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EFFECT OF DIETARY BETAINE SUPPLEMENTATION ON POULTRY PERFORMANCE, CARCASS, AND BLOOD CHEMISTRY

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ABSTRACT

Betaine serves a dual role as both an osmolyte and a methyl donor. Due to its inclusion of methyl groups, it has the potential to reduce dietary methionine requirements. Additionally, as a zwitterion, betaine exhibits osmolytic properties that assist animals to cope with osmotic stress. Numerous studies have explored the effects of betaine, though their findings have not always been consistent. However, dietary betaine continues to attract significant interest for its roles as an osmoprotectant, a methionine-sparing agent, and an antioxidant. Researchers have extensively examined its impact on poultry growth performance, body composition, and overall productivity. Some of the most frequently cited benefits of betaine supplementation include improved high ambient temperature tolerance or heat stress tolerance, increased flock survivability, and enhanced breast meat yield. As an essential nutritional compound, betaine may play a crucial role in helping poultry withstand heat stress and suboptimal management conditions. One of the most widely discussed aspects of betaine research is its ability to partially replace methionine in poultry diets. Studies consistently report certain benefits, despite varying findings. Betaine and methionine are commonly incorporated into poultry feed due to their effectiveness in promoting growth, enhancing feed efficiency, improving meat quality, and mitigating heat stress in commercial poultry farming. Given these advantages, this article aims to examine the role of betaine as a feed additive in poultry production, particularly its influence on growth performance, carcass traits, meat quality, antioxidant activity, and its function in heat stress management.

***Keywords**:* Betaine, choline, methionine, poultry, metabolism, performance, heat stress.

INTRODUCTION

With the rising demand for poultry meat, intensive farming practices have been widely adopted to maximize production efficiency. However, these practices can lead to several challenges, including compromised animal welfare, diminished meat quality, and altered flavor profiles (Petracci *et al.,* 2009; Maznouk, 2025). Recently, there has been a growing interest in utilizing natural plant extracts to improve animal health and productivity (Mahmoud *et al.,* 2025). Betaine, a trimethyl derivative of glycine, is naturally present in various plants, such as alfalfa meal, wheat, and sugar beet (Chendrimada *et al.,* 2002). As part of broader nutritional strategies aimed at enhancing poultry meat quality, betaine has gained attention for its physiological and

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nutritional benefits (Dong *et al.,* 2020). As a methyl donor, betaine contributes to osmoregulation, antioxidant defense, and nutrient metabolism in poultry (Eklund *et al.,* 2005; Alirezaei *et al.,* 2012; Attia *et al.,* 2018).

Initial studies on betaine in poultry nutrition concentrated on its function in averting perosis and enhancing growth. Betaine compound is a by-product of sugar beet processing and is also referred to as "glycine betaine" or "trimethylglycine." The two most common forms of betaine include betaine hydrochloride (C_5H_{12}-$ClNO_2$) and anhydrous betaine ($C_5H_{11}NO_2$). It is highly water-soluble and can be incorporated into poultry rations as a liquid supplement, a dry powder, or a crystalline powder dissolved in drinking water. Studies have demonstrated that supplemental betaine positively influenced growth performance, muscle yield, lipid metabolism, and immune function (Attia *et al.,* 2009; Akhavan-Salamat & Ghasemi, 2016). Additionally, betaine has been identified as a lipotropic agent that facilitates fat mobilization from the liver and promotes lipid turnover within the body (Saunderson & Mackinlay, 1990). It has also been utilized in low-crude protein diets with a high metabolizable energy-to-protein ratio to optimize poultry nutrition (Ghasemi & Nari, 2020). Betaine's osmoregulatory function is necessary to preserve intestinal enzyme stability and cellular protein integrity under environmental stressors, ultimately leading to improved poultry performance (Ratriyanto *et al.,* 2010). Furthermore, betaine has been implicated in protecting against acute and chronic liver dysfunctions by mitigating oxidative stress at the mitochondrial level and modulating satellite cell activity (Fig. 1). Its regulatory effects go beyond liver health; they also affect the immune system, the heart, the nervous system, and the kidneys (Kidd *et al.,* 1997; Sakomura *et al.,* 2013). Given these multifaceted benefits, betaine continues to be widely explored as a valuable additive in modern poultry feeds.

