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Aloe vera as a feed additive in broiler chicken production: A Review

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Abstract
Growth promoters in poultry feeds can be categorized as Antibiotic growth promoters (AGP) and Non–Antibiotic growth promoters (NAGP). Constant treatment of poultry by antibiotics has resulted in residual effects and bacterial resistance. Due to such threats research studies are constantly looking for alternatives to AGP. NAGP in poultry feeds may have a number of beneficial effects including rapid development of a healthy gut microflora and stabilization of digestion along with improved feed efficiency. Among NAGP, phytogenics are drawing much attention nowadays. *Aloe vera* is one of such plants, having antibacterial, antiseptic, anti-inflammatory, immune-modulatory, anti- oxidant, anti-cancerous, anti-mutagenic, anti-hypersensitivity, wound-healing, anti-viral, anti-fungal, anti-diabetic and anti-parasitic effects. Due to these properties various research studies has been conducted to investigate the role of *Aloe vera* as herbal feed additive in broiler industry. This paper reviews the effects of *Aloe vera* on growth performance, intestinal microflora, carcass characteristics, haemato-biochemical parameters, immune response, coccidiosis, mortality pattern and cost of production of broilers.

Keywords: *Aloe vera*, growth performance, carcass characteristics, haemato-biochemical parameters, immune response, broiler chicken

1. Introduction
The basic objectives of modern broiler farming are faster growth, high feed conversion efficiency and livability. The economics of production is very important criteria for broiler production where feed is the major important factor affecting the productive performance and economics of broiler production, next to genetic potential. To ensure more net return and to minimize high expenditure on feed are the main challenges, for which many research strategies have been practiced such as introducing feed supplements and feed additives.
Growth promoters are agents added to poultry feeds in order to enhance the feed conversion efficiency and body growth and broadly can be categorized as Antibiotic growth promoters (AGP) and Non–Antibiotic growth promoters (NAGP). In the past the major growth promoters were antibiotics. Antibiotic growth promoters have been helpful in improvement of growth performance and feed conversion ratio in poultry (Miles *et al.*, 2006; Dibner and Buttin, 2002 and Izat *et al.*, 1990) [54, 24, 43]. However, constant treatment of poultry by antibiotic may result in residues of these substances in poultry products and bacteria resistance against treatments in human body. Due to such threats to human health, use of antibiotics in poultry is banned in many countries (Owens *et al.*, 2008; Alcicek *et al.*, 2004; Botsoglou and Fletouris 2001 and Hinton, 1988) [64, 5, 12, 42]. On the other hand use of NAGP is commonly regarded as favourable alternatives to AGP in poultry production. The main advantage of NAGP over AGP is that they usually do not bear any risk regarding bacterial resistance or undesired residues in meat. Addition of NAGP to feeds of poultry may have a number of beneficial effects, including rapid development of a healthy gut microflora and stabilization of digestion along with improved feed efficiency. NAGP include predominantly organic acids, probiotics, prebiotics, synbiotics, phytogenics, feed enzymes and immune stimulants. Among these alternatives, phytogenics are drawing much attention nowadays.
Phytogenics are derived from herbs, spices or aromatic plants and have shown antimicrobial, antifungal, antiviral, antioxidant or sedative properties. A complex mixture of bioactive compounds present in them is known for their appetizing effects, since they increase the palatability of the feed and stimulate endogenous digestive enzymes. Moreover, phytogenics

have a pronounced impact on the gut microflora. Many studies have been carried out on using additives including herbs, as alternatives to antibiotics, with direct or indirect effects on intestinal microflora in poultry products (Taylor, 2001) [74]. Several studies have shown antimicrobial properties of herb extracts (Cowan, 1999 and Hammer *et al.*, 1999) [17, 38] which can improve intestinal microflora population and enhance health in bird's digestive system through reduction in number of disease making bacteria (Mitsch *et al.*, 2004) [55]. In addition, modified harmful microbial population in intestines will change intestinal morphology. Intestinal health is of great importance in poultry for improved performance and reduced feed conversion ratio (Montagne *et al.*, 2003) [57]. However, other properties of herbs, such as antioxidant, antiviral, immunomodulatory properties and their effects on performance and digestive health cannot be ignored.

Aloe vera is one of such plants, having a great medicinal potential (Ezeibekwe *et al.*, 2009) [30]. *Aloe vera* is a succulent, stemless herb found widely in India, China and many Egyptian countries, having more than 70 biologically active compounds. Many studies have shown antibacterial, antiseptic, anti-inflammatory and immune-modulator effects of *Aloe vera* (Moorthy *et al.*, 2009; Gautam *et al.*, 2004 and Madan *et al.*, 2008) [58, 59, 33, 4]. Many studies have also shown anti- oxidant and anti-cancerous properties of *Aloe vera* (El-Shemy *et al.*, 2010 [29] and Nwaoguikpe *et al.*, 2010) [62]. Apart from the above, anti-mutagenic effects and anti-hypersensitivity effects of *Aloe vera* have also been reported by some researchers (Snezana *et al.*, 2007 and Strickland, 1993) [71].

