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Efficacy of Phyto-Genic Products to Control Field Coccidiosis in Broiler Chickens

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ABSTRACT

The primary objective of this study was to evaluate the effectiveness of utilizing commercially available Phyto-genic products in preventing and controlling field coccidiosis in broiler chickens, compared to the most used chemical drugs. Five treatment groups were established, with a random allocation of 12,000 1-day-old broiler chicks. Six repetitions were conducted for each treatment, with 400 birds in each repetition. Three commercial formulas of Phyto-genic origin (Phyto-1, Phyto-2, Phyto-3) were used. Nicarbazin and Narasin, chemical drugs, were assigned as the control group. These products were added to the basal diets (BD) to formulate 5 dietary treatments (T): (T1) control fed BD supplemented with (Maxiban®) in starter and (Monteban®) in grower and finisher diets; (T2) fed BD supplemented with (Maxiban®) in starter diet and Phyto-1 (Aflocox D®) in grower and finisher feed diet; (T3) fed BD + Phyto-1; (T4) fed BD + Phyto-2 (Aflocox plus®), and (T5) fed BD + Phyto-3 (Herb-All COCC-X®). The results showed that the Phyto-genic blends improved the body weight, body weight gain, and overall feed conversion ratio to a level similar to that of the group fed the chemical coccidiostat drugs, with no significant differences among them. As well, mortality and lesion scores were not affected (P>0.05) among treatments. The study concluded that these Phyto-genic blends can be safely used as alternatives to the chemically synthesized drugs, either alone or in a shuttle program, for the control of poultry coccidiosis.

Key words: Coccidiostat; Herbal extracts; Ionophore; Coccidiosis; Chickens; Broilers.

INTRODUCTION

The poultry industry faces significant challenges due to internal parasitic diseases that cause chronic losses without external symptoms. Among these diseases, avian coccidiosis is the most prevalent, attributed to nine distinct Eimeria (*E*) species responsible for causing coccidiosis in domestic chickens (*Gallus gallus domesticus*) (Bachaya et al. 2015). These species include *E. maxima*, *E. acervulina*, *E. tenella*, *E. necatrix*, *E. brunetti*, *E. mitis*, *E. praecox*, *E. Hagani*, and *E. mivati* (Shirley et al. 1983; Vrba et al. 2011), coccidiosis costs the industry approximately 7.7 to 13.0 billion pounds per year in prophylaxis, treatment, and production losses (Blake et al. 2020). Several aspects contribute to coccidiosis development, featuring a direct life cycle, transmission through fecal-oral transmission, the presence of resistant sporulated oocysts and resistant strains (Abbas et al. 2011), and a significant potential for oocyst reproduction. (Remmal et al. 2011).

In the context of control, the enduring and formidable immunity elicited by Eimeria infections highlights vaccination as a potent alternative to anticoccidial medications (Chapman et al. 2002; Allen et al. 2005). However, vaccines might induce severe hemorrhagic reactions or malabsorptive coccidiosis, leading to a decrease in the performance and uniformity of the flock especially when it coincides with poor management (Shirley et al. 2005).

Since the 1950s, the majority of broiler chickens have been raised with the inclusion of an anticoccidial drug in their diet (Chapman 2001). Approximately 99% of broilers were reared using at least one feed containing an anticoccidial drug (Chapman 2009). Microbial infections negatively affect poultry production, and antibiotics are no longer effective due to antibiotic-resistant bacteria (Chapman et al. 2002; Abbas et al. 2011; Swelum et al. 2021; Yaqoob et al. 2021). As a result of persistent pressure from governments and consumers to prohibit the administration of drugs in animals meant for human

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consumption, alternative methods for managing coccidiosis has emerged (Abbas et al. 2015, 2019, 2017c; Khater et al. 2020; Kandeel et al. 2022). Phyto-genic compounds such as phenolic compounds, peptides, and essential oils offer a solution to this problem, due to their role as potent antimicrobial agents effective against Gram-negative and/or Gram-positive bacteria (Abou-Kassem et al. 2021; El-Tarabily et al. 2021).

More than 1200 plants possess antiprotozoal effects. A selection of these plants has been utilized in poultry diets due to their capacity to promote growth and trigger natural immune responses (Willcox and Bodeker 2004; Muthamilselvan et al. 2016). The recent attitude in the world is to produce chickens without using any drugs or chemotherapy to obtain products free of drug residues which negatively influences human health and the development of more drug-resistant strains.

