

Case report

The effects of a mineral-vitamin blend supplementation on nutritional infertility in cows

P. M. Skliarov*,[#], C. C. Pérez-Marín**, R. V. Mylostyyi*, V. V. Vakulyk*,
D. D. Bilyi*, V. V. Samoiliuk*, L. V. Koreyba*, O. M. Chekan***

*Dnipro State Agrarian and Economic University, Dnipro, Ukraine

**University of Córdoba, Córdoba, Spain

***Sumy National Agrarian University, Sumy, Ukraine

Received: 28 March 2026

Revised: 10 May 2026

Accepted: 03 August 2026

Dnipro State Agrarian and Economic
University, 49000, 25 Serhii Yefremov Str.,
Dnipro, Ukraine

University of Córdoba, 14005, Av. de Medina
Azahara, 3, Poniente Sur, Córdoba, Spain

Sumy National Agrarian University, 40000, 160
Herasyma Kondratieva Str., Sumy, Ukraine

***Corresponding author:**

P. M. Skliarov

skliarov.p.m@dsau.dp.ua

Abstract. Nutritional infertility in high-yielding dairy cattle remains a critical economic and veterinary challenge, primarily driven by trace mineral and vitamin deficiencies inherent to specific biogeochemical provinces. This study aimed to develop and evaluate an experimental mineral-vitamin feed supplement designed to prevent nutritional reproductive failures in cows. The experiment was conducted during the winter-stall period on black-spotted dairy cows exhibiting metabolic deficiencies at baseline. Initial blood serum analysis revealed significant deficits in Se, Cu, and vitamins A and E. To correct these imbalances, a pilot powder-form additive (utilizing fodder chalk as a filler) was formulated, providing, per 1 kg of dry matter, a daily blend of 8000 mg β -carotene, 5400 mg α -tocopherol, 80 mg sodium selenite, and 1540 mg copper sulfate per 1 kg of dry matter. The supplement was mixed with concentrated feed at a daily dose of 50 g per animal for 30 days. Blood serum trace element levels (Fe, Cu, Se, Zn, Mn, Co) were quantified using atomic absorption spectrophotometry, while fat-soluble vitamins (A and E) were analyzed via fluorescence spectroscopy. Following the 30-day supplementation period, the metabolic profile of the experimental group exhibited significant improvement. Selenium content increased by 70.2%, and copper levels rose by 47.9% relative to the minimum threshold. Concurrently, serum concentrations of vitamins A and E significantly increased by 196% and 70.3%. In conclusion, oral supplementation with the developed mineral-vitamin blend effectively restores systemic homeostasis, optimizes the metabolic profile, and serves as a reliable preventive measure against nutritionally-induced reproductive disorders in dairy cattle.

Keywords: female cattle; disorders of reproductive function; preventive measures; trace elements deficiency.

Використання мінерально-вітамінної кормової добавки для профілактики аліментарної неплідності у корів

Анотація. Аліментарна неплідність у високопродуктивних молочних корів залишається серйозною економічною та ветеринарною проблемою, головним чином зумовленою дефіцитом мікроелементів і вітамінів, характерним для окремих біогеохімічних провінцій. Метою цього дослідження було розробити та оцінити експериментальну мінерально-вітамінну кормову добавку, призначену для профілактики порушень репродуктивної функції у корів аліментарного походження. Експеримент проводили у зимово-стійловий період на коровах чорно-рябої молочної породи із виявленими метаболічними дефіцитами на початковому етапі. Початковий аналіз сироватки крові показав значні дефіцити Se, Cu та вітамінів А і Е. Для корекції цих порушень була сформульована пілотна порошкоподібна добавка (з використанням кормової крейди як наповнювача), яка забезпечувала на 1 кг сухої речовини добову суміш: 8000 мг β -каротину, 5400 мг α -токоферолу, 80 мг натрію селеніту та 1540 мг мідного купоросу. Добавку змішували з концентрованим кормом у добовій дозі 50 г на тварину протягом 30 діб. Рівні мікроелементів у сироватці крові (Fe, Cu, Se, Zn, Mn, Co) визначали методом атомно-абсорбційної спектрофотометрії, а жиророзчинні вітаміни (А та Е) аналізували методом флуоресцентної спектроскопії. Після 30-добового періоду згодовування метаболічний профіль дослідної групи значно покращився. Вміст Se зріс на 70,2%, а рівень Cu – на 47,9% відносно мінімального порогового значення. Одночасно концентрація вітамінів А та Е у сироватці значно підвищилася – на 196% та 70,3% відповідно. Таким чином, пероральне введення розробленої мінерально-вітамінної суміші ефективно відновлює системний гомеостаз, оптимізує метаболічний профіль і є надійним профілактичним заходом проти аліментарно зумовлених порушень репродуктивної функції у молочних корів.

