



Effect of combination of garlic powder with black pepper, cinnamon and aloe vera powder on the growth performance, blood profile, and meat sensory qualities of broiler chickens

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ABSTRACT

This study was conducted to evaluate dual herb combinations as phytogetic alternative to antibiotic growth promoters in broilers. One-day old broiler chicks (225) were randomly distributed to 5 treatments with 3 replicates of each. The dietary treatments comprised basal diet as control (C); antibiotic group receiving 0.1 g/kg of oxytetracycline (AB); 1.5% garlic powder + 0.5% black pepper (GB); 1.5% garlic powder + 0.5% cinnamon powder (GC) and basal diet with 1.5% garlic powder + 1.0% whole leaf aloe vera powder (GA). Body weight and feed consumed were recorded weekly and accordingly feed conversion ratio and protein efficiency ratio were calculated. At the end of 5th week, 2 birds per replicate were sacrificed to determine the carcass characteristics, meat sensory evaluation, blood parameters, duodenum morphology and faecal microbial load. The result revealed that inclusion of herbal combinations improved the weight gain compared to other treatments. All herbal combinations improved the flavour, tenderness and overall acceptability score of meat. Dietary regimen significantly affected the haemoglobin, PCV and TP parameters. Herbal combinations affected the fat digestibility and phosphorus retention, and improved the villus height: crypt depth. It can be concluded that herbal combinations studied have the potential to replace the prevalent antibiotic growth promoters used in broiler chicken.

Key words: Aloe Vera, Black pepper, Chicks, Cinnamon, Garlic, Meat quality

Presence of antibiotic residue in poultry products due to consistent and irrational use of sub-therapeutic dose of antibiotic in poultry feed as growth promoters (AGP) has created a lot of concern among scientist fraternity for finding its alternative (Mansoub 2010). Natural feed additives like herbs have become the first preference of researchers for evaluation of their potency in replacing the prevalent AGP's. Various herbs, extracts and phytochemicals have been tried by researchers across the globe with promising results. Our previous studies have revealed that black pepper at 0.5% (Singh *et al.* 2018a), whole bulb garlic powder at 1.5% (Singh *et al.* 2015), cinnamon powder at 0.5% (Singh *et al.* 2014a) and whole leaf aloe vera powder at 1.0% (Singh *et*

al. 2014b) inclusion can be used as an alternative to conventional AGP with added advantage of improvement in organoleptic properties of meat. There are sporadic reports on use of different dual herbal combinations in poultry. Hence, the present study was conducted to evaluate the associative effect of two herbs, viz. garlic + black pepper, garlic + cinnamon and garlic + aloe vera powder on growth performance, nutrient utilization, sensory characteristics of meat, haematological parameters, duodenum morphology and faecal microbial load.

MATERIALS AND METHODS

The experiment was conducted at Poultry farm of the University after obtaining the approval from Animal Ethic Committee. Day old broilers chicks (225; strain IBL-80 of the University) were procured from University hatchery. Each bird was weighed on arrival and randomly assigned to 5 different dietary treatments using completely randomized design. Each dietary treatment had 3 replicates with 14 birds (7 male: 7 female) in each. The feeding was done in two phases, i.e. starter (0–21 days) and finisher (22–35 days) phase. For each phase, 5 isocaloric and isonitrogenous diets were formulated (Table 1). Basal diet served as control (C); basal diet supplemented with

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antibiotic growth promoter (oxytetracycline @ 0.1 g/kg) acted as antibiotic group (AB); with 1.5% garlic powder + 0.5% black pepper as GB; with 1.5% garlic powder + 0.5% cinnamone powder as GC and basal diet with 1.5% garlic powder + 1.0% whole leaf aloe vera powder as GA. Dose rate of these herbs were used based on the result of previous studies on different level of individual herb (Singh *et al.* 2014a, Singh *et al.* 2014b, Singh *et al.* 2015, Singh *et al.* 2018) All the experimental diets were analysed for proximate principles, phosphorus and calcium content using standard procedure. Ingredients and chemical composition of starter and finisher diets is presented in Table 1. Weighed amount of respective diet was offered daily to all groups to ensure *ad lib.* feeding. Fresh and clean water was made available to the birds throughout the experimental period. The birds were reared on deep litter system maintaining standard managemental practices throughout the experimental period.

Growth performance and carcass characteristics: Body weight was recorded at weekly interval i.e. 7, 14, 21, 28 and 35 days of age to determine the weekly body weight and weight gain. Feed residue left of each replicate was also recorded at weekly interval to calculate feed intake and feed conversion ratio. On 35th day, two birds (one male and one female) of identical body weight from each replicate were sacrificed. The birds were starved for 12 h but drinking water was provided *ad lib.* Birds were killed by severing the jugular vein and carotid artery on one side of the neck and allowed to bleed. Each bird was defeathered and eviscerated maintaining proper hygiene. The eviscerated weight and weight of liver, gizzard, heart, and abdominal fat parameters were recorded and expressed in term of g/100 g of body weight.

Balance studies: A metabolism trial was conducted at the age of five weeks. Two birds (one male and one female) from each replica with comparable body weights were selected and shifted in cage. The birds were housed in cages for a period of 5 days. During this period, weighed amount of feed was offered to the birds twice daily. After two days of adaptation period, the feed residue was removed. Weighed amount of fresh feed was offered to each group, for three consecutive days. Fresh water supply and 24 h light were assured during metabolic trial. The feed residue was removed on the 5th day and weighed back to record the actual consumption of feed for each group. Dropping voided by each group were collected daily, weighed and dried separately at 80°C in hot air oven after the addition of 10 ml of 1:4 sulphuric acid. Three day dried droppings of each group were pooled and grounded for chemical analysis.

Sensory evaluation of meat: The dressed birds were also assessed for meat sensory evaluation. A 7 member experienced panel of Department of Livestock Product Technology, GADVASU, evaluated the samples for appearance, colour, flavour, tenderness, juiciness and overall acceptability using 8 point descriptive scale (Keeton 1983), where 8, extremely desirable and 1, extremely undesirable. The panellists were acquainted with the descriptive scale in two session before the start of experiments. Three sittings (21) were conducted for each replicate. The panellists were seated in a room free of noise and odours, and suitably illuminated. The meat was cooked in salt and water for around 15 min till the internal temperature reached to 72°C. This full done meat sample was coded and served warm to the panellists. Water was provided in between samples to cleanse the mouth palate.

Blood parameters: Blood samples of three birds from

Table 1. Ingredients composition of starter and finisher feed

Ingredient (%)	Starter (S)					Finisher (F)				
	C	AB	GB	GC	GA	C	AB	GB	GC	GA
Maize	56.5	56.49	54.5	54.5	54.0	60.60	60.59	58.6	58.6	58.1
Soybean meal	39.0	39.0	39.0	39.0	39.0	33.00	33.00	33.00	33.00	33.00
Oil	0.5	0.5	0.5	0.5	0.5	2.0	2.0	2.0	2.0	2.0
DCP	1.7	1.7	1.7	1.7	1.7	2.0	2.0	2.0	2.0	2.0
LSP	1.5	1.5	1.5	1.5	1.5	1.75	1.75	1.75	1.75	1.75
Herbal combination	–	–	2.0	2.0	2.5	–	–	2.0	2.0	2.5
Oxytetracycline (g)	–	10	–	–	–	–	10	–	–	–
Additives*	+	+	+	+	+	+	+	+	+	+
<i>Analysed value (DM Basis) (%)</i>										
CP	21.76	21.76	21.41	22.00	20.36	19.66	19.67	19.31	20.01	19.65
EE	2.04	2.17	2.25	1.82	2.10	4.48	4.21	4.34	3.99	3.93
CF	5.41	5.17	5.74	5.19	5.08	4.63	4.63	4.85	4.81	4.77
Ash	7.36	7.68	6.70	7.65	8.22	8.96	7.27	9.06	6.67	6.23
AIA	0.67	0.71	0.45	0.67	0.45	1.36	1.07	1.22	1.18	0.79
Ca	1.16	1.12	1.07	1.07	0.96	1.23	1.12	1.30	1.23	1.07
Av. P	0.63	0.61	0.66	0.68	0.62	0.64	0.62	0.68	0.60	0.61