Herbal mixers or extracts are commercially available, and the combinations are already used in some countries for coccidiosis control (Abbas et al. 2010, 2012; Zaman et al. 2012; Idris et al. 2017; Hussain et al. 2022; Jamil et al. 2022; Hussain et al. 2023). Most of these natural compounds and their component can have an effect directly on the parasite by interfering oocyst wall formation and inhibiting sporulation (del Cacho et al. 2010; Abbas et al. 2015; Fatemi et al. 2015), in addition to their potential to improve intestinal health status to help the host to fight against the coccidial infection and fasten the recovery rate because the herbal compounds have immunomodulatory, antioxidative and anti-inflammatory effects (Abbas et al. 2012; Wunderlich et al. 2014; Abbas et al. 2017a, 2017b; Hussain et al. 2017; Idris et al. 2017; Hussain et al. 2023). Additionally, the probability of developing resistance to natural products is less than that associated with anticoccidial drugs (Quiroz-Castañeda and Dantán-González 2015; Ashour et al. 2020). Moreover, herbal extracts may aid in coccidiosis recovery (Arczewska-Włosek and Świątkiewicz 2012). The herbs' biological properties, such as their potential anticoccidial effects, have been attributed to flavonoids and other polyphenols (Masood et al. 2013). The use of chemically synthesized anti-coccidial drugs is a necessary practice in Jordan like in many different parts of the world. The removal of these drugs from the diets of broiler chickens will allow the coccidian protozoa to develop very fast in the intestines of the birds, leading to severe pathogeneses and huge economic losses (Arczewska-Włosek and Świątkiewicz 2013). The aforementioned reasons of health drawbacks for humans and the emergence of resistant strains of the microbes, force scientists to find alternatives to chemically manufactured drugs. Hence, the primary goal of this research was to examine how a commercial blend of plant extracts and compounds could be used to manage coccidiosis in broiler chickens at the field level on a large commercial scale. The plant-derived products were compared to ionophore and chemical drug programs.

MATERIALS AND METHODS

Ethical Institutional Review Board (IRB) approval

The experimental protocols were approved by the Scientific Research Council of the University of Jordan and approved by the Institutional Animal Care and Use Committee (72/2021).

Birds and Housing

A total of 12,000 one-day-old Ross 308 broiler chicks were purchased from a nearby commercial hatchery for the purpose of this study. Prior to their arrival at the experimental site, the chicks received *in ovo* vaccination against infectious bursal disease viruses, and at day one, they underwent course spray vaccination for infectious bronchitis virus and Newcastle disease virus in the hatchery. All the broiler chicks were reared in the experimental house located at the Union for Agricultural Development and Slaughtering Company (AL-Zarqa, Jordan). The dimensions of the house were measured to be 12 x 80 meters, providing adequate space for the experimental setup. The housing facility comprised a total of 30 separate concrete floor pens, each covered with a 5 cm layer of wood shavings. All treatments for the experiment's purposes were kept in the same house to ensure equal conditions for all treatments. To ensure optimal conditions for bird welfare and growth, a fully closed system was implemented, and the housing facility was equipped with automated control panels for environmental parameters such as temperature, light duration, and ventilation. The stocking density in each pen was 400 birds carefully managed to ensure that it did not exceed 32 kilograms per square meter. Throughout the study, all environmental parameters were meticulously adjusted in accordance with the Ross 308 broiler management guide.

Feed and Tested Products and Experimental Design

Basal diets were manufactured at AL-Tahoneh private feed mill (AL-Zarqa, Jordan). The diets were free of antibiotics and coccidiostats (Table 1). A specialized computer program (Brill Software V1.36.017) was used to formulate the basal diets to meet the nutrient requirements of broilers according to Ross 308 Strain Guideline. All basal diets were isocaloric and isonitrogenous. The composition of the basal diets (starter, grower, and finisher) is shown in Table 1.

Phyto-1 (Aflocox D®) was provided by Innovad® (Innovad, SA/NV. Belgium). It is a blend of 100% natural plant bio-active ingredients that have been formulated to provide four key modes of action to mitigate the risk of coccidiosis. The bioactive components are saponins, flavonoids, phenolics, terpenes, carotenoids, and alkaloids. Phyto-2 (Aflocox plus®) was provided by Innovad® (Innovad, SA/NV. Belgium). The mixture of dried herbs, plant extracts, pigment, esterified fatty acids (butyric, lauric, sorbic acid), medium chain fatty acids (capric, caprylic), calcium propionate, and essential oils. Phyto-3 (Herb-All COCC-X®, manufactured by Life Circle Nutrition AG, Switzerland is an herbal blend containing many plants, the fundamental components of the herbal blend consist of conessi tree (*Holarrhena antidysenterica*) and garlic (*Allium sativum*). Prominent constituents encompass flavonoids, triterpenoids, steroidal alkaloids, tannins, phenolic acids, and saponins. Anticoccidial Premix (Maxiban®) provided by Elanco™ (Elanco, USA). Maxiban is a granulated blend, in a 50:50 ratio, of Nicarbazin (a chemical anticoccidial) and Narasin (an ionophore), acting synergistically to combat coccidiosis. 10% Narasin Premix (Monteban®**)** is an ionophore provided by Elanco™ (Elanco, USA), Narasin effectively manages coccidia and bacterial enteritis and protects intestinal integrity.

Table 1: Basal diet composition and nutrient content

Ingredients	unit	Starter	Grower	Finisher
		(1-12 d)	(13-24 d)	(25-35 d)
Corn	kg	579.4	616.7	666.5
Soybean Meal	kg	370	335	285
Soy oil	kg	14	15	20
Limestone	kg	14	14	13
Lysine Sulphate	kg	3.1	2.3	2.3
Mono calcium phosphate	kg	7	5.5	5
Salt	kg	2	2	2
Sodium Bicarbonate	kg	1.5	1.5	1.5
Threonine	kg	1.3	1	0.7
Methionine	kg	3.5	3	0
L- Valine	kg	0.1	0	0
Broiler Mineral Premix	kg	1	1	1
Choline Chloride 70%	kg	0.4	0.4	0.4
Betaine HCl	kg	0.3	0.3	0.3
Broiler Vitamins Premix	kg	1.1	1	1
Mycotoxin binder	kg	1	1	1
Avizyme 1505	kg	0.2	0.2	0.2
Axtraphy 10000	kg	0.1	0.1	0.1
Total kg		1000.000	1000.000	1000.000
Calculated Analysis				
Metabolizable Energy	Kcal/kg	3,100.00	3,150.00	3,240.00
Crude Protein	%	23	21.5	19.5
Crude Fat	%	4.5	4.7	5.5
Crude Fiber	%	2.3	2.3	2.2
Calcium	%	1	0.95	0.9
Avi.Phosphorus	%	0.48	0.435	0.395
Digestible lysine	%	1.28	1.15	1.03
Digestible methionin	%	0.51	0.59	0.5
Digestible methionin +Cysteine	%	0.95	0.87	0.8
Digestible threionin	%	0.86	0.77	0.69
Digestible valine	%	0.96	0.87	0.78
Sodium	%	0.16	0.16	0.16
Chloride	%	0.19	0.19	0.19

The following dietary treatments (T) were formulated: (T1) control-fed BD that is commonly used by broiler farmers and supplemented with (Nicarbazin and Narasin) in starter, Narasin in grower and finisher diets; (T2) fed BD supplemented with Nicarbazin and Narasin in starter diet and Phyto-1 (Aflocox D®) in grower and finisher feed diet; (T3) fed BD + Phyto-1; (T4) fed BD + Phyto-2 (Aflocox plus®), and (T5) fed BD + Phyto-3 (Herb-All COCC-X®).

Upon their arrival, the batch of 12,000 chicks was randomly partitioned into five treatments, with each treatment receiving its corresponding additive. All replicates were floor systems, where these replicates were randomly distributed over the experimental house. Each treatment contains 2400 birds divided into 6 replicates with 400 birds per replicate. Table 2 summarizes all experimental groups and their calculated feed additives as recommended by manufacturers. This research was done on a large-scale model which is a real farm status to investigate if herbal products are able to control naturally occurring coccidiosis which presents normally in the field on the floor system of all broiler houses, so no challenge of coccidial infection was given.

Live Performance and Growth Parameters

Average Body Weight

The body weights of birds were weekly recorded on days (0, 7, 14, and 28) as part of the study. Fifteen percent of the birds in each pen were randomly selected for weighing, and the average body weight (BW) for each treatment was calculated.

Feed Intake

The amount of feed consumed per floor pen was measured on days 14 and 28 throughout the study. The total amount of feed provided to each pen per day was divided by the total number of chicks to calculate the average feed intake (FI). The feed conversion ratio (FCR) was calculated on days 14 and 28. It was determined by dividing the amount of feed intake (FI) by the average body weight gain, the data from feed intake (FI) and body weight gain (BW) were used to calculate the FCR on a day 14, 28, and as a total at the end of the experiment.

Mortality

All instances of bird mortality were recorded and weighed on a pen basis. Necropsies were performed on the deceased birds to determine the cause of death.

Coccidial Lesion Scoring

On day 21 of age, lesion scoring was done by using the technique outlined by Johnson and Reid (1970). Five birds from each treatment group were selected in a random manner, their weights were recorded, and after euthanasia by cervical dislocation, necropsies were performed. The intestines were divided into four sections: upper, middle, lower, and ceca. Each section was scored separately for lesions. The scoring of lesions ranged from 0 to 4, with 0 denoting the absence of lesions and 4 indicating the most severe cases (Johnson and Reid 1970).

Table 2: Experimental groups and Phyto-genic and anticoccidial additives used in each dietary phase

Treatment	Starter diet		Grower diet		Finisher diet	
	Drug/	kg/ton		kg/ton		kg/ton
T1	Narasin/nicarbazin	0.5	Narasin	0.7	Narasin	0.7
T2	Narasin/nicarbazin	0.5	Phyto-1	0.5	Phyto-1	0.5
T3	Phyto-1	1	Phyto-1	0.5	Phyto-1	0.5
T4	Phyto-2	1	Phyto-2	0.5	Phyto-2	0.5
T5	Phyto-3	1	Phyto-3	1	Phyto-3	0.5

Phyto-1: Aflocox D®, Phyto-2: Aflocox plus®, Phyto-3: Herb-All COCC-X®.

