Evaluation of anticoccidial effect of *Khaya senegalensis* stem bark on the performance of three strains of egg type chickens

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Abstract

This study was carried out to evaluate the anticoccidial effect of *Khaya senegalensis* on growth and production performance of three strains of layer chickens. Three hundred and sixty day old commercial chicks were randomly allotted into 15 treatment combinations in a 5x3 factorial design with three strains of layer chickens: Isa Brown, Nera Black and Oba Blue and five coccidiostat treatments: control, 100 g/ton of conventional coccidiostat (sulphaquinoxaline), 100 g/ton of *K. senegalensis* in the basal diet between 21st -27th and 42nd -48th day, 200 g/ton *K. senegalensis* in the basal diet between 21st -27th and 42nd -48th day and 100 g/ton *K. senegalensis* in the basal diet continuously. Each of the groups had three replicates of 8 chicks raised in a deep litter system. Weight gain reduced ($p<0.05$) in chicks and pullets fed control diet in the three strains. Mortality was highest in Isa Brown chickens fed control diet while the lowest chick mortality occurred in Oba Blue birds with or without supplementation or medication. Egg weight was heaviest ($p<0.05$) in Isa brown birds with the lightest in Oba blue birds. From this study, *K. senegalensis* reduced oocyst count in all the strains and compared favourably with commercial anticoccidiostat. Isa Brown birds were more susceptible to coccidiosis, however more productive in terms of egg weight. It can be concluded that *Khaya senegalensis* can be used as an organic cocccidiostat in poultry production.

Keywords: Chicks, egg quality, oocyst count, layer strains

Introduction

An outbreak of diseases in a poultry flock has a very high negative economic impact on the flock as well as on the poultry producer. Coccidiosis is the most prevalent intestinal parasitic diseases of poultry worldwide (Amae *et al*., 2012; Ashenafi *et al*., 2004). The disease appears to reach climax at 5-7 wk of age and as age exceeds 7 wk, most birds develop immunity and increase resistance to the disease (Bowman, 2009; Taylor *et al*., 2007) while Julie (1999) reported that all ages of poultry are susceptible to coccidiosis infection.

The control of the disease relies almost entirely on coccidiocidal drugs. As a result of some adverse effects of coccidial drugs on the health of birds are prolonged withdrawal period, drug residual effects and emergence of multiple drug resistant *Emeria spp.* (Newman, 2002). Nutritionists have resorted to devising and implementing many different drug based programmes in coccidiosis control in an attempt to achieve optimal efficacy with minimal side effects. Chapman (1999) reported that no single anticoccidial drug can win the war against coccidiosis, hence plants which contain different types of secondary metabolites could act against coccidiosis. Researchers are also beginning to appreciate the role of medicinal plants in livestock; this is as a result of the effectiveness, low cost and the availability of these herbal medicinal plants (Tiwari *et al*., 2004). Shafaei *et al*. (2011) reported that the widespread use and popularity of herbal medicines do not guarantee their efficacy and safety; therefore, there is the need for detailed scientific analyses and adequate information on commonly used herbal drugs. *Khaya senegalensis* (Mahogany) is a medicinal plant that is widely used to treat various diseases for several human and animal ailments due to their antiviral, antifungal and bactericidal properties (Arbonnier, 2004; Abdelgaleil and Nakatani, 2003). The stem bark extract is used for treating jaundice, malaria, dermatoses and hookworm infections **(**Gill, 1992**)**. Atawodi *et al*. (2009) reported that the stem bark of *Khaya senegalensis* contained catechin and procyanidins, also it possessed both the highest antioxidant potential and highest radical scavenging capacity among the plant parts. The ethanolic crude extract of the stem bark of *Khaya senegalensis* was reported to possess free radical scavenging activity (Lompo *et al*., 2007). Several studies reported the stem bark was not toxic (Adebayo *et al*., 2011; Sule *et al*., 2008). According to Onu *et al*. (2013) the LD_{50} of the extract was greater than 5000 mg kg^{-1} body weight. Although, other studies revealed that chronic treatment induced hepatotoxicity and cytolytic effect on liver (Abubakar *et al*., 2009; Kolawole *et al*., 2012; Yakubu *et al*., 2005). This study was undertaken to evaluate the production performance, egg quality and oocyst count for three strains of laying hens fed *Khaya senegalensis* supplemented diets.