*Additives per 100 kg ration : Vitamin A, 8,25,000 IU; Vitamin D3, 1,20,000 IU; Riboflavin, 500 mg; Vitamin K, 100 mg; Vitamin E, 800 mg; Thiamin, 80 mg; Pyridoxine, 160 mg; Cynacobalamin, 800 mg; Niacin, 1200 mg; Calcium pantothenate, 800 mg; Manganese Sulphate, 25 g; Zinc Sulphate, 25 g; Ferrous sulphate, 10 g; Copper sulphate, 500 mg; Potassium iodide, 100 mg; Lysine, 0.060 g (S), Methionine, 0.150 g (S) 0.100 g (F) Coccidiostat, 60 g; Toxin binder, 50 g; Salt, 300 g.

each treatment on 35 days were collected from jugular vein in two EDTA and non EDTA containing vial. Serum was separated from the latter. EDTA containing sample was used for determining haemoglobin (haemometer method) and packed cell volume while serum was used for other parameters like glucose, triglycerides, cholesterol, total protein and albumin. The measurements were taken using commercial Siemens autopack kits with RA 50.

Duodenum morphology: After thorough gross examination, small representative pieces (approximately 0.5 cm thickness) of duodenum were collected from each sacrificed bird and fixed in 10% neutral buffered formalin. After proper fixation for 3–4 days, tissues were cut into thinner sections (1–2 mm thick). The tissues were washed in running water for 7–8 h, dehydrated in ascending grades of ethyl alcohol, cleared in benzene and embedded in paraffin wax (melting point 58°C). The paraffin blocks were prepared and the sections were cut at 4–5 μ thickness with a hand operated microtome. The paraffin embedded sections were then passed through sequential steps of deparaffinisation in xylene, rehydration through descending grades of ethyl alcohol to running water. Sections were stained by routine haematoxylin and eosin stain.

Faecal microbial load: Fresh faecal material was collected in morning hours on last day of metabolic trial and same was sent to Department of Veterinary Microbiology, GADVASU. Viable bacterial cell counting was carried out using Miles-Misra technique (Quinn *et al.* 2000). Serial tenfold dilution of the faecal samples containing bacteria were carried out as accurately as possible to minimize avoidable errors and an aseptic

technique was used. Ranges of dilution were used and an inoculum of 0.02 ml, delivered as a drop was placed on the agar (Brain heart infusion agar for total bacterial load and Hichrome *E. coli* agar for *E. coli*). At least 4 drops per sample dilution were used. The inoculums were allowed to dry and the plates were incubated at 25–37°C for 24–48 h. Colony count obtained from the sample inoculums were then used to determine the number of bacteria/ml of original sample.

Statistical analysis: Growth performance, carcass characteristics and sensory evaluation and other data were subjected to analysis of variance using SPSS (version 16) and treatments mean were compared using Duncan's multiple range tests at 95% significant level.

RESULTS AND DISCUSSION

Growth performance: Significant ($P < 0.05$) effect of the dietary treatment was observed on final body weight (FBW) and body weight gain (BWG) during starter phase (Table 2). Supplementation of herbal combinations namely GB, GC and GA significantly ($P < 0.05$) improved the FBW, BWG, FI/B/D, FCR and PER than the C and AB groups; however, FBW and BWG in GB, GC and GA did not differ significantly ($P < 0.05$) from each other. In finisher phase, birds fed on GC and GA diets attained significantly ($P < 0.05$) higher body weight than C and AB groups. This might be due to their significantly ($P < 0.05$) higher feed consumption. Contrary to starter phase, best ($P < 0.05$) FCR and PER were found in AB group than all other treatments studied. Supplementation of herbal combinations deteriorated ($P < 0.05$) the FCR during this phase as poorest ($P < 0.05$)

Table 2. Effect of herbal combinations for 5 weeks on growth performance in broilers

