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Impact of Dietary Nucleotide in Poultry Feeding

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Abstract

The usage of antibiotics resulted in the development of antibiotic resistant pathogenic bacteria and alters the gut microflora of the gastrointestinal tract. These antibiotic residues also pose a potential treat to consumers' health. Due to health concerns, most of the countries have baned the use of antibiotics in poultry production. Nucleotides play an important role to nearly all biological processes. Nucleotides serve as the fundamental components of DNA and RNA, and are integral to cellular metabolism, functioning as energy carriers (ATP), participating in cell signaling (cAMP) and constituting essential cofactors (NAD^+). The predominant feed ingredients possess comparatively low levels of nucleotides. The supplementation of nucleotides in animal feed enhances the overall production efficiency. The application of nucleotides results in superior feed efficiency, bolstered immunity and enhanced gut health, thereby establishing them as a significant alternative to antibiotic growth promoters in poultry production.

Keywords: Alternatives, Antibiotic, Nucleotides, Poultry

Introduction

Nucleotides, low-molecular-weight intracellular biomolecules, are the basic unit of DNA, RNA, ATP and other key coenzymes which are essential for every organism to be part of both structural and functional roles towards cell division in forming new cells in case of growth and tissue repair and other various biological role like coding for proteins, hormones, enzymes, metabolic pathways and several other essential molecules in the body (Table 1). Without adequate nucleotide levels, all of these processes could be disturbed in a healthy bird. Similarly to biomolecules like amino acids, nucleotides can also be synthesized through *de novo* process within the body or could be salvaged and recycled from other molecules (Figure 1). Unlike in other species, poultry have a relatively higher metabolism due to their growth rate and higher body temperature, which burdens up in requirement of building blocks like nucleotide, demanding for external supplement of nucleotides in diet rather than depending on *de novo* synthesis. Dietary supplementation of nucleotides in poultry feeding can help to reduce the stress from depletion of nucleotides utilized in cell proliferation and differentiation in certain level, especially during the early growth period.

Table 1: Nucleotides role in cellular and biological function

Nucleotides	Cellular function	Biological role
ATP	Actine-myosin interaction	Muscle contraction
NTP	RNA synthesis (translation)	Protein synthesis
dNTP	DNA synthesis (replication)	Proliferation
NAD, FAD	Redox reactions	Metabolism
Coenzyme A	Krebs cycle	Fatty acids metabolism
UDP-glucose	Neoglycogenesis	Liver functions, muscle growth

The inclusion of dietary nucleotides in chicken nutrition has gained popularity due to their potential to enhance growth performance, immunological response and overall health in birds. Nucleotides, a category of macromolecules, are essential for physiological activities such as DNA synthesis, bioenergetics and gastrointestinal health. This article offers a detailed review of dietary nucleotides and their impact

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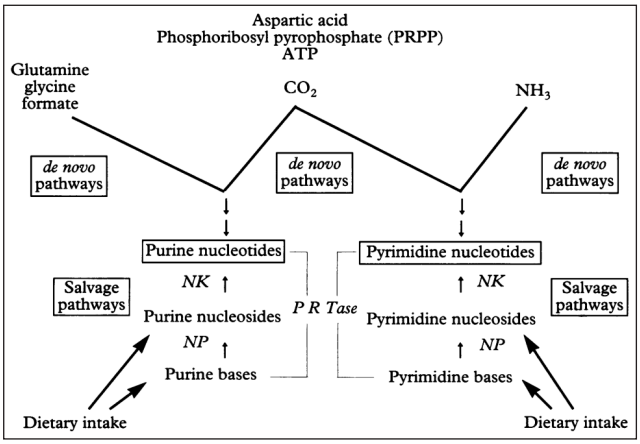

Figure 1: Pathways of purine and pyrimidine metabolism

on broilers, focusing on growth performance and health outcomes, while correlating these findings with the previous research investigations (Hassanein *et al.*, 2023; Zahran *et al.*, 2020).

Sources of Dietary Nucleotides

Dietary sources of nucleotides are naturally found in feed ingredients like animal and fish products and by-products, legumes and yeast with a high availability especially in organ meat; whereas, its availability in oil and oilseeds, soybean meal and corn were very low in level. Previously, it was believed that supplementation of dietary nucleotides was non-essential nutrient in farm animal feeding. It was assumed that animals could synthesize adequate nucleotides to fulfill their physiological requirements through *de novo* synthesis or a salvage mechanism. However, in later days it was learnt that only *de novo* synthesis could not provide sufficient nucleotides to meet the physiological needs under certain circumstances, such as speedy growth, reproduction and ecological stressors. Hence the concept of feeding nucleotides in feed has evolved leading to formulation of dietary nucleotides. Out of which many natural resources for dietary nucleotides, yeast forms the best source for feeding animals owing to their cost effeteness and its mass production.

Impact of Dietary Nucleotides on Poultry

Supplementation of dietary nucleotides in poultry feeding had shown several biological benefits (Figure 2), such as improved production performance, immune modulation, enhanced immune response towards vaccination, improved gut health during *Eimeria* and *Clostridium* infections, stress response and enhanced meat quality.

Growth Performance

Feeding dietary nucleotides in poultry feed has shown to have positive effect on the growth performance in poultry. Nucleotides are basic building blocks of DNA, their need during rapid cell growth or cell division is highly essential. It would be a rate-limiting factor in chicks especially in broiler production; hence an exogenous supplementation would aid in overcoming the shortfall during early growth stage and also directly diminishes the energy demand for the *de novo* synthesis of nucleotides. In several studies, usage of yeast based dietary nucleotides resulted in higher daily

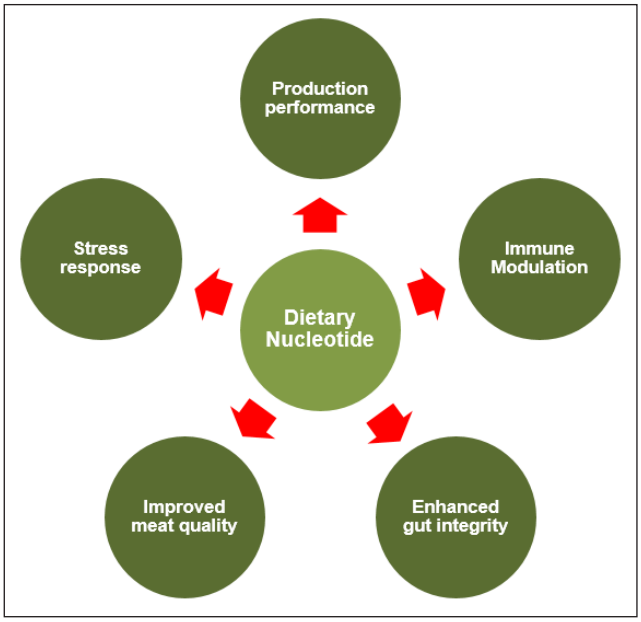

Figure 2: Benefits of dietary nucleotide

weight gain, higher body weight and better feed conversion ratio. These supplementations were found much effective only during the early stages of growth especially first three weeks of age, in promoting weight gain.

Studies indicate that nucleotides enhance growth performance by increasing body weight gain and improving feed conversion ratio (FCR), particularly during the starter phase (Hassanein *et al.*, 2023; Zahran *et al.*, 2020). For instance, broilers provided with nucleotide-supplemented diets exhibited higher body weight and better FCR, compared to control (Abo-Sriea *et al.*, 2024; Kreuz *et al.*, 2020). These improvements are attributed to the role of nucleotides in optimizing nutrient utilization and enhancing metabolic efficiency.

But also it was found that dietary nucleotide supplementation was beneficial in later stages of growth during high density stocking or dirty litters by means of elevating the stress. Birds fed with yeast based nucleotides showed higher body weight which in turn resulted in higher carcass yield and more returns. Apart from growth performance it was also noticed to have effect on the egg production, livability, fertility and hatchability. Additionally, supplementation has been associated with increased economic efficiency in poultry farming by reducing feed costs and improving growth rates. Research demonstrates that nucleotide supplementation can lead to higher profitability by reducing feed costs and improving growth rates (Zahran *et al.*, 2020). Zahran *et al.* (2020) concluded that broilers fed nucleotide-supplemented diets had a higher economic efficiency ratio compared to control groups.

Immune Modulation

Bacterial and viral infections are commonly encountered problems in large scale poultry farming distressing both health and productivity. Conventionally, antibiotics and other agents are usually used as prophylactic or therapeutic in poultry industry in order to control or to check bacterial infections. But, owing to rise in consumer concerns and

awareness usage of antibiotics and other agents were considerably reduced. Also owing to rise in alarming rate of antimicrobial resistance among pathogenic organism in poultry had led to think of alternatives to improve poultry health. As a result, many European nations have prohibited the use of antibiotics as a growth promoter in livestock feeding. This had led to search and demand for alternatives to antibiotics, where these dietary nucleotides could play as immune modulators and aid in reducing the antibiotics load in poultry industry. To have faster and strong immune response against infection or invading pathogens the bird should have good immune status both innate and adaptive immunity to protect itself from the pathogen.