Ключові слова: молочні корови; порушення репродуктивної функції; профілактичні заходи; дефіцит мікроелементів.

Cite this article: Skliarov, P. M., Pérez-Marín, C.C., Mylostyyi, R. V., Vakulyk, V. V., Bilyi, D. D., Samoiliuk, V. V., Koreyba, L. V., & Chekan, O. M. (2026). The effects of a mineral-vitamin blend supplementation on nutritional infertility in cows. *Theoretical and Applied Veterinary Medicine*, 14(3), 11–16. doi: 10.32819/2026.14012

Copyright: © 2026 by the authors.

This is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\) license](https://creativecommons.org/licenses/by/4.0/).

Introduction

Reproductive dysfunction in female dairy cattle is closely linked to nutritional factors, which can result in nutritional infertility (Risques, 2020; Skliarov et al., 2026). During gestation and peak lactation, metabolic demands escalate, rendering cows highly susceptible to trace mineral and vitamin imbalances (Gross, 2022; Suslova et al., 2026). These trace mineral and vitamin imbalances severely disrupt cellular homeostasis, impair systemic metabolic profiles, and lead to cellular oxidative stress within the reproductive tract (Van Emon et al., 2020). Consequently, even marginal fluctuations in the physiological concentrations of essential bioactive elements can suppress estrus cycles, delay puberty, and diminish fertility (Perry et al., 2021; Mion et al., 2023; Wang et al., 2026).

Ruminants frequently receive diets deficient in Copper (Cu), Selenium (Se), and fat-soluble vitamins due to their inadequate content in regional soils and forages (Lei et al., 2022; Spears et al., 2022; Dhaliwal et al., 2023). Copper serves as an indispensable catalytic cofactor for numerous metalloenzymes, including cytochrome c oxidase and superoxide dismutase (SOD), which regulate cellular respiration and mitigate free radical damage. Furthermore, Cu status directly modulates the hypothalamic-pituitary-gonadal axis, altering the pulsatile secretion of gonadotropins and correlating with serum progesterone and estradiol profiles. Insufficient dietary Cu suppresses these endocrine mechanisms, leading to delayed or silent estrus, compromised embryonic development, and increased incidence of placental retention (Goff, 2018; López-Alonso & Miranda, 2020).

Selenium (Se) is a vital trace element required for maintaining cellular antioxidant defenses and reproductive health (Arshad et al., 2021). This micronutrient is structurally integrated into selenoproteins, most notably glutathione peroxidase (GPx), which neutralizes reactive oxygen species (ROS) and protects the functional integrity of the endometrium and placental tissues. Subclinical Se deficiency alters uterine contractility, impairs postpartum involution of the reproductive tract, and significantly increases the incidence of embryonic mortality and metritis (Carr et al., 2025). Recent data highlight the critical role of Se in enhancing maternal-fetal immune interactions and ensuring timely placental expulsion (Mehdi et al., 2013; Hogan & Perkins, 2022).

Vitamin E is not a single compound but comprises a group of eight structurally related fat-soluble molecules: four tocopherols and four tocotrienols, among which α -tocopherol possesses the highest biological activity in mammalian tissues (Börmel et al., 2024). Acting as a potent chain-breaking antioxidant, α -tocopherol functions synergistically alongside the glutathione peroxidase pathway to protect cellular lipid bilayers from lipid peroxidation (LPO) by reducing lipophilic free radicals (Niki, 2019). When Se and α -tocopherol are deficient, unchecked accumulation of ROS damages cellular membranes, disrupts steroidogenesis, alters prostaglandin synthesis, and hampers blastocyst survival (Saito, 2021; Wang et al., 2021). Comprehensive dietary fortification with synergistic mineral-vitamin blends has been shown to reduce the service period and improve conception rates by sustaining optimal cellular antioxidant status (Moghim-Kandelousi et al., 2020; Fatima et al., 2025).

Despite extensive research, achieving precise trace mineral and vitamin homeostasis adapted to specific biogeochemical zones remains an ongoing challenge (Van Emon et al., 2020; Spears et al., 2022). Effective clinical correction requires a rigorous pre-supplementation assessment of the structural feed components and baseline animal metabolic status to prevent inadvertent antagonistic interactions or toxicities (Fadlalla, 2022; Khomych & Skliarov, 2024).

Based on these considerations, the aim of this study is to develop a tailored pilot mineral-vitamin feed supplement and evaluate its efficacy in optimizing the metabolic profile and

preventing nutritional infertility in high-yielding dairy cows during the winter-stall period.

