The effect of nano-chromium and niacin on some hematological parameter and physiological vital indicators in Awassi lambs during the summer

Abdul Qader Mahmoud1 and Emad Gh. Alabbasy2

1,2 Tikrit University - College of Agriculture Department of Animal Production, Tikrit, Iraq.

1E-mail: abdalqider·m·j@gmail·com

2E-Mail : dr.emadghaib@tu.edu.iq

Abstract

This study was conducted in the fields and laboratories of the College of Agriculture at Tikrit University for the period from 15/7/2024 to 15/10/2024 for a period of (90) days, preceded by a preparatory period of (15) days to accustom the lambs to the concentrated feed to determine the effect of treatment with nano_chromium and treatment with niacin on some blood biochemical parameters, immunoglobulins, and the concentration of some hormones. (16) Awassi lambs were used in this experiment, their ages ranged between (3-4) months and with an average initial weight of 25.3 ± 0.9 kg. The experimental treatments were divided into four treatments, the treatments were randomly distributed into four treatments, the first was the control, the second was the addition of nano-chromium at a rate of (4) mg/day/lamb, the third treatment was the addition of niacin (4) g/day/lamb, and the fourth treatment was the addition of niacin (4) g/day/lamb with chromium (4) mg/day/lamb and 4 lambs per treatment. These results showed no significant differences ($p \leq 0.05$) between nano chromium and niacin in some physiological characteristics of Awassi lambs for the 45-90 stages in hemoglobin level, while the results of packed cell volume indicated a significant decrease ($p \leq 0.05$) in the third treatment (niacin 4g) and the fourth treatment (niacin + chromium) compared to the control group during the first draw of 45 days, while there was no effect of nano chromium, niacin and their mixture on the volume of packed red blood cells over a period of 90 days. The results also indicated a significant decrease ($p \leq 0.05$) in the number of red blood cells for the third and fourth treatments compared to the control group for a period of 45 days, while there was no significant effect of the study treatments on the number of red blood cells during the 90-day period. Regarding the total white blood cell count and lymphocyte count, there was no significant effect of chromium and niacin for the period 45-90. Regarding weight gain, there was no effect of nano chromium, niacin and the mixture on the weight gain rate of lambs throughout the experiment days. Regarding rectal temperature, we find a significant decrease in the rectal temperature of lambs in the second group compared to the fourth group (mixture) for the period 45 days, while the rectal temperature increased significantly in the mixture (fourth) compared to the control group at 60 days. As for day 75 of the experiment, the rectal temperature increased significantly in both groups three and four compared to the control, while there was no significant difference between the treatments for days 15-30-90 of the experiment. Regarding the effect of chromium and niacin on respiration, the results of the statistical analysis showed a significant increase in the niacin (third) and niacin-

chromium (mixture) groups compared to the chromium (second) group on day 15 of the experiment. Conversely, the second, third, and fourth treatments significantly decreased compared to the control group on days 45, 60, and 75, while there was no effect of the treatments on respiration rates on days 30 and 90 of the experiment. Regarding heart rate, we found no significant differences between the treatments during the experiment period (days 15, 30, 45, and 90). However, the third and fourth groups significantly decreased compared to the control group on day 75 of the experiment, and the third group also decreased compared to the control group on day 60 in heart rate.

Introduction

Heat stress is one of the most significant challenges facing animal production in hot and arid regions, negatively impacting production, reproductive performance, and overall animal health. Awassi lambs, one of the most important sheep breeds in the Middle East, are frequently exposed to heat stress during the summer, leading to reduced growth rates, reduced feed conversion efficiency, and impaired immune response. In recent years, scientific research has focused on the use of nutritional supplements as an effective strategy to mitigate the effects of heat stress in ruminants. Among these supplements, nano-chromium and niacin have emerged as promising elements for improving animals' ability to adapt to heat stress conditions. This study aims to investigate the effect of nano-chromium and niacin supplementation on heat stress in Awassi lambs, focusing on their effects on productive traits, physiological responses, hematological parameters, and stress indicators. The review also reviews the potential mechanisms of action of these supplements and the practical applications of their use in feeding Awassi lambs under heat stress conditions. Physiological responses to heat stress include measurable reactions in sheep, such as increased respiratory rate and heart rate, elevated body temperature, increased water consumption, decreased urination and standing time, as well as weakened immune systems and decreased reproductive performance (1). Heat stress also causes metabolic changes, increased free radical and antioxidant imbalances in the body, hormonal changes, and changes in feeding behavior, all of which negatively impact animal production and health (2). Recent studies have indicated that heat stress negatively affects growth rates, milk production, and calving success, ultimately impacting overall sheep productivity (3). In recent years, researchers have focused their attention on the use of nutritional supplements as a strategy to mitigate the effects of heat stress and improve animal physiological, immune, and production performance. Among these supplements, nano-chromium and niacin have emerged as promising agents for improving animal performance under heat stress conditions. Studies have shown that adding chromium to sheep feed improves birth weight, daily weight gain, and digestibility, and reduces diarrhea in newborn lambs (4). With the development of nanotechnology, chromium nanoparticles have emerged as a more effective alternative to conventional chromium, featuring a larger surface area and better penetration and absorption capacity (5). Studies have shown that chromium nanoparticles improve production performance, enhance immune response, and reduce oxidative stress in animals (6). On the other hand, niacin (vitamin B3) is an essential vitamin that plays an important role in energy metabolism, acting as a key