Statistical Analysis

The Statistical Analysis System (SAS Institute, 2010, Version 9.1.3) was utilized for conducting the statistical analysis. In this process, each pen was considered as an experimental unit. The data were tested for normality and analyzed through one-way ANOVA, which was applied using the proc GLM procedure of SAS. Results were considered statistically significant if the p-value ≤0.05. To differentiate means for significant interactions, Tukey's test was used.

RESULTS

Live Performance and Growth Parameters

Effects of different treatments on live performance and growth parameters are shown in Tables 3-6. The placement body weight of chicks at day 0 was similar (P>0.05). The body weight of the birds in the different treatments followed the normal pattern and was the same (P>0.05). The results of average body weight gain on days 14 and 28 of age and the average overall body gain weights were the same with no significant differences found among the treatments compared to the control treatment (Tables 3 and 4). The results of average feed intake at day 14 show significant differences (Table 5), where T2 and T3 had higher feed intake compared with T4 and T5, where T3 was the lowest feed intake. There were no differences in average feed intake at day 28 but overall average feed intake shows significant differences among treatment groups (P<0.05), T1, T2, and T5 had higher feed intake than T3 and T4 (Table 5). The outcomes of the calculated FCR demonstrated significant differences in the treatments when compared to the control treatment at day 14 with no significant difference at day 28 and in the overall feed conversion ratio (P>0.05) (Table 6). For mortality percentages, there were no significant differences recorded among groups.

Coccidial Lesion Scores

The necropsy findings on the euthanized birds confirmed the presence of a natural incidence of coccidiosis in all treatments. The results of the effects of different treatments (T2, T3, T4, and T5) on coccidia lesion scores showed that there were no significant differences observed when compared to the control treatment (T1: Anticoccidials).

DISCUSSION

This study confirmed that there is a strong potential to control the natural coccidiosis infection in chickens by using safe Phyto-genic blends. The results of the intestinal lesion scouring confirmed the incidence of natural

Table 3: Means for the effect of different treatments on body weight (g) of broiler birds.

Treatments	D0	D7	D14	D28
T1: Maxiban+ Monteban	42.0	174.0	490.0	1579.0
T2: Maxiban+Phyto-1	42.0	171.0	486.0	1575.0
T3: Phyto-1	42.0	170.0	483.0	1564.0
T4: Phyto-2	42.0	173.0	491.0	1570.0
T5: Phyto-3	42.0	172.0	489.0	1571.0
SEM	0.00	2.7487	4.5338	7.0867
P-Value	-	0.9238	0.7293	0.7049

SEM, pooled standard error of the mean. Phyto-1: Aflocox D, Phyto-2: Aflocox plus, Phyto-3: Herb-All COCC-X.

Table 4: Means for the effect of different treatments on Average Body Weight Gain (g/bird) of broiler birds.

Treatments	Average Body Weight Gain (g/bird)		
	Day 14	Day 28	Overall
T1: Maxiban+Monteban	450.0	1129.0	1539.0
T2: Maxiban+Phyto-1	446.0	1129.0	1535.0
T3: Phyto-1	443.0	1121.0	1524.0
T4: Phyto-2	451.0	1119.0	1530.0
T5: Phyto-3	449.0	1122.0	1531.0
SEM	4.5338	3.1091	7.0867
P-Value	0.7293	0.1798	0.7049

SEM, pooled standard error of the mean. Phyto-1: AflocoxD, Phyto-2: Aflocox plus, Phyto-3 Herb-All COCC-X.

Table 5: Means for the effect of different treatments on Average feed intake (g/bird) of broiler birds.

	Average feed intake (g/bird)		
Treatments	Day 14	Day 28	Overall
T1: Maxiban+Monteban	499.4^{a}	1424.7^{b}	1924.1^{a}
T2: Maxiban+Phyto-1	498.7^{a}	1416.9^{b}	1915.6^{a}
T3: Phyto-1	483.5^{b}	1412.2^{b}	1896.7^{b}
T4: Phyto-2	487.1^{ab}	1411.7^{b}	1898.8^{b}
T5: Phyto-3	495.3^{ab}	1418.7^{b}	1914.0^{a}
SEM	2.8867	2.8867	2.8867
P-Value	0.0057	0.0001	0.0001

^{a,b,c} – means with different letters in the same column are significantly different at P<0.05; Tukey test after a significant one-way-ANOVA (P<0.05). SEM, pooled standard error of the mean. Phyto-1: Aflocox D, Phyto-2: Aflocox plus, Phyto-3: Herb-All COCC-X.

