Tannins

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There are diverse challenges in the poultry production industry that decrease the productivity and efficiency of poultry production, impair animal welfare, and pose issues to public health. Furthermore, the use of antibiotic growth promoters (AGP) in feed, which have been used to improve the growth performance and gut health of chickens, has been restricted in many countries. Tannins, polyphenolic compounds that precipitate proteins, are considered as alternatives for AGP in feed and provide solutions to mitigate challenges in poultry production due to their antimicrobial, antioxidant, anti-inflammatory and gut health promoting effects. However, because high dosages of tannins have antinutritional effects when fed to poultry, determining appropriate dosages of supplemental tannins is critical for their potential implementation as a solution for the challenges faced in poultry production.

Keywords: Tannins,poultry production,animal welfare

1. Introduction

Poultry products including meat and eggs account for a significant part of global food production and constitute a protein staple throughout the world [1]. The United States Department of Agriculture (USDA) reported in 2016 that global egg production was approximately 70 million tons, and poultry meat production reached more than 100 million tons, which accounted for more than one-third of global meat production [2]. Moreover, global poultry production continues to increase annually [1]. However, there are many challenges in the poultry industry including: bacterial infection (salmonellosis); parasitic infection (coccidiosis); oxidative stress, including that caused by heat stress; welfare issues such as food pad dermatitis (FPD); and nitrogen and greenhouse gas emissions which can cause severe economic losses, threaten food safety and public health, impair animal welfare, and induce environmental pollution [2][3][4][5].

Antibiotic growth promoters (AGP) have been supplemented to chicken diets to improve growth performance and gut health, predominantly due to their antimicrobial effects and immunomodulatory functions in chickens [6][7]. However, because of the increased public concern about the transmission of antibiotic-resistant bacteria from poultry products, the use of AGP in poultry production has been banned or restricted in many countries [8][9][10]. In addition, some producers in the U.S. poultry industry have opted to entirely remove the use of antibiotics and instead raise chickens using “no antibiotics ever (NAE)” or “raised without antibiotics (RWA)” approaches [11][12]. As a consequence, the efficiency of poultry production has decreased due to increases in various bacterial and parasitic infections and reductions in the growth rate of chickens [13]. In addition, because there is no “magic bullet” that can replace AGP, some poultry producers are still using antibiotics in the U.S. and in many other countries, and the use of antibiotics for livestock animals in the world is expected to increase, possibly owing to population growth which is associated with a greater demand for livestock products in middle-income countries [14]. Therefore, it is essential to find alternatives to AGP, which must be cost-effective, eco-friendly and have antimicrobial and growth-promoting effects, without causing side effects (e.g., generation of resistant bacteria) to the animals and humans [15].

Tannins, defined as polyphenolic compounds that can precipitate proteins, are secondary metabolites, which are found in plants, seeds, bark, wood leaves and fruit skins and serve as plant defense mechanisms against predation [16]. High concentrations of tannins have been shown to have antinutritional effects in monogastric animals because tannins can decrease feed intake, nutrient digestibility and growth performance of chickens [17][18]. However, recently in poultry production, tannins have garnered a great deal of attention as an alternative for AGP because of their antimicrobial, antioxidants and anti-inflammation properties [19][20][21]. In addition, many tannins are considered sustainable feed additives, as they derive from byproducts of plant-based agriculture and industry. For example, chestnut tannins, which are already sometimes supplemented to poultry, are obtained by the distillation of wood that is used in the building industry [22]. However, the effects of tannins on the growth performance and gut ecosystem of the chickens are still inconsistent and their mode of action is unclear. Therefore, it is important to understand the chemical properties and biological effects of tannins to maximize the use of supplemental tannins in chickens.

2. Strategies to Maximize the Effects of Supplemental Tannins in the Chickens

2.1. Heat Process on Tannins

Some in-vitro studies showed that heat processed HT had better antimicrobial and antioxidant properties than unprocessed HT [23][24]. This would be because heat processing could partially hydrolyze tannic acid and release gallic acid molecules, and these newly produced gallic acid and galloyl groups had enhanced antimicrobial and antioxidant effects compared to the fresh tannic acid [25]. González et al. [26] also reported that thermal process of hamamelis virginiana containing gallotannins and CT improved efficacy of antioxidant properties for inhibiting lipid oxidation. However, because CT are hardly hydrolyzed, enhanced antioxidant of heat-processed hamamelis virginiana probably due to hydrolyzation of gallotannins in hamamelis virginiana rather than hydrolyzation of CT. Thus, while in-vitro studies found that heat process of tannins could improve their functional properties (e.g., antioxidant and antimicrobial effects) compared to unprocessed HT, it is unknown yet whether heat-processed tannins have more beneficial effects on animal models.

2.2. Co-Supplementation of Tannins with other Bioactive Compounds

Supplementation of tannins with other bioactive compounds could be more beneficial to chickens than supplementing tannins alone for several reasons: (1) complexed form with proteins or polysaccharides of tannins inhibit tannins to form a complex with endogenous and dietary proteins and metal ions; (2) distinct properties of bioactive compounds can show synergistic effects to antimicrobial effects against both gram negative and positive bacteria; (3) different bioactive compounds affect gut health in different ways, which can lead to synergistic effects in animals; and (4) by providing more than two bioactive compounds, pathogenic bacteria are hard to generate resistant system against diverse bioactive compounds. Table 1 shows that tannins have potentials to show synergistic effects with other bioactive compounds.