ISSN 2072-3857

component when combined with the enzymes NAD and NADP, which participate in oxidation-reduction reactions in the body (7). Studies have indicated that adding niacin to ruminant feed helps mitigate the effects of heat stress by dilating peripheral blood vessels, which increases heat loss through the skin (8). Furthermore, niacin improves feed conversion efficiency, increases milk production, and improves rumen function in ruminants (9). A recent study also demonstrated that niacin stimulates the conversion of type II to type I muscle fibers in sheep, accompanied by an increase in the gene expression of PPARGC1A (10). Awassi sheep are one of the most important sheep breeds in Iraq, characterized by their ability to adapt to different environmental conditions and their high meat and milk production (11). However, the performance of this breed varies depending on the production environment and breed, with the improved Palestinian Awassi sheep being the heaviest and most productive (12).

Awassi sheep in Iraq are exposed to the effects of heat stress in the summer, which negatively impacts their physiological, productive, and immune performance. A recent study indicated that shearing Awassi lambs reduces heat stress, which positively impacts productive performance and carcass characteristics (13). A second study demonstrated that adding selenium and vitamin E to the diet of Awassi sheep improves the physiological and reproductive performance of this breed (14). This suggests that the use of appropriate nutritional supplements could be an effective strategy for improving the performance of Awassi sheep under heat stress conditions. As mentioned above, this study aims to evaluate the effect of nano-chromium and niacin supplementation on the physiological, productive and immune performance of Awassi lambs, taking into account their role in reducing heat stress, improving physiological traits, growth and enhancing immunity to improve the productivity of Awassi sheep under heat stress conditions in Iraq.

Materials and Methods

Time and Place of the Experiment

This study was conducted in the fields and laboratories of the College of Agriculture, Tikrit University, from July 15, 2024, to October 15, 2024, for period of (90) days. This was preceded by a preparatory period of (15) days to acclimate the lambs to the concentrated feed.

Animal Management and Housing

We used (16) Awassi lambs in this experiment. The animals were prepared from local sheep feed in Salah al-Din Governorate. Their ages varied between 3-4 months, with an average initial weight of 25.3 + 0.90 kg. The lambs were weighed after the (15)-day period. The lambs were then cut off from the feed for 12 hours to stabilize the initial weight using an electronic field balance. Lambs were randomly assigned to four feeding treatments according to weight, with four lambs per group. The average weights of these groups were close (25.3±0.3, 25.200±0.28, and 24.950±0.16) kg, respectively. The lambs were also numbered with plastic numbers, and the numbers of the lambs for each treatment were placed on the rearing cages. The group feeding system was applied to the lambs in the experimental treatments. The experimental animals were housed in semi-open pens designed to provide suitable environmental conditions. The lambs were placed in cages with an area

ISSN 2072-3857

of 15 m2 and dimensions of 3 x 5 m in a semi-open pen. All cages were equipped with plastic containers for concentrated feed and roughage (wheat straw) and 5-liter water drinkers. Mineral salt cubes were placed in front of the lambs throughout the experiment. The experimental treatments were randomly assigned to four groups: the first was the control treatment; the second was supplemented with nano-chromium (4 mg/day/ lamb); the third was supplemented with niacin (4 g/day/ lamb); and the fourth was supplemented with chromium (4 mg/day lamb /) and niacin (4 g/day/ lamb), with four lambs per treatment. A fixed diet of concentrated feed was provided to all treated animals, and niacin and chromium were added to the concentrated feed throughout the 90-day experimental period.