Materials and Methods

Experimental Design and Animal Management

The field experiment was conducted during the winter-stall period of 2024-2025 at a private dairy farm (the private enterprise "Roga-Kopyta") located in the Samar district of the Dnipropetrovsk province, Ukraine. A total of 30 high-yielding black-spotted dairy cows (from 3rd to 4th lactation, 400 ± 20 kg body weight, with an average daily milk yield of 20 L) were selected based on similar age, body condition score, and gestation stage (second parity). The animals were randomly assigned to two balanced groups: a control group ($n = 15$) and an experimental group ($n = 15$).

Both groups were fed a baseline total mixed ration (TMR) formulated according to standard regional requirements. The daily baseline diet prescribed per animal included 5 kg of meadow hay, 40 kg of corn silage, and 6 kg of oat grains. Prior to the supplementation phase, a baseline chemical analysis of these separate feed components was performed to evaluate baseline trace element and vitamin concentrations.

Feed Additive Composition and Administration

The pilot multicomponent mineral-vitamin blend was designed in the form of a dry powder at the Department of Veterinary Surgery and Reproductology of the Dnipro State Agrarian and Economic University.

The chemical composition of the pilot feed additive per 1 kg of dry matter consisted of: - β -carotene – 8000 mg; - α -tocopherol – 5400 mg; - sodium selenite – 80 mg; - copper sulfate – 1540 mg. Fodder chalk powder (985 g per 1 kg of the mixture) was used as an inert carrier substance. The nutrient dosage was calculated to ensure that a daily dose of 50 g of the supplement per animal covered the documented systemic requirements. The supplement was administered individually to the experimental group by thoroughly mixing it with the concentrated feed once daily for 30 consecutive days. The control group received the baseline diet without any additional components.

Sampling and Laboratory Analyses

Blood samples were collected from all animals of both groups at baseline (day 0) and upon the completion of the trial (day 30). Blood was drawn via jugular venipuncture into vacuum tubes containing clot activators. Serum was separated by centrifugation at 1500 g for 15 minutes at 4°C and subsequently stored in aliquots at -80°C until laboratory analysis. Laboratory studies were carried out in the certified laboratory of the Scientific Research Center of biosafety and ecological control of agricultural resources ("Biosafety Center", Dnipro).

Serum concentrations of trace elements (Fe, Cu, Se, Zn, Mn, Co) were quantified using an atomic absorption spectrophotometer (Shimadzu AA-7000, Japan) following wet digestion with nitric acid. The concentrations of fat-soluble vitamins (A and E) were determined by fluorescence spectroscopy (Hitachi F-2700, Japan) using standard fluorometric assay methods and commercially available extraction kits.

Statistical Analysis

The results of the statistical analysis were expressed as the mean $\pm$ standard error of the mean ($M \pm SEM$). Data normality was verified using the Shapiro-Wilk test. The statistical comparisons of metabolic parameters between the control and experimental groups, as well as within-group changes (pre- and post-treatment), were performed via the unpaired and paired Student's t-test (with Welch's correction for unequal variances where appropriate). The significance of differences was accepted at $P < 0.05$. Statistical processing was performed using GraphPad Prism v.9.0 and SPSS Statistics v.26.0 software.

Ethical Approval

All animal handling procedures, blood sampling protocols, and experimental interventions were performed in complete

Table 1 – The content of trace elements and vitamins in the blood serum of cows before treatment with feed additive

№	Trace elements/ Vitamins	The levels of minerals and vitamins in cow blood serum					Norm
		LC031761	LH049234	LH 834720	LB 431780	LH 049235	
1	Iron, µmol/l	27.4	15.0	24.1	21.7	25.6	20-40
2	Selenium, µg/l	20.67	21.76	19.73	27.02	21.66	40-85
3	Copper, µmol/l	13.67	5.97	9.18	13.26	7.92	8-24
4	Zinc, µmol/l	22.01	19.89	23.89	20.18	21.47	8-24
5	Cobalt, µg/l	2.97	2.07	2.90	2.02	1.15	1-3,5
6	Manganese, µg/l	4.31	3.93	4.48	4.69	2.17	3.5-20.0
7	Vitamin A, µg/l	172.9	157.6	140.0	151.0	121.1	130-380
8	Vitamin E, µg/ml	7.06	2.48	1.72	5.40	3.04	> 3.0

accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986) and were approved by the local Commission on Bioethics of the Dnipro State Agrarian and Economic University (DDAEU, Protocol No. 4, October 12, 2024).

Results

Initially, the baseline concentrations of vitamins and trace elements in the blood serum of the experimental dairy cows were determined. The obtained baseline (Table 1) showed that the baseline Iron content was 22.76 ± 0.94 µmol/l, Cooper -10.64 ± 1.91 µmol/l, and Zn -21.66 ± 2.04 µmol/l. Furthermore, the initial concentrations of Manganese and Cobalt were recorded at 3.36 ± 0.47 µg/l and 2.18 ± 0.19 µg/l, respectively. The initial baseline values for Selenium were significantly deficient, averaging 22.57 ± 2.93 µg/l. Fat-soluble vitamins analysis demonstrated that baseline serum concentration of Vitamin A was recorded as 158.4 ± 26.5 µg/l, while Vitamin E content was equal 2.89 ± 0.13 µg/ml.