Table 6: Means for the effect of different treatments on Feed Conversion Ratio (kg feed/kg gain) of broiler birds

Treatments	Feed conversion ratio (kg feed/kg gain)		
	Day 14	Day 28	Overall
T1: Maxiban+Monteban	1.110^{ab}	1.260^{b}	1.250^{a}
T2: Maxiban+Phyto-1	1.116^{a}	1.256^{b}	1.250^{a}
T3: Phyto-1	1.090^{bcd}	1.260^{b}	1.243^{a}
T4: Phyto-2	1.080^{dc}	1.263^{b}	1.240^{a}
T5: Phyto-3	1.100^{abc}	1.263^{b}	1.250^{a}
SEM	0.0056	0.0025	0.0045
P-Value	0.0009	0.0002	0.3513

^{a,b,c,d} – means with different letters in the same column are significantly different at P<0.05; Tukey test after a significant one-way-ANOVA (P<0.05). SEM, pooled standard error of the mean. Phyto-1: Aflocox D, Phyto-2: Aflocox plus, Phyto-3: Herb-All COCC-X.

coccidiosis infection in all treatments at the same level. The occurrence of natural coccidiosis infection is very common in all birds reared on floor systems. All the necropsied birds in these treatments showed similar levels of naturally induced coccidiosis. Amazingly, all Phyto-genic treatments showed similar levels of lesion scores to that of birds fed the chemical drugs. In addition, the performance and mortality rates of all Phyto-genic groups were similar to those of the chemically treated group. In response to the drawbacks and adverse effects associated with the use of chemical coccidiostat drugs on birds, workers, consumers, and the environment, there has been a global trend toward replacing chemical products with natural safe alternatives (Cervantes and McDougald 2023). Commercial herbal products have emerged in recent years, prompting numerous studies to compare their efficacy with that of chemical counterparts and explore their potential as safe, effective, and cost-efficient alternatives for controlling avian coccidiosis (FEEDAP 2010).

Abbas et al. (2012) has comprehensively reviewed the effect of a wide range of botanicals against a various Eimeria species in poultry and concluded that this can be a promising area for the effective and sustainable solution of coccidiosis. Likewise, this experiment was designed to compare the efficacy of a conventional coccidiostat with natural herbal alternatives. The results demonstrated that all types of feed additives used in this study effectively controlled field coccidiosis and can be used to replace the chemical drugs used to control coccidiosis at the field. However, no significant differences were observed among the five trial treatments in terms of average body weight and daily weight gain (ADWG). Interestingly, the T1 (ionophore and chemical) and T2 (ionophore and chemical + Aflocox D) treatments exhibited a significantly higher average feed intake (on day 14) compared to T4 (Aflocox plus) and T5 (Herb-all COCC-X), while T3 had the lowest average feed intake. There were no significant differences in average FI from day14 to 28 but the average of overall FI was higher in T1, T2 and T5 compared to T3 and T4. Feed conversion ratio (FCR) on day 14 was better in T3, T4, T5 than ionophore and chemical treatment. However, there were no significant differences on day 28 and in overall FCR. Diminished oxidative stress in broilers results in elevated metabolism and greater feed consumption, subsequently leading to enhanced weight gain and improved FCR in the groups treated with essential oils, as noted by Ding et al. (2022); Saeed et al. (2023). The current results are in general agreements with previous research (Rüegge and Fayed 2022). All treated groups displayed similar intestinal lesions resulting from field coccidiosis without any significant differences. The findings of no effect on mortality and lesions scoring among all treatments are similar to what was obtained by other herbal extract blend (Arczewska-Włosek and Świątkiewicz 2012). Both herbal products and ionophores can reduce intestinal lesion scores, but they do not entirely eradicate them. These findings align with the results obtained *in vitro* studies conducted by Abbas et al. (2019) and Hussain et al. (2022). The existence of partially impaired lesions, incapable of complete sporulation and reinfection, might trigger the immune system in a way akin to live vaccination, as described in previous work (Chapman 1999; Noack et al. 2019).

In contrast to our finding, previous studies reported that ionophores were more efficient in controlling coccidiosis compared to herbal extracts (Scheurer et al. 2013). The inefficiency of tested plant extracts, as compared to the findings of this study, can be attributed to various factors, involving variations in the plant composition employed in this study as opposed to other blends, the inclusion of intact plants, and differences in the techniques of preparation. However, when compared with other chemical preparations like monensin, herbal products demonstrated comparable anticoccidial efficacy (Song et al. 2020).

Conclusion

The newly designed pure herbal products used in this experiment exhibit promising potential for controlling coccidiosis in poultry flocks at a large commercial scale in the field when the dose is used according to manufacturer recommendations. Supported by earlier research conclusions, this study recommends the replacement of traditional chemical anticoccidial products with commercially available herbal alternatives. Such a shift not only alleviates concerns regarding chemical residues in meat and the emergence of microbial resistance, but also presents multiple advantages to the broiler sector in terms of efficacy, safety, and cost-efficiency.

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The data of this research was extracted from the PhD dissertation of the first author.

Authors contribution

The first author “Alaa Hailat is a Ph.D. student, who conducted the field trial and supervised it, collected the data, and wrote the manuscript. Anas Abdelqader and Mohammad Gharaibeh are the advisors, and they have been involved directly in the conceptualization of the experiment proposal, supervising the student, statistical analyses of the data, reviewing the manuscript, and providing the research fund.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

Abbas A, Abbas RZ, Khan MK, Raza MA, Mahmood MS, Saleemi MK, Hussain T, Khan JA and Sindhu ZUD, 2019. Anticoccidial effects of *Trachyspermum ammi (Ajwain)* in broiler chickens, Pakistan Veterinary Journal 39(2): 301–304. https://doi.org/10.29261/pakvetj/2019.056

Abbas A, Iqbal Z, Abbas RZ, Khan MK and Khan JA, 2015. In-vitro anticoccidial potential of *Saccharum officinarum* extract against *Eimeria* oocysts, Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromaticas 14(6): 456–461.

