Physiological Functions of Tryptophan and Its Application in Livestock and Poultry Feed: Postprint

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Abstract

Tryptophan, as a functional essential amino acid, can improve animal growth performance, regulate feed intake and lactation, and enhance antioxidant capacity and immune function. Applied as a feed additive in low-protein diets, tryptophan can reduce dietary protein levels while maintaining normal animal production performance, thereby alleviating the shortage of protein feed ingredients and mitigating environmental pollution from animal waste. This review summarizes the physicochemical properties, metabolic pathways, and physiological functions of tryptophan in livestock and poultry, providing a reference for its scientific and rational application in animal production.

Full Text

Physiological Function and Dietary Application of Tryptophan in Livestock and Poultry

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Abstract: Tryptophan, as a functional essential amino acid, plays important roles in improving growth performance, modulating feed intake and lactation, enhancing anti-oxidative and immune functions, and so on in animals. When used as a dietary additive to a low-protein diet, tryptophan will reduce dietary protein level, but not alter production performance of animals, which results in relieving the current protein deficiency and decreasing the environment pollution caused by the waste of animal production. This paper reviewed the physicochemical properties, metabolic pathways, and physiological functions of tryptophan in livestock and poultry in order to provide knowledge for scientific and reasonable application of tryptophan in animal production.

Key words: tryptophan; metabolic pathway; physiological function; livestock and poultry; regulation

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1. Tryptophan Metabolic Pathways

Tryptophan serves as a crucial functional amino acid that regulates various physiological processes in animals. Approximately 2-3% of dietary tryptophan is utilized for protein synthesis, while the remaining 1-3% participates in metabolic pathways that produce bioactive compounds. Tryptophan metabolism primarily occurs through two major pathways: the serotonin pathway and the kynurenine pathway.

The serotonin pathway begins with tryptophan hydroxylase (TPH1), which converts tryptophan into 5-hydroxytryptophan, subsequently forming serotonin (5-HT). This pathway predominantly occurs in the gastrointestinal tract and brain, where serotonin acts as a critical neurotransmitter regulating mood, appetite, and gut motility. The kynurenine pathway, accounting for approximately 95% of tryptophan degradation, involves the conversion of tryptophan to kynurenine via indoleamine 2,3-dioxygenase. Kynurenine then metabolizes into various bioactive compounds including kynurenic acid, anthranilic acid, and quinolinic acid, which play important roles in immune modulation and neurological function.

2. Physiological Functions of Tryptophan

2.1 Immune Function Tryptophan exhibits significant immunomodulatory effects in animals. Research demonstrates that dietary supplementation with 0.04% L-tryptophan can improve humoral immune responses in broiler chickens [2], while 0.06% L-tryptophan enhances cellular immune function [3]. In weaned piglets, tryptophan supplementation increases serum immunoglobulin G (IgG) levels and improves immune organ indices [4]. Studies also show that 0.05% L-tryptophan in pig diets enhances lymphocyte proliferation, phagocytic activity, and serum antibody titers [5], while improving immune responses against swine fever virus and increasing IgG and IgM levels [6].

The immunomodulatory mechanisms involve multiple pathways. Tryptophan serves as a precursor for 5-HT, N-acetylserotonin, and melatonin, which regulate immune function through the nuclear factor-kappa B (NF- B) signaling pathway, thereby reducing pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α). Additionally, N-acetylserotonin promotes nitric oxide production by inducing nitric oxide synthase expression, further modulating immune responses. Tryptophan also regulates T-cell differentiation, converting naive T cells into regulatory T cells, which subsequently influences B-cell activation and IgG synthesis [7].

2.2 Antioxidant Function Tryptophan and its metabolites possess notable antioxidant properties. Studies indicate that 0.18% dietary tryptophan supplementation in weaned piglets increases superoxide dismutase (SOD) activity and glutathione (GSH) content while elevating glutathione peroxidase (GSH-Px) activity [8]. Other research demonstrates that L-tryptophan enhances SOD and GSH-Px activities while reducing malondialdehyde (MDA) levels [9]. The antioxidant effects are achieved through direct free radical scavenging and upregulation of antioxidant enzyme gene expression. Tryptophan metabolites, particularly melatonin, exhibit potent antioxidant capacity by neutralizing reactive oxygen species and upregulating SOD and GSH-Px activities, thereby reducing oxidative damage.

2.3 Appetite Regulation Tryptophan plays a critical role in regulating feed intake through its metabolites. Studies show that increasing dietary L-tryptophan from deficient to adequate levels (0.146% to 0.152%) significantly improves feed intake and growth performance in piglets [13]. The appetite-stimulating effects occur through two primary mechanisms: first, by increasing 5-HT synthesis, which modulates satiety signals; and second, through competition with other large neutral amino acids (LNAA) for blood-brain barrier transport, influencing brain tryptophan availability and subsequent 5-HT synthesis.

Recent research reveals that tryptophan also regulates appetite through ghrelin, a key hunger hormone. Zhang et al. [14] demonstrated that 0.13% tryptophan supplementation in weanling pigs increased plasma ghrelin levels and feed intake, establishing a positive correlation between tryptophan, ghrelin, and appetite regulation. Tryptophan appears to stimulate ghrelin secretion through both direct mechanisms and indirect pathways involving 5-HT signaling, with different receptors (5-HT1A and 5-HT2C) exerting distinct effects on appetite stimulation [15].

2.4 Lactation Function Tryptophan significantly influences lactation performance in sows. Paulicks et al. [16] reported that dietary tryptophan levels affect milk yield and composition, with optimal supplementation at 1.9 g/kg diet improving lactation performance. The mechanism involves tryptophan' s role in protein synthesis and its metabolites' effects on mammary gland function. During lactation, increased nutrient demand requires higher tryptophan intake to support milk production and maintain sow body condition. Studies on other amino acids like threonine and valine confirm that balanced amino acid profiles, including adequate tryptophan, are essential for optimal lactation performance [17-18].

2.5 Other Physiological Functions Tryptophan supplementation reduces plasma cortisol and noradrenaline concentrations, alleviating stress responses in pigs [21]. It also improves meat quality by reducing MDA content and enhancing antioxidant capacity in muscle tissue [19]. Additionally, tryptophan modulates intestinal health by improving intestinal morphology, enhancing barrier function, and regulating gut microbiota composition [20]. These multifaceted effects contribute to overall animal health and production efficiency.

In conclusion, tryptophan functions extend beyond protein synthesis to encompass immune modulation, antioxidant defense, appetite regulation, lactation support, and stress alleviation. As a functional amino acid, tryptophan holds significant potential for improving animal production efficiency and product quality while reducing environmental impact through lower dietary protein levels. Further research should optimize tryptophan supplementation strategies for different animal species and production stages to maximize its physiological benefits.

Note: Figure translations are in progress. See original paper for figures.