Materials and Methods

Test material

The outer stem bark layers of *Khaya senegalensis* tree were obtained from the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) farm, Opeji village, Odeda Local Government Abeokuta Ogun State, South-West, Nigeria. The stem barks were sun-dried and ground to powdery form of 44 microns in size and referred to as *Khaya senegalensis* stem bark meal (KSSB). KSSB was stored in an air tight container before inclusion in the diet. The results obtained from the phytochemical identification screening of the stem barks of *K. senegalensis* showed they contained saponins, tannins, reducing sugars, aldehyde, phlobatannins, flavonoids, terpenoids, alkaloids, glycoside and anthroquinones.

Experimental birds and diets

A total of 360 day-old chicks of three strains of Isa Brown, Nera Black and Oba Blue were used for the experiment. Isa Brown and Nera Black chicks were purchased from Chi Farms Ajanla Ibadan, Oyo State, while Oba Blue chicks were obtained from Obasanjo Farms Abeokuta, Ogun State. They were reared in a deep litterred, well ventilated and hygienic poultry house. KSSB was incorporated into the basal chick, grower and layer diets as detailed in Table 2.

Table 2: Composition of experimental basal diet (%)

Ingredient	Starter (0 – 8 weeks)	Grower (9 – 20 weeks)	Layers
Maize	53.00	58.00	47.00
Groundnut cake	12.00	9.00	5.00
Soyabean meal	18.00	8.00	20.00
Fish meal	4.00	0.00	1.00
Wheat offal	6.90	19.00	15.80
Bone meal	3.00	3.00	2.50
Oyster shell	2.00	2.00	8.00
*Premix	0.25	0.25	0.25
Salt	0.30	0.25	0.25
Lysine	0.30	0.25	0.10
Methionine	0.25	0.25	0.10
Total	100.00	100.00	100.00
Crude protein (%)	22.81	16.93	17.06
Metabolizable energy (MJ/kg)	11.72	11.11	10.93

*Premix for chick per kg of diet: Vitamin A 10,000 iu; vitamin D_3 900 iu; copper 0.1 mg; vitamin E, 50.0 mg; manganese 8.5 mg; vitamin K 2.0 mg; iron 75.0 mg; vitamin B_1 2.0 mg; folic acid 5.0 mg; vitamin C 26.0 mg; pantothenic acid 20.0 mg; vitamin B_6 2.0 mg; choline 1200 mg; vitamin B_{12} 0.01 mg; niacin 50 mg; zinc 70 mg; biotin 0.2 mg.
*Premix for grower per kg of diet: Vitamin A 8,000 iu; vitamin D 1,200 iu; copper 2.0 mg; vitamin E, 31.0 mg; manganese 80 mg; vitamin B_2 10.0 mg; pantothenic acid 150.0 mg; iodine 1.2 mg; selenium 0.1 mg; cobalt 2 mg.
*Premix for layer per kg of diet: Vitamin A 100,000iu; vitamin D_3 20000iu; vitamin E 100iu; vitamin K 20mg; thiamine 15mg; riboflavin B_2 40mg; pyridoxine B_6 15 mg; niacin 150mg; pantothenic acid 50mg; folic acid 5 mg; biotin 0.2mg; choline chloride 12 mg; antioxidant 1.25g; manganese 0.8 g; zinc 0.5 g; iron 0.2g; copper 0.5g; iodine 0.12g; selenium 2mg; cobalt 2mg.

Experimental design

Three hundred and sixty day old commercial chicks were randomly and equally allotted into 15 treatment combinations in a 5x3 factorial design with three strains of layer chickens: Isa Brown, Nera Black and Oba Blue and five coccidiostat treatments: 1) control, 2) 100 g/ton of conventional coccidiostat (sulphaquinoxaline), 3) 100 g/ton of KSSB in the basal diet fed between 21st to 27th and 42nd to 48th day, 4) 200 g/ton KSSB in the basal diet fed between 21st to 27th and 42nd to 48th day and 5) 100 g/ton KSSB in the basal diet fed continuously. Each of the groups had three replicates of 8 chicks.

Data collection

Performance parameters: Feed intake and body weights were taken weekly, while mortality was recorded as it occurred. Egg production per pen was recorded daily; eggs were weighed and measured every two wk. The height of the albumen was determined using a standard tripod micrometer after which the yolk was weighed to calculate the Haugh unit according to Haugh (1937).