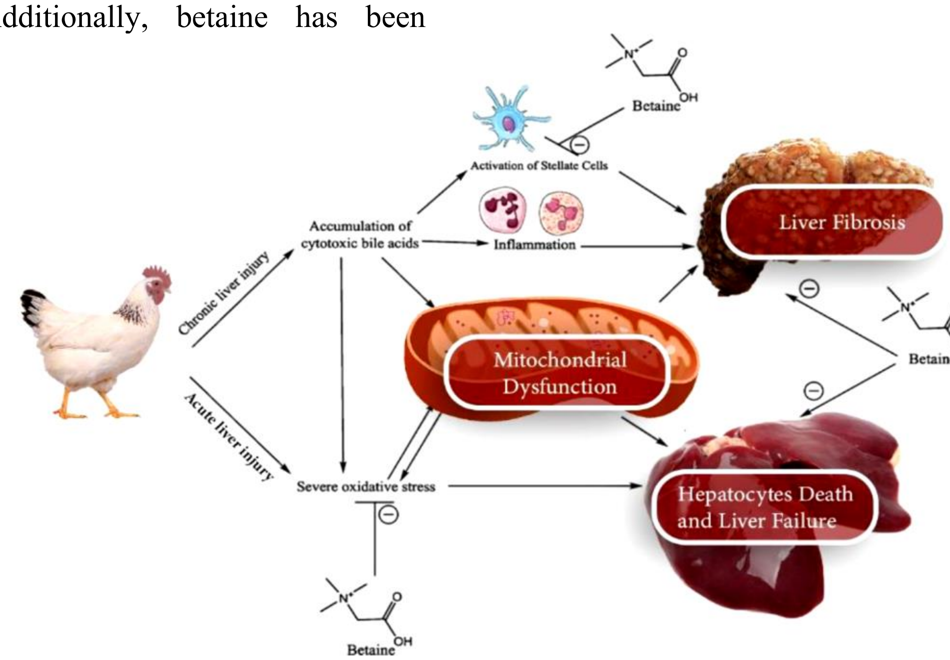

Figure 1: The mechanism of betaine in poultry liver injuries (Alagawany *et al.,* 2022)

Synthesis and chemical structure of betaine

Chickens are capable of synthesize betaine from choline, which they obtain through their diet. This endogenous production occurs in the liver, where choline, after being absorbed by the intestinal epithelium, is transported via portal circulation. Upon entering hepatic cells through active transport, choline primarily crosses membranes of mitochondria (Porter *et al.,* 1993). The enzyme choline oxidase catalyzes the conversion of choline to betaine aldehyde, which is subsequently processed by betaine aldehyde dehydrogenase to form betaine. The newly synthesized betaine then diffuses into the cytosol through membranes of mitochondria (Porter *et al.,* 1992).

Regardless of whether betaine is sourced internally or externally, it plays a critical role in cellular metabolism. Betaine can either help cells keep their fluid balance by acting as an osmolyte, or help make methionine by acting as a methyl donor. Structurally, betaine is a zwitterionic compound consisting of a positively charged trimethyl ammonium group and a negatively charged carboxyl group (Singh *et al.,* 2022). It is a trimethylated derivative of glycine, characterized by its small size, high solubility, and neutral nature. Chemically, it is known as N, N, N-trimethylammonioacetate (Alagawany *et al.,* 2022).

The advantageous of dietary betaine supplementation on poultry
Growth and Productivity

Incorporating betaine into poultry diets has been shown to enhance key performance metrics, such as feed utilization and average weight gain. Studies have demonstrated these benefits in broiler chickens (Zulkifli *et al.,* 2004; Sayed & Downing, 2011) and ducks (Wang *et al.,* 2004). Research by Awad *et al.* (2014) found that adding betaine at levels of 0.5, 1.0, or 1.5 g/kg diet significantly improved viability rate, feed conversion ratio (FCR), live body weight (LBW), and body weight gain (BWG) as well. Similarly, El-Shinnawy (2015) reported that broilers fed diets containing 1.0, 1.5, 2.0, or 2.5 g/kg of betaine exhibited notable increases in LBW and BWG. Additional research demonstrates that betaine supplementation is especially advantageous in conditions of heat stress. Nofal *et al.* (2015) found that levels of 0.1% or 0.2% betaine significantly improved final live weight and BWG in growing chicks exposed to heat stress. Shakeri *et al.* (2018) showed that adding 1 g/kg of betaine to broiler diets not only alleviated heat stress, but also improved BWG, FCR, and breast muscle development. They attributed these benefits to reduced respiration rates and lower rectal temperatures, which allow birds to utilize energy more efficiently for muscle growth, rather than thermoregulation.

In ducks, betaine supplementation in combination with vitamin C and reduced feed withdrawal has been shown to enhance live weight gain (LWG) under heat stress conditions. However, the improvement in LWG ranged from only 4.3% to 6.3%, without affecting feed intake (Downing, 2022). Park & Park (2017) reported that diets containing 700 ppm of betaine positively influenced short-chain fatty acids (SCFAs), biochemical blood markers, and overall body weight in broiler ducks under heat stress conditions. Bang *et al.* (2015) investigated the effects of feeding Cherry Valley ducks (*Anas platyrhynchos*) a diet containing 800 ppm betaine under heat stress conditions. They found that offering this diet twice daily significantly enhanced growth performance. Another study by Park & Zammit (2019) explored how ducks aged 22–42 days responded to a combination of feed restriction, betaine (800 mg/L), and vitamin C (300 mg/L) at 34°C. Their results showed that heat stress lowered LWG by 28.6%, but the combined treatment with betaine lessened the drop to only 10.2%. Betaine has also been shown to influence fat metabolism. Studies on geese indicate that supplementing their diets with betaine can lower fat deposition and promote lipolysis during the finishing stage, thereby decreasing overall energy needs and feed consumption (Yu *et al.,* 2013). Research by Su *et al.* (2009) further suggests that betaine supplementation reduces abdominal fat in Landes geese while improving liver weight and repairing hepatic damage, changes that could have positive economic implications for poultry producers (Su *et al.,* 2009).

Carcass Characteristics

Supplementing poultry diets with varying concentrations of betaine has been linked to improvements in breast muscle yield and reductions in body fat content across multiple poultry species. Studies have shown that betaine enhances breast muscle development in broilers (Esteve-Garcia & Mack, 2000; McDevitt *et al.,* 2000; Virtanen & Rosi, 1995), while simultaneously decreasing body fat levels in broiler chickens (Gholami *et al.,* 2015; Nofal *et al.,* 2015), turkeys (Remus, 2020), and ducks (Wang *et al.,* 2004). Adding betaine at concentrations of 0.1% or 0.2% to poultry diets has resulted in significant improvements in carcass weight, dressing percentage, and yields of thighs, breasts, and giblets (Nofal *et al.,* 2015). El-Shinnawy (2015) further observed that broilers supplemented with betaine exhibited higher breast yield, a greater proportion of total edible parts, and overall improved carcass characteristics. Notably, during heat stress conditions, dietary betaine supplementation proved especially effective in increasing breast muscle weight, particularly in broilers raised during the summer months (Enting *et al.,* 2007).

