, supporting its potential application in livestock nutrition to improve productivity in arid regions.

Keywords: *Rumex*; Helianthus; Bentonite; Blood biochemistry; Sheep.

Article History
Article # 25-102
Received: 05-Mar-25
Revised: 01-May-25
Accepted: 15-May-25
Online First: 16-Jul-25

INTRODUCTION

Kazakhstan has vast areas of agricultural land, providing a practical basis for supplying livestock farms with feed (Kuanyshbayeva et al., 2025). However, over the past decade, there has been a steady trend towards a reduction in the area under forage crops (Petrov et al., 2024). Meanwhile, the number of farm animals in the country has been steadily increasing. In 2017, the cattle population stood at 6,247 thousand heads, and small livestock at 17,947 thousand. By 2022, these numbers had grown by 34.4% and 5.94%, respectively, reaching 8,395 thousand for cattle and 19,014 thousand for small livestock (Kopzhanova, 2023). Regionally, as of October 1, 2023, the Almaty region alone had more than 553.6 thousand heads of cattle and 3.2 million sheep. Given the high number of farm animals, there is an acute shortage of feed. Therefore, at the governmental level, an additional 10 billion tenge (~ 22.1 million US dollars) has been financed for feed purchases (Business Information Center Capital, 2023).

One of the primary reasons for the low level of feed production is the arid climate of semi-desert zones, which hinders farms from creating timely green feed reserves. This situation negatively affects the fattening of young animals and the production of high-quality livestock products (Smailov et al., 2015; Gnezdilova et al., 2025). In this context, the use of non-traditional forage plants that can grow in arid conditions and compensate for the feed shortage when raising farm animals in the agro-industrial complex is becoming increasingly important.

Rumex K-1 (*Rumex patientia* × *Rumex tianshanicus*), an interspecific hybrid of spinach and Tien Shan sorrel, is a fodder plant rich in vitamins, trace elements, and protein. This perennial plant has a strong root system that can reach depths of up to 3m, which is crucial in arid regions (Usova & Usov, 2017; Fomichev et al., 2021). Since the end of the last century, *Rumex* K-1 has been successfully incorporated into livestock feeds in the Commonwealth of Independent States (CIS countries), the European Union (EU) and China. Furthermore, recent studies have reported

Cite this Article as: Bakhtiyarova S, Kapysheva U, Makashev Y, Zhaksymov B, Makashev Y, Kalekeshov A, Junussova A and Bimenova Z, 2025. Novel feed mixture from non-traditional forage plants for young farm animals. International Journal of Agriculture and Biosciences 14(6): 1231-1239. https://doi.org/10.47278/journal.ijab/2025.108

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the successful incorporation of *Rumex* into a protein-vitamin feed product with antioxidant and probiotic properties (Fomichev et al., 2021) and its use as a multi-enzyme raw material that enhances digestion and metabolism in ruminants (Kryukov et al., 2021). In Central Asian countries, *Rumex* leaf flour was used as a feed additive in broiler chicken diets (Azzam et al., 2020), while in Spain, *Rumex* was included as an ingredient in pig feed (Fabà et al., 2019). The therapeutic use of certain *Rumex* spp. has also been investigated; for instance, in Turkey, *Rumex* was studied for the treatment of type II diabetes in humans (Degirmenci et al., 2002; Al-Masri et al., 2024; Ayele et al., 2024). Indeed, *Rumex*-derived products ("Ruminal" and decoctions) have been proven to beneficially affect haemostasis, erythropoiesis, and leukocytopoiesis in lambs, as well as product quality (Kositsa, 2015; Yatusevich et al., 2020). National researchers confirmed the potential of *Rumex* K-1 to serve as a source of protein, iron (Fe) and other nutrients, considering its extended period of use (10–15 years). It also demonstrates high biomass and seed yields (30–50 and 0.09–0.095t ha^{-1}, respectively), along with an essential protein content of 23–29% (Kukusheva & Stepanov, 2016, 2019).