HU = 100*log10 (h-1.7W 0.37+7.6)
where
HU = Haugh unit,
h= observed height of the albumen in mm and
W = weight of egg in g.

Oocyst count

Samples of droppings of 3 chicks per replicate were investigated for oocyst excretion from 5 to 8 d after treatment. The counting of oocysts was done using McMaster parasitological technique (MAFF, 1986) and the number of oocysts per g of faecal sample was calculated.

Statistical analysis

All data were analysed using factorial analysis of variance of a general linear model (GLM) of SAS 9.1 for Windows (SAS 2002) and means were separated using the Duncan's Multiple Range Test.

Results and Discussion

The result of the growth performance of chicks fed *Khaya senegalensis* supplemented diets as shown in Table 3 revealed that the final weight and weight gain of the chicks were significantly affected by KSSB treatments and layer strains. Chicks supplemented with *K. senegalensis* and sulphaquinoxaline had higher ($p<0.05$) weight gain than the chicks fed control diet, while chicks on continuous *K. senegalensis* supplementation had the highest ($p<0.05$) weight gain in all the strains. ISA Brown pullets supplemented with either sulphaquinoxaline or *K. senegalensis* and Nera Black pullets with or without supplementation had higher ($p<0.05$) body weight than Oba Blue pullets at 20 wk of age. In Oba Blue birds the effect of *K. senegalensis* was limited in improving the body weight.

Table 3: Growth performance of egg type chickens fed diets supplemented with *Khaya senegalensis* stem bark meal (KSSBM)

Strain	Diet*	Initial weight (g/bird)	Final weight at 8 wks (g/bird)	Weight gain at 8wks (g/bird)	Feed intake at 8 wks (g/bird)	Weight at 20 wks (g/bird)	Feed intake 8-20 wks (g/bird)	Age at 1st egg (days)
Isa Brown	1	35.28^{ab}	552.65^{e}	517.37^{e}	1481.83^{e}	1356.67^{c}	5215	150.67^{a}
	2	35.29^{ab}	582.19^{de}	546.90^{cde}	1505.26^{de}	1436.67^{ab}	5565	143.00^{bc}
	3	35.29^{ab}	613.24^{bcd}	577.95^{bcd}	1612.95^{bc}	1432.00^{a}	5465	143.67^{bc}
	4	35.28^{ab}	630.85^{abc}	595.57^{abc}	1670.84^{ab}	1453.33^{a}	5639	145.00^{b}
	5	35.28^{ab}	670.38^{a}	635.10^{a}	1675.21^{ab}	1480.00^{a}	5771	145.00^{b}
Nera Black	1	35.29^{ab}	624.96^{abcd}	589.67^{abcd}	1634.50^{b}	1423.33^{b}	5212	139.67^{cd}
	2	35.27^{bc}	654.94^{ab}	619.67^{ab}	1663.17^{ab}	1453.33^{b}	5550	133.67^{ef}
	3	35.28^{ab}	627.12^{abc}	591.84^{abc}	1666.35^{ab}	1463.33^{ab}	5637	130.33^{fg}
	4	35.30^{a}	637.07^{abc}	601.77^{abc}	1710.61^{a}	1468.94^{a}	5666	131.33^{fg}
	5	35.28^{ab}	675.95^{a}	640.67^{a}	1668.89^{ab}	1482.00^{a}	5714	130.33^{fg}
Oba Blue	1	35.25^{c}	571.80^{de}	536.55^{de}	1530.29^{de}	1296.67^{d}	5350	135.33^{de}
	2	35.25^{c}	590.13^{cde}	554.87^{cde}	1561.71^{cd}	1360.00^{c}	4905	130.67^{efg}
	3	35.25^{c}	585.50^{cde}	550.25^{cde}	1559.23^{cd}	1326.67^{cd}	4777	127.33^{g}
	4	35.25^{c}	592.38^{cde}	557.13^{cde}	1548.59^{cd}	1346.67^{c}	5100	128.00^{g}
	5	35.25^{c}	606.80^{bcde}	571.55^{bcde}	1556.78^{cd}	1352.88^{c}	5138	128.00^{g}
	SEM	0.00357	7.636	7.635	13.0464	11.225	232.72	1.307
P-values	Diet (D)	0.4335	<.0001	<.0001	<.0001	0.0001	0.4999	<.0001
	Strain (S)	<.0001	<.0001	<.0001	<.0001	<.0001	0.2576	<.0001
	DxS	0.0002	0.0002	0.0002	<.0001	<.0001	0.7367	<.0001