Table 1. Effects of tannins with other bioactive compounds on the chickens.

Tannins	Other Bioactive Compounds	Outcomes	References
100 mg/kg tannic acid extract	**Probiotics (1 × 10^4 spores/kg *Bacillus coagulans*)**	**Improved feed conversion ratio of coccidiosis vaccinated broilers.**	[27]
240 mg/kg tannic acid	**Organic acids (420 mg/kg lactic, 480 mg/kg butyric acid and 480 mg/kg acetic acid)**	**Decreased *S. enteritis* horizontal transmission in broiler chickens**	[28]
Chestnut tannins	**Saturated short medium chain fatty acids (C4:0 to C12:0)**	**Showed strong antimicrobial effects in in-vitro conditions and did not affect growth performance and meat quality of in-vivo chicken models.**	[22]

Probiotics are living microorganisms which beneficially affect the host animals by enhancing animal's intestinal microbial balance [29]. Probiotics may have different mode of actions from tannins to inhibit the growth of pathogenic bacteria and to improve gut health of chickens. Probiotics can improve gut integrity by modulating immune system and maintaining microflora of chickens and tannins, while tannins can show antioxidant and anti-inflammatory properties [30]. However, one of the concerns of using probiotics with tannins could be that tannins may show antimicrobial effects against probiotics. However, Khalil [31] showed that gallic acid and catechin polyphenols did not inhibit the growth of Streptococcus thermophilus (probiotics), and Pacheco-Ordaz et al. [32] reported that catechin, gallic, vanillic, ferulic and protocatechuic acids selectively inhibit the growth of pathogenic bacteria without decreasing viability of probiotics. More studies are required to establish synergistic effects and mechanisms of tannins and probiotics in in-vivo chicken models.

Organic acids, known as strong antimicrobials, are organic compounds with acidic properties. Tannins inhibit the growth of pathogens predominately by inhibiting activities of microbial enzymes and modulating bacterial membrane, but organic acids penetrate bacterial cell wall, and bacteria have to spend a lot of energy to pump out hydrogen molecules, which causes bacterial death [33][34]. Furthermore, organic acids are known to improve intestinal morphology and gut barrier integrity by being energy sources for epithelial cells, which may imply that organic acids with tannins can show synergistic effects [35][36][37]. Thus, combination of tannins and organic acids can have synergistically increased antimicrobial effects and gut health promoting effects due to different mode of actions.

2.3. Supplementation of Combined or Encapsulated Form of Tannins

If tannins are combined with proteins, polysaccharides and ions before being included in the chickens feed, the tannins in complexes would not bind dietary and endogenous proteins and metal ions in chickens. The tannin complexes would be loose in the high pH (>7.0) in the intestine of chickens, and proteins in the tannin complexes can be degraded by digestive enzymes in the small intestine of chickens [38][39]. However, Lee et al. [40] showed that supplementation of albumin-tannin complexes still decreased growth performance and negatively modulated microbiota, hematological indices and plasma iron status of weaning piglets. The delivery of tannin-protein or polysaccharide complexes in the GIT of chickens, and effects of diverse dosages of supplemental tannin complexes on growth rate and gut health of chickens should be further investigated.

Encapsulation techniques, which offer a physical barrier for bioactive compounds and separate the core material from the environment until their release, have obtained a lot of attention in the livestock industry because encapsulation can maximize the efficacy of feed additives that have stability, cost and environmental issues. Encapsulation has been applied to various vulnerable feed additives such as essential oils [41][42][43], probiotics [44], organic acids [45], bacteriophages[46], zinc [47] and exogenous enzymes [48]. Diverse materials including proteins [41][49], lipids [45], carbohydrates (starch) [43], and polysaccharides [46][50] have been used to encapsulate bioactive compounds.

Encapsulation techniques can be applied to decrease side effects and maximize benefits of tannins in chickens. Encapsulation of tannins can depress the protein binding capacity of tannins, which decreases feed intake by making astringent taste and digestibility of proteins and induces dietary and endogenous protein losses [51]. In addition, more tannins can be delivered to small or large intestine where many pathogens propagate by decreasing bioavailability for absorption in the upper GIT of chickens. Adejoro et al. [52] showed that lipid-encapsulated acacia tannin extracts reduced methane production and enhanced neutral detergent fiber digestibility in sheep. A study by Wang et al. [53] reported that microencapsulated tannic acid improved intestinal morphology in duodenum, increased expression of ileal nutrient transporters (sodium-dependent neutral amino acid transporter; B^0AT1 and peptide transporter 1; PepT1) and modulate microbiota without affecting growth performance of weaned piglets even though ileal maltase activity and gene expression of jejunal sodium-dependent glucose transporter 1 (SGLT1) was reduced. Future studies are required to develop effective encapsulated tannins and to determine appropriate dosages of encapsulated tannins for chickens.

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