THE IMPACT OF NITROGEN ON BIRDS AND ITS IMPLICATIONS FOR THE ENVIRONMENT: A REVIEW

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Abstract

This study explores nitrogen and its role in the avian organism, considering the conditions of poultry farming in Romania. Following an evaluation of the specialized literature, in order to meet the nutritional requirements of birds, their feed must be composed of high-quality nutrients that play a metabolic role in the process of growth and maintenance of homeostasis in the body.

A clean poultry farming process involves protecting the environment by recycling litter in agriculture. At the same time, a healthy farming process requires the implementation of biotechnologies at farm level, and the socio-economic dimension must respond to the current demands of chicken meat consumers. The study covers the pathophysiological concepts related to nitrogen catabolism and its influence on the homeostasis of avian organisms, as well as some of the most important pathologies associated with ammonia produced in industrial poultry farming. The discussions also provide guidelines for effective and healthy management, including for the environment. In conclusion, strategically closing the nitrogen cycle through modern poultry farm management based on proper nutrition, innovative biotechnologies, and controlled reuse of litter is a sustainable solution for improving bird welfare and health, protecting the environment, and increasing food safety. Active involvement of the Romanian scientific community in the development and application of these practices is necessary.

Key words: *poultry management, nitrogen, ammonia, agriculture*

INTRODUCTION

In the avian organism, nitrogen produced by protein catabolism is converted into uric acid, which is the main form of nitrogen excretion. Thus, the main indicator of nitrogen metabolism in birds is uric acid [1]. In poultry, the excretion products are urea, amino acids, and mainly uric acid (70-80%), which, in contact with the external environment and microbes in manure, is converted into ammonia [2,3]. The secretion of these compounds excreted through the avian kidneys is influenced by an increased protein intake and directly regulated by the increase in water intake required in this situation.

Current trends and biotechnology in poultry farming are shaped by the increasing availability of amino acids (AA) and the development of low-protein diets to reduce nitrogen excretion. The amount of nitrogen excreted by the kidneys depends largely on digestible AA. Failure to meet the bioequivalence ratio of AA leads to variations in the amount of uric acid depending on protein deficiency (AA deficiencies), metabolic imbalance, and excessive intake of protein and AA [4]. For example, replacing soybean meal in poultry feed affects minerals, fiber, and energy forms and eliminates a source of potassium.

Uric acid synthesis is influenced by several factors: protein intake; intracellular energy reserves; AA; tetrahydrofolate (a derivative of folic acid); ammonia; adenosine deaminase; nucleoside purine;

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The manuscript was received: 02.03.2026
Accepted for publication: 21.04.2026

the enzymatic activity of xanthine oxidase and dehydrogenase [5]. Furthermore, the integrity of the renal territory and local vascular quality play a decisive role in maintaining homeostasis. Another form of nitrogen is found as urea circulating in the blood. The biochemical indicator urea (mg/dL) is a useful metabolite for detecting AA imbalances and, together with total proteins concentration (g/dL), contributes to the detection of protein deficiency in broiler flocks.

An animal's amino acid requirements are dynamic and are influenced by genetic profile, age, and physiological status. Consequently, nitrogen exhibits daily circadian variations and therefore it is necessary to evaluate the evolution of this parameter, in the form of uric acid (UA mg/dl), over time (feeding/growth period), and according to the feeding behavior of meat hybrids. Since uric acid is the end product of purine catabolism and is closely linked to N metabolism, it reflects the metabolic state of the body [6]. Laboratory results are linked in this case to the main characteristics monitored for growth performance assessment: feed intake, average daily gain (ADG), and feed conversion ratio (FCR), [7]. Azotemia (the accumulation of non-protein nitrogen compounds in the blood) is determined by measuring urea, nitrogen, and creatinine concentrations, together with the urea/creatinine ratio, which is significant for the clinical interpretation of renal function.