*Diet 1- Control without KSSBM.
Diet 2 - 100 g/ton of sulphaquinoxaline on 21st -27th and 42nd-48th day.
Diet 3- 100g/ton KSSBM on 21st -27th and 42nd-48th day.
Diet 4- 200g/ton KSSBM on21st -27th and 42nd-48th day.
Diet 5- 100 g/ton KSSBM continuously from 0-8 weeks
SEM= Standard error of mean
^{abcdefg}Means in the same column with the different superscript are significantly different (p<0.05)

Feed intake decreased (p<0.05) in all the three strains of layer chicks fed the control diet when compared with the other treatment groups for each strain. However, the least feed intake was obtained from IB chicks (p<0.05) while Nera Black chicks fed *K. senegalensis* continuously in the diet consumed the highest (p<0.05) quantity of feed.

In each of the strains, birds fed the control diet came into lay latest (p<0.05) than birds in other treatment groups. Oba Blue pullets came into lay earlier than others; this was closely followed by Nera Black pullets while ISA Brown birds came into lay latest (p<0.05) irrespective of the dietary treatment.

Mortality was highest in all strains of chicks fed the control diet, with ISA Brown chicks recording the highest ($p<0.05$) and Oba Blue the least mortality as indicated in Table 4. The oocyst count was higher ($p<0.05$) in chicks fed the control diet in all the strains at the first count, while similar trend was observed at the second count in ISA Brown and Nera Black. IB chicks recorded the highest oocyst at both counts, however the least ($p<0.05$) oocyst count was obtained from Oba Blue chicks. This result revealed that the prevalence of coccidiosis was higher after 27^{th} day than after 48^{th} day.

Table 4: Oocyst count and survivability of layer chickens fed diets supplemented with *Khaya senegalensis* stem bark meal (KSSBM)

Strain	Diet*	1^{st} Oocyst count ($x10^3$)	2^{nd} Oocyst count ($x10^3$)	Mortality at 8 wk (%)	Mortality at 28 wk (%)
Isa Brown	1	52.71^{a}	33.19^{a}	43.33^{a}	10.00^{a}
	2	13.74^{ef}	11.76^{de}	3.33^{cd}	0.00^{b}
	3	15.12^{def}	13.18^{c}	13.33^{bc}	3.33^{b}
	4	18.48^{d}	11.48^{d}	6.67^{bcd}	0.00^{b}
	5	12.68^{f}	10.22^{e}	0.00^{d}	0.00^{b}
Nera Black	1	40.93^{b}	29.87^{b}	16.67^{b}	3.33^{b}
	2	16.38^{de}	11.33^{de}	3.33^{cd}	0.00^{b}
	3	13.59^{ef}	13.61^{c}	10.00^{bcd}	0.00^{b}
	4	13.77^{ef}	12.25^{d}	3.33^{cd}	0.00^{b}
	5	12.13^{f}	11.04^{de}	3.33^{cd}	0.00^{b}
Oba Blue	1	24.56^{c}	12.85^{cd}	6.67^{bcd}	0.00^{b}
	2	14.68^{def}	10.41^{e}	0.00^{d}	0.00^{b}
	3	13.85^{ef}	10.37^{e}	0.00^{d}	0.00^{b}
	4	12.02^{f}	10.87^{de}	3.33^{cd}	0.00^{b}
	5	10.34^{g}	10.14^{e}	0.00^{d}	0.00^{b}
	SEM	2.0980	1.275	2.0845	0.585
P-values	Diet (D)	<.0001	<.0001	<.0001	0.0070
	Strain (S)	0.0034	0.2150	0.0009	0.0208
	DxS	<.0001	<.0001	<.0001	0.0006