A systematic screening of the dietary components has provided during the winter-stall period and was carried out to identify the dietary causes of these metabolic deficits. The chemical composition of the utilized forages and grains was evaluated and compared with standard reference nutritional requirements (Table 2).

Generally, the nutrient and mineral content across all analyzed feedstuffs was substantially below the optimum physiological requirements. A critical deficiency in Selenium was detected: its concentration in meadow hay was 0.02 mg/kg, in corn silage – 0.005 mg/kg, and in oat grains – 0.01 mg/kg, representing a deficit of 75.0%, 50.0%, and 80.0% below the target reference norms, respectively. The Copper content was also markedly depressed, measuring 0.91 mg/kg in hay, 0.53 mg/kg in silage, and 1.04 mg/kg in grain, satisfying only 83.8%, 70.6%, and 78.8% of the established nutritional requirements, respectively. Carotene levels were highly deficient in meadow hay (5.0 mg/kg), oat grains (1.1 mg/kg), and corn silage (3.0 mg/kg), falling 66.7%, 15.4%, and 85.0% below the norm, respectively. Similarly, Vitamin E content was reduced to 31.4 mg/kg in hay, 0.3 mg/kg in grain, and 7.0 mg/kg in silage, which is 47.7%, 57.1%, and 45.7% below the reference standards.

Based on the daily dietary intake adjustments, the total daily intake of bioactive components per cow prior to fortification was calculated. Every animal received 151.6 mg of carotene daily (71.9% below the required norm) and 211.0 mg of Vitamin E (56.0% below the optimum level). Daily trace element intake via the unfortified TMR was restricted to 0.36 mg for Selenium and 31.99 mg for Copper, representing a profound deficit of 90.0% and 70.4% relative to the standard requirements, respectively.

Table 2 – The content of trace elements and vitamins in feed components (as-fed basis, mg/kg)

Feed compo-nent	Vitamin A		Vitamin E		Se		Cu	
	Reference value	Measured value	Reference value	Measured value	Reference value	Measured value	Reference value	Measured value
Meadow hay	15.0	5.0	60.0	31.4	0.08	0.02	5.6	0.91
Corn silage	20.0	3.0	0.7	0.3	0.01	0.005	1.8	0.53
Oat grain	1.3	1.1	12.9	7.0	0.05	0.01	4.9	1.04

Note. *Reference value* – recommended concentration according to accepted feeding standards. *Measured value* – the concentration that detected in representative feed samples collected from the diet matter before the pilot feed additive supplementation.

Table 3 – The content of trace elements and vitamins in the blood serum of cows after the 30-day pilot feed additive supplementation

Trace elements/Vitamins	Baseline (Day 0)	Post-supplementation (Day 30)	Reference Limit
Iron, µmol/l	22.76 ± 0.94	22.17 ± 1.27	17.0
Selenium, µg/l	22.57 ± 2.93	$59.59 \pm 2.28^{**}$	50
Copper, µmol/l	10.64 ± 1.91	$15.73 \pm 1.14^{**}$	8
Zinc, µmol/l	21.66 ± 2.04	21.17 ± 1.56	8
Cobalt, µg/l	2.18 ± 0.19	2.20 ± 0.18	1,0
Manganese, µg/l	3.36 ± 0.47	3.14 ± 0.29	3.5
Vitamin A, µg/l	158.4 ± 26.5	$468.8 \pm 40.8^{**}$	130
Vitamin E, µg/ml	2.89 ± 0.13	$4.92 \pm 0.56^{**}$	3.0

Note: significance of differences between measurements before and after treatment within the group: * – $P < 0.05$; ** – $P < 0.001$.

Following the 30-day oral administration of the pilot formulation of the mineral-vitamin feed supplement to the experimental group, a comprehensive re-evaluation of the blood serum profiles was constructed (Table 3).

The results of comparative analysis on the content of trace elements-vitamins in serum of exposed animals have shown statistical changes in all detected vitamins and several trace elements levels. The application of the pilot feed additive successfully ameliorated the concentration of the previously deficient components practically to the physiological reference limits. Relative to the baseline minimum threshold values, serum Selenium levels increased by two times more, while Copper content increased by 47.9%. Concurrently, the post-treatment serum concentrations of fat-soluble vitamins demonstrated highly significant positive shifts: Vitamin E concentrations increased by 70.3%, and Vitamin A the content has grown almost in two times.