Besides *Rumex* K-1, Jerusalem artichoke (*Helianthus tuberosus*) has become widely recognized in the food and agricultural industries of many countries, including Kazakhstan, due to its high content of pectin, vitamins, inulin, and biologically active compounds (BACs) (Mahkamov et al., 2019; Partoev et al., 2020; Zhaksygulova et al., 2022). *H. tuberosus* produces tubers and highly nutritious green biomass, yielding up to 30t ha^{-1}. Plant biomass is harvested twice a year, once when the plant reaches 80-100cm in height and in October. The harvest value of *H. tuberosus* biomass can reach 55t ha^{-1} or even more, contributing to the plant's practical importance in farming regions with arid climates, such as the south of Almaty and Atyrau regions, Kazakhstan. Furthermore, Jerusalem artichoke, having multivitamins and a wide mineral composition, can be cultivated on marginal lands as a low-cost auxiliary feed crop (Starovoitov et al., 2013a, 2013b, 2015). Indeed, the positive influence of *H. tuberosus* on animal fertility was detected, contributing to the idea of utilizing the plant as a non-traditional forage crop given to its richness in pectin, inulin and BACs, especially polyunsaturated fatty acids (FAs) (Cai et al., 2021).

Considering the high nutritional value of *Rumex* K-1 and *H. tuberosus*, the current study aimed at evaluating the effectiveness of the mixture Topirum, consisting of powdered green biomass of the above plants along with montmorillonite (bentonite). It was hypothesised that the developed mixture Topirum will effectively compensate for the deficiency of daily feeds' nutrients and minerals, thereby advancing the agro-industrial complex in Kazakhstan. Bentonite (TAGBENT LLP, Kazakhstan; https://tagbent.com) used for mixture development has been confirmed to prevent feed mineral deficiency and improve the growth and productivity of cattle and livestock. Bentonite, a finely dispersed clay composed of minerals from the montmorillonite group, possesses high binding capacity, adsorption, catalytic and antimicrobial activity, making it a valuable ingredient in premixes and feeds (Sapargaliev & Kravchenko, 2007; Danilov & Vorobyov, 2012). Numerous studies have shown that adding minerals in the form of premixes to the daily diet of farm animals significantly increases weight gain (Markowiak & Śliżewska, 2018; Ramalan et al., 2022). Due to its structural layering, bentonite easily mixes with any powdered additives, making it ideal for developing therapeutic, preventive, and health-improving preparations for cattle and livestock.

The current study focused on developing an affordable and nutritious feed mixture using local montmorillonites combined with the dried green biomass of non-traditional forage plants, *Rumex* K-1 and *H. tuberosus*, cultivated in arid regions of Kazakhstan. Additionally, the study aimed to provide physiological and biochemical evidence for the efficacy of the developed feed mixture, Topirum, while presenting a promising opportunity to expand the food supply in the country's arid regions.

MATERIALS & METHODS

Feed Mixture Preparation

The green biomass of 8–10-week-old plants (40-50cm in height) of *Rumex* K-1 (*Rumex patientia* × *Rumex tianshanicus*) and Jerusalem artichoke (*H. tuberosus*) was harvested, dried, powdered, and used as the main source of active substances in the feed mixture. Bentonite (benthophosphocalzenite), a montmorillonite from the Tagansky deposit (TAGBENT LPP, Kazakhstan; https://tagbent.com), was used as a natural adsorbent in the form of a fine powder. The components of the feed mixture were combined in equal parts (ratio of 1:1:1), with 330-350g each of the green biomass of *Rumex* K-1, green biomass of Jerusalem artichoke, and bentonite per 1.0kg of the mixture.

The feed mixture was prepared in a special tank with constant stirring until a homogeneous soft mass was obtained. The resulting mixture was then dried on special stands in the open air. The following criteria determined the readiness of the raw material: the powder should be finely dispersed to the touch and crumble easily into pieces. Next, the feed mixture powder, Topirum, was packaged in 5kg paper bags. During storage, hygienic and technical conditions were maintained per sanitary regulations (TR, TS 021/2011). The nutrient composition of the feed mixture Topirum is shown in Table 1.

Experimental Conditions and Farm Management

The experiment was conducted at two small-scale peasant farms located in the Almaty region of Kazakhstan, approximately 58km apart. Both farms are situated in semi-arid zones and share similar climatic and topographic characteristics, with daily temperature variations ranging between +5°C and +30°C during the study period. Both farms used the same type of housing (ventilated barns with straw bedding), feeding regimen, water supply system, and staffing levels. To ensure uniformity, all experimental procedures, including feeding, weighing, and blood sampling, were carried out by trained personnel.