Treatments Parameter	C	AB	GB	GC	GA	SEM	P value
<i>Starter phase</i>							
IBW (g)	36.67	37.67	37.00	37.33	37.67	0.153	0.152
FBW (g)	433.80 ^a	460.89 ^a	534.32 ^b	549.22 ^b	538.55 ^b	13.605	0.001
BWG (g)	397.80 ^a	423.23 ^a	497.22 ^b	511.88 ^b	500.92 ^b	13.487	0.001
FI/B/D (g)	37.66 ^a	39.96 ^{ab}	40.84 ^{ab}	41.84 ^b	42.93 ^b	0.622	0.044
FCR	1.99 ^b	1.98 ^b	1.73 ^a	1.72 ^a	1.80 ^a	0.039	0.010
PER	2.32 ^a	2.32 ^a	2.71 ^b	2.65 ^b	2.73 ^b	0.056	0.002
<i>Finisher phase</i>							
FBW (g)	1168.8 ^a	1222.1 ^{ab}	1278.5 ^{bc}	1320.5 ^c	1310.8 ^c	17.240	0.002
BWG (g)	735.05	761.28	744.23	771.34	772.23	8.878	0.657
FI/B/D (g)	111.49 ^{ab}	107.69 ^a	115.05 ^b	122.91 ^c	123.17 ^c	1.816	0.001
FCR	2.13	1.98	2.17	2.23	2.24	0.037	0.153
PER	2.40	2.60	2.39	2.24	2.28	0.043	0.105
<i>Overall period</i>							
IBW (g)	36.67	37.67	37.00	37.33	37.67	0.153	0.152
FBW (g)	1168.8 ^a	1222.1 ^{ab}	1278.5 ^{bc}	1320.5 ^c	1310.8 ^c	17.240	0.002
BWG (g)	1132.1 ^a	1184.5 ^{ab}	1241.5 ^{bc}	1283.2 ^c	1273.1 ^c	17.186	0.002
FI/B/D (g)	66.08 ^a	67.05 ^{ab}	70.53 ^{bc}	74.04 ^c	74.27 ^c	1.033	0.003
FCR	2.04	1.98	1.99	2.02	2.04	0.014	0.590
PER	2.36	2.47	2.51	2.39	2.44	0.021	0.121

IBW, Initial body weight; FBW, final Body weight; BWG, body weight gain; FI/B/D, feed intake per bird per day; FCR, feed conversion ratio; PER, protein efficiency ratio. ^{a,b,c}Means bearing different superscripts in a row differ significantly ($P < 0.05$).

FCR and PER were observed in GC and GA groups. In overall period (0–5 weeks), highest ($P<0.05$) weight gain was attained by birds fed on GC and GA diets compared to birds fed on C and AB diets which could be due to higher feed intake. Data revealed that inclusion of all the herbs combination studied in this experiment had more pronounced impact on growth during the starter phase. Saeid *et al.* (2013) revealed that supplementation of garlic powder and black seed plant premix @ 0.5% resulted in significant higher body weight, weight gain and feed intake as compared to that of control group, but FCR was not influenced by dietary treatments ($P<0.05$). Garlic as a natural feed additive, improved the growth, FCR and decreased mortality (Tollba and Hassan 2003). The improved performance due to the black pepper might be due to that it favourably stimulates the digestive enzymes of pancreas, enhances digestive capacity, reduces the gastrointestinal food transit time (Srinivasan 2007), arousing digestive liquid in stomach and eradication of infectious bacteria (Tazi *et al.* 2014) increases production of saliva and gastric secretions, there by improves appetite (Meghwal and Goswami 2012). The reason for the increased body weight in cinnamon fed broilers may be due to increased serum immunoglobulin level (Sang-oh *et al.* 2013), as well as the antibacterial activity (Singh *et al.* 2018b) of the cinnamon. Present results are in line with the finding of Onu (2010) who reported significantly improvement in final body

weight, weight gain and FCR with supplementation of garlic and ginger at 0.25% level.