With numerous properties, *Aloe vera* is among the most well-known herbs. This member of *Liliaceae* is similar to cactus in appearance and mostly grows in arid regions of Asia and Africa (Boudreau and Beland, 2006) [13]. Major ingredients of *Aloe vera* include anthraquinones, saccharides, vitamins, enzymes, and low-molecular-weight compounds (Choi and Chung, 2003) [15] which give *Aloe vera* its anti-inflammatory, immunomodulatory, wound-healing, anti-viral, anti-fungal, anti-tumor, anti-diabetic, and anti-oxidant effects (Christaki and Florou-Paneri, 2010) [16]. Numerous studies suggest that many benefits of *Aloe vera* are attributable to polysaccharides contained in *Aloe vera* gel, which compose a large part of dry matter in this gel (Hamman, 2008) [37]. In other words, almost 60% of dry matter of *Aloe vera* gel is composed of polysaccharides (McAnalley, 1989) [52]. A compound often analyzed by researchers is the polysaccharide acemannan which has immunomodulatory, anti-microbial, and anti-tumor effects (Choi and Chung, 2003) [15].

The middle major parts of *Aloe vera* leaves consist of the gel. Studies discovered different properties of *Aloe vera* gel, including wound healing, anti-parasitic, anti-viral, anti-fungal and anti-bacterial properties (Boudreau and Beland, 2006; Reynolds and Dweck, 1999) [13, 67]. An important *Aloe vera* gel complex which has received attention from researchers is the polysaccharide acemannan – a mannose polymer (Reynolds and Dweck, 1999) [67]. Studies revealed that properties of *Aloe vera*, including wound healing, immunomodulatory, and antibacterial properties, may stem from acemannan (Mascolo *et al.*, 2004) [50]. Studies performed on the effects of *Aloe vera* gel and of polysaccharide contained in *Aloe vera* (acemannan) on the broilers have shown that *Aloe vera* gel can improve the immune response in broilers (Chinnah *et al.*, 1992 and Valle-paraso *et al.*, 2005) [14, 76]. In addition, Lin *et al.* (2005) [47] reported improved intestinal microflora in broilers as a result of acemannan treatment. The process reduced *E. coli* count and increased *lactobacillus* count.

Since it is extremely important to avoid using AGP in poultry feed for the purpose of producing healthy foods and maintaining human health, the present paper aims to review effects of *Aloe vera* as a natural feed additive on broilers. Although a broad range of studies on *Aloe vera* mainly suggests its effects on immune response in poultry, we will also review other effects of *Aloe vera*, such as impacts on growth performance, intestinal microflora, carcass characteristics, haemato-biochemical parameters, cost of production, mortality pattern and anticoccidial effects in broilers, as discovered by other studies in this area.

Effect on growth performance

Greater body weight and better feed conversion ratio (FCR) are among important economic goals in broiler farming. The bans on application of AGP have affected this goal, resulting in poor growth performance of broilers. Many studies have examined potential effects of feed additives, like prebiotics, probiotics, organic acids, and herbs, on growth performance compared to those of antibiotics. An experiment for comparing the effects of *Aloe vera* gel (mixed with feed) and AGP (virginiamycin) indicated that AGP (virginiamycin) resulted in better growth performance compared to the performance of groups that received *Aloe vera* gel (at 1.5, 2, and 2.5%), and the control group while no significant ($P<0.05$) difference was observed between the antibiotic group and the 2% *Aloe vera* gel group in terms of body weight gain and FCR (Darabighane *et al.*, 2011b) [23]. Mmereole (2008) [56] proposed that *Aloe vera* leaf powder (1%) can be used as a proper alternative for AGP (Teramycin). Body weight and body weight gains were significantly ($P<0.05$) higher in birds fed diet containing *Aloe vera* supplement than birds fed control diet. Wang *et al.* (2007) [78] determined the effect of *Aloe vera* powder and extract on production performance and immune function of broiler chickens. Results revealed that the body weight, feed conversion ratio, immunity index of spleen and activities of natural killer cells were significantly ($P<0.05$) higher in treatment group than control group. Darabighane *et al.* (2011) [19, 21] concluded that the groups treated by *Aloe vera* gel showed better performance and heavier dressing percentage compared to the control group. Furthermore, among the different groups, the antibiotic group experienced higher level of body weight gain, better feed conversion ratio and heavier dressing percentage compared to other groups, showing no significant ($P<0.05$) difference from the 2% *Aloe vera* gel group, although the groups treated by *Aloe vera* gel consumed more feed than the antibiotic group. On the other hand, increased villus height, reduced crypt depth and raised villus height/crypt depth ratio in the 2% *Aloe vera* gel suggest that *Aloe vera* gel mixed with broiler's diet at the 2% level can provide a suitable alternative to virginiamycin for improving performance. Bolu *et al.* (2013) [11] observed that the growth parameters, such as survival, weight gain, feed conversion efficiency were significantly ($P<0.05$) higher in poults given 30 ml/l *Aloe vera* gel (0% mortality, 17.18g/day and 2.89), respectively. Histological results of the organs (breast muscle, liver, spleen and ileum) showed normal morphological pattern for poults subjected to 20 ml/l *Aloe vera* gel while those kept on 30 ml/l showed normal organ architecture for breast muscle, spleen and ileum but not for the liver. Similarly, birds raised on commercial antibiotics showed normal organ

morphology compared with the positive control. However, the birds challenged with *E. coli* without aloe gel addition (negative control) showed abnormal morphological pattern for all the organs investigated. There were also no adverse effects of *Aloe vera* gel on turkey poults health, as determined from the analysis of various haematological parameters and serum metabolites. The results indicated that *Aloe vera* gel inclusion at 20 ml/l in drinking water could successfully replace antibiotics in turkey poults rearing. Moorthy *et al.* (2009) [58, 59] observed that a significant (P<0.05) difference in hen housed egg production, feed conversion ratio and return over feed cost in 0.1 percent *Aloe vera* fed group compared to other treatment groups. No significant difference was observed in feed consumption, percent hen day egg production and percent broken eggs. It can be concluded that inclusion of 0.1 percent *Aloe vera* in White Leghorn diet is economical compared to its combination with turmeric and probiotic at 0.1 percent level. Singh *et al.* (2013) [59] concluded that *Aloe vera* has potential to be a growth promoter in broiler chicks and its growth promoting effects are comparable to that of antibiotic growth promoter (AGP). Several studies have been conducted to examine the effects of *Aloe vera* powder on growth performance of broilers. Mehala and Moorthy (2008) [53] fed broilers with *Aloe vera* powder (0.1 and 0.2%) and Curcuma longa powder (0.1 and 0.2%) and a mixture of these two powders, and reported no significant difference in body weight gain and FCR, except for the first week of treatment. In addition, no difference was observed in terms of feed intake. Alemi *et al*. (2012) [7, 49] reported a better growth performance in broilers treated with 0.75% and 1% *Aloe vera* gel powder compared to the 0.5% *Aloe vera* gel powder group and the control group. Olupona *et al*. (2010) [63] supplemented broiler drinking water with *Aloe vera* and reported an increase in final body weight, weekly body weight gain, and average feed intake in the groups that received *Aloe vera* (at 15, 20, 25, 25, and 30 cm^3/dm^3). In addition, improvement in FCR was observed for broilers treated with *Aloe vera* compared to the control group, but the difference was not significant. Hassanbeigy-Lakeh *et al*. (2012) [40] supplemented broiler drinking water with *Aloe vera* gel (0.6, 1.2, 1.8, 2.4, and 3 ml per liter) and found that *Aloe vera* gel had no effect on feed intake over the total experiment period, and that the largest body weight gain and the smallest FCR was observed in the 1.8 (ml per liter) *Aloe vera* gel group. On the other hand, Sinurat *et al*. (2002) [70] examined *Aloe vera* gel and whole leaf added to broiler feed in both dry and fresh forms and found that adding fresh gel (0.25 g/kg) and dry gel (0.25 and 0.1 g/kg) improves FCR. Eevuri and Putturu (2013) [27] found that *Aloe vera* supplementation in broilers ration increased the body weight gain, feed efficiency and decreased the feed intake.

Findings on the effects of *Aloe vera* on growth performance are inconsistent and these discrepancies can be attributed to the form of supplement (leaf powder, gel powder, or fresh gel), dosage, or whether *Aloe vera* is added to feed or drinking water. However, particular attention must be paid to anti-bacterial activities and improvement in immune response as these two factors may contribute to better growth performance in broilers (Yang *et al*., 2009) [79], and studies confirm these two properties (anti-bacterial effect and improvement in immune response) for *Aloe vera*. In fact, anti-bacterial properties of *Aloe vera* improve intestinal microflora and reduce pathogens, thereby changing intestinal morphology and improving growth performance. On the other hand, by improving immune response in broilers and increasing body resistance, *Aloe vera* indirectly affects growth performance. Sinurat *et al*. (2002) [70] conducted an experiment including different forms of *Aloe vera* (fresh gel, dry gel, fresh whole leaf or dry whole leaf). The *Aloe vera* was supplemented into the feed with concentrations of 0.25, 0.5 and 1 g/kg (equal to dry gel). Standard diets with or without antibiotics were also included as control. The diets were fed to broilers from day old to 5 weeks and the performances were observed. Results showed that the aloe bioactives did not significantly (P>0.05) affect final body weight of broilers as compared with the control. Supplementation of 0.25 g/kg fresh gel, 0.25 and 1.0 g/kg dry gel significantly (P<0.05) improved feed conversion by 4.7, 4.8 and 8.2%, respectively as compared with the control. This improvement was a result of reduction in feed intake or dry matter intake without reducing the weight gain. However, supplementation of whole *Aloe vera* leaves could not improve feed conversion in boilers. It is concluded that the bioactives of *Aloe vera* could be used as feed supplement to improve feed efficiency in broilers with no deleterious effect on weight gain, carcass yield, abdominal fat levels and internal organs. The effective concentrations of *Aloe vera* gel as a feed supplement based on dry matter conversion were from 0.25 g/kg fresh gel, 0.25 and 1.0 g/kg dry gel. Amaechi and Iheanetu (2014) [9] conducted an experiment to evaluate the effects of dietary inclusion of *Aloe vera* to substitute antibiotic growth promoter (Enramycin) on performance, carcass characteristics and intestinal micro flora of broiler chicks. The results obtained showed that *Aloe vera* powder groups and antibiotic group brought about higher body weight gain and feed intake compared to the control group. However, significant differences (P<0.05) were observed in feed conversion ratio between the groups treated by *Aloe vera* powder, antibiotic Enramycin and the control group.

Effects on intestinal microflora

Balance of intestinal microflora in broilers is an important factor contributing to improved growth performance and immune response, and anti-bacterial compounds, like herbs, play a significant role in balancing and improving intestinal microflora in chickens. Numerous studies have reported anti-bacterial effects of *Aloe vera* gel (Kwon *et al*., 2011; He *et al*., 2011; Pandey and Mishra, 2010; Mbanga *et al*., 2010; Alemdar and Agaoglu, 2009; Agarry *et al*., 2005) [46, 65, 51, 6, 1]. Few experiments have been carried out on the impacts of *Aloe vera* on intestinal microflora in broilers. The studies, however, indicate that *Aloe vera* can improve intestinal microflora and its ecosystem in broilers' intestines; increase in *Aloe vera* gel in broiler feeds (1.5%, 2%, and 2.5%) leads to increased Lactobacillus count and decreased E. coli count (Darabighane *et al*., 2012) [20]. In addition, Jiang *et al*. (2005) [4] reported an increase in Lactobacillus count and Bifidobacteria count as well as a reduction in E. coli count when acemannan (0.1% and 0.05%), polysaccharide (0.1%), and *Aloe vera* gel (0.1%) were added to broiler feed. In the same vein, Dai *et al*. (2007) [18] found that herbs and polysaccharide contained in *Aloe vera* can reduce E. coli count while increasing the number of Lactobacillus and Bifidobacteria. Although the exact mechanism through which *Aloe vera* affects intestinal microflora in broilers is unknown, it is likely that this effect is similar to the anti-bacterial effects of some herbs and mushrooms that improve intestinal microflora. On the other hand, it is also likely that the polysaccharide contained in *Aloe vera* (acemannan) follows a mechanism like that of prebiotics since studies found

prebiotic-like impacts of polysaccharides contained in medicinal herbs and mushrooms (Guo *et al*., 2003, 2004 b) [35, 36]. Other researchers attribute anti-bacterial effects of *Aloe vera* to its fumaric acid content (He *et al*., 2011).