Table 1: Blood cellular composition of the studied animals before and after consuming the standard diet and the feed mixture Topirum

Samples of feed mixtures/ indicator (%)	Green mass of Rumex K-1 g/kg	Green Jerusalem artichoke mass g/kg
Dry matter	59.2	19.68
Crude protein	9.25	3.76
crude fat	2.49	6.50
Raw fiber	15.52	4.31
BEV	54.52	7.53
Sugar	26.47	19.45
Starch	41.0	45.8
Ash	54.12	3.59
Calcium mg/100g	6.01	0.14
Phosphorus mg/100g	0.40	0.78
Potassium mg/100g	3.21	4.29
Magnesium mg/100g	0.38	0.17
Tryptophan	0.96	0.014-0.058
Methionine	2.11	0.03
Lysine	3.88	0.134
Threonine	4.69	0.124
Feed unit, kg	0.49	0.20
Digest. protein, g	108.0	28.0
, energy, MJ	2.89	9.6
EKE energet.feed.ed.	0.29	0.87

Experimental Layout

Fifty rams of various breeds (Gissar, Bayys, Merino, and Romanovskaya), aged 8 to 10 months, were selected randomly and divided into control and experimental groups. The control group received a standard feedlot diet, consisting of 1.5kg of palletized concentrates made from grain crops (oats and wheat) and dry hay ('GOODZHEM German Feed Mill' LLP, Taraz, Kazakhstan; http://www.goodzhem.kz) per head daily.

The daily diet of the experimental group consisted of 1.3 kg of pelletized concentrates, to which 200g of a feed mixture powder, Topirum, was added, calculated at 5g/kg of body weight. One package (5kg) of the feed mixture was sufficient for 25 sheep. Over 30 days, a total of 300kg of Topirum was prepared and consumed by the experimental group.

Topirum is a locally developed feed supplement composed of equal parts (1:1:1) of dried green biomass of Rumex K-1 (Rumex patientia × Rumex tianshanicus), Helianthus tuberosus (Jerusalem artichoke) and montmorillonite clay (bentonite) sourced from the Tagan deposit. The mixture was formulated and produced by the research team at the Institute of Genetics and Physiology, Almaty, Kazakhstan.

Physiological and Biochemical Analysis

Every morning for 30 days, the animals were weighed on specially adapted, fenced electronic scales (Classic-500, China) installed on the site. Blood samples were taken from the jugular vein before and after the 30-day observation period for both the control and experimental groups.

For blood analysis, a hematology analyzer (KX-219, Sysmex Corporation, Japan), an electrolyte analyzer (AVL9190, Roche Diagnostics, Austria), and an automated biochemistry analyzer (A-25, BioSystems, Spain) were used, along with test kits, according to standards as demonstrated by Vasileva (2000). The levels of total protein, albumin, glucose, cholesterol, alanine aminotransferase (ALT), aspartate transaminase (AST), alkaline phosphatase (ALP-DEA), triglycerides, creatinine, urea, and total bilirubin were measured using standard commercial reagents on biochemistry analyser (A-25, BioSystems, Spain) (Kondrakhin et al., 2004; Medvedeva, 2013).

The blood samples were anticoagulated with heparin (2-3UmL^{-1}), centrifuged at 1500rpm for 10min; then erythrocytes were separated from plasma. Blood plasma samples were analysed *in vivo* for total protein content following the biuret technique to calculate malondialdehyde (MDA) and the level of lipid peroxidation (LPO) by measuring the content of intermediate (diene conjugates) and final (malondialdehyde) peroxidation products. In addition, catalase (CAT) activity on the cell membranes of blood erythrocytes was assessed (Babenko & Goynatsky, 1976).

Statistical Analysis

The data analysis was performed using RStudio software (version 2023.06.0 Build 421, RStudio PBC, 2023). One-way or Repeated Measures ANOVA was used to confirm statistical significance, with significance declared at $P<0.05$. The data were presented in the following format: arithmetic mean±SD (Lakin, 1990).

RESULTS & DISCUSSION

Influence of 'Topirum' Feed Mixture on Body Weight Alterations

Before the experiment establishment, the average weight of sheep in the control and experimental groups was 39.1±1.81 and 38.0±2.85kg ($P = 0.085$). In the control group of sheep fed a standard diet, the average daily weight gain ranged from 140 to 170g per animal. In the experimental group, where the diet was supplemented with 200g of a feed mixture 'Topirum' daily, the average weight gain ranged from 220-280g per sheep. Thus, the daily weight gain in the experimental group was 80-100g higher compared to the control group (Fig. 1a).

In the experimental group, within 30 days of introducing the developed feed mixture into the diet, the average weight of each sheep increased from 38.0 to 47.1kg (by 24.1%). In contrast, the average weight of the control group animals increased from 39.1 to 42.3kg (by 8.19%). Thus, after 30 days of consuming the feed mixture 'Topirum', the average weight of the experimental group was 11.9% greater than that of the control group animals (Fig. 1b).

Influence of Topirum Feed Mixture on Haematological Alterations

Haematological analysis of blood samples collected from animals under study showed that all values fell within the reference range for 8-10-month-old sheep (Table 2). In the control group, the only significant change observed was a 10.7% increase ($P<0.05$) in red blood cell (RBC) count. In the experimental group, which received the "Topirum" feed mixture, both RBC and haemoglobin (HGB) values changed significantly after 30 days of consumption. Specifically, RBC increased by 33.9% ($P<0.01$) and HGB by 18.5% ($P<0.05$) compared to the values analysed before initiating the study (Table 2).

Table 2: Blood cellular composition of the studied animals before and after consuming the standard diet and feed mixture Topirum

Index	Unit	Ref. values for 8-10-month-old sheep	Time	Ctrl	% to before	Exp	% to before	P-value	% to Ctrl
RBC	× 10^6 μL^{-1}	8.0-16.0	Before	8.98±0.21	100	8.99±0.31	100	0.965	-
			After	9.94±0.39	111	12.0±0.38	134	<0.01	121
			P-value	P<0.05		P<0.001			
HGB	g dL^{-1}	80.0-160	Before	111±8.30	100	114±9.50	100	0.692	-
			After	119±8.60	-	135±8.60	119	0.085	-
			P-value	P>0.3		P<0.05			
WBC	× 10^3 μL^{-1}	6.0-14.0	Before	6.98±0.23	100	6.95±0.31	100	0.899	-
			After	6.88±0.33	-	6.93±0.35	-	0.866	-
			P-value	P>0.689		P>0.944			

Notes: Ref. – reference; Ctrl – control group; Exp – experimental group; RBC – red blood cells; HGB – haemoglobin; WBC – white blood cells

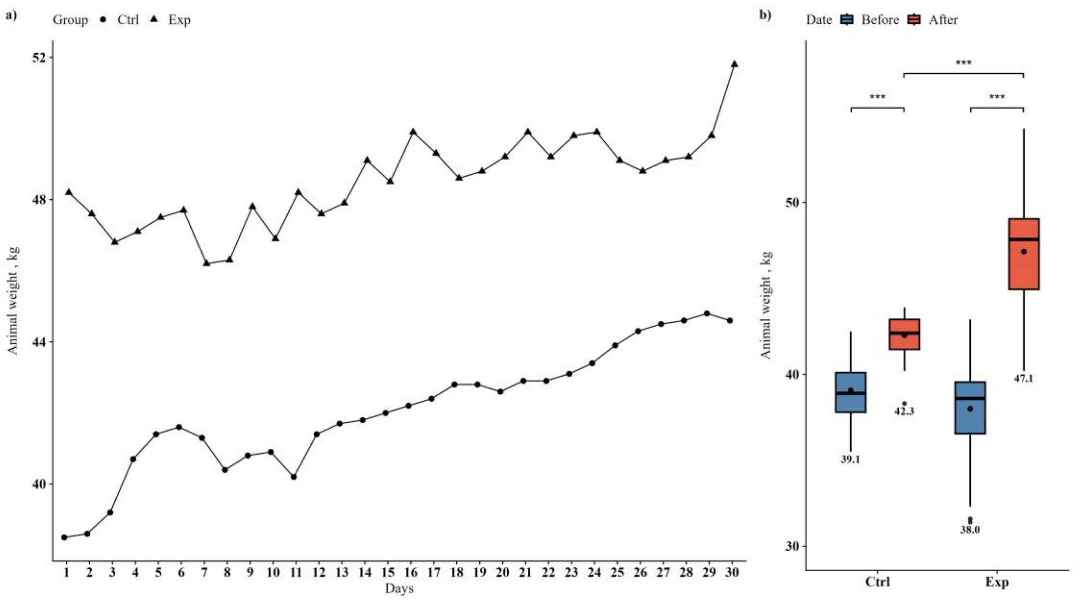

Fig. 1: Average weight changes during the 30 days in the control and experimental groups.