Cost effectiveness and benefit cost ratio (BCR): Feed cost/kg weight gain during starter phase was not significantly different (Table 3). The highest ($P<0.05$) feed cost/kg weight gain during overall period was observed in GA group followed by GB and the lowest ($P<0.05$) was in AB group. Inclusion of all the herbs combinations studied improved ($P<0.05$) the BCR during the starter period. However during overall period, the highest ($P<0.05$) BCR was found in AB group and was comparable with GC group. The significance in feed cost per kg weight gain and BCR during overall period is mainly due to variation in the starter and finisher feed cost owing to inclusion of different herbs combinations.

Nutrient utilization: Dietary treatments significantly ($P<0.05$) affected either extract (crude fat) digestibility or per cent phosphorus retention. Lowest ($P<0.05$) ether extract digestibility was found in GA group. Birds fed on AB diet had highest ($P<0.05$) per cent phosphorus retention (Table 4).

Phytogenic substances improves the gut microflora (Peric *et al.* 2009), modify the digestive secretion morphology (Jamroz *et al.* 2003) which increases the digestibility of the nutrients and ultimately the performance (Kroismayr *et al.* 2008). The improved digestibility of fat and calcium retention can be justified that supplementation of black pepper reduces the microbial load in gut (Eevuri and Putturu 2013) and improved the absorption surface (Cardoso *et al.* 2012) thereby improving the absorption of nutrients.

Carcass characteristics: Dietary regimes failed to significantly ($P<0.05$) effect the dressing percentage, liver and abdominal fat parameters. The highest ($P<0.05$) gizzard weight and heart weight was observed in C group (Table 5).

Abou-Elkhair *et al.* (2014) also reported the non significant ($P<0.05$) impact of mixture of black pepper + turmeric and black pepper + coriander @ 0.5% each on the dressing percentage, gizzard, heart, spleen, thymus and bursa of fabricus at 35 day of age. Abnormalities in the weight of the internal organs like liver, kidney, and gizzard might be due to increased metabolic rate of the organs in

Table 3. Effect of herbal combinations on cost effectiveness and benefit cost ratio

Treatment	Feed cost/ kg (₹)		Feed cost per kg weight gain (₹)		BCR	
	Starter	Finisher	Starter	Overall	Starter	Overall
C	24.88	24.39	49.63 ^b	51.03 ^{ab}	0.953 ^a	1.25 ^{bc}
AB	24.90	24.41	49.41 ^b	48.74 ^a	0.977 ^a	1.31 ^c
GB	27.43	26.93	47.32 ^{ab}	53.90 ^c	1.06 ^{bc}	1.22 ^{ab}
GC	25.93	25.43	44.50 ^a	51.85 ^{bc}	1.13 ^c	1.27 ^{bc}
GA	28.02	27.55	50.49 ^b	57.16 ^d	1.02 ^{ab}	1.17 ^a
SEM	0.345	0.346	0.785	0.824	0.018	0.015
P value			0.078	0.001	0.007	0.003

^{a,b,c}Means bearing different superscripts in a column differ significantly ($P<0.05$).

Table 4. Effect of dietary treatment on per cent nutrients digestibility

Parameters	C	AB	GB	GC	GA	SEM	P Value
DDM	70.76	70.28	70.22	70.14	70.34	0.630	0.999
DCP	67.53	67.96	67.13	66.24	67.26	0.673	0.966
DFAT	81.37 ^b	81.20 ^b	82.23 ^b	79.70 ^b	77.68 ^a	0.501	0.009
DMDCF	21.48 ^a	23.35 ^{ab}	27.67 ^{ab}	21.31 ^a	31.09 ^b	1.441	0.108
DMDCa	46.73	49.88	49.16	45.05	43.84	1.458	0.704
DMDP	42.87 ^{ab}	49.93 ^b	44.63 ^{ab}	38.91 ^a	38.85 ^a	1.366	0.023

DDM, Dry matter digestibility; DCP, digestibility of crude protein; DFAT, digestibility of crude fat; DMDCF, dry matter digestibility of crude fibre; DMDCa, dry matter digestibility of calcium; DMDP, dry matter digestibility of phosphorus. ^{a,b,c}Means bearing different superscripts in a row differ significantly ($P<0.05$).

attempt to reduce the toxic elements or anti-nutritional factors to non toxic metabolites. So, lower gizzard and heart weight in GB, GC and GA reflected better internal status or lesser toxic elements metabolites.