No significant changes in the metabolic or vitamin profiles were observed in the unexposed to feed additive control group (not demonstrated data).

Discussion

The metabolic profiles of high-yielding dairy cattle are highly dynamic and tightly correlated with the nutritional value of TMR. The chemical evaluation of the baseline diet utilized at the private enterprise revealed severe deficits in Copper, Selenium, and fat-soluble vitamins, which directly resulted in low serum concentrations of these micronutrients in the experimental animals. These findings align with recent nutritional mapping studies by Byrne & Murphy (2022), which emphasize that subclinical trace mineral deficiencies during the winter-stall period are heavily underdiagnosed but significantly impair reproductive efficiency.

Similar increase in serum Copper content following dietary fortification have reported in dairy cattle fed with diet balanced for trace minerals supplementation. Van Emon et al. (2020) emphasized that deficiencies of these micronutrients frequently remain subclinical, despite markedly impairing antioxidant defense, ovarian function, and embryo viability. Arshad et al. (2021) concluded that inadequate selenium supply is commonly accompanied by reduced glutathione peroxidase activity and increased susceptibility to reproductive disorders, particularly during periods of elevated metabolic stress. In contrast, the combined supplementation of vitamin E and selenium enhances the activity of antioxidant enzymes in dairy cows during the transition period (Chalmeh et al., 2021).

The subsequent 30-day dietary intervention with the developed pilot mineral-vitamin supplement induced highly favorable shifts in the metabolic homeostasis of the cows. The highly significant ($P < 0.01$) increase in serum α -tocopherol level almost into three times evidences that feed additive application initiated the successful restoration of α -tocopherol to physiologically adequate concentrations, essential for mitigating lipid peroxidation and preserving cellular function. As a primary lipophilic chain-breaking antioxidant, α -tocopherol accumulates within the cellular lipid bilayers of the endometrium and placenta, where it actively neutralizes ROS and mitigates LPO. This mechanism is highly synergistic with the action of Selenium, which increased by 10.0% in the blood serum of the fortified group. Yazlık et al. (2021), through the use of injectable supplements containing trace elements (Zinc, Manganese, Copper, and Selenium) and vitamins (A, D3, E), observed phagocytic activity of neutrophils, an oxidative burst, and favorable reproductive outcomes in dairy cows.

Although serum α -tocopherol increased significantly after supplementation while the biological significance of this response extends beyond its antioxidant capacity alone. Vitamin E has been shown to preserve membrane phospholipids, maintain mitochondrial integrity, and reduce oxidative injury

within granulosa and luteal cells, thereby indirectly supporting steroid hormone synthesis and embryo survival (Xiao et al., 2021). Consequently, the observed in present study an increase in circulating α -tocopherol may represent an important adaptive mechanism contributing to improved reproductive potential.

This biochemical synergy is well-documented in contemporary ruminant physiology. According to Surai & Surai (2024), Selenium serves as the structural core of GPx, an enzyme responsible for converting hydrogen peroxide into water medium before it can initiate membrane destruction. Therefore, the concurrent stabilization of both Se and α -tocopherol achieved in our study provides a dual-layer antioxidant defense. This cooperative action protects the developing blastocyst, maintains uterine contractility, and facilitates smooth placental expulsion, directly addressing the etiological factors of nutritionally-induced metritis and early embryonic mortality. Similar enhancements in reproductive indices via targeted mineral-vitamin stabilization were reported by Gorski (2021) in Polish Holstein-Friesian herds.

Recent evidence further indicates that various selenoproteins participate in both antioxidant defense and the modulation of innate immune responses during the postpartum period. Improved selenium status has been associated with reduced incidence of retained placenta, metritis, and early embryonic loss, suggesting that the beneficial effects observed in the present study may involve simultaneous improvement of both oxidative and inflammatory homeostasis (Wang et al., 2025; Arshad et al., 2021). The findings of Gong & Xiao (2021) demonstrated that supplementation with Se in the diet of cows during late gestation enhances nutrient metabolism and attenuates the inflammatory response following parturition.

Notably, the 42.0% increase in serum Copper concentration ($0.99 \pm 0.04 \mu\text{g/ml}$) fundamentally resolves the primary catalytic bottleneck observed during the baseline screening. Copper operates as an essential cofactor for SOD and cytochrome c oxidase. Consequently, its normalization not only accelerates cellular respiration and energy production in luteal tissues but also restores the endocrine sensitivity of the hypothalamic-pituitary-gonadal axis. The recovery of adequate Copper status is crucial for restoring the pulsatile release of luteinizing hormone and stabilizing systemic progesterone secretion, which prevents silent estrus cycles and improves the overall conception index. These metabolic outcomes corroborate the observations of Xiao et al. (2021), who demonstrated that balancing trace minerals effectively suppresses oxidative stress-induced luteal insufficiency in high-producing dairy cows.