Comparing the control and experimental groups after the 30-day period revealed that the "Topirum" feed mixture beneficially affected RBC count values, showing a 21.1% increase (P<0.01), with a tendency to increase HGB as well (P<0.01). This suggests that prolonged consumption of the mixture can significantly increase HGB levels. HGB is a key indicator of oxidative and metabolic processes in the body. It transports oxygen (O_2) and carbon dioxide (CO_2) and binds toxic substances. A slight increase in HGB levels within the physiological norm in the experimental sheep was ensured by an increase in RBC count, which plays a crucial role in maintaining acid-base and respiratory balance as well as immune resistance (Kamyshnikov, 2009). Regarding white blood cell (WBC) count, no significant alterations were found within or between the groups under study.

Many other studies support the idea that feed mixtures can increase HGB and RBC levels of cattle. According to Kozinec et al. (2024), the feed additive "MDK" with the yeast *Saccharomyces boulardii*, administered at 10g/head/day, positively influenced the haematological parameters of young cattle. Specifically, it increased the number of RBCs by 3.2% and haemoglobin levels. The study of Kushwaha et al. (2022) found that dietary supplementation of copper, both inorganic and nano forms, resulted in higher haemoglobin (HGB) content, packed cell volume (PCV), and red blood cell (RBC) count in growing Sahiwal heifers compared to the non-supplemented group.

Influence of 'Topirum' Feed Mixture on Blood Biochemical Composition

Biochemical analysis of blood samples collected after 30 days from the control group showed a significant increase in albumin (13.5%), alkaline phosphatase (ALP-DEA; 38.3%), and alanine aminotransferase (ALT; 16.9%) at P<0.05. Moreover, in the experimental group, the increases were more pronounced, specifically protein content increased by 17.1%, albumin by 26.2%, glucose by 39.6% (P<0.01), and creatinine by 70.0% (P<0.01), compared to the baseline data (Fig. 2).

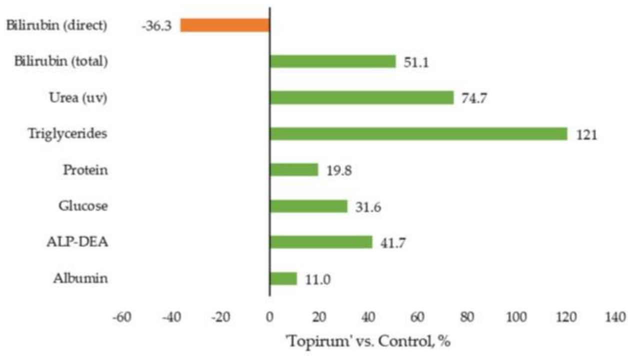

Fig. 2: Visualisation of the feed mixture 'Topirum' influence on blood biochemistry. Note: only significant influence of feed mixture 'Topirum' on blood biochemistry is shown.

Urea, uric acid, and creatinine levels in the blood indicate the state of protein metabolism. These substances are formed in the liver, enter muscle cells and the rumen, providing nitrogen to the rumen microflora and energy to muscles, and are ultimately excreted through the kidneys. Initial downward shifts in the levels of urea, creatinine, and uric acid in sheep reflect deficiencies in protein metabolism and ruminal digestion (Fomichev et al., 2020; Mishurov, 2021). The minimum level of creatinine indicates the energy supply in the cells and a deficiency of nutrients in the daily diet. After 30 days, the control group showed no changes in uric acid and urea levels (Table 2). In contrast, the experimental group exhibited a significant increase in urea (79.3%) and uric acid (25.1%). The urea/creatinine ratio in the experimental group remained within 0.06 (<0.08), indicating the effectiveness of the feed mixture as a source of protein-lipid nutritional components and the absence of factors contributing to pathological abnormalities in the liver and heart. The study of Carneiro de Souza et al. (2021) evaluated the effects of different protein sources and inclusion levels on nitrogen metabolism in Nellore feedlot steers. Results showed that diets based on soybean meal and urea increased blood urea nitrogen levels. In contrast, alternative protein sources like corn gluten meal and dried distillers' grains led to more favourable nitrogen utilization and stable blood metabolite profiles.

The levels of triglycerides in the control group corresponded to the minimum reference values, reflecting a deficiency of fat components in the daily diet of young sheep. In the experimental group, this indicator increased and fluctuated within the maximum physiological norm after introducing the Topirum feed mixture into the diet (Table 3).