The literature aims to improve and understand the strategy of administering low crude protein diets and its impact on nitrogen balance, litter quality, and uric acid [5]. These nutritional formulas have the potential to reduce nitrogen excretion, with implications for the environment, production sustainability, and animal welfare, and by complying with legislation on reducing nitrogen (N) emissions, EU Directive 2016/2284 [5].

Nitrogen excretion involves osmoregulation, as it can activate mechanisms that increase water intake. Polyuria influences the increase in litter moisture and has a nutritional cause. Sodium and chloride are the primary osmolytes responsible for the cortico-medullary osmotic gradient. The osmolarity that exists in the renal interstitial fluid is a factor involved in the generation of concentrated urine in birds [8].

Thus, the most important key factors influencing the nitrogen cycle between the organism and the environment affect the rights of birds raised for meat to health and well-being, as well as the right to life by ensuring comfort and the conditions necessary for optimal functioning. On the other hand, the most important environmental issue during the commercial rearing of broiler chickens is ammonia production due to the bacterial degradation of uric acid [9].

MATERIAL AND METHOD

This article is a review study based on a critical analysis of the scientific literature on nitrogen metabolism in birds, the impact of nutrition on nitrogen excretion, litter quality, ammonia emissions, and their implications for bird health, the environment, and food safety. The articles were selected by consulting the main databases, Google Scholar, Research Gate, Web of Science, Scopus, PubMed, CABI Digital Library ebooks, CABI VETMED Resource, and the editorial platforms of specialized journals such as *Poultry Science*, *Animals*, *Frontiers in Veterinary Science*, *Animal Nutrition*, and *Physiological and Biochemical Zoology*. Searches were conducted using combinations of relevant keywords, such as nitrogen metabolism in poultry, ammonia emission, poultry litter, broiler nutrition, amino acid turnover, environmental impact of poultry production and avian physiology.

Books and papers published between 1998 and 2025 were considered, with an emphasis on studies published in the last 5 years to ensure the information is up to date. Original articles, meta-analyses, experimental studies, relevant book chapters, and editorials addressing physiological, nutritional, microbiological, zootechnical, and environmental aspects related to nitrogen use and disposal in poultry production were included.

RESULTS AND DISCUSSIONS

Birds use approximately 30-50% of the nitrogen ingested during their metabolism, and the excreted portion is a potential source of ammonia emissions [10,11]. The growth performance of Ross 308 chicks is determined by age-specific changes, depending on protein intake and the blood profile of proteins in the body. The total nitrogen content in excrement increases with age and thus reflects nitrogen intake [11].

Approximately two thirds of ingested nitrogen in poultry is eliminated through excretion as uric acid and undigested dietary protein in feces [12,13]. Long-term exposure to high levels of ammonia (NH_3) can cause adverse effects in humans and animals, such as decreased performance, mucosal inflammation, and respiratory diseases [14]. Physiological changes can also occur at around 15 ppm NH_3, and scientific studies have concluded that the onset of changes could actually be influenced by values as low as 10 ppm NH_3. From this point of view, the stress factors analyzed are: exposure time to ammonia, animal density, and growth rate [15]. Therefore, it is necessary to understand the physiological effects in order to control the factors. The nitrogen content in litter tends to increase with the accumulation of excrement in the litter. Typically, NH_3 levels are higher inside farms in the second half of the production cycle. High ambient humidity aggravates ammonia-induced inflammation of the respiratory mucosa, causing Th1/Th2 imbalance and nuclear factor-κB activation. Increased relative humidity in the shelter can potentiate the adverse effects of ammonia [16].

Published research demonstrates that effective ammonia mitigation in commercial broiler facilities relies on three complementary approaches: nutritional strategies that reduce nitrogen excretion through balanced amino acids ratios, incorporation of feed additives such as enzymes and probiotics to enhance nutrient absorption and digestive efficiency, and environmental management practices including adequate ventilation, moisture control, and timely litter removal to prevent bacterial degradation of nitrogenous waste.

Renal pathophysiology induces poor performance and an increased risk of infections, very poor health in birds, with a high incidence of leg injuries, morbidity, mortality, low slaughter yield, etc. A symptom of nephrotoxicity is kidney dysfunction, and important markers of kidney function are uric acid (UA), urea, creatinine (CRE), and blood urea nitrogen (BUN), [17]. For example, a dietary treatment with carvacrol oil can significantly reduce uric acid concentration in poultry [18]. It is important to boost the host's immune response in order to cope with various environmental stressors, such as pathogens and toxins. Designing an appropriate program for the use of natural diet fortifiers at specific times during the broiler production cycle can decrease the ability of infectious bronchitis virus (IBV) to induce disease, regardless of strain type [18]. The use of probiotics or synbiotics can alter the ratio between renal and fecal N excretion in broiler chickens, influencing the dynamics of ammonia [19]. Phytobiotics also have an immunomodulatory role and represent a therapeutic method of supporting the body in immune and metabolic disorders [20,21].

By analyzing management practices, we look at the effect of ventilation, animal density, and growth rate as management options for reducing the negative effect of ammonia on production parameters. Exposure of animals to high concentrations of ammonia causes irritation of the limbs, mucous membranes, and respiratory tract, including conjunctivitis and other dermatitis. Thus, a high concentration of NH_3 indirectly influences gene expression, affecting the immune response and productivity [15]. Ventilation serves to maintain adequate air quality inside the shelter where the chicks are raised. Uric acid degradation produces ammonia, leading to elevated concentrations in the litter. The common issues caused by poor housing conditions include frostbite, which is often the result of high humidity and cold temperatures; corneal burns from high ammonia levels caused by poor ventilation (the most common mistake is aggressively reducing airflow to maintain temperature); bumblefoot and dermatitis from wet litter [22].

The literature specifies that reducing stocking density can facilitate a better response of birds to unfavorable environmental conditions. The impact of nitrogen up to the physiological limit and the identification of the passing threshold into the pathophysiological area in birds is legislatively regulated by Directive 2010/75/EU (maximum concentration of ammonia emissions allowed in European countries: 20 ppm). According to studies in the professional literature, the main methods for effectively reducing ammonia emissions are: optimizing feed formulas and additives to reduce uric acid excretion, while respecting physiological requirements and thus the welfare of the birds; maintenance of optimal litter conditions through adequate ventilation and prompt waste removal to prevent enzymatic conversion of uric acid to NH_3 by urease-producing bacteria. In poultry production, uricolysis or the breakdown of uric acid by commensal microorganisms and bacteria (*Bacillus*), leads to NH_3 release, under favorable conditions of warmth and high moisture content [23,24]. The quality of the litter can be ensured by constantly recording and evaluating the following parameters: humidity (%); pH; volatilized ammonia; along with water consumption. Ambient temperatures, moisture content, and alkalinity of the litter define the concentrations of NH_3 released [9].

Daily water consumption is lower in broilers fed a reduced crude protein concentration, as less protein catabolism means lower ammonia production. Osmoregulation response, the effects of ammonia, and reduced polyuria in diets low in crude protein lead to a decrease in litter moisture.

Soybean-based carbohydrates include polysaccharides and oligosaccharides such as sucrose, raffinose, and stachyose. Poultry cannot efficiently digest raffinose and stachyose because they lack α-(1→6)-galactosidase, which influences the consistency of their excreta. Indigestible carbohydrates increase the viscosity and stickiness of droppings, even when litter moisture remains within acceptable limits.

Dissolved ammonia elevates litter pH and increase alkalinity, causing chemical irritation and footpad dermatitis. The combination of controlled litter moisture and decreased nitrogen excretion from low-protein diets synergictically reduces the prevalence of this welfare concern.

Recycling nitrogen in agriculture, along with increased demand for locally grown cereals and legumes, can reduce dependence on imports in the North-East of Romania. Locally grown ingredients will also encourage biodiversity and reduce the carbon footprint of poultry production [25]. From protecting nature to food safety and ongoing exposure to pathogenic diversity, it is no wonder that poultry farming is such a controversial topic these days.