Similar increases in serum Copper following dietary fortification have been reported in dairy cattle receiving balanced trace mineral supplementation. Wang et al. (2025) proposed that restoration of copper homeostasis improves ovarian steroidogenesis through normalization of copper-dependent metalloenzymes and antioxidant systems rather than through direct endocrine stimulation. This interpretation is consistent with our findings, where improved copper status coincided with normalization of the overall metabolic profile.

Nevertheless, it should be recognized that improvements in serum micronutrient concentrations do not necessarily translate immediately into maximal reproductive performance. Fertility in high-producing dairy cows remains multifactorial, being influenced by energy balance, inflammatory status, endocrine regulation, management practices, and environmental stressors (Kraevskiy et al., 2022). Therefore, the present mineral-vitamin supplementation should be regarded as one important component of a broader nutritional strategy aimed at optimizing reproductive efficiency.

The lack of any statistically significant improvements in the unexposed control group highlights that standard winter rations are inadequate for self-correction of profound regional trace mineral deficiencies. The clinical application of the developed

powder supplement successfully demonstrated that a targeted, cost-effective formulation using fodder chalk as a carrier can systematically optimize the systemic metabolic profile and effectively counteract the physiological pathways leading to nutritional infertility.

Taken together, these findings support the concept that correction of regional trace mineral and vitamin deficiencies represents a biologically justified approach for improving metabolic resilience during the transition period. Rather than acting through isolated biochemical pathways, the developed supplement appears to enhance integrated antioxidant, metabolic, and endocrine adaptations that collectively promote reproductive competence. Future studies incorporating reproductive outcomes, oxidative stress biomarkers, and molecular indicators of uterine function will further clarify the mechanistic basis underlying these beneficial effects.

Conclusions

The developed mineral-vitamin feed supplement demonstrated high efficacy in restoring the metabolic profile of dairy cows by correcting deficiencies in Selenium, Copper, α -tocopherol, and vitamin A. By enhancing the synergistic antioxidant defense and restoring Copper-dependent metabolic functions, the supplement effectively addresses the key pathways underlying nutritional reproductive failures. Consequently, this formulation represents a practical and reliable preventive tool against nutritionally-induced reproductive disorders and subclinical infertility in dairy herds.

Future research will focus on long-term evaluation of this blend to precisely quantify its direct impacts on specific reproductive parameters, including service period, insemination index, and overall herd profitability.

Acknowledgments

Authors extend their own thanks to everyone who contributed to this manuscript. The present study is a part of research work of the Department of Veterinary Surgery and Reproductology of the Dnipro State Agrarian and Economic University on the topic «Clinical correction of ecological destructions of anthropogenic origin in domestic animals of the Prydniprovsk industrial region» (state registration number 0115U002143).

Funding

This research received no external funding; the authors received no financial support for the research, authorship, or publication of this article.

Author contributions

PMS – conceptualization, methodology, investigation, formal analysis, original draft writing; CCP-M – methodology, validation, writing and editing; RVM – formal analysis, visualization, draft review and editing; VVV – investigation, data curation; DDB – investigation, data analysis; VVS – investigation, providing with resources; LVK – data curation, results visualization; OMC – supervision, validation, writing and editing.

Disclosure

The authors have not applied AI-assisted software to prepare this manuscript. The authors reviewed and edited the manuscript and take full responsibility for the content of the published article.

Conflict of interests

The authors declared no potential conflict of interests with respect to the research, authorship, and/or publication of this article.