Abbas A, Iqbal Z, Abbas RZ, Khan MK and Khan JA, 2017a. Immunomodulatory activity of *Pinus radiata* extract against coccidiosis in broiler chicken. Pakistan Veterinary Journal 37: 145–149.

Abbas A, Iqbal Z, Abbas RZ, Khan MK, Khan JA, Hussain K, Mahmood MS and Rizwan HM, 2017b. Immunomodulatory effects of *Camellia sinensis* against coccidiosis in chickens. Journal of Animal and Plant Sciences 27(2): 415–421.

Abbas Asghar, Iqbal Z, Abbas RZ, Khan MK, Khan JA, Sindhu Z ud D, Mahmood MS and Saleemi MK, 2017c. In vivo anticoccidial effects of *Beta vulgaris* (sugar beet) in broiler chickens. Microbial Pathogenesis 111: 139–144. https://doi.org/10.1016/j.micpath.2017.07.052

Abbas RZ, Colwell DD and Gilleard J, 2012. Botanicals: an alternative approach for the control of avian coccidiosis. World's Poultry Science Journal 68(2): 203–215. https://doi.org/ 10.1017/S0043933912000268

Abbas RZ, Iqbal Z, Blake D, Khan MN and Saleemi MK, 2011. Anticoccidial drug resistance in fowl coccidia: the state of play revisited. World's Poultry Science Journal 67(2): 337–350, https://doi.org/10.1017/S004393391100033X

Abbas RZ, Iqbal Z, Khan MN, Zafar MA and Zia MA, 2010. Anticoccidial activity of *Curcuma longa L*. in broilers. Brazilian Archives of Biology and Technology 53: 63–67. https://doi.org/10.1590/S1516-89132010000100008

Abou-Kassem DE, Mahrose KM, El-Samahy RA, Shafi ME, El-Saadony MT, Abd El-Hack ME, Emam M, El-Sharnouby M, Taha AE and Ashour EA, 2021. Influences of dietary herbal blend and feed restriction on growth. carcass characteristics and gut microbiota of growing rabbits, Italian Journal of Animal Science 20(1): 896–910. https://doi.org/10.1080/1828051X.2021.1926348

Allen PC, Jenkins MC and Miska KB, 2005. Cross protection studies with *Eimeria maxima* strains. Parasitology Research 97(3): 179–185. https://doi.org/10.1007/s00436-005-1423-6

Arczewska-Włosek A and Świątkiewicz S, 2012. The effect of a dietary herbal extract blend on the performance of broilers challenged with *Eimeria* oocysts. Journal of Animal and Feed Sciences 21(1): 133–142. https://doi.org/10.22358/jafs/66058/2012

Arczewska-Włosek A and Świątkiewicz S, 2013. Improved performance due to dietary supplementation with selected herbal extracts of broiler chickens infected with *Eimeria spp*. Journal of Animal and Feed Sciences 22(3): 257–263. https://doi.org/10.22358/jafs/66141/2013

Ashour EA, El-Hack MEA, Shafi ME, Alghamdi WY, Taha AE, Swelum AA, Tufarelli V, Mulla ZS, El-Ghareeb WR and El-Saadony MT, 2020. Impacts of green coffee powder supplementation on growth performance, carcass characteristics, blood indices, meat quality and gut microbial load in broilers. Agriculture 10(10): 457. https://doi.org/10.3390/agriculture10100457

Bachaya HA, Abbas RZ, Raza MA, Iqbal Z, Rehman TU, Baber W and Hussain R, 2015. Existence of coccidiosis and associated risk factors in broiler chickens in Southern Punjab, Pakistan. Pakistan Veterinary Journal 35(1): 81–84.

Blake DP, Knox J, Dehaeck B, Huntington B, Rathinam T, Ravipati V, Ayoade S, Gilbert W, Adebambo AO, Jatau ID, Raman M, Parker D, Rushton J and Tomley FM, 2020. Re-calculating the cost of coccidiosis in chickens. Veterinary Research 51(1): 115. https://doi.org/10.1186/s13567-020-00837-2

del Cacho E, Gallego M, Francesch M, Quílez J and Sánchez-Acedo C, 2010. Effect of artemisinin on oocyst wall formation and sporulation during *Eimeria tenella* infection. Parasitology International 59(4): 506–511. https://doi.org/10.1016/j.parint.2010.04.001

Cervantes HM and McDougald LR, 2023. Raising broiler chickens without ionophore anticoccidials. Journal of Applied Poultry Research 32(2): 100347. https://doi.org/10.1016/J.JAPR.2023.100347