Effect on carcass characteristics

Darabighane *et al*. (2011) [19, 21] concluded that the groups treated by *Aloe vera* gel showed heavier dressing percentage compared to the control group. Furthermore, among the different groups, the antibiotic group experienced heavier dressing percentage compared to other groups, showing no significant difference from the 2% *Aloe vera* gel group. Singh *et al*. (2013) [69] concluded that *Aloe vera* has potential to be a growth promoter in broiler chicks and its growth promoting effects are comparable to that of antibiotic growth promoter (AGP). Group that was given *Aloe vera* showed numerically higher dressing percentage as compared to control group and drug control group. Eevuri and Putturu (2013) [27] found that *Aloe vera* supplementation in broilers reduced the fat accumulation, increased dressing percentage, liver weight, spleen weight and whole giblet weights. Fallah (2015) [31] conducted an experiment to evaluate the effects of supplementing different levels of *Aloe vera* gel and garlic powder on carcass characteristic and internal organ mass of broiler chickens. Results showed no significant difference ($P>0.05$) in internal organs weight like gizzard, spleen, bursa of fabricius, proventriculus and abdominal fat at 42 days of age between control and treated groups. The other results of this investigation showed that broilers receiving *Aloe vera* gel and garlic powder had lower abdominal fat relative weight compared to control group. However, the highest thighs, breast and total carcass weights were observed with supplementation of *Aloe vera* gel + garlic powder than other groups. Although, there was no significant difference ($P>0.05$) between the control and treated groups in neck, wing and head relative weight. The highest relative weight of liver, spleen, gizzard, thighs and breast were observed in group 4 at 42 days of age. Amaechi and Iheanetu (2014) [9] concluded that the antibiotic group showed better dressing weight than the *Aloe vera* powder and the control groups. There was no significant difference ($P>0.05$) seen between the group treated with 1.5% *Aloe vera* powder and the antibiotic group regarding body weight gain and dressing weight.

Effect on haemato- biochemical parameters

Egger *et al*. (1996) [28] reported that CARN 750, an acemannan from *Aloe vera* has haematoaugmenting properties in mice. They observed a significant ($P<0.05$) increase in the absolute number of polymorphonuclear cells, lymphocytes and monocytes in mice fed with CARN 750. Valle paraso *et al*. (2006) [76] studies the effect of oral supplementation of *Aloe vera* on the immune response of broiler chicken to NCD. They observed that 2% solution prepared from extract of fresh *Aloe vera* was effective in increasing mean antibody titers to NCD. There was a significant ($P<0.05$) increase in total WBC count along with absolute differential count of monocytes, lymphocytes and heterophils. Altug *et al*. (2010) [8] evaluated the effect of *Aloe vera* and β-glucan on lymphocyte subsets, haematological parameters and immunoglobulin concentration following vaccination in dogs. They observed that there was increase in platelet count, WBC's, peripheral blood mononuclear lymphocyte counts, peripheral blood polymorphonuclear lymphocyte counts, neutrophils, monocytes, PCV, haemoglobin concentration. The CD3, CD4 and CD8 T-lymphocyte and B-lymphocyte ratio as well as serum IgG and IgM concentration were also increased. Ajabnoor (1990) [2] observed the effect of *Aloe vera* on blood glucose levels in normal and alloxan diabetic mice. There was a highly significant ($P<0.05$) decrease in serum glucose level after intra-peritoneal administration of bitter principle of *Aloe vera*. Rajasekaran *et al*. (2001) [66] studied the effect of oral administration of *Aloe vera* gel in alloxan induced diabetes mellitus in experimental rabbits. *Aloe vera* gel at a concentration of 500 mg/Kg body weight showed a significant ($P<0.05$) decrease in blood glucose level and serum lipid profile confirming the hypoglycemic and hypolipaemic effects of *Aloe vera*. Akinmoladun and Akinloye (2004) [4] investigated the effect of *Aloe vera* on lipid profile and fasting blood sugar concentration of rabbits fed with high cholesterol diet. They observed that total plasma cholesterol and fasting blood glucose levels were decreased as compared to control group indicating hypoglycemic and hypolipaemic effects of *Aloe vera*. Zhang *et al*. (2007) [82] conducted an experiment to see the effect of *Aloe vera* and propolis preparation on blood biochemical indices of broilers. They observed that there were significantly ($P<0.05$) higher contents of serum globulins, dextrose, urea nitrogen and calcium as well as activity of SGOT in broilers of treatment group. Madan *et al*. (2008) [4] observed that administration of *Aloe vera* extract to Swiss albino mice (300 mg/kg i.p.) daily for five days, significantly ($P<0.01$) increases the total white blood cells count. Further, it increases humoral immune response, as demonstrated from the increase in plaque-forming cells in the spleen and circulating antibody titer. On the other hand, assessment of blood parameters showed an increase in total white blood cell and lymphocyte counts on days 37 and 52 for broilers that received 2% *Aloe vera* gel (mixed with drinking water) compared to the control group (Valle- Paraso *et al*., 2005) [76]. Eevuri and Putturu (2013) [27] found that *Aloe vera* supplementation in broilers significantly reduced the serum cholesterol, serum triglycerides and increased the humoral response against NCD vaccine. Darabighane *et al*. (2011 a) [22] reported an increase in total white blood cell count of broilers as a result of adding *Aloe vera* gel to broiler feeds. In another study that used *Aloe vera* gel powder in broiler feeds, a significant increase was observed in total white blood cell count, red blood cell count, and haemoglobin in groups treated with *Aloe vera* gel powder compared to the control group, with the 1% *Aloe vera* gel powder group showing the highest haemoglobin, red blood cell, and white blood cell count (Mahdavi *et al*., 2012) [49]. In examining the effects of *Aloe vera* on lymphoid organs, researchers reported relative weight gain in these organs of broilers (Darabighane *et al*., 2012; Akhtar *et al*., 2012; Feng *et al*., 2011 and Jiang *et al*., 2005) [20, 3, 32, 4]. Besharatian *et al*. (2012) [10] did not observe a significant difference in weight of lymphoid organs, but reported a weight gain in spleen and bursa. Such relative increase in the weight of lymphoid organs as a result of adding *Aloe vera* to feed or drinking water suggests immune (humoral and cellular) system readiness against antigens. Furthermore, it has been reported that adding acemannan to NDV vaccine resulted in a significant increase in antibody titer against NDV, 21 days after injection, compared to broilers that were injected vaccines that did not contain acemannan, while adding acemannan to infectious bursal disease virus vaccine had no effect on improving antibody titer 21 days after injection, although on days 28 and 35 a significant difference was observed in antibody titer (Chinnah *et al*., 1992) [14]. In addition, the polysaccharides contained in