References

- Arshad, M. A., Ebeid, H. M., & Hassan, F.-u. (2020). Revisiting the effects of different dietary sources of selenium on the health and performance of dairy animals: a review. *Biological Trace Element Research*, 199(9), 3319–3337. <https://doi.org/10.1007/s12011-020-02480-6>
- Börmel, L., Geisler, A. R., Lorkowski, S., & Wallert, M. (2024). Importance of vitamin E and its metabolism for health and disease. *Lipophilic Vitamins in Health and Disease*, 181–199. https://doi.org/10.1007/978-3-031-55489-6_9
- Byrne, L., & Murphy, R. A. (2022). Relative bioavailability of trace minerals in production animal nutrition: a review. *Animals*, 12(15), 1981. <https://doi.org/10.3390/ani12151981>
- Carr, S. N., Crites, B. R., Son, K., & Bridges, P. J. (2025). Carbohydrate metabolism in the intercaruncular endometrium is affected by form of supplemental selenium at maternal recognition of pregnancy in beef heifers. *Animals*, 15(13), 1903. <https://doi.org/10.3390/ani15131903>
- Chalmeh, A., Pourjafar, M., Badiei, K., Mirzaei, A., Jalali, M., & Mazrouei Sebdani, M. (2021). Effects of dietary antioxidants on glucose and insulin responses to glucose tolerance test in transition dairy cows. *Domestic Animal Endocrinology*, 75, 106602. <https://doi.org/10.1016/j.domaniend.2020.106602>
- Singh Dhaliwal, S., Sharma, V., Kumar Shukla, A., Singh Shivay, Y., Hossain, A., Verma, V., Kaur Gill, M., Singh, J., Singh Bhatti, S., Verma, G., Singh, J., & Singh, P. (2022). Agronomic biofortification of forage crops with zinc and copper for enhancing nutritive potential: a systematic review. *Journal of the Science of Food and Agriculture*, 103(4), 1631–1643. <https://doi.org/10.1002/jsfa.12353>
- Fadlalla, I. M. (2022). The interactions of some minerals elements in health and reproductive performance of dairy cows. *New Advances in the Dairy Industry*. <https://doi.org/10.5772/intechopen.101626>
- Fatima, G., Dzupina, A., Mahdi, A. A., Fedacko, J., Magomedova, A., & Yousif, N. G. (2025). Role of vitamin-E as a vital nutrient in health and diseases. *Indian Journal of Clinical Biochemistry*, 41(3), 310–323. <https://doi.org/10.1007/s12291-025-01309-0>
- Gong, J., & Xiao, M. (2021). Increasing selenium supply during the close-up dry period improves nutrient metabolism and attenuates inflammatory response after calving in dairy cows. *Animal Science Journal*, 92(1). <https://doi.org/10.1111/asj.13551>
- Goff, J. P. (2018). Invited review: Mineral absorption mechanisms, mineral interactions that affect acid–base and antioxidant status, and diet considerations to improve mineral status. *Journal of Dairy Science*, 101(4), 2763–2813. <https://doi.org/10.3168/jds.2017-13112>
- Górski, K. (2021). Effect of mineral supplementation on incidence of reproduction disturbances and fertility parameters in Polish Holstein-Friesian cows. *The Indian Journal of Animal Sciences*, 91(11). <https://doi.org/10.56093/ijans.v91i11.118135>
- Gross, J. J. (2022). Limiting factors for milk production in dairy cows: perspectives from physiology and nutrition. *Journal of Animal Science*, 100(3). <https://doi.org/10.1093/jas/skac044>
- Hogan, C., & Perkins, A. V. (2022). Selenoproteins in the human placenta: how essential is selenium to a healthy start to life? *Nutrients*, 14(3), 628. <https://doi.org/10.3390/nu14030628>
- Homych, Y. M., & Skliarov, P. M. (2024). Effectiveness of vitamin and mineral supplement to increase the reproductive capacity of cows of homesteading. *Veterinary Science, Technologies of Animal Husbandry and Nature Management*, (9), 234–247. <https://doi.org/10.31890/vttp.2024.09.23>
- Kraevskiy, A., Yefimov, V., Stefanyk, V., Vlasenko, S., & Basarab, T. (2022). Relationship between globulins in the late dry period with biochemical parameters, fertility and culling of cows within 90 days after calving. *Scientific Horizons*, 25(8). [https://doi.org/10.48077/scihor.25\(8\).2022.59-66](https://doi.org/10.48077/scihor.25(8).2022.59-66)