*Diet 1- Control without KSSBM.
Diet 2 -100 g/ton of sulphaquinoxaline on 21^{st} -27^{th} and 42^{nd}-48^{th} day.
Diet 3- 100g/ton KSSBM on 21^{st} -27^{th} and 42^{nd}-48^{th} day.
Diet 4- 200g/ton KSSBM on21^{st} -27^{th} and 42^{nd}-48^{th} day.
Diet 5- 100 g/ton KSSBM continuously from 8-20 weeks
HDP= Hen day production
SEM= Standard error of mean
^{abcdefg}Means in the same column with the different superscript are significantly different ($p<0.05$)

Table 5 shows that percentage hen day production (HDP) at 28 wk increased ($p<0.05$) as we move across the dietary treatment in all the bird strains. HDP was highest in the three strains fed *Khaya senegalensis* continuously in the diet. Egg weight was similar across the treatment groups for each of the three strains. Egg size was largest ($p<0.05$) in ISA Brown hens followed by Nera Black hens, while the least egg weight was laid by Oba Blue hens. The egg shell thickness was significantly different ($p<0.05$) across the strains - eggs from ISA Brown and Nera Black hens had similar shell thickness with a slight reduction in those fed the control diet. Oba Blue birds laid thinner shell eggs across the treatments when compared with eggs laid by ISA Brown and Nera Black hens.

Table 5: Egg qualities of laying hens fed diets supplemented with *Khaya senegalensis* stem bark meal (KSSBM) at 28 weeks

Strain	Diet*	Hen-day (%)	Egg weight (g)	Egg shape index	Haugh unit (%)	Shell thickness (mm)
Isa Brown	1	57.30^{f}	61.75^{ab}	0.650	81.12	0.640^{b}
	2	71.02^{cd}	61.34^{ab}	0.710	81.71	0.643^{ab}
	3	69.71^{d}	62.90^{a}	0.663	81.97	0.663^{ab}
	4	72.95^{bc}	63.60^{a}	0.680	81.06	0.670^{ab}
	5	73.65^{ab}	64.18^{a}	0.695	81.59	0.668^{ab}
Nera Black	1	60.63^{e}	58.01^{bc}	0.683	80.82	0.640^{b}
	2	71.14^{cd}	59.86^{ab}	0.660	81.53	0.670^{ab}
	3	71.57^{cd}	56.55^{c}	0.633	84.24	0.673^{a}
	4	70.76^{cd}	57.60^{bc}	0.617	81.32	0.660^{ab}
	5	73.48^{ab}	60.25^{ab}	0.638	82.56	0.671^{a}
Oba Blue	1	70.04^{d}	49.97^{d}	0.627	82.01	0.470^{c}
	2	71.32^{cd}	50.13^{d}	0.613	81.38	0.440^{c}
	3	72.21^{bc}	48.64^{d}	0.680	81.50	0.460^{c}
	4	74.26^{a}	47.74^{d}	0.753	80.78	0.467^{c}
	5	75.00^{a}	50.25^{d}	0.698	81.86	0.466^{c}
	SEM	0.844	1.101	0.0114	0.3149	0.0160
P- values	Diet (D)	<.0001	0.0910	0.8457	0.3953	0.0603
	Strain (S)	0.0064	<.0001	0.7440	0.8716	<.0001
	DxS	<.0001	<.0001	0.4033	0.7924	<.0001

*Diet 1- Control without KSSBM.
Diet 2 - 100 g/ton of sulphaquinoxaline on 21st -27th, 42nd-48th day.
Diet 3- 100g/ton KSSBM on 21st -27th and 42nd-48th day.
Diet 4- 200g/ton KSSBM on21st -27th and 42nd-48th day.
Diet 5- 100 g/ton KSSBM continuously from 8-28 weeks
SEM-Standard error of mean
^{abcd}Means in the same column with the different superscript are significantly different ($p<0.05$)

The improved performance obtained in birds fed *K. senegalensis* diets might be the result of the potential for saponins to improve the absorption of nutrients by the intestinal mucosal surface (McAllister *et al*., 1998). These saponins are steroidal glycosides with strong surfactant activity, reducing the superficial tension of fluids and allowing better absorption of nutrients by the intestinal epithelium. The natural ability of saponins to form pores in cell membranes (Plock *et al*., 2001) and the beneficial effect on intestinal turnover (Alfaro *et al*., 2007) might have allowed better absorption of nutrients by the intestinal epithelium.