Chapman HD, 1999. Anticoccidial drugs and their effects upon the development of immunity to *Eimeria* infections in poultry. Avian Pathology 28(6): 521–535. https://doi.org/10.1080/03079459994317

Chapman HD, 2001. Use of anticoccidial drugs in broiler chickens in the USA: Analysis for the Years 1995 to 1999. Poultry Science 80(5): 572–580. https://doi.org/10.1093/ps/80.5.572

Chapman HD, 2009. A landmark contribution to poultry science—Prophylactic control of coccidiosis in poultry. Poultry Science 88(4): 813–815. https://doi.org/10.3382/ps.2008-00316

Chapman HD, Cherry TE, Danforth HD, Richards G, Shirley MW and Williams RB, 2002. Sustainable coccidiosis control in poultry production: the role of live vaccines. International Journal for Parasitology 32(5): 617–629. https://doi.org/10.1016/S0020-7519(01)00362-9

Ding Y, Hu Y, Yao X, He Y, Chen J, Wu J, Wu S, Zhang H, He X and Song Z, 2022. Dietary essential oils improves the growth performance, antioxidant properties and intestinal permeability by inhibiting bacterial proliferation, and altering the gut microbiota of yellow-feather broilers. Poultry Science 101(11): 102087. https://doi.org/10.1016/j.psj.2022.102087

El-Tarabily KA, El-Saadony MT, Alagawany M, Arif M, Batiha GE, Khafaga AF, Elwan HAM, Elnesr SS and E. Abd El-Hack M, 2021. Using essential oils to overcome bacterial biofilm formation and their antimicrobial resistance. Saudi Journal of Biological Sciences 28(9): 5145–5156. https://doi.org/10.1016/J.SJBS.2021.05.033

Fatemi A, Razavi SM, Asasi K and Torabi Goudarzi M, 2015. Effects of *Artemisia annua* extracts on sporulation of Eimeria oocysts. Parasitology Research 114(3): 1207–1211. https://doi.org/10.1007/s00436-014-4304-z

FEEDAP, 2010. EFSA Panel on Additives and Products or Substances used in Animal Feed, 2010. Scientific Opinion on the safety and efficacy of Maxiban® G160 (narasin and nicarbazin) for chickens for fattening. EFSA Journal 8(4): 1574. https://doi.org/10.2903/j.efsa.2010.1574

Hussain K, Abbas A, Alanazi HAH, Alharbi AMA, Alaiiri AA, Rehman A, Waqas MU, Raza MA, Yasin R and Ahmad B, 2023. Immunomodulatory Effects of *Artemisia brevifolia* Extract against Experimentally Induced Coccidiosis in Broiler Chicken. The Pakistan Veterinary Journal 43(2): 333–338. https://doi.org/10.29261/pakvetj/2023.026

Hussain K, Alsayeqh AF, Abbas A, Abbas RZ, Rehman A, Waqar Z, Rehman TU and Mahmood MS, 2022. Potential of *Glycyrrhiza glabra (Licorice)* extract an alternative biochemical and therapeutic agent against coccidiosis in broiler chickens. Kafkas Üniversitesi Veteriner Fakültesi Dergisi 28(5): 585–591. https://doi.org/10.9775/kvfd.2022.27620

Hussain K, Zafar Iqbal, R. Z. Abbas and Muhammad Kasib Khan, 2017. Immunomodulatory Activity of *Glycyrrhiza glabra* Extract against Mixed *Eimeria* Infection in Chickens. International Journal of Agriculture and Biology 19(04): 928–932. https://doi.org/10.17957/IJAB/15.0397

Idris M, Abbas RZ, Masood S, Rehman T, Farooq U, Babar W, Hussain R, Raza A and Riaz U, 2017. The potential of antioxidant rich essential oils against avian coccidiosis. World's Poultry Science Journal 73(1): 89–104. https://doi.org/10.1017/S0043933916000787

Masood S, Abbas RZ, Iqbal Z, Mansoor MK, Sindhu ZUD, Zia MA and Khan JA, 2013. Role of natural antioxidants for the control of coccidiosis in poultry. Pakistan Veterinary Journal 33(4): 401-407.

Jamil M, Aleem MT, Shaukat A, Khan A, Mohsin M, Rehman T ur, Abbas RZ, Saleemi MK, Khatoon A, Babar W, Yan R and Li K, 2022. Medicinal plants as an alternative to control poultry parasitic diseases. Life 12(3): 449. https://doi.org/10.3390/life12030449

Johnson J and Reid WM, 1970. Anticoccidial drugs: Lesion scoring techniques in battery and floor-pen experiments with chickens. Experimental Parasitology 28(1): 30–36. https://doi.org/10.1016/0014-4894(70)90063-9

Kandeel M, Akhtar T, Zaheer T, Ahmad S, Ashraf U and Omar M, 2022. Anti-parasitic Applications of Nanoparticles: A Review. Pakistan Veterinary Journal 42(2): 135-140. https://doi.org/10.29261/pakvetj/2022.040