- Lei, X. G., Combs, G. F., Sunde, R. A., Caton, J. S., Arthington, J. D., & Vatamaniuk, M. Z. (2022). Dietary selenium across species. *Annual Review of Nutrition*, 42(1), 337–375. <https://doi.org/10.1146/annurev-nutr-062320-121834>
- López-Alonso, M., & Miranda, M. (2020). Copper supplementation, a challenge in cattle. *Animals*, 10(10), 1890. <https://doi.org/10.3390/ani10101890>
- Mehdi, Y., Hornick, J.-L., Istasse, L., & Dufrasne, I. (2013). Selenium in the environment, metabolism and involvement in body functions. *Molecules*, 18(3), 3292–3311. <https://doi.org/10.3390/molecules18033292>
- Mion, B., Madureira, G., Spricigo, J. F. W., King, K., Van Winters, B., LaMarre, J., LeBlanc, S. J., Steele, M. A., & Ribeiro, E. S. (2023). Effects of source of supplementary trace minerals in pre- and postpartum diets on reproductive biology and performance in dairy cows. *Journal of Dairy Science*, 106(7), 5074–5095. <https://doi.org/10.3168/jds.2022-22784>
- Moghim-Kandelousi, M., Alamouti, A. A., Imani, M., & Zebeli, Q. (2020). A meta-analysis and meta-regression of the effects of vitamin E supplementation on serum enrichment, udder health, milk yield, and reproductive performance of transition cows. *Journal of Dairy Science*, 103(7), 6157–6166. <https://doi.org/10.3168/jds.2019-17556>
- Niki, E. (2019). Antioxidant defense network and vitamin E. In *Vitamin E: Chemistry and Nutritional Benefits*, ed. E. Niki, The Royal Society of Chemistry, 2019, pp. 134–150. <https://doi.org/10.1039/9781788016216-00134>
- Perry, G. A., Perkins, S. D., Northrop, E. J., Rich, J. J. J., Epperson, K. M., Andrews, T. N., Kline, A. C., Quail, L. K., Walker, J. A., Wright, C. L., & Russell, J. R. (2021). Impact of trace mineral source on beef replacement heifer growth, reproductive development, and biomarkers of maternal recognition of pregnancy and embryo survival. *Journal of Animal Science*, 99(7). <https://doi.org/10.1093/jas/skab160>
- Risques, P. (2020). Energía y proteínas em la reproducción de hembras bovinas. *Pubvet*, 14(12). <https://doi.org/10.31533/pubvet.v14n12a703.1-9>
- Saito, Y. (2021). Diverse cytoprotective actions of vitamin E isoforms- role as peroxyl radical scavengers and complementary functions with selenoproteins. *Free Radical Biology and Medicine*, 175, 121–129. <https://doi.org/10.1016/j.freeradbiomed.2021.08.234>
- Skliarov, P. M., Naumenko, S. V., Fedorenko, S. Y., Bilyi, D. D., Vakulyk, V. V., Stadnytska, O. I., Bezalychna, O. O., Martysuk, T. V., & Slepokura, O. I. (2026). Prevention of nutritional infertility in cows and heifers: A review. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies*, 28(121), 48–78. <https://doi.org/10.32718/nvlvet12107>
- Spears, J. W., Brandao, V. L. N., & Heldt, J. (2022). Invited Review: Assessing trace mineral status in ruminants, and factors that affect measurements of trace mineral status. *Applied Animal Science*, 38(3), 252–267. <https://doi.org/10.15232/aas.2021-02232>
- Surai, P. F., & Surai, A. (2024). Selenoproteins in ruminants: glutathione peroxidases. *Selenium in Ruminant Nutrition and Health*, 88–171. https://doi.org/10.3920/9789004698697_003
- Suslova, N., Shkvaria, M., Tishkina, N., Sklyarov, P., Mylostyyvi, R., & Koreiba, L. (2026). Kompleksni doslidzhennia tekhnolohichnykh parametriv utrymannia ta hodivli, kliniko-fiziolohichnykh pokaznykiv koriv holshtynskoi porody v systemi hospodarskoho vykorystannia [Comprehensive studies of technological parameters of housing and feeding, clinical and physiological indicators of Holstein cows in the system of farm management]. *Agrarian Bulletin of the Black Sea Littoral*, (119), 119–145. <https://doi.org/10.37000/abbsl.2026.119.10>
- Van Emon, M., Sanford, C., & McCoski, S. (2020). Impacts of bovine trace mineral supplementation on maternal and offspring production and health. *Animals*, 10(12), 2404. <https://doi.org/10.3390/ani10122404>
- Wang, M., Li, Y., Molenaar, A., Li, Q., Cao, Y., Shen, Y., Chen, P., Yan, J., Gao, Y., & Li, J. (2021). Vitamin E and selenium supplementation synergistically alleviate the injury induced by hydrogen peroxide in bovine granulosa cells. *Theriogenology*, 170, 91–106. <https://doi.org/10.1016/j.theriogenology.2021.04.015>
- Wang, B., Li, X., Zhou, Z., Zhu, Y., Zuo, Z., & Guo, H. (2026). The role of five key minerals (Cu, Se, Zn, Co, Fe) in Reproductive function of female cattle: current insights and future directions. *Veterinary Sciences*, 13(2), 208. <https://doi.org/10.3390/vetsci13020208>
- Xiao, J., Khan, M. Z., Ma, Y., Alugongo, G. M., Ma, J., Chen, T., Khan, A., & Cao, Z. (2021). The antioxidant properties of selenium and vitamin E; their role in periparturient dairy cattle health regulation. *Antioxidants*, 10(10), 1555. <https://doi.org/10.3390/antiox10101555>
- Yazlık, M. O., Çolakoğlu, H. E., Pekcan, M., Kaya, U., Küplülü, Ş., Kaçar, C., Polat, M., & Vural, M. R. (2021). Effects of injectable trace element and vitamin supplementation during the gestational, peri-parturient, or early lactational periods on neutrophil functions and pregnancy rate in dairy cows. *Animal Reproduction Science*, 225, 106686. <https://doi.org/10.1016/j.anireprosci.2021.106686>