In ducks, the inclusion of betaine at 1.0 to 1.5 g/kg diet significantly enhanced breast muscle yield (Awad *et al.,* 2014). However, research by Sun *et al.* (2008) and Yang *et al.* (2022) indicated that although betaine supplementation did not have a major effect on liver, gizzard, or giblet weights, it notably reduced abdominal fat deposition. Additionally, some studies reported no significant impact of betaine on carcass weight, breast yield, or internal organ development in broilers (Sakomura *et al.,* 2013; Konca *et al.,* 2008). Similarly, Al-Tamimi *et al.* (2019) found that betaine and/or creatine supplementation did not influence most carcass traits, apart from a minor effect on the redness of breast muscle.

In geese, feeding with betaine-enriched diets resulted in higher liver weight and lower abdominal fat accumulation compared to birds subjected to overfeeding regimens (Su *et al.,* 2009). Furthermore, a comparative study examining the effects of DL-methionine (1.2 g/kg diet) and betaine (0.5 g/kg diet) on carcasses and growth performance suggested that betaine outperformed methionine in improving feed efficiency, growth rate, and meat quality in ducks during the starter phase (Wang *et al.,* 2004).

Biochemical parameters

Betaine also exerts notable biochemical effects, particularly in lipid metabolism. The liver turns free fatty acids into triglycerides (TG), which are then used to make lipoproteins or phospholipids. Lipoproteins, primarily secreted into the bloodstream, such as the very low-density lipoproteins (VLDL), serve as carriers of lipids, while phospholipids are essential structural components of cell membranes. The synthesis of phospholipids occurs within the smooth endoplasmic reticulum (SER) and cytosol, whereas lipoproteins undergo assembly in the Golgi apparatus before being released into circulation (Harper *et al.,* 1973). Su *et al.* (2009) reported that geese supplemented with betaine exhibited increased liver weight alongside reduced abdominal fat deposition compared to overfed groups. Betaine supplementation also led to significant increases in the levels of plasma cholinesterase (ChE), high-density lipoprotein (HDL), lactate dehydrogenase (LDH), and alanine aminotransferase (ALT), indicating a potential role in lipid metabolism and liver function regulation.

Beyond lipid metabolism, betaine has been shown to possess strong antioxidant properties. Nutautaitė *et al.* (2020) found that including 1 to 2 g betaine/kg in broiler diets lowered malondialdehyde (MDA) levels in breast muscle, highlighting betaine’s ability to reduce oxidative stress and preserve cellular antioxidant reserves. Moreover, supplementing broiler diets with 1 g betaine/kg improved breast muscle tenderness, further suggesting that betaine enhances meat quality through its antioxidative mechanisms. The antioxidant function of betaine is linked to its role in mitigating oxidative damage and lipid peroxidation by restoring S-adenosyl methionine (SAM), a key methyl donor involved in cellular detoxification. Chen (2022) demonstrated that broilers fed betaine or hydrochloride betaine exhibited increased glutathione peroxidase (GPX) activity and higher glutathione (GSH) levels in breast muscles, coupled with reduced MDA concentrations in both breast and thigh muscles. The high-dose betaine group exhibited a significant increase in total antioxidant capacity (T-AOC; $P = 0.003$) and total superoxide dismutase (T-SOD) activity in breast muscle, along with heightened GPX activity in thigh muscle.

SOD (superoxide dismutase) is an important antioxidant enzyme that catalyzes the conversion of the superoxide anion (O_2^-) into hydrogen peroxide (H_2O_2), which is subsequently neutralized by glutathione S-transferase (GST), catalase (CAT), and GPX (Alirezaei *et al.,* 2012). These enzymes work in concert, to protect cells from oxidative stress by breaking down reactive oxygen species (ROS) into non-toxic byproducts, thereby maintaining cellular homeostasis (Kheradmand *et al.,* 2010). Alirezaei *et al.* (2012) further confirmed that a dietary inclusion of 1,000 mg/kg betaine reduced lipid peroxidation while enhancing the activity of antioxidant enzymes in broiler breast muscle.

The beneficial impacts of betaine on antioxidant status in muscle have been observed not only in poultry, but also in other livestock and aquatic species, including ducks, lambs, and fish (Adjoumani *et al.,* 2017; Chen *et al.,* 2019; Dong *et al.,* 2020). The role of glutathione (GSH) as a non-enzymatic antioxidant is critical in scavenging free radicals and protecting tissues from oxidative damage under the GSH antioxidant system. Meanwhile, total antioxidant capacity (T-AOC) serves as a comprehensive measure of the body's overall antioxidant defenses (Wu *et al.,* 2004; Deng *et al.,* 2018).

Protective Effects of Betaine

The benefits of dietary betaine stem from its multiple physiological functions, which include:

1. Acting as an extracellular osmolyte, reducing the activity of Na+/K+ ATPases and consequently lowering energy expenditure (Moeckel *et al.,* 2002; Tsai *et al.,* 2015).
2. Minimizing gastrointestinal tract (GIT) energy demands during stress conditions (Cronjé, 2015).
3. Serving as a methyl donor, which promotes DNA methylation and enhances methionine remethylation from homocysteine, thereby supporting protein synthesis (Shakeri *et al.,* 2018).

CONCLUSION

Adding betaine to poultry diets has proven beneficial in boosting the growth performance of broiler chickens and other bird species. It improves the quality of the carcass, helps maintain osmotic balance, and helps birds deal with heat stress. Betaine enhances cellular function and overall resilience in adverse conditions by serving as an osmoprotectant and methyl donor. Despite its known advantages, further research is required to fully understand its mode of action and metabolic roles in birds, enabling more effective dietary strategies for improved productivity and health in poultry farming.

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تأثير الإضافة الغذائية من البيتايين على أداء الدواجن، وخصائص الذبيحة، وكيمياء الدم

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يؤدي البيتايين دورًا مزدوجًا كعامل حماية أسموزي وكمانح لمجموعة الميثيل، وبفضل احتوائه على مجموعات الميثيل، فإنه يمتلك القدرة على تقليل الاحتياجات الغذائية من الميثيونين، بالإضافة إلى ذلك، وباعتباره جزيئًا متأينًا، يُظهر البيتايين خصائص أسموليتية تساعد الحيوانات على التكيف مع الإجهاد الأسموزي. وقد تناولت العديد من الدراسات تأثيرات البيتايين، لكن نتائجها لم تكن دائمًا متسقة، ومع ذلك لا يزال البيتايين محل اهتمام كبير بسبب أدواره كعامل حماية أسموزي، ومُوفر للميثيونين، ومضاد للأكسدة. وقد تم فحص تأثيره بشكل مكثف على نمو الدواجن وتكوين الجسم والإنتاجية بصورة عامة، ومن أبرز الفوائد الشائعة للإضافة الغذائية من البيتايين تحسين التحمل لدرجات الحرارة المرتفعة أو الإجهاد الحراري وزيادة معدل الحيوية في القطيع وزيادة نسبة لحم الصدر، وباعتباره مركبًا غذائيًا أساسيًا، قد يلعب البيتايين دورًا مهمًا في مساعدة الدواجن على تحمل الإجهاد الحراري والظروف البيئية غير المثالية، ومن أكثر الجوانب التي تم مناقشتها في أبحاث البيتايين قدرته على تعويض جزئي للميثيونين في علائق الدواجن، وعلى الرغم من تفاوت النتائج بين الدراسات، إلا أن هناك فوائد معينة تم التحصل عليها باستمرار، ويتم إدخال أو إضافة كل من البيتايين والميثيونين بشكل شائع في أعلاف الدواجن نظرًا لقدرتهما على تعزيز النمو وتحسين كفاءة التحويل الغذائي وتحسين جودة اللحوم والتخفيف من آثار الإجهاد الحراري في تربية الدواجن على نطاق تجاري. ونظرًا لفوائده العديدة, تهدف هذه المقالة إلى دراسة دور البيتايين كإضافة غذائية في إنتاج الدواجن، مع التركيز على تأثيره على النمو وخصائص الذبيحة وجودة اللحم والنشاط المضاد للأكسدة ودوره في معالجة الإجهاد الحراري.