Sensory evaluation of meat: Dietary regimes significantly ($P<0.05$) influenced the sensory parameters studied except the juiciness of the meat (Table 6). GB, GC and GA and AB significantly ($P<0.05$) improved the appearance, colour, flavour, tenderness and overall acceptability of the meat compared to control.

Puvaca *et al.* (2013) reported the beneficial effect of phytoadditive compounds on meat quality may be due to presence of antimicrobial and antioxidants properties in these. Amending the diet of broiler with black pepper and cinnamon powder improved the quality of chicken meat including colour, flavour, texture and overall acceptability (Singh *et al.* 2014a, 2018).

Blood biochemistry: Dietary treatment significantly ($P<0.05$) effect the HB, PCV and TP parameters of the broilers (Table 7). Highest ($P<0.05$) Hb level was observed in GC group and was comparable with C and GB groups respectively. Highest ($P<0.05$) PCV was observed in C and GC groups and lowest ($P<0.05$) was found in GA. Supplementation of garlic and aloe vera combination

lowered the cholesterol level as compared to control. Abou-Elkhair *et al.* (2014) observed the significant ($P<0.05$) impact of 0.5% black pepper and 0.5% turmeric powder and 0.5% black pepper and 2.0% coriander seed combinations on the total protein, glucose and triglyceride level. Garlic (Singh *et al.* 2017), aloe vera (Rajasekaran *et al.* 2006), cinnamon (Rahman *et al.* 2013) and black pepper (Singh *et al.* 2018b) are reported to possess cholesterol lowering properties. The combinations of these herbs as tried in the present results showed similar trends. Results of present study were in line with Shahverdi *et al.* (2013) who found that supplementation of 0.02% black pepper alone and in combination with red pepper (0.1% each) significantly ($P<0.05$) lowered the Hb and PCV value as compared to control group.

Duodenum morphology and faecal bacterial count: Dietary treatments failed to effect the villus height significantly ($P<0.05$). Deepest ($P<0.05$) crypt depth was noticed in C group than the other treatments (Table 8). Lowest ($P<0.05$) villus height /crypt depth ratio was noticed in C group, which reflected the poor performance of this group. Saeid *et al.* (2013) also reported that addition of 0.5% garlic powder and combination of garlic powder and black seed @ 0.5% level significantly ($P<0.05$) improved

Table 5. Effect of herbal combinations on carcass characteristics in broilers

Parameter	C	AB	GB	GC	GA	SEM	P value
Dressing percentage	52.00	54.15	52.53	51.23	51.70	0.437	0.269
Liver*	3.85	3.44	3.67	3.11	3.16	0.126	0.284
Gizzard*	3.32 ^c	3.18 ^{bc}	3.13 ^{bc}	2.47 ^a	2.59 ^{ab}	0.114	0.029
Heart*	1.09 ^b	0.797 ^a	0.918 ^{ab}	0.745 ^a	0.712 ^a	0.047	0.025
Abdominal fat*	2.39	2.01	1.67	2.09	2.44	0.128	0.328

a,b,cMeans bearing different superscripts in a row differ significantly ($P<0.05$). *(g/100 g).

Table 6. Effect of herbal combinations on sensory qualities of chicken meat

Parameter	C	AB	GB	GC	GA	SEM	P value
Appearance and colour	6.89 ^a	7.30 ^b	7.31 ^b	7.45 ^b	7.41 ^b	0.043	0.031
Flavour	6.96 ^a	7.21 ^b	7.33 ^b	7.21 ^b	7.29 ^b	0.048	0.039
Tenderness	6.75 ^a	7.21 ^b	7.03 ^{ab}	7.17 ^b	7.25 ^b	0.067	0.023
Juiciness	6.87	7.13	7.08	7.02	7.23	0.065	0.544
Overall acceptability	6.67 ^a	7.33 ^b	7.03 ^{ab}	7.08 ^{ab}	7.21 ^b	0.068	0.047

a,b,cMeans bearing different superscripts in a row differ significantly ($P<0.05$).