Aloe vera can improve immune system response in chickens that received *B. avium* inactivated vaccine (Sun *et al*., 2011) [73]. Moreover, it has been reported that adding *Aloe vera* and β-glucan led to stimulation of humoral and cellular immune response in dogs after vaccination (Altuğ *et al*., 2010) [8].

Many studies have examined immunomodulatory effects of *Aloe vera* and many researchers have attributed these effects on humoral and cellular immune response to acemannan (Tizard and Ni, 1998) [75]. However, one should also take into account indirect immunomodulatory effect resulting from intestinal microflora since *Aloe vera* can reduce the number of pathogens in intestines, thereby improving immune response and body resistance. Bolu *et al*. (2013) [11] observed that there were no adverse effects of *Aloe vera* gel on turkey poults health, as determined from the analysis of various haematological parameters and serum metabolites. The results indicated that *Aloe vera* gel inclusion at 20 ml/liter in drinking water could successfully replace antibiotics in turkey poults rearing. Mmereole (2008) [56] reported increase TEC, PCV, TLC, MCH, MCV, MCHC values in *Aloe vera* treated group as compared to antibiotic supplemented group. Singh *et al*. (2013) [69] reported higher Hb, PCV, TLC, total plasma glucose and serum calcium values in group containing diet supplemented with *Aloe vera* as compared to control group.