Veterinary Care

All animals underwent a standardized and regular veterinary health program under the supervision of specialized veterinarians to ensure they were free of diseases and external and internal parasites throughout the trial period. All lambs received a schedule of vaccinations and veterinary care, and were examined at the beginning of the trial to ensure the animals' health and safety. The most prominent vaccines used against the most important diseases during the preliminary period were: (Baghdad Pentavalent subcutaneous vaccine against enterotoxaemia, a dose for mange and itching (oil dose), a dose for pneumonia treatment, and a dose for worms) as follows:

1- Ultrachoice: An important vaccine and treatment used to treat enterotoxaemia in sheep.

2- Blotetra (Oxytetracycline): An antimicrobial antibiotic used to treat various types of infections, such as those affecting the skin, respiratory system, urinary tract, ears, and eyes.

3- Levozan (wormer for sheep, goats, and cows): Used to combat various types of worms. Among the worms that infect the digestive and respiratory systems, as well as liver flukes.

4- Intermectin 10 mgis an antiparasitic used to treat mange, heartworm, and ticks.

5- Tylosan 200 mgis effective against pneumonia, fever, necrotizing dermatitis, and pneumonia.

Animal Nutrition

Lambs were fed a standardized ration throughout the experiment. The ration consisted of the basic components of concentrated feed, with the chemical composition shown in Table (1). The ration was provided to the animals at a daily rate equivalent to 3% of the live body weight of each animal, with clean drinking water available at all times. The concentrated feed was provided twice daily, in the morning and evening, and the remaining feed was collected the following day before the new meal was provided to calculate the daily feed intake. Throughout the experiment, the daily feed ration for the lambs was adjusted weekly after taking the new weight of the lambs at the beginning of the week and for the duration of the experiment. Wheat straw was provided to the lambs in the morning and could be increased if necessary in the evening. Water in the drinking troughs was replaced. In the morning, the feed is increased several times during the day if necessary and throughout the trial period. Feed is discontinued 12 hours before the lambs are weighed to ensure accurate weight.

ISSN 2072-3857

Table1: Chemical composition of the trial feed

%	Chemical composition of feed
17.76	Total Protein
11.75	Moisture
6.74	Crude Fiber
2.1	Ether Extract
5.14	Crude Ash
88.25	Dry Matter
2771	Metabolizable Energy

Sample Collection and Laboratory Tests

Complete Blood Count (CBC)

A complete blood count (CBC) was performed on whole blood samples collected in tubes containing EDTA anticoagulant using a Veterinary Automated Hematology Analyzer. The device was operated and calibrated according to the manufacturer's instructions. Measured parameters included red blood cell (RBC) count, hemoglobin concentration (Hb), packed cell volume fraction (Hct or PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red blood cell distribution width (RDW), platelet count (PLT), and total white blood cell count (WBC).

Physiological Measurements

•Body Weight: Each lamb was weighed using a precision electronic livestock scale (Livestock scale). Weights were recorded in kilograms (kg). To ensure accuracy, the scale was zeroed before weighing each animal. (15)

• Weight Gain:

The rate of weight gain was calculated by weighing the lambs from the beginning of the experiment and continuously weekly until the end of the experiment by subtracting the subsequent weight from the previous weight, as shown in the formula below:

Weight gain (kg) = subsequent weight - previous weight. (16)

• Respiration Rate: The number of respirations for each animal was measured while at rest by observing and counting the number of chest or flank movements (inhalation and exhalation) per minute using a stopwatch. The rate was recorded in breaths/minute. (17)

• Rectal Temperature: The rectal temperature of each animal was measured using a digital veterinary thermometer. The tip of the thermometer was moistened with a lubricant and gently inserted into the animal's rectum for a few minutes until the reading stabilized, or according to the

Discussion

manufacturer's instructions. The temperature was recorded in degrees Celsius (°C). (18)

• Heart Rate: The heart rate (pulse) of each animal was measured while at rest by palpating the femoral arterylocated on the inner side of the upper hind thigh. The fingertips (not the thumbs) were used to gently press on the artery, and the number of beats per minute was counted using a stopwatch. The rate was recorded in beats/minute. (19)

Statistical Analysis

The experiment was designed according to a completely randomized design (CRD). Data were statistically analyzed using the Statistical Analysis Program (SAS) according to the following mathematical model:

$Yij=\mu+ti+eig$

Means between groups were compared using Duncan's Multiple Range Test to determine significant differences at a significance level of ($P<0.05$).