Significant changes were noted in the blood of both control and experimental sheep regarding the aspartate transaminase (AST) and ALP activity. Initially, both groups exhibited an increase in the cellular enzyme AST, with levels 50-60% above the maximum reference value, which persisted after 30 days. The content of ALP was within the maximum reference value at the start, but after 30 days, it increased by 38.3% in the control group and doubled (by 93.2%) in the experimental group. ALP is an important indicator of the metabolic status of a growing organism. The relationship between increased ALP and enzymatic activity in the blood with the productivity of farm animals has been confirmed by numerous studies. In particular, the activity of AST and ALT in the blood of young cattle and livestock significantly increases (up to 4 times) depending on age and weight gain rate (Soboleva et al., 2012; Mishurov et al., 2018; Zharikov & Kaneva, 2021). In the current study, a significant increase in enzymatic activity alongside the rise in ALP following the introduction of the 'Topirum' feed mixture into the daily diet confirms the active growth of musculoskeletal mass in young animals (Table 3).

The blood samples of sheep fed a 'Topirum' feed mixture containing green biomass of Rumex K-1 and Jerusalem artichoke, along with montmorillonite, showed higher levels of total protein due to increased albumin levels, the main building protein. In addition, higher concentrations of glucose, creatinine, triglycerides, cholesterol, and AST were detected. These changes reflect enhanced activity in protein, carbohydrate, and fat metabolism, and increased metabolic processes in the liver, which are typical during the development and growth of the musculoskeletal mass in farm animals (Dementieva, 2014). These results coincide with the ones of Matache et al. (2023): the inclusion of *Rumex* species in livestock feed has been shown to enhance the nutritional profile by providing a higher concentration of essential nutrients such as proteins, vitamins, and minerals. Specifically, *Rumex* serves as a rich source of bioactive compounds and phytonutrients, contributing to improved feed efficiency and animal health.

Table 3: Blood biochemical composition of the studied animals in the control and experimental groups. Percent (%) was calculated only for significant changes

Parameters	Unit	Ref. values	Time	Ctrl	% to before	Exp	% to before	% to Ctrl	P-value		
									Group	Time	G × T
Albumin	g L^{-1}	35.0-54.1	Before	38.6±0.40c	100	38.5±0.90c	100	-	<0.05	<0.001	<0.05
			After	43.8±1.00b	113	48.6±2.31a	126	111			
ALP-DEA	U L^{-1}	27.0-156	Before	132±3.90c	100	134±13.1c	100	-	<0.01	<0.001	<0.01
			After	182±8.40b	138	258±25.5a	193	142			
ALT	U L^{-1}	15.0-44.0	Before	42.1±2.52	100	42.3±2.50	100	-	0.074	<0.001	0.086
			After	49.2±1.21	117	55.3±3.70	131	-			
AST	U L^{-1}	49.0-123	Before	174±11.4	100	203±19.0	100	117	<0.05	0.241	0.888
			After	188±9.30	-	214±23.1	-	114			
Cholesterol	mML^{-1}	1.1-2.3	Before	1.24±0.02bc	100	1.19±0.01c	100	-	1.00	<0.001	<0.01
			After	1.89±0.04ab	-	2.29±0.17a	192	-			
Creatinine	μM L^{-1}	76.0-174	Before	84.4±1.30bc	100	81.8±2.80c	100	-	0.564	<0.001	<0.05
			After	95.0±4.60ab	-	139±9.00a	170	-			
Glucose	mM L^{-1}	2.4-4.5	Before	4.03±0.04	100	4.09±0.10	100	-	0.056	<0.001	0.333
			After	4.34±0.15	-	5.71±0.60	140	132			
Protein (total)	g L^{-1}	59.0-78.0	Before	80.7±0.60	100	81.8±1.30	100	-	<0.05	0.355	0.065
			After	80.0±2.50	-	95.8±6.10	117	120			
Triglycerides	mM L^{-1}	0.20-0.56	Before	0.20±0.01	100	0.19±0.06	100	-	0.233	<0.01	0.130
			After	0.24±0.01	-	0.53±0.04	279	221			
Urea (uv)	mM L^{-1}	3.7-9.3	Before	4.52±0.15	100	4.55±0.21	100	-	0.145	<0.05	0.192
			After	4.67±0.03	-	8.16±1.30	179	175			
Uric acid	μM L^{-1}	-	Before	20.0±1.19	100	19.1±1.40	100	-	0.665	<0.01	0.197
			After	22.1±2.31	-	23.9±1.60	125	-			
Bilirubin (total)	μM L^{-1}	0.7-8.6	Before	4.75±0.26	100	4.51±0.30	100	-	0.413	<0.01	0.061
			After	5.38±0.40	-	8.13±0.73	180	151			
Bilirubin (direct)	μM L^{-1}	-	Before	3.09±0.07 a	100	2.92±0.21 a	100	-	<0.001	<0.01	<0.01
			After	3.20±0.23 a	-	2.04±0.22 b	69.9	63.8			

Notes: Ref. – reference; Ctrl – control group; Exp – experimental group; tendency ($P<0.10$) marked bold.