Effects on immune response

Improved or reinforced immune response in poultry creates resistance against diseases, and health of a flock, which can be the result of preparedness of immune system against pathogenic agents, is an important factor in improving homogeneity, long life, and growth performance of birds. Therefore, greater emphasis has been placed by researchers on improving immune response. Previous studies show that the polysaccharides contained in medicinal herbs and mushrooms can improve the response of immune system (Guo *et al*., 2004 a) [34]. An important property of *Aloe vera* that has been the subject of many *in vivo* and *in vitro* experiments is improvement in immune response, probably due to the acemannan contained in *Aloe vera* (Harlev *et al*., 2012; Djeraba and Quere, 2000; Zhang and Tizard, 1996; Karaca *et al*., 1995) [39, 25, 81, 45]. Acemannan contained in *Aloe vera* gel is a β (1-4)-linked acetylated mannan containing mannose that can attach to mannose receptors in macrophages (Karaca *et al*., 1995) [45] and activate these macrophages. In addition, acemannan can stimulate production of cytokines, release of nitric oxide (Zhang and Tizard, 1996; Karaca *et al*., 1995) [81, 45]. Experiments on chickens suggest promoted macrophage activities in broilers caused by the acemannan contained in *Aloe vera* (Djeraba and Quere, 2000; Karaca *et al*., 1995) [25, 45]. In a study on *Aloe vera* effects on humoral immunity of broilers, Darabighane *et al*. (2012) [20] reported an increase in antibody titer against Newcastle disease virus (NDV) on days 24 and 38 by adding *Aloe vera* gel to broiler feeds (at 1.5%, 2%, and 2.5%). These findings are consistent with those of Valle-Paraso *et al*. (2005) [76] who reported that broilers treated with 2% *Aloe vera* gel (mixed with their drinking water) showed significant increase in antibody titer against NDV on days 37 and 52, compared to the control group. In another study, Alemi *et al*. (2012) [7, 49] added *Aloe vera* gel powder (at 0.5%, 0.75%, and 1%) to broiler feeds and reported an increase in antibody titer against NDV. Moreover, another study reported an improvement in antibody titer in broilers against NDV as a result of adding acemannan (0.1% and 0.05%), polysaccharide (0.1%), and *Aloe vera* gel (0.1%) to broiler feed (Jiang *et al*., 2005) [4]. Yet, another study reported reduced loss and clinical symptoms, in infections by NDV, as a result of using *Aloe secundiflora* in broilers (Waihenya *et al*., 2002) [77]. In addition to *Aloe vera* effects on antibody titer against NDV, researchers have investigated antibody titer against sheep red blood cells (SRBC). For instance, Darabighane *et al*. (2012) [20] observed an increase in antibody titer against SRBC in broilers treated with *Aloe vera* gel, compared to the control group, and Akhtar *et al*. (2012) [3] reported that ethanol and aqueous extracts of *Aloe vera* pulp orally administered at 300 mg/kg body weight/day for three consecutive days to broilers increased antibody titer against SRBC compared to the control group. In a study on antibody titer against SRBC, Besharatian *et al*. (2012) [10] reported an increase in total immunoglobulin of 35-day-old broilers that received *Aloe vera* leaf powder (0.5% and 1% mixed with feed) and aqueous extract of *Aloe vera* leaf (15 and 30 ml/l, added to drinking water). Another study on the effects of *Aloe vera* gel powder (mixed with feed) on antibody titer against SRBC found a significant increase in antibody titer for the groups treated with 0.75% and 1% *Aloe vera* gel powder compared to the control group and the group receiving 0.5% *Aloe vera* gel powder (Mahdavi *et al*., 2012) [49]. Furthermore, Shokraneh *et al*. (2012) [68] reported an increase in antibody titer against SRBC in broilers as a result of continuous increase in *Aloe vera* gel in drinking water at 0.5%, 0.75%, and 1% as well as in intermittent application of *Aloe vera* gel at 1% (using *Aloe vera* for 5 days and stopping the application for 9 days); the group that continuously received 1% *Aloe vera* gel added to drinking water had the highest level of antibody titer. The findings of Besharatian *et al*. (2012) [10], Akhtar *et al*. (2012) [3], and Darabighane *et al*. (2012) [20] in connection to effects of *Aloe vera* on cellular immunity after PHA-P injection indicate improved cellular immune response in broilers that received *Aloe vera*: *Aloe vera* leaf powder (0.5% and 1%) and aqueous extract of *Aloe vera* leaf (15 and 30 ml/l) (Besharatian *et al*., 2012) [10], ethanolic extract of *Aloe vera* pulp (300 mg/ kg body weight/day for three consecutive days) (Akhtar *et al*., 2012) [3], and 2.5% *Aloe vera* gel (Darabighane *et al*., 2012) [20] showed the best performance compared to other groups. Therefore, *Aloe vera* can affect humoral and cellular immunity as evidenced by those studies that examined *Aloe vera* effects on immune response of broilers. On the other hand, assessment of blood parameters showed an increase in total white blood cell and lymphocyte counts on days 37 and 52 for broilers that received 2% *Aloe vera* gel (mixed with drinking water) compared to the control group (ValleParaso *et al*., 2005) [76]. In addition, Darabighane *et al*. (2011 a) [22] reported an increase in total white blood cell count of broilers as a result of adding *Aloe vera* gel to broiler feeds. In another study that used *Aloe vera* gel powder in broiler feeds, a significant increase was observed in total white blood cell count, red blood cell count, and hemoglobin in groups treated with *Aloe vera* gel powder compared to the control group, with the 1% *Aloe vera* gel powder group showing the highest hemoglobin, red blood cell, and white blood cell count (Mahdavi *et al*., 2012) [49]. In examining the effects of *Aloe vera* on lymphoid organs, researchers reported relative weight gain in these organs of broilers (Darabighane *et al*., 2012; Akhtar *et al*., 2012; Feng *et al*., 2011; Jiang *et al*., 2005) [20, 3, 32, 4]. Besharatian *et al*. (2012) [10] did not observe a significant difference in weight of lymphoid organs, but reported a weight gain in spleen and bursa. Such relative increase in the weight of lymphoid organs as a result of adding *Aloe vera* to feed or drinking water suggests immune (humoral and