The improved performance of birds fed continuously with *Khaya senegalensis* in the diet could be due to increased concentration as a result of prolonged usage. Umar *et al*. (2010) reported that *K. senegalensis* stem bark showed in vitro and in vivo anti trypanosomal activity in a dose-dependent manner against the parasite.

The amelioration observed in the birds as a result of the reduction in the oocyst effects demonstrated by *K. senegalensis* treatedted groups might be as a result of the tannin and saponin content of the medicinal plant. Saponins cause the inhibition of protozoon development by interacting with the cholesterol present on the parasite cell membrane, thus resulting in parasite death (Wang *et al*., 1998). Tannins were shown to bind cell walls of bacteria, preventing growth and protease activity (Jones *et al*., 1994). *Khaya senegalensis* was reported to have anticoccidial effects against coccidiosis infection by reducing oocyst excretion and mortality in chicks. The anticoccidial effects (oocyst count and weight gain) of *K. Senegalensis* could be attributed to their antioxidant properties due to the presence of procyanidin and catechin which may be lethal to the parasites by inducing oxidative stress. The presence of the organic substances may have been responsible for antimicrobial activity of this plant extract. Procyanidin is observed to have anti-inflammatory effects and modulation of cyclooxygenase and lipoxygenase activities (Cos *et al*., 2004). Catechin and catechin-related compounds have been shown to be powerful anti-oxidants which can inhibit the growth and invasion of oral carcinoma cells (Hsu *et al*., 2002) and are involved in the modulation of xenibiotic metabolizing enzymes (Lin, 2002). Botanical antioxidants play a major role in the control of coccidiosis due to the association of coccidial infection with the lipid peroxidation of intestinal mucosa (Naidoo *et al*., 2008). Tannins have shown potential antiviral activity (Ibrahim *et al*., 2004), and antibacterial activity (Akiyama *et al*., 2001). According to Masood *et al*. (2014), the possible mechanisms of antioxidant activity of tannins are free radical scavenging activity, chelation of transition metals and inhibition of prooxidative enzymes. The decline in mortality could probably be attributed to the disease prevention of *K. senegalensis*. Mortality plays a major role in determining profitability of layer chickens. Farooq *et al*. (2001) reported a significant and negative association of mortality with net profit. Wang *et al*. (2008), in a study on anticoccidial effect of grape seed proanthocyanidine extract (natural polyphenolic antioxidant) against *E. tenella* infection, reported a significant reduction in mortality and improved bird performance.

The prevalence rate of coccidiosis in ISA Brown birds might be related with strain differences. Oba Blue birds had a higher resistance to coccidiosis-causing protozoa- *Emeria spp.* and this might have a relationship to survival rate which was superior to ISA Brown and Nera Blue birds. This finding is in line with that of Gari *et al*. (2008) of high prevalence of coccidiosis in deep litter system of Rhode Island Red chickens.

The ability of the birds supplemented with *K. senegalensis* to come into lay earlier than those fed the control diet could be attributed to the action of phytochemical properties of *K. senegalensis* on hormones responsible for egg formation. Nworgu *et al*. (2012) reported the effect of basil leaf supplement on oestrogen, initializing and follicle stimulating hormones. The heavy weight of ISA Brown birds could also have resulted in high hen-day production as laying progressed. Scott and Silversides (2000) reported positive correlation between body weight and egg production. The differences in the shell thickness had been attributed to the various strains. Egg quality was reported to have a genetic basis and the parameters of egg quality varied between strains of hens (Pandey *et al*., 1986; Silversides *et al*., 2006). Oni *et al*. (1991) reported that strains that attained sexual maturity early ended up laying lighter eggs than those that matured late.

Conclusion

In this study, it can be concluded that Isa Brown, Nera Black and Oba Blue chickens performed best in relation to weight gain, hen day production, survivability and oocyst count when *K.senegalensis* was included at 100 g/ton continuously in the diet. The effect of *K.senegalensis* was more evident on Isa Brown chickens due to their high susceptibility to coccidiosis, followed by Nera Black chickens. Minimal effect was observed in Oba Blue chickens. *K. senegalensis* has anticoccidial activity which was reflected in the reduction of oocyst count and survivability rate. This approach will be particularly useful in organic poultry production where use of chemical agents and antibiotic growth promoters is circumscribed. It will also be useful to farmers in rural areas where veterinary drugs are expensive and sometimes unavailable.

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