The use of a feed mixture from non-traditional forage plants such as *Rumex* K-1 and Jerusalem artichoke demonstrated several advantages: high-calorie content (reflected in increased glucose, albumin, and ALP levels) and protein saturation, alongside moderate activity of cholesterol, creatinine, and triglycerides. These results indicate a tendency towards a stable increase in fat and muscle mass without the development of pathological abnormalities in the hepatobiliary system.

The lipid peroxidation (LPO) of erythrocyte cell membranes in blood samples from both control and experimental groups of sheep was investigated to evaluate metabolic activity, which in turn depends on redox reactions at the cellular level, with free radical oxidation (FRO) playing a crucial role. The increase in free radicals activates numerous reactions required for normal physiological processes. However, excessive FRO can damage membrane processes, disrupting metabolic activities and reducing the productivity of farm animals (Kirbas et al., 2014; Kashirina et al., 2022).

LPO products include primary oxidation products of polyunsaturated fatty acids (FAs), such as diene conjugates (DC), which are metabolized into secondary peroxide products like malondialdehyde (MDA) and acetone. These compounds accumulate on cell membranes, destroy subcellular structures, disrupt tissue respiration, and lead to inflammation. Increased LPO can cause an imbalance in the enzymatic and non-enzymatic components of the antioxidant defence system, resulting in oxidative stress.

Enzymatic oxidation is essential for renewing the phospholipid bilayer of cell membranes, forming biologically active compounds (BACs), detoxifying the body, and participating in metabolic reactions. In contrast, non-enzymatic oxidation leads to the accumulation of peroxides, significantly reducing the activity of the antioxidant system's limiting and controlling mechanisms (Tihanov & Shabanov, 2022).

The levels of DC and MDA were determined as quantitative markers of LPO in the current study. The concentrations of DC, a primary product, and MDA, a secondary product of LPO, were used to indicate the intensity of the LPO process and to serve as markers of the degree of endogenous intoxication (Del Rio et al., 2005). Typically, high levels of MDA are associated with severe endogenous free radical toxicity. The activity of catalase (CAT) was considered an indicator of enzymatic activity or anti-peroxide protection, as well as an antioxidant. An increase in CAT synthesis is linked with the need to utilise excess peroxides and the products of their further metabolism. Therefore, CAT activity was examined as a criterion for LPO activity.

The evaluation of the antioxidant properties of the blood plasma in the experimental group showed an increase in CAT by 1.6 times and a decrease in oxidative activity by 1.2 times. In the control group, after 30 days of observation, the levels of primary and secondary oxidation products were as follows: DC - 0.163±0.02, MDA - 1.162±0.013, and CAT - 0.234±0.005. In the experimental group, the levels were DC - 0.134±0.002, MDA - 0.967±0.08, and CAT - 0.382±0.05 (P≤0.01). A decrease in primary and secondary peroxidation products at the cellular level was observed, indicating a low level of nutritional factors stimulating oxidative processes. An increase in the level of CAT was noted, indicating pronounced protective antioxidant properties of the novel feed mixture. Consequently, after 30 days of feeding with the 'Topirum feed mixture, an increase in the antioxidant properties of the blood was revealed, attributed to the inclusion of green plant matter in the mixture.

High animal productivity relies on the optimal functioning of all organs and systems. Monitoring the biochemical parameters of blood in farm animals is essential for timely intervention and mitigating adverse external or internal factors that influence the animal's health. In healthy animals, stable blood properties reflect proper feeding, food safety, and metabolic activity (Chizhova & Romahova, 2012; Klimanova et al., 2020). Blood biochemistry during animal development highlights the need to expand the food supply to compensate for nutrient deficiencies in the diet (Demidovich, 2019).