Dietary nucleotides enhance both the humoral and the cellular immunity in broiler chickens, improving their resistance to infections and vaccination response. Studies by Kreuz *et al.*, (2020) and Abo-Sriea *et al.* (2024) have reported increased serum immunoglobulin G (IgG) levels, higher antibody titers and improved phagocytic activity in broilers fed nucleotide-supplemented diets. These immune-enhancing effects are particularly beneficial in challenging conditions, such as inflammatory stress or pathogen exposure.

Feeding of dietary nucleotides had proven to enhance the immune status by means of increased production of leukocytes and macrophages. In mycotoxin challenged study showed feeding of dietary nucleotides had enhanced DNA repair in immune cells due to free radicals and cellular death. Also several studies had showed improved performance during challenged conditions compared to dietary nucleotides unfed chickens. In poultry production vaccination is a routine practice to protect flock from most of the viral diseases to prevent and control of infectious diseases. Dietary yeast nucleotides found to have activated a rapid and stronger antibody response against the regular vaccines used in poultry industry. In a study feed with dietary nucleotides found attaining effective protection antibody level one week prior to the control group. Dietary nucleotide feeding has shown increased immune organ weight compared to the control group.

Gut Health and Integrity

The positive effects on gut health and on intestinal microbiota were well established through several research works in chickens. Owing to rapid growth and development, the younger birds possess an immature digestive tract; the role of dietary nucleotides in promoting intestine growth and gut maturation has been extensively documented. Supplementation with dietary nucleotides led to an improved gut microbiome, which in turn enhanced production performance, as well as increased concentrations of lactic acid-producing bacteria and a diversified intestinal microbiota.

Nucleotides have a positive impact on intestinal morphology, particularly villus height and crypt depth. Research indicates that additional nucleotides result in an increased villus height in the jejunum and ileum, thus increasing the absorptive surface area which facilitates nutrient absorption (Kreuz *et al.*, 2020). This improvement in small intestinal morphology is important for digestion and nutrient absorption.

Research by Wu *et al.* (2018) showed that yeast based nucleotides supplementation improved poultry intestinal health, as it resulted in higher villi count and increased height to crypt depth measurements of intestinal villi. Nucleotides assist in restoring gut microbiota balance by eliminating harmful bacteria (*e.g.*, Clostridia) and promoting beneficial microorganisms. Research indicates that supplementation with nucleotides decreases levels of harmful microorganisms (*e.g.*, Clostridia) and stimulates beneficial microorganisms (Abo-Sriea *et al.*, 2024). A balanced gut microbiota promotes a healthier gut environment and overall enhanced performance.

Meat Quality

When chickens were administered nucleotides, it was observed that the treatment group meat exhibited increased tenderness and a deeper red hue, which was increasing the aesthetic value of meat leading to fetching higher price than the normal meat. Owing to nucleotide feeding, the gut health has been improved leading to better digestion of nutrients, which in turn leads to production of meat having enhanced nutritional characteristics like higher iron contents, increased lipids with elevated degrees of unsaturation that have advantageous health effects on people.

Stress Response and Antioxidant Benefits

Nucleotides are also believed to improve antioxidant status in broilers. It is also studied that dietary nucleotide supplementation enhances antioxidant enzyme activity, including glutathione peroxidase (GPx) and superoxide dismutase (SOD), while reduces the malondialdehyde (MDA) levels. Consequently, this enhancement in antioxidant capacity safeguards against the oxidative stress and promotes the preservation of cellular health.

Under stressful conditions, mortality in treated birds with nucleotide was reduced approximately by 30% upon control birds. During stress, cellular damage will be in higher rate due to release free radicals, higher levels of nucleotides will be needed in this period for cell repair mechanism. Salvaging of nucleotides or *de novo* synthesis of nucleotide during this period may delay the process of alle*via*ting the cellular stress. Hence, direct feeding of nucleotide *via* diet may hasten the process and aid birds to cope up with the stress conditions. Dietary nucleotides in *C. perfringens* infected chickens reflected positively on the growth performance and also improved the intestinal barrier function and intestinal histomorphology.

Conclusion

Nucleotides are semi-essential nutrients; however, during periods of rapid growth, stress or diseased conditions, the body's natural synthesis may not be adequate to meet physiological demands. Hence, the supplementation of nucleotides boosts the production performance and also enhances the immune system. Broiler productivity and well-being improve through nucleotide supplementation because this intervention enhances body weight, FCR and immunity

as well as gut health and antioxidant capacity. Additionally, nucleotide supplementation provides an economic value to poultry diets due to its advantages. However, proper determination of nucleotide supplementation amounts leads to maximizing benefits without adding unnecessary costs. It is concluded that dietary nucleotides are determined to be a beneficial alternative to antibiotics for chickens.

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