ISSN 2072-3857

Table2: Hematological parameters

Treatments				Duration Day	The adjective
Treatment Fourth Cr + Ni	Treatment third Niacin 4 gm	Treatment second Cr 4 mg	Treatment first control		
0.29±12.82a	0.50±12.30a	0.46±14.92 a	0.65±14.75 a	45	Hemoglobin gm/dl
0.65±12.17 a	0.45 ±11.5a	2.31 ± 11.7a	.47±13.22a 0	90	
1.57±32.27b	0.97±32.85b	2.37±34.32 ab	0.73±38.02a	45	Packed cell volume%
1.45 ± 30.82a	0.92 ± 28.9a	5.34 ± 27.9a	1.47 ± 33.85a	90	
0.30 ± 7.80b	0.24 ± 7.84b	0.46 ± 8.41ab	0.14 ± 9.05a	45	Red blood cell X10^6
0.32 ± 7.49a	0.23 ± 7.07a	1.25 ± 6.74a	0.32 ± 8.12a	90	
2.94 ± 19.925a	1.5 ± 13.525a	2.62 ± 17.70a	6.5 ± 22.8a	45	White blood cell X10^3
0.5 ± 14a	0.72 ± 12.9a	3.37 ±10.97a	3.95 ±17.57a	90	

ISSN 2072-3857

2.98 ± 54.85a	4.40 ± 67.15a	2.304 ± 60.55a	5.9 ± 67.05a	**45**	**Lymphocytes %**
2.82 ± 42.77a	8 ± 48.4a	5.61 ± 46.12a	6.54 ± 55.92a	**90**	

Different letters in a row to every trait indicate significant differences at (P≤ 0.05)

Table 1... shows the effect of nano-chromium and niacin on some physiological characteristics of Awassi lambs. There were no significant differences (p≤0.05) in hemoglobin levels for both stages 45 and 90. Meanwhile, the results of packed cell volume indicated a significant decrease (p≤0.05) in the third treatment (4g niacin) and the fourth treatment (niacin + chromium) compared to the control group during the first draw at 45 days. However, nano-chromium, niacin, and their mixture had no effect on the packed red blood cell volume over a 90-day period. The results also indicated a significant decrease (p≤0.05) in the number of red blood cells in the third and fourth treatments compared to the control group over the 45-day period, while there was no significant effect of the study treatments on the number of red blood cells over the 90-day period. Regarding total white blood cell counts and lymphocyte counts, there was no significant effect of chromium and niacin for the 45-90 days.

The significant decrease on day 45 of the experiment can be explained by the fact that niacin is known to have a vasodilator effect on cutaneous blood vessels, which aids in heat dissipation. This dilation may lead to fluid redistribution and a temporary increase in plasma volume, causing a decrease in red blood cell concentration. The lack of differences on day 90 of the experiment may indicate that the animals are physiologically adapting to the conditions and treatments, as fluid regulation mechanisms stabilize, blood circulation improves, and blood viscosity decreases under heat stress.

ISSN 2072-3857

Table3: Body weight

Table3 shows that nanochromium, niacin, and the mixture had no effect on the weight gain rate of lambs throughout the experiment.

Today's weight 90	Today's weight 75	Today's weight 60	Today's weight 45	Today's weight 30	Today's Weight 15	Treatments
1.17±47.7 a	1.15±44.6 a	1.12±41.44 a	1.26±38.5 a	1.24±33.58 a	1.02±27.02 a	Treatment first Control
2.37±49.11 a	1.84±45.66 a	1.92±41.75 a	1.54±39.73 a	1.69±34.96 a	1±28.17 a	Treatment second Cr
3.14±53.73 a	2.67±48.85 a	2.2±44.80 a	1.59±41.17 a	1.26±35.53 a	0.95±28.38 a	Treatment third Ni
1.32±48.77 a	1.32±46.08 a	1.4±4276 a	1.3±39.86 a	0.83±35.75 a	0.34±28.60 a	Treatment fourth Cr +Ni

Different letters in a row to every trait indicate significant differences at (P≤ 0.05)

