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INFLUENCE OF DIETARY GRADED LEVELS OF COMMERCIAL HERBAL EXTRACT BLEND SUPPLEMENTATION ON GROWTH PERFORMANCE, MEