We are IntechOpen, the world’s leading publisher of Open Access books
Built by scientists, for scientists

6,600 Open access books available
177,000 International authors and editors
195M Downloads

154 Countries delivered to
TOP 1% Our authors are among the most cited scientists
12.2% Contributors from top 500 universities

WEB OF SCIENCE™
Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected. For more information visit www.intechopen.com
Abstract

In recent years, there has been a surge in antibiotic resistance in both humans and animals, as well as increased public concern over medication residues in animal products. As a result, the use of antibiotics as growth promoters in chicken has been banned in the European Union, and consumer pressure is likely to lead to their removal in other countries. More recently, the United States of America adopted the same restriction in 2017. Different alternatives to antibiotics have been proposed as a measure to eliminate pathogens or to improve growth and feed conversion in poultry, such as probiotics, enzymes, bacteriophages and antimicrobial peptides, herbal compounds and organic acids. These substances exert their effects on the gastrointestinal biota and digestion processes, directly or indirectly. Humic substances (HS) in animal applications have shown improved live-weight, growth rates and feed intakes by improving immune functions and gut health. In poultry nutrition as an alternative to growth-promoting has been proven with promising results on the growth and health of birds. Additional research suggests that HS can increase gut integrity and performance when combined with good nutrition, management, and biosecurity policies. Therefore, recent results of HS extracted from vermicompost in poultry will be described in this chapter.

Keywords: humic substances, vermicompost, gut health, poultry

1. Introduction

During the previous decade, the poultry business has been the most active and fastest-growing sector in the worldwide market for the production of meat directed to human consumption. The world’s population is forecasted to double by 2050, and agricultural production is expected to double as well [1]. The supply of protein of animal origin in countries like Mexico is insufficient to fulfill the population’s demand; nevertheless, the OECD-FAO Agricultural Outlook 2016–2025 projects that chicken meat output will expand at a pace of 2.9 per cent per year on average between average 2016 and 2025. As a result, national output and consumption will continue to rise [2]. Increased livestock output must be done with the most efficient use of resources as possible, without compromising environmental integrity or animal or human health. For achieving this, one of the most significant obstacles is the restriction to
the use of growth-promoting antibiotics (GPA) as feed additives due to concerns about pathogenic bacteria developing antibiotic resistance, which represents a threat to human and animal health [3]. As a result, non-pharmacological growth promoters have been studied for decades in an attempt to replace or alternate the application of conventional promoters [4].

Humic substances (HS) are one of the alternative additives that has been studied for several years as a means to promote animal health. HS has been employed in agriculture for many years to enrich the soils, but because of their many qualities, they have been recently resurrected in environmental sciences and the human biomedical sector [5, 6]. In veterinary medicine, HS have been used as antidiarrheal, analgesic, immunostimulatory, and antibacterial agents [7]. When HS has been combined with the correct ration, husbandry, and biosecurity procedures, has been shown to enhance intestinal integrity and performance in chickens [8–11].

The majority of HS used in these studies were commercial products generated from mineral sources such as lignites and leonardite Vermicompost, from which compost and leachates are produced, is one of the first HS sources employed by Gomez and Angeles [11, 12], they have been reported to have promising advantages in poultry production as growth promoters.

2. Humic substances

HS are organic macromolecules that play an important role in biochemistry; they are a fraction of soil organic matter and have the highest density in soil and composts. They are produced by the biodegradation of organic matter, which involves physical, chemical, and microbiological processes [5], in which eukaryotes (worms and fungi) and prokaryotes (aerobic bacteria) further decompose organic matter [11]. HS are a natural component of streams, lakes, and oceans, containing the majority of the nutrients in the soil, accounting for approximately 80% of the carbon in soils and 60% of the dissolved carbon in the aquatic environment [13].

Based on their solubility, HS are classified as humic acids (HA), fulvic acids (FA) and humin. It has been stated that the isolating and characterizing of the organic components of soils is challenging due to the breakdown products of organic matter associated with other minerals [5]. For the first time, Senn and Kingman [14] characterized the molecular structure of HS, determining that the oxidized sites provide the molecule with a negative charge, allowing it to attach to mineral ions.

HA molecules have a wide range of weight and size, ranging from hundreds to thousands of atomic mass units, and are constituted of aromatic units, units linked by oxygen and nitrogen, functional groups mostly linked to carboxylic acids, phenols, and hydroxyl alcohol, ketone and quinone groups [15]. These chemical properties provide HA with the capacity to serve as a surfactant, binding to a variety of substances and generating hydrophobic and hydrophilic chemical complexes [16]. HS are excellent at transporting and binding organic and inorganic agents in the environment because of this function, which is combined with their colloidal characteristics [17]. The great electron transport capability of HS in oxidation–reduction processes is their principal attraction [6, 18]. HS also can develop bindings with ions such as Mg$^{2+}$, Ca$^{2+}$, Fe$^{2+}$, and Fe$^{3+}$ due to the presence of carboxylic groups and phenolates. Creating chelate compounds with one or more of these ions and controlling metal ion bioavailability [19].
2.1 Use of humic substances in animals

HS have been used as an antidiarrheal, analgesic, immunostimulatory and antimicrobial agent in veterinary practices in Europe [7]. Furthermore, they have been shown to have a strong affinity for binding to heavy metals, mutagens, minerals, bacteria, and aflatoxins [20]. HS can be used orally in horses, ruminants, pigs and poultry for the treatment of diarrhoeas, dyspepsia and acute intoxications following the recommendations of the Committee for Veterinary Medicinal Products of the European Agency for the Evaluation of Medicinal Products [7].

In vitro studies of the antioxidant properties of HS in doses of 0.1 per cent in rat liver, the organ with the highest metabolic function and responsible for the metabolism of pharmacological compounds, found that HS aids in the elimination of free radicals and superoxide radicals, as well as maintaining the balance in the oxidation–reduction reactions of the mitochondria [21]. In rats with 2/3 of their liver removed, the administration of HS resulted in liver regeneration [18].

When rats were administered HS in their drinking water, Yasar [22] discovered a considerable rise in weight, as well as an increase in epithelial surface, intestinal villi length, and crypt depth.

2.2 Use of humic substances in poultry

The effects of different concentrations of HS in the diet on live weight, feed consumption, carcass characteristics, and gastrointestinal characteristics in broilers have been extensively studied [8, 23–26]. The addition of HS in the drinking water or feed improves most of the productive parameters, such as daily weight gain, in addition to enhancing the carcass yield of broilers.

According to Jin [27], the feed conversion does not change at 21 days but improves at 42 days, implying that the increase in weight gain and feed conversion efficiency might be due to the stimulating impact of HS in the digestive system and the nutrient utilization in metabolic processes. Adding HS to laying and broiler chickens can boost profitability by improving the production performance, reducing mortality, lowering feed conversion, and increasing egg output [28].

HS have been used to reduce mycotoxicosis in chicken due to its adsorbent capability [29–31]. Several studies have found that HS reduces ammonia emissions to the environment [9, 32, 33]. Similarly, in farms with a high density of chicken population, HS have been found to have a considerable anti-stress impact, reducing the negative effects of chronic stress in laying hens in production [34].

The mechanism through which HS affects poultry performance remains unclear. According to Shermer [35], HS might affect poultry performance by modifying the microbiota in the gastrointestinal tract, particularly in Escherichia coli populations, by altering the pH and promoting a greater activity of intestinal enzymes and feed digestibility. Several trace elements in HS can act as co-factors, increasing the activity of numerous enzymes involved in digestion and metabolic processes [36].

3. Humic substances derived from vermicompost

Vermicomposting is a bio-oxidative process that involves the breakdown of organic materials by litter-dwelling detritivorous earthworm species. Earthworms
are important because they fragment organic materials and increase surface area, but microscopic species in the earthworm stomach and their castings are responsible for the actual decomposition [37, 38]. These gut and cast-related processes are considered to have a significant impact on the properties of vermicompost. *Eisenia fetida*, *Eisenia andrei*, and *Dendrobaena veneta* are the earthworm species used in vermicomposting. *E. fetida* is one of the most frequently utilized earthworm species due to its high rate of organic matter digestion, tolerance to environmental conditions, fast reproductive rate and short life cycle, and tolerance to handling [39].

Two phases can be distinguished in vermicomposting: 1) an active phase in which earthworms process the waste through physical comminution, ingestion, and microbial decomposition, and 2) a maturation-like phase in which earthworms move to fresher layers of undigested waste and microbes provide additional decomposition [40].

Bacteria and fungi are the two primary kinds of microorganisms involved in the composting process. Bacteria degrade sugars and other easily accessible organic materials faster than fungus. They are, therefore, crucial in the early phases of composting, when the feedstocks contain large quantities of carbohydrates. More complex compounds, such as hemicellulose, starch, and even lignin, can be degraded by actinomycetes. They are more common in the later stages of composting, after the majority of easily degradable substrates have been used [41].

The fresh organic matter (animal manure, food wastes, green wastes, agricultural leftovers, etc.) is transformed into more stable humus-like substances, nutrients are recycled, and energy is created throughout the composting process [42]. The process should be aerobic, with a portion of it taking place under thermophilic circumstances. It minimizes phytotoxicity, removes pathogens, and stabilizes the material in terms of nitrogen and oxygen demand, avoiding N immobilization by soil biota, which competes with the plant for limited nitrogen resources [43].

### 3.1 Establishment of vermicompost

The establishment of our vermicompost took place in the greenhouse area, which has concrete and stone walls and a white polyethylene roof ([Figure 1](#)). The temperature inside the greenhouse is maintained throughout the year, with maximum temperatures of 35°C and minimum temperatures of 15°C, as well as relative humidity of 70–80%. *Eisenia Foetida* is used in vermicompost; and it is composed of 50% pastures from the area/50% sheep manure; with an internal temperature of 15–25°C, a pH of 6.5 to 7.5 and relative humidity of 80–90%.

Vermicompost is made by enclosing a 2 × 5 m rectangular space with bricks and covering it with polypropylene ([Figure 2](#)). To reduce the bacterial content, the organic material and manure are first pre-composted for a month. The components are then combined and placed in the compost's lower side; worms are then sewn on top, and the compost is watered. Finally, a part of the organic material is coated over the compost to protect it from light rays, covered with black polyethylene ([Figure 3](#)).

The compost is moistened once a week, vegetable matter is added once a week, and all parameters are checked regularly for upkeep. To collect the compost, the vermicompost must grow for four months. The worm harvest is conducted first, and then the compost is sifted to eliminate any unprocessed organic and inorganic elements. The compost was preserved after being oven-dried for 24 hours at 60°C.
3.2 Humic substances extraction/isolation

HA, FA, and humin are the three main types of humic compounds found in soils and sediments [5, 13]. A strongly basic aqueous solution of sodium hydroxide or potassium hydroxide is used to extract HS from humus and other solid phases. The HS precipitate in this solution when the pH is adjusted to 1 with hydrochloric or sulfuric acid, leaving the FA in the solution (upper section) [19, 44]. This is the most important distinction: FA are insoluble in alkaline media, while HA are insoluble in acid media, and humin are insoluble at any pH (Figure 4).
In addition to alkaline solvents, chelating agents, organic solvents, and aqueous saline solutions have been proposed for the extraction of HS. Alkaline solvents are the most efficient and commonly utilized of them [44]. The extraction of HA with NaOH is a standard method for isolating HA, with an extraction efficiency of more than 80% of samples from soils (Table 1).

The isolation and extraction of HS from the earthworm compost were carried out using an alkaline extraction process. Sodium hydroxide (0.1 M NaOH) was used in a ratio of 5:1 parts of compost (mL/g); it was left to rest for 24 h at room temperature, and then filtered through a 125 μm mesh; sulfuric acid was added (H2SO4, 10%),
Use of Humic Substances from Vermicompost in Poultry
DOI: http://dx.doi.org/10.5772/intechopen.102939

<table>
<thead>
<tr>
<th>Agent</th>
<th>HS extraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaOH</td>
<td>80</td>
</tr>
<tr>
<td>Na4P2O7</td>
<td>30</td>
</tr>
<tr>
<td>Organic chelators</td>
<td>30</td>
</tr>
<tr>
<td>Acetyl-acetone/Hydroxyquinone</td>
<td>30</td>
</tr>
<tr>
<td>Formic acid</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 1. Agents used for the extraction of humic substances.

<table>
<thead>
<tr>
<th></th>
<th>Humic acid</th>
<th>Fulvic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>C_{110}H_{105}N_{50}O_{50}</td>
<td>C_{68}H_{42}N_{20}O_{18}</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>2325.028</td>
<td>619.398</td>
</tr>
<tr>
<td>Elemental composition</td>
<td>C (56.82), H (4.55), N (4.22), O (34.41)</td>
<td>C (48.48), H (2.77), N (2.26), O (46.49)</td>
</tr>
<tr>
<td>Density, g/cm³</td>
<td>1.870 ± 0.10</td>
<td>1.935 ± 0.06</td>
</tr>
</tbody>
</table>

Table 2. Estimated chemical properties of the humic and fulvic acid molecules, extracted from vermicompost.

Figure 5. The flat structure of a humic acid molecule with aromaticity (a) and flat structure of a fulvic acid molecule with aromaticity (b).
rectifying a pH of 2. The solids and liquids were separated by decantation. The precipitate (HA) was washed two times with distilled water to remove sulfuric acid residues and between each washing it was centrifuged for 20 min at 5000 rpm. Then, to remove the remnants of sulfuric acid, in a rotary evaporator, the sample was dried at 60°C until it had a gel consistency. Finally, it was dried in an oven at 60°C. The result was a yellowish-brown powder with a pH of 10.

For the identification of functional groups, the extracted HS were analyzed using an infrared spectrophotometer with Fourier transformation with attenuated total reflectance (FTIR-ATR); the elemental analysis was carried out using energy dispersive X-Ray spectroscopy (EDS); and the crystal types were detected with X-ray diffraction (XRD). These results were used for the calculation of aromaticity and were published in a previous paper [45]. Additionally, the chemical properties (Table 2) and the flat structures of the HS molecules with aromaticity (Figure 5) using the chemistry software ACD Lab v.12 (Advanced Chemistry Development, Toronto, Canada) were estimated [46].

4. Use of humic substances from vermicompost in poultry

Various in vitro and in vivo models for evaluating the behavior of different chemicals in chicken supplements have recently been established in our lab. The in vitro digestion model replicates broiler body temperature, peristaltic motions, enzymatic and pH conditions in each simulated compartment (crop, proventriculus, and small intestine) [47, 48]. In addition, in vivo models of intestinal inflammation in birds have been employed. Non-starch polysaccharide-rich diets [49, 50]; dexamethasone [51]; dextran sodium sulfate (DSS) [52, 53]; and 24 hours of feed restriction [54, 55]. With the help of these research models, we have been able to elucidate some effects of HA.

Firstly, two experiments were conducted to evaluate the effects of HA on recovery of Salmonella Enteritidis (SE) [56]; there were no effects of HA on SE recovery in an in vitro digestive system, or in Salmonella intestinal colonization, bacterial numbers in ceca, intestinal IgA, or serum FITC-d in neonatal broiler chicks.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Intestinal viscosity (cP Log_{10})^b</th>
<th>Serum FITC-d (ng/mL)^c</th>
<th>Liver bacterial translocation (Log_{10} cfu/g)^d</th>
<th>Liver enrichment culture^e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control FR</td>
<td>0.13 ± 0.01^f</td>
<td>828.58 ± 32.85^g</td>
<td>2.83 ± 0.09^h</td>
<td>12/12(100%)</td>
</tr>
<tr>
<td>0.2% HA + FR</td>
<td>0.24 ± 0.03^f</td>
<td>544.62 ± 41.84^f</td>
<td>1.60 ± 0.04^f</td>
<td>7/12 (59%)^*</td>
</tr>
</tbody>
</table>

aData expressed as Mean ± SE.

^bIntestinal viscosities evaluated in Log_{10} (in centipoise, cP = 1/100 dyne sec/cm^2), n = 5 chickens/group.

^cSerum (FITC-d) was evaluated in 20 chickens/group.

^dLiver bacterial translocation was evaluated in 12 chickens/group.

^eData expressed as positive/total chickens (%).

^fSuperscripts within columns indicate significant difference at P < 0.05. P < 0.001.
Additionally, a second study was carried out [57], to evaluate direct or indirect impacts of HA on intestinal integrity because of their physical and chemical features. Using a 24-hour feed restriction model, the aim was to investigate how HA affected intestinal viscosity, leaky gut, and ammonia excretion in broiler chicks. The experimental group was given 0.2% HA had increased intestinal viscosity and showed lower levels of FITC-d, bacterial liver translocation, and ammonia in the excreta. It was confirming its advantages, enhancing the viscosity and the integrity of the intestine (Table 3).

The previous researches were the first to address the effects of HA from vermicompost on bacterial challenges with SE both in vitro and in vivo in chicks; furthermore, the mechanism of action of HA on the maintenance of intestinal integrity in poultry was demonstrated for the first time. In line with this finding, Mudronová [58] reported that HS positively regulates MUC-2 gene expression.

In further research in broilers fed an extract of HS from vermicompost, increased carcass yield and lactic acid bacteria (LAB) and reduced coccidian oocysts excretion were observed; but increased Clostridium perfringens (CP) counts were also seen compared to broilers fed diets supplemented with GPA (Figure 6) [45].

In a recent report, broilers kept in floor pens from 1 to 42 days of age and fed increasing levels of HS from vermicompost, showed lower feed intake (FI) and overall mortality, besides, a better feed conversion rate (FCR) compared to negative control birds not supplemented with HS and positive control birds added with antibiotics (Table 4) [59]. The greatest benefits of adding HS were observed in the last period of the trial, from 29 to 42; these findings closely resemble the observations in previous research. For the authors, it is unknown whether improved FCR from 29 to 42 days was dependent on, or independent of, the addition of HS from 1 to 14 and 15–28 days. This topic deserves further clarification in future research.

Although, HS have been proven to have prospective benefits in chicken production as growth promoters, data on their antimicrobial properties are inconsistent. Using an in vitro chicken digestive system, it was essential to examine the effect of HA isolated from vermicompost on the recovery of Salmonella Enteritidis (SE), E. coli (EC), C. perfringens (CP), Bacillus subtilis (BS), and Lactobacillus salivarius (LS). In general,
the number of microorganisms counted increased in the final simulation, remarkably when the HA inclusion concentration increased (Tables 5 and 6).

HS may be utilized as substrates by bacteria since they are organic sources of carbon, nitrogen, phosphorus, and other nutrients. In this way, they can be used as prebiotics to enhance nutrient digestion.

Subsequently, 28-year-old broilers were challenged to a radical change in diet, in addition to inducing immune stress when vaccinated against Newcastle, Infectious bronchitis and Salmonella, with the intention of causing damage to the intestinal mucosa. The results of this research [60] show that HS does not prevent intestinal mucosal atrophy but increase the number of goblet cells, and probably the mucus layer, compared to chickens that received the treatment without GPA.

On the other hand, when compared to a commercial zeolite, the adsorption capacity of HA against AFB1 when added to the feed in a 1% concentration exhibited the maximum effectivity of capture (Figure 7).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop counts</th>
<th>Proventriculus counts</th>
<th>Intestine counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SE</td>
<td>EC</td>
<td>CP</td>
</tr>
<tr>
<td>Control</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Control+</td>
<td>7.18</td>
<td>7.18</td>
<td>7.18</td>
</tr>
<tr>
<td>HA (0.1%)</td>
<td>7.07</td>
<td>7.54</td>
<td>7.16</td>
</tr>
<tr>
<td>HA (0.2%)</td>
<td>7.18</td>
<td>7.52</td>
<td>7.34</td>
</tr>
<tr>
<td>HA (0.5%)</td>
<td>6.79</td>
<td>7.72</td>
<td>7.28</td>
</tr>
<tr>
<td>HA (1%)</td>
<td>6.89</td>
<td>7.88</td>
<td>7.36</td>
</tr>
<tr>
<td>SEM</td>
<td>0.069</td>
<td>0.104</td>
<td>0.126</td>
</tr>
</tbody>
</table>

The initial inoculum of SE, EC and CP in the feed was 10^8 CFU/g.

Data are expressed as log_{10} CFU.

Standard error of the mean.

Values in columns with different letters differ significantly (P ≤ 0.0001).
Use of Humic Substances from Vermicompost in Poultry
DOI: http://dx.doi.org/10.5772/intechopen.102939

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop counts</th>
<th>Proventriculus counts</th>
<th>Intestine counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BS</td>
<td>LS</td>
<td>BS</td>
</tr>
<tr>
<td>Control-</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Control+</td>
<td>6.72</td>
<td>4.64</td>
<td>1.46</td>
</tr>
<tr>
<td>HA (0.3%)</td>
<td>6.69</td>
<td>4.50</td>
<td>1.67</td>
</tr>
<tr>
<td>HA (0.2%)</td>
<td>6.57</td>
<td>5.33</td>
<td>1.68</td>
</tr>
<tr>
<td>HA (0.5%)</td>
<td>6.52</td>
<td>5.12</td>
<td>1.70</td>
</tr>
<tr>
<td>HA (1%)</td>
<td>6.71</td>
<td>5.49</td>
<td>1.89</td>
</tr>
<tr>
<td>SEM</td>
<td>0.054</td>
<td>0.140</td>
<td>0.079</td>
</tr>
</tbody>
</table>

The initial inoculum of BS and LS in the feed was $10^8$ CFU/g.

Data are expressed as log$_{10}$ CFU.

Standard error of the mean.

Values in columns with different letters differ significantly ($P \leq 0.0001$).

Table 6.
Effect of humic acids on the counts of Bacillus subtilis and Lactobacillus salivarius* under an in vitro poultry digestive model**.

<table>
<thead>
<tr>
<th>Humic substances, µg/L of water</th>
<th>0</th>
<th>161</th>
<th>322</th>
<th>483</th>
<th>654</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>35.24</td>
<td>36.15</td>
<td>35.77</td>
<td>35.87</td>
<td>36.48</td>
<td>0.522</td>
</tr>
<tr>
<td>Dry Weight (%)</td>
<td>2.10</td>
<td>1.99</td>
<td>2.07</td>
<td>2.05</td>
<td>2.13</td>
<td>0.060</td>
</tr>
<tr>
<td>Ashes (%)</td>
<td>38.11</td>
<td>40.13</td>
<td>39.32</td>
<td>39.18</td>
<td>39.57</td>
<td>0.539</td>
</tr>
<tr>
<td>Ashes (mg)</td>
<td>802.0</td>
<td>797.0</td>
<td>814.8</td>
<td>804.8</td>
<td>845.3</td>
<td>28.075</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>40.20</td>
<td>36.94</td>
<td>42.04</td>
<td>42.20</td>
<td>36.70</td>
<td>1.648</td>
</tr>
<tr>
<td>Ca (mg)</td>
<td>320.3</td>
<td>298.5</td>
<td>342.3</td>
<td>339.4</td>
<td>307.9</td>
<td>18.551</td>
</tr>
<tr>
<td>P (%)</td>
<td>14.02</td>
<td>14.01</td>
<td>14.10</td>
<td>14.15</td>
<td>14.14</td>
<td>0.050</td>
</tr>
<tr>
<td>P (mg)</td>
<td>112.6</td>
<td>111.8</td>
<td>114.8</td>
<td>113.9</td>
<td>119.4</td>
<td>4.203</td>
</tr>
</tbody>
</table>

Dry matter, ashes, calcium and phosphorus content of the tibia of 21 days old broiler chickens added with increasing levels of humic substances in the drinking water*.

Table 7.

<table>
<thead>
<tr>
<th>Humic substances, µg/L of water</th>
<th>0</th>
<th>161</th>
<th>322</th>
<th>483</th>
<th>654</th>
<th>SEM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>42.25</td>
<td>43.06</td>
<td>43.16</td>
<td>43.35</td>
<td>42.17</td>
<td>0.440</td>
</tr>
<tr>
<td>Dry Weight (%)</td>
<td>7.79</td>
<td>8.32</td>
<td>8.26</td>
<td>8.39</td>
<td>8.21</td>
<td>0.218</td>
</tr>
<tr>
<td>Ashes (%)</td>
<td>35.84</td>
<td>35.64</td>
<td>35.11</td>
<td>36.34</td>
<td>35.34</td>
<td>0.596</td>
</tr>
<tr>
<td>Ashes (mg)</td>
<td>2785.5</td>
<td>2966.1</td>
<td>2894.4</td>
<td>3046.8</td>
<td>2891.0</td>
<td>73.941</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>34.73</td>
<td>33.17</td>
<td>35.81</td>
<td>35.98</td>
<td>31.11</td>
<td>1.242</td>
</tr>
<tr>
<td>Ca (mg)</td>
<td>969.0</td>
<td>984.0</td>
<td>1039.2</td>
<td>1102.5</td>
<td>891.9</td>
<td>45.542</td>
</tr>
</tbody>
</table>
Finally, the addition of HS extracted from vermicompost in piglet feed at weaning [61] improved the weight gain and feed efficiency during 1–42 days post-weaning. The final body weight at 42 days, weight gain and feed efficiency were higher with the inclusion level of 0.50% HS. Most of the productive responses showed an increasing linear pattern as the addition of HS increased.

5. Conclusions

Although, the antibacterial activity of HS/HA is unclear, they might be regarded as viable alternatives to replace or alternate the use of antibiotics in poultry. As was documented, HS extracted from vermicompost improve performance, increase intestinal viscosity and intestinal integrity in poultry. These benefits have been attributed to the macro colloidal structure of HS, which ensures effective protection on gastric and intestinal mucous membranes, as well as the promotion of mucin synthesis in the gut. However, their applications depend on the source and the way they are extracted. HS stimulates the growth of microorganisms, suggesting that they can be used as prebiotics.
In addition, multiple doses were investigated, which might have contributed to the differences in response variables among our investigations. It can also be argued that whether in a more challenging environment, the effects of HS may be better. Finally, our working team is focusing on elucidating the mechanism by which HS exert their effects on the intestinal mucosa and the intestinal microbiota.

Acknowledgements

This research was supported by the Arkansas Biosciences Institute under the project: Development of an avian model for evaluation early enteric microbial colonization on the gastrointestinal tract and immune function. CONACYT provided funding to carry out several experiments described in this chapter through the project “Efficacy of an extract of humic substances as a growth promoter, reducing infectious diseases and increasing the profitable production of meat of birds and pork” (PDCPN 2017/4777).

Conflict of interest

The authors declare no conflict of interest.
References

[1] La CA, La AY, Todos NP. El Estado Mundial de la Pesca y la Acuicultura. ROMA: FAO; 2016


[32] Henderson PA. The growth of tropical fishes. In: Val AL, Vera MF, Randall DJ, editors. The Physiology...
The Global Antimicrobial Resistance Epidemic - Innovative Approaches and Cutting-Edge Solutions


acids on intestinal viscosity, leaky gut and ammonia excretion in a 24 hr feed restriction model to induce intestinal permeability in broiler chickens. Animal Science Journal. 2018;89(7):1002-1010