Table 7. Effect of herbal combinations on blood parameters of broilers

Parameter	C	AB	GB	GC	GA	SEM	P value
Hb (gm%)	11.00 ^{bc}	10.15 ^a	10.25 ^{ab}	12.20 ^b	9.07 ^a	0.357	0.041
PCV (%)	37.33 ^b	32.33 ^{ab}	32.33 ^{ab}	38.33 ^b	28.17 ^a	1.247	0.027
GLU (mg/dl)	316.67	287.33	293.33	329.33	287.33	7.107	0.212
TG (mg/dl)	121.59	108.65	105.01	117.25	105.10	3.955	0.640
CHOL (mg/dl)	139.67 ^b	120.33 ^{ab}	129.00 ^{ab}	129.67 ^{ab}	107.67 ^a	3.962	0.089
TP (g/dl)	4.60 ^{bc}	4.33 ^{ab}	4.80 ^c	4.53 ^{bc}	4.23 ^a	0.062	0.006
ALB (g/dl)	1.70	1.73	1.83	1.63	1.63	0.043	0.625

a,b,cMeans bearing different superscripts in a row differ significantly ($P<0.05$).

Table 8. Effect of herbal combinations on duodenum morphology and faecal bacteria count in broilers

Parameter	C	AB	GB	GC	GA	SEM	P value
Villus height (μm)	2127.71	1941.08	1948.45	1929.51	1881.56	45.774	0.552
Crypt depth (μm)	139.83 ^b	91.89 ^a	77.44 ^a	77.64 ^a	89.97 ^a	8.018	0.046
Villus height : crypt depth	15.22 ^a	21.12 ^b	25.16 ^b	24.85 ^b	20.91 ^b	1.000	0.003
Total bacterial (10^5) organisms /ml of sample	5.50 ^{bc}	2.33 ^a	5.57 ^{bc}	4.67 ^b	6.95 ^c	0.483	0.008
<i>E. coli</i> (10^5) organism/ml of sample	3.83	1.17	2.70	2.60	ND	0.495	0.094

^{a, b, c}Means bearing different superscripts in a row differ significantly ($P < 0.05$).

the villus height, crypt depth and crypt depth to villus height ratio as compared to control group. Longer villi increased the surface area for nutrient absorption. The crypt can be described as villus factory and large crypt indicates fast tissue turnover and a high demand for new tissue (Yason *et al.* 1987). Further, villus: crypt ratio is an indicator of digestive capacity of small intestine. Present findings are in agreement with Awaad *et al.* (2014) who reported that supplementation of specific combination of carvacrol, cinnamaldehyde and *capsicum oleoresin* significantly ($P < 0.05$) increased the villus height and villus height/crypt depth ratio and decreased the crypt depth in ileum as compared to control. Among herbal combination fed groups, lowest total bacterial count per ml of faecal sample was observed in GC group. Overall, significantly ($P < 0.05$) lowest total bacterial count was found in antibiotic fed group. *E. coli* count was considerably higher in control group when compared to rest of the treatments. Individually, garlic, black pepper and cinnamon (Singh *et al.* 2017, Singh *et al.* 2018a, Singh *et al.* 2018b) and aloe vera (Lawrence *et al.* 2009) found to possess antibacterial properties, however the synergistic effect was not observed in present study. Further study is required to evaluate the potential dose of active ingredient present in these herbs to inhibit the growth of bacteria and their interaction with active ingredient of other herbs.

The study concluded that all herbal combinations studied have the potential to act as growth promoters besides improving the meat sensory parameters and duodenum morphology in broiler. Perusal of data analysis revealed that impact of these herbal combinations on growth was more pronounced in starter phase with a significant better FCR compared to control and antibiotic fed groups. Further study is recommended where these herbal combinations included only in starter phase, only in finisher phase and overall phase to evaluate the exact impact of herbs on growth *vis-a-vis* phase of broiler.

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