Litter from poultry farms can be successfully used to fertilize agricultural soils due to its high nitrogen content, ensuring plant growth by providing essential nutrients such as phosphorus and potassium [26,27]. The addition of poultry manure to the soil increases its fertility through the decomposition of organic matter and the production of carbon dioxide, ultimately leading to increased grain root growth [28]. Thus, agricultural application of poultry manure along with copper and zinc supplementation can improve the yield of green bean (*Phaseolus vulgaris L.*) seeds. Also, for tomatoes (*Solanum lycopersicum L.*) very good results have been recorded and the use of chicken manure in this form has positive effects on productivity in organic farming [5]. Although nitrogen represents a relatively small proportion of total body mass, it plays a fundamental role in metabolic processes and it is an essential structural element of the organism. Ammonia and nitrates are important sources of nitrogen for plants in general. Ammonium salts underlie the generation of amino acids through reactions with certain ketoacids, while nitrates are assimilated by the plant cell after a reduction process [29].

Adding poultry manure to the soil increases soil fertility through the decomposition of organic matter and the production of carbon dioxide, ultimately leading to increased grain yields. Chicken manure mixed with zinc and copper has beneficial effects on green bean production in terms of green bean seed yield [28]. Therefore, the use of poultry litter in agriculture reduces the amount of chemical fertilizers.

The concept of "clean production" is based on the efficient organization of the initial stages of decomposition and processing of poultry manure, which leads to a higher utilization of animal manure as fertilizer for agricultural crops. An alternative approach that allows for accurate assessment of the environmental impact of NH_3 losses from agricultural practices is the dosimeter tube method, known as the dositube method, according to Van Andel et al. (2021). By ensuring adequate nutrition for plants, combined with the use of microorganisms that stimulate plant growth, it is possible to achieve functional balance and sustainable agriculture. A relevant example is the association of corn seeds with *Azospirillum brasilense* and the use of chicken litter as fertilizer, a combination that has positive effects on *Zea mays* L. crops, as reported by Vitto et al. (2022).

Scientific studies have shown the benefits for improving and increasing the yield of peas, green beans, tomatoes, rice, and wheat [31,32]. Domestic vegetable cultivation (peas, lupins, field beans, soybeans) is practiced in temperate zones. Peas have an optimal growth yield in the absence of precipitation and at extreme air temperatures. Legume seeds are a sustainable alternative to soybeans in poultry feed. For nutritional and ecological reasons, growing vegetables for animal and human nutrition has become important. Peas are an effective source of protein that enhances production parameters and exhibits AA bioavailability similar to soybean meal, with a particular emphasis on lysine and methionine, which are necessary for poultry and pig production [32].

As production expands in line with consumer demand, the future must be improved by adopting technology and alternative nutritional strategies, thus changing practices in order to minimize the negative impact on the environment. [33]. Housefly larvae (*Musca domestica* L.) can be successfully reared on chicken, pig, and cattle manure, both in a laboratory and industrially. Mass rearing of insects on farm manure can provide a source of protein for animal feed, but also a partial solution for reusing surplus manure and protecting the environment [34]. The use of nitrogen fertilizers is cheaper and more accessible, and ammonia is the key component of fertilizers [34,35]. According to Maikol et al. (2021), chicken manure improved the total nitrogen concentration in the soil, the availability of total phosphorus in the soil, the bioavailability of cations (Ca, K, Mg, Na, and Si), soil fertility by increasing soil pH, and by reducing Al and Fe. Proper fertilization implies the use of plant growth biostimulants (modern agriculture), which have the role of reducing the adverse effects of stress factors on plants. Poultry waste acts as a soil biostimulant by improving plant nitrogen absorption, chelating phytotoxic heavy metals, and providing antioxidant compounds that enhance stress tolerance.