ISSN 2072-3857

Table 4: Rectal Temperature

rectal temperature per day 90	rectal temperature per day 75	rectal temperature per day 60	rectal temperature per day 45	rectal temperature per day 30	rectal temperature per day 15	Treatments
1.15±35.21 a	0.29±36.28 b	0.19±38.19 b	0.15±38.12 ab	0.44±38.31 a	0.24±39.40 a	Treatment first Control
0.25±36.66 a	0.15±36.86 ab	0.31±38.35 ab	0.21±37.91 b	0.94±37.33 a	0.54±39.47 a	Treatment second Cr
0.14±36.91 a	0.13±37.03 a	0.27±38.83 ab	0.27±37.96 ab	0.21±38.38 a	0.1±38.90 a	Treatment third Ni
0.12±36.36 a	0.17±37.31 a	0.22±39.17 a	0.40±38.86 a	0.08±38.73 a	0.07±39.22 a	Treatment fourth Cr +Ni

Different letters in a row to every trait indicate significant differences at (P≤ 0.05)

Table 3 shows a significant decrease in the rectal temperature of the lambs in the second group compared to the fourth group (mixed) for a period of 45 days. Rectal temperature in the mixed group (fourth) increased significantly compared to the control group at 60 days. On day 75 of the experiment, rectal temperature increased significantly in both groups three and four compared to the control group, while there was no significant difference between the treatments for days 15, 30, and 90 of the experiment.

The decrease in rectal temperature in the second treatment at day 45 can be explained by the fact that Nano chrome contributes to

ISSN 2072-3857

improving metabolic efficiency and cellular thermoregulation by enhancing insulin sensitivity, leading to more effective glucose utilization and energy production (20). This can also be explained by the fact that niacin dilates peripheral blood vessels, which improves heat dissipation efficiency and helps maintain optimal body temperature (21).

Table 5: Respiration

Respiration by the day 90	**Respiration by the day 75**	**Respiration by the day 60**	**Respiration by the day 45**	**Respiration by the day 30**	**Respiration by the day 15**	**Treatments**
7.44±69.50 a	7.96±89 **a**	2.02±124.5 **a**	2.02±124.5 **a**	5.45±116.2 **a**	14.43±111 **ab**	**Treatment first Control**
8.41±5825 **a**	10.85±65.75 **ab**	6.01±76 **b**	6.01±76 **b**	1.73±114 **a**	10.63±87.25 **b**	**Treatment second Cr**
11.86±7133 **a**	4.16±62 **b**	6.64±73 **b**	6.35±73 **b**	5.69±99.33 **a**	18.92±149 **a**	**Treatment third Ni**
5.12±55.5 **a**	4.94±57 **b**	6.16± 71.25 b	6.16±71.25 **b**	8.66±108 **a**	6.36±133 **a**	**Treatment fourth Cr +Ni**

Different letters in a row to every trait indicate significant differences at (P≤ 0.05)

In Table 4, regarding the effect of chromium and niacin on respiration, the statistical analysis results showed a significant increase in the niacin (third) and niacin-chromium (mixture) groups compared to the chromium (second) group on day 15 of the experiment.

Conversely, the second, third, and fourth treatments significantly decreased compared to the control group on days 45, 60, and 75, while there was no effect of the treatments on respiration rate on days 30 and 90 of the experiment.

The initial increase in respiration rate in the niacin and mixture treatments can be explained as a compensatory mechanism to meet increased oxygen demand, possibly due to increased metabolism. Subsequently, the second, third, and fourth experiments, during the 45, 60, and 75 periods, showed that niacin and Nano-chromium contributed to the release of antioxidants and inflammatory mediators, which reduced lung inflammation and subsequently improved lung function (22). Niacin may also have contributed to improving mitochondrial oxidative phosphorylation, thus enhancing the efficiency of cellular respiration (23).

Table 6: Heart rate

Heart rate per day 90	**Heart rate per day 75**	**Heart rate per day 60**	**Heart rate per day 45**	**Heart rate per day 30**	**Heart rate per day 15**	**Treatments**
7.96±84.75 **a**	3.67±114 **a**	4.73±113.75 **a**	5.18±115.5 **a**	0.47±110.75 **a**	1.47±116 **a**	**Treatment first** **Control**
4.44±86.75 **a**	2.9±97.5 **b**	2.21±109.5 **ab**	2.25±113.25 **a**	5.23±117.5 **a**	3.47±116.75 **a**	**Treatment second** **Cr**
4±73 **a**	6.5±94 **b**	491±93.66 **b**	5.5±99 **a**	9.56±113.33 **a**	8.11±113.33 **a**	**Treatment third** **Ni**
2.34±73 **a**	7.03±88 **b**	7.83±104.25 **ab**	8.52±107.25 **a**	8.19±126 **a**	4.26±122.75 **a**	**Treatment fourth**