cellular) system readiness against antigens. Furthermore, it has been reported that adding acemannan to NDV vaccine resulted in a significant increase in antibody titer against NDV 21 days after injection, compared to broilers that were injected vaccines that did not contain acemannan, while adding acemannan to infectious bursal disease virus vaccine had no effect on improving antibody titer 21 days after injection, although on days 28 and 35 a significant difference was observed in antibody titer (Chinnah *et al*., 1992) [14]. In addition, the polysaccharides contained in *Aloe vera* can improve immune system response in chickens that received B. avium inactivated vaccine (Sun *et al*., 2011) [73]. Moreover, it has been reported that adding *Aloe vera* and beta-glucan led to stimulation of humoral and cellular immune response in dogs after vaccination (Altuğ *et al*., 2010) [8]. Many studies have examined immunomodulatory effects of *Aloe vera* and many researchers have attributed these effects on humoral and cellular immune response to acemannan (Tizard and Ni, 1998) [75]. However, one should also take into account indirect immunomodulatory effect resulting from intestinal microflora since *Aloe vera* can reduce the number of pathogens in intestines, thereby improving immune response and body resistance.

Effects on coccidiosis

Coccidiosis is one of the costliest and the most common diseases in poultry farming industry with detrimental impacts on growth performance. An excellent way to control coccidiosis is to use anticoccidial drugs. However, high treatment costs and heightened resistance against these drugs have shifted attentions toward herbs for controlling the disease. Application of *Aloe vera* for treatment of poultry diseases is not limited to large-scale farming (industrial applications); for example, different species of aloe can be found in Zimbabwe, and in Mushagash, smallholder farmers use *Aloe vera* and aloe spicata to treat broilers with coccidiosis (Mwale *et al*., 2005) [61]. In an *in vitro* experiment to compare the effects of *Aloe vera* and aloe spicata on inhibition of the sporulation of avian coccidia oocysts, Mwale *et al*. (2006) [60] reported that increase in *Aloe vera* and aloe spicata content significantly decreases coccidia oocyst count. Yim *et al*. (2011) [80] reported that broilers that received *Aloe vera* powder (0.1%, 0.3%, and 0.5%) had smaller fecal oocyst shedding count compared to infected group fed with the standard diet. In addition, Akhtar *et al*. (2012) [3] found in their studies that fecal oocyst shedding in broilers orally administered with ethanol and aqueous extracts of *Aloe vera* pulp at 300 mg/kg body weight/day for three consecutive days was significantly lower compared to the infected control group. Moreover, broilers that received aqueous extract of *Aloe vera* pulp had the lowest mean score lesion in caeca and intestine in comparison to the control group and the group that received ethanol extract of *Aloe vera* pulp. Also Darabighane and Zarei (2011) [19, 21] reported that broilers receiving 2.5% *Aloe vera* gel added to their feed had the smallest fecal oocyst shedding among all groups. Since *Aloe vera* positively affects immune response and previous studies well established the role of immune system in treatment of coccidiosis in poultry, the anticoccidial effects of *Aloe vera* are attributable to stimulation of immune system. Akhtar *et al*. (2012) [3] attributed anticoccidial effects of *Aloe vera* to production of antibody against coccidiosis, which probably reduces the number of fecal egg and increases weight gain. Yim *et al*. (2011) [80] argued that through cellular mediated response, *Aloe vera* can provide a more favorable effect compared to antibody response. In general, and based on the findings of the previous studies, *Aloe vera* is regarded as a proper alternative for treating coccidiosis in a more economical way. Durrani *et al*. (2008) [26] concluded that giving aloe extract @ 10 ml/liter to broilers in drinking water resulted in better weight gain and feed efficiency. On the other hand, better antibody titer against IB and IBD and lower coccidia oocysts' count in bedding material of the broilers was found in birds, receiving aloe extract @15 ml/liter of drinking water.

Effect on mortality and cost of production

Moorthy *et al*. (2009) [58, 59] observed that a significant ($P<0.05$) difference in return over feed cost in 0.1 percent *Aloe vera* fed group compared to other treatment groups. No significant difference was observed in feed consumption, percent hen day egg production and percent broken eggs. It can be concluded that inclusion of 0.1 percent *Aloe vera* in White Leghorn diet is economical compared to its combination with turmeric and probiotic at 0.1 percent level. Eevuri and Putturu (2013) [27] found that *Aloe vera* supplementation in broilers decreased the mortality rates and the cost of feed has been decreased from 6.2 to 13.5%.

Conclusion

Aloe vera, as an additive to broiler chicken feed, has great potentials for improving growth performance, carcass characteristics, haemato-biochemical parameters, intestinal health, immune system response and cost of production. It can also be used in controlling coccidiosis. Advantages of *Aloe vera* added to broiler feeds depend on several factors: form of use (powder, gel, extract (ethanolic or aqueous), polysaccharide extracted from gel), dosage, genetics of broilers, ingredients of diet, and farm management. Therefore, more studies are required to determine effective dosage and form of use.

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