Currently, feed additives from non-traditional raw materials are being developed in many countries. In China, a mixture of amaranth seeds (*Suaeda glauca*) has been developed to boost small sheep productivity (Sun & Zhou, 2010). Curcumin has been found to promote lipid metabolism and improve antioxidant status in sheep (Jiang et al., 2019). In India, a flour mixture from drought-resistant *Moringa* seeds has been developed (EL-Hedainy et al., 2020). Mexican researchers have formulated a diet for young sheep that includes a dry concentrate of poly-herbs, such as nightshade (*Withania somnifera*), basil (*Ocimum tenuiflorum*), vine (*Tinospora cordifolia*), and fruit tree (*Emblica officinalis*), previously unused (Razo Ortiz et al., 2020). Moreover, the need for analysing blood biochemistry in all studies is especially emphasised as an indicator of sheep well-being and comparability with the corresponding reference values (Sarmin et al., 2021; Nedeva et al., 2022).

The application of the newly developed 'Topirum' feed mixture for 30 days led to increased concentrations of total protein, albumin, glucose, cholesterol, and enzymatic activity, indicating enhanced protein- carbohydrate- fat metabolism (Aristov et al., 2023). A study of LPO on plasma cell membranes showed consistently low oxidative processes in the blood of sheep who consumed the Topirum feed mixture for 30 days, suggesting its high antioxidant and protective effects. Significant biochemical changes in the blood of sheep were detected after 30 days of feeding with Topirum. Indeed, with the continued inclusion of 'Topirum' key components in the diet during the fattening period, farmers can achieve rapid weight gain and produce high-quality meat from healthy animals. Nowadays, farms in the Almaty region have expressed interest in improving their feed supply by using non-traditional perennial forage crops. Hence, it may provide an opportunity to expand the farms' feed supply with nutritious, protein- and pectin-rich mixtures, enhancing the growth rate of young animals.

Conclusion

The novelty of this research lies in the development and testing of a previously unreported combination of

Rumex K-1, H. tuberosus, and montmorillonite as a single, locally sourced feed additive. Unlike prior studies that focused on these components individually, the present study demonstrates the synergistic effects of this formulation on protein metabolism, antioxidant protection, and musculoskeletal development in sheep under semi-arid conditions.

The supplementation of sheep diets with the 'Topirum' feed mixture, consisting of *Rumex patientia* × *Rumex tianshanicus*, *Helianthus tuberosus*, and bentonite, significantly enhanced their growth performance and metabolic health. Over 30 days, the experimental group, receiving 200g of 'Topirum daily, showed an average daily weight gain of 220-280g, compared to 140-170g in the control group. This resulted in a 24.1% increase in average weight for the experimental group (from 38.0 to 47.1kg) versus an 8.19% increase in the control group. Haematological analysis indicated significant increases in RBC count (33.9%) and HGB levels (18.5%) in the experimental group, suggesting enhanced oxygen transport due to 'Topirum' supplementation. Biochemical analyses revealed significant increases in protein (17.1%), albumin (26.2%), glucose (39.6%), and creatinine (70.0%) in the experimental group, indicating improved protein metabolism and nutritional status. Urea and uric acid levels also increased significantly (by 79.3 and 25.1%, respectively) in the experimental group, further supporting the enhanced protein metabolism. The activity of ALP increased by 93.2% in the experimental group, compared to a 38.3% increase in the control group, indicating improved metabolic status and active musculoskeletal growth.

Thus, study findings suggest potential applications of the feed mixture 'Topirum' in enhancing livestock productivity and health, warranting further research to explore its broader impacts and optimise its use in animal husbandry.

DECLARATIONS

Funding: This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, grant number AP19676489.

Acknowledgment: The authors would like to thank the editors and reviewers for their valuable contributions to the manuscript.

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

Data Availability: Data will be available upon request to the corresponding author.

Ethics Statement: The animal study protocol was approved by the Institutional Ethics Committee of the Republican State Enterprise with the Right of Economic Management "Institute of Genetics and Physiology" of the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Protocol No. 6 dated 03.11.2022, ref. No. 12-315).

Author's Contributions: Conceptualization, UK, and SB; methodology, EM; software, BZ; validation, AJ, EM and EM; formal analysis, UK; investigation, AK; resources, BZ; data curation, SB; writing—original draft preparation, UK; writing—review and editing, AK; visualization, SB; supervision, UK; project administration, UK; funding acquisition, UK. All authors have read and agreed to the published version of the manuscript.

Generative AI Statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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