Khater HF, Ziam H, Abbas A, Abbas RZ, Raza MA, Hussain K, Younis EZ, Radwan IT and Selim A, 2020. Avian coccidiosis: Recent advances in alternative control strategies and vaccine development. Agrobiological Records 1: 11–25. https://doi.org/10.47278/journal.abr/2020.004

Muthamilselvan T, Kuo T-F, Wu Y-C and Yang W-C, 2016. Herbal remedies for coccidiosis control: a review of plants, compounds, and anticoccidial actions. Evidence-Based Complementary and Alternative Medicine 2016: 1–19. https://doi.org/10.1155/2016/2657981

Noack S, Chapman HD and Selzer PM, 2019. Anticoccidial drugs of the livestock industry, Parasitology Research. 118(7): 2009–2026. https://doi.org/10.1007/s00436-019-06343-5

Quiroz-Castañeda RE and Dantán-González E, 2015. Control of avian coccidiosis: Future and present natural alternatives. BioMed Research International 2015: 1–11. https://doi.org/10.1155/2015/430610

Remmal A, Achahbar S, Bouddine L, Chami N and Chami F, 2011. In vitro destruction of *Eimeria* oocysts by essential oils. Veterinary Parasitology 182(2–4): 121–126. https://doi.org/10.1016/j.vetpar.2011.06.002

Rüegge K and Fayed RH, 2022. Comparative anticoccidial potential of Maxiban 160 and Herb-All COCC-X against Eimeria species infestation on intestinal lesion and oocyte shedding in broilers fayed. Journal of Applied Veterinary Sciences 7(2): 1–6. https://doi.org/10.21608/javs.202

Saeed Z, Abbas RZ, Khan MK and Saleemi MK, 2023. Anticoccidial activities of essential oil of *Amomum subulatum* in broiler chicks., Pakistan Journal of Agricultural Sciences 60: 377-384. https://doi.org/10.21162/PAKJAS/23.54

Scheurer W, Spring P and Maertens, 2013. Effect of 3 dietary Phyto-genic products on production performance and coccidiosis in challenged broiler chickens. Journal of Applied Poultry Research 22(3): 591–599. https://doi.org/10.3382/japr.2013-00726

Shirley MW, Jeffers TK and Long PL, 1983. Studies to determine the taxonomic status of *Eimeria mitis*, Tyzzer 1929 and *E. mivati*, Edgar and Seibold 1964. Parasitology 87(2): 185–198. https://doi.org/10.1017/S0031182000052550

Shirley MW, Smith AL and Tomley FM, 2005. The biology of avian *Eimeria* with an emphasis on their control by vaccination. Advances in Parasitology 60: 285–330, https://doi.org/10.1016/S0065-308X(05)60005-X

Song X, Li Y, Chen S, Jia R, Huang Y, Zou Y, Li L, Zhao X and Yin Z, 2020.Anticoccidial effect of herbal powder “shi ying zi” in chickens infected with *Eimeria tenella*. Animals 10(9): 1–15. https://doi.org/10.3390/ani10091484

Swelum AA, Elbestawy AR, El-Saadony MT, Hussein EOS, Alhotan R, Suliman GM, Taha AE, Ba-Awadh H, El-Tarabily KA and Abd El-Hack ME, 2021. Ways to minimize bacterial infections, with special reference to *Escherichia coli*, to cope with the first-week mortality in chicks: an updated overview. Poultry Science 100(5): 101039. https://doi.org/10.1016/j.psj.2021.101039

Vrba V, Poplstein M and Pakandl M, 2011. The discovery of the two types of small subunit ribosomal RNA gene in *Eimeria mitis* contests the existence of *E. mivati* as an independent species. Veterinary Parasitology 183 (1–2): 47–53. https://doi.org/10.1016/j.vetpar.2011.06.020

Willcox ML and Bodeker G, 2004. Traditional herbal medicines for malaria. BMJ 329(7475): 1156–1159. https://doi.org/10.1136/bmj.329.7475.1156

Wunderlich F, Al-Quraishy S, Steinbrenner H, Sies H and Dkhil MA, 2014. Towards identifying novel anti-*Eimeria* agents: trace elements, vitamins, and plant-based natural products, Parasitology Research 113(10): 3547–3556. https://doi.org/10.1007/s00436-014-4101-8

Yaqoob MU, El-Hack MEA, Hassan F, El-Saadony MT, Khafaga AF, Batiha GE, Yehia N, Elnesr SS, Alagawany M, El-Tarabily KA and Wang M, 2021. The potential mechanistic insights and future implications for the effect of prebiotics on poultry performance, gut microbiome, and intestinal morphology. Poultry Science 100(7): 101143. https://doi.org/10.1016/J.PSJ.2021.101143

Zaman MA, Iqbal Z, Abbas RZ and Khan MN, 2012. Anticoccidial activity of herbal complex in broiler chickens challenged with *Eimeria tenella*. Parasitology 139(2): 237–243. https://doi.org/10.1017/S003118201100182X