ISSN 2072-3857

						Cr +Ni

Different letters in a row to every trait indicate significant differences at (P≤ 0.05)

Table 5 shows no significant differences between the treatments over the course of the experiment, days 15, 30, 45, and 90. However, the third and fourth groups showed significant decreases in heart rate compared to the control group on day 75 of the experiment. The third group also showed a decrease in heart rate compared to the control group on day 60. The stability and improvement in heart rate on days 60-75 can be explained by the Nano-chromium and niacin contributing to improved peripheral vascular function and reduced resistance (24). (This is enhanced by the decrease in temperatures in niacin and chromium treatments) .

ISSN 2072-3857

References

-1Physiological traits as affected by heat stress in sheep - A review. (2024). ResearchGate

.-2The Impact of Heat Stress on the Physiological, Productive. (2024). MDPI, 2077-0472/14/8/1241

-3Heat stress impact on sheep production. (2025). ResearchGate, 381824897

-4Proposed mechanism for performance of chromium in the cell. (2025). ResearchGate, 342610417.

-5Farooq, N., ur Rehman, Z., Hareem, A., Masood, R., Ashfaq, R., Fatimah, I., ... & Parveen, N. (2024). Graphene Oxide and Based Materials: Synthesis, Properties, and Applications–A Comprehensive.

-6Influence of Dietary Chromium and Vitamin E Supplementation. (2025 .(

-7Role of niacin supplementation in dairy cattle. (2024). ResearchGate, 317562200

-8Heat Stress Mitigation through Feeding and Nutritional Interventions. (2024.(

-9Nutritional Strategies to Alleviate Stress and Improve Welfare. (2024 .(

-10Research Progress on the Regulating Factors of Muscle Fiber. (2024 .(

-11Determinants of meat and milk production of Awassi sheep in Syria (2024. (

-12Awassi sheep as a genetic resource and efforts for their genetic improvement. (2024 .(

-13The effects on Awassi lambs body weight and carcass characters. (2024 .(

-14Reproductive Performance and Physiological Responses in Awassi. (2024 .(

-15González-García, E., Friggens, N. C., Tolkamp, B. J., Rooke, J. A., & Dwyer, C. M. (2018). Using automatically recorded feeding behaviour and weighing data to predict lamb growth. Computers and Electronics in Agriculture, 150, 341–348

-16Zhao, Y., Zhang, M., Wang, Q., Liang, X., Hou, L., Zhang, Y.,&Zhou, P (2021.(

Integrated analysis of mRNA and miRNA expression profiles reveals muscle growth differences between high and low average daily gain in Hu sheep.

Frontiers in Veterinary Science, 8, 791573.

-17Merck Veterinary Manual. (2025). Resting respiratory rates – sheep: 16–34 breaths per minute

-18Merck Veterinary Manual. (2024). Normal Rectal Temperatures in Domestic Animals. Merck & Co., Inc. Retrieved from .

-19Merck Veterinary Manual. (2024). Resting heart rates – sheep. In Merck Veterinary Manual. Merck&Co., Inc.

-20Xie, Y., et al. (2025). Microbiome-metabolomics analysis insight into the effects of

chromium picolinate supplementation on growth performance in broilers. Poultry Science,

. 104 https://www.sciencedirect.com/science/article/pii/S0032579125002792 (2 .(

9 -21Kumar, V., et al. (2025). A Review on Their Impacts on Cardiac Health. Biomedicines,

.241 ,(1) 13https://www.mdpi.com/2227-9059/13/1/241

ISSN 2072-3857

-22Fu, C., Zhang, L., Luo, J.,&Zhang, Y. (2025). Niacin may modulate the production and

release of inflammatory mediators, reducing lung inflammation and improving respiratory

function and overall health. Frontiers in Nutrition, 12, 1471549.

4 -23Braga, R.R., et al. (2024). NAD replenishment restores mitochondrial function and

2-

prevents muscle atrophy in aged mice. The Journal of Physiology, 602(24.(

https://physoc.onlinelibrary.wiley.com/doi/10.1113/JP288453

-24Jomova, K., et al. (2024). Heavy metals: toxicity and human health effects. Archives of

Toxicology, 98(12), 3903-3920. https://link.springer.com/article/10.1007/s00204-024-

03903

ISSN 2072-3857