Prolonged exposure to NH_3 emissions affects the immune system, causes behavioral disorders (cannibalism is not a normal behaviour in birds), disrupts production characteristics, and all these conditions manifest as stress-inducing factors in birds and cause serious consequences throughout the production chain. Poultry farms should consider measures to integrate the rearing environment into nature in order to protect the welfare of birds, consumers, and nature. For example, obtaining vermicompost from animal excrement is a sustainable option for recycling nutrients and mitigating toxic gas emissions, such as ammonia, and are also a renewable source of humic substances which, when added to broiler feed, have the ability to improve growth, nitrogen retention, and reduce ammonia emissions from manure [37].

Environmental factors play an important role in the dynamics of microorganisms associated with poultry litter. Gutierez and colleagues analyzed the inhibition kinetics of urease-producing bacteria, such as *Corynebacterium urealyticum*, and the results indicated that high levels of ammonia in poultry litter can enhance the presence of pathogens that impact human health, such as *Salmonella spp.* [26].

An increased moisture level in litter stimulates the proliferation of pathogenic bacteria in the growing environment and is a contributing factor in the occurrence of diseases such as crusty dermatitis caused by *Cnemidocoptes mutans*, feather loss dermatitis, and other types of infections. In addition, poultry litter is characterized by a high organic nitrogen content, and the ammonia resulting from its decomposition influences the survival capacity of *Salmonella enterica* serovar *Typhimurium*.

Avian species worldwide harbor *Campylobacter jejuni*, *C. coli*, and *C. lari* as intestinal commensals, with widespread ditribution in both domestic and wild bird populations as well as aquatic environments. Despite colonizing hosts asymptomatically, *Campylobacter spp*. exhibit pathogenic potential, with *C. jejuni* specifically inducing chronic imflammatory responses, enteral tissue pathology and diarrhea in broiler chickens. The spread of *Campylobacter spp*. in farm chickens usually occurs through horizontal transfer via feed or drinking water.

Poultry litter represents an ecological concern, because is a primary source of *Salmonella* contamination. Pathogen survival in litter depends on heat treatment, storage conditions, and litter type, all of which influence zoonotic transmission risks to humans via the food chain. Control strategies include both environmental management and dietary interventions. Microencapsulated essential oils (thymol, carvacrol) and organic acids (sorbic acid) efectively reduce *Salmonella* colonization in broilers, protecting intestinal health and decreasing pathogen dissemination into litter. The favorable effects of eliminating salmonella from the poultry farming environment consist of reduced contamination and in the carcasses subsequently obtained in slaughterhouses [39]. A good example is the spraying of nanoparticles of zinc oxide, copper oxide, and aluminum sulfate, which have been shown to have an antibacterial effect in mitigating environmental problems in poultry shelters [40].

Studies in the scientific literature indicate that many countries in the European Union are facing outbreaks of avian influenza, and the main factor incriminated in its transmission is transport from one farm to another, given the existence of wild birds that can transmit the influenza virus to domestic birds. Since the viral load is ubiquitous in the shelter, accumulated in dust particles, it is necessary to update and reevaluate dust sampling and collection strategies for the early detection of influenza virus in poultry [41]. It is not recommended to establish treatment, but rather to implement disease prevention measures that are superior to the classic approach.

CONCLUSIONS

This biotechnological circuit in poultry farming should be further investigated to demonstrate the importance of respecting natural laws, from ensuring the health and welfare of poultry and consumers to protecting the environment. Management and the measures applied should be better reviewed, and the Romanian scientific community should contribute morally and socially to gathering clear information to support these issues.

The welfare and health of birds are influenced by nutritional factors (AA), the rearing system (zootechnical factors), vaccinations, prophylactic measures and treatments. Considering the ethical aspects of veterinary actions, as well as environmental protection and integration for food safety, we can deduce the importance of updating prophylaxis management and managing how sanitary-veterinary prevention methods should be applied in poultry farming in Romania. A strategic closure of the nitrogen cycle in nature through broiler farms consists of reusing the litter every two weeks by adding new litter. The integration of modern technological solutions, including the potential development of automated litter management systems, may contribute to improving veterinary management practices and supporting the healthy rearing of meat-type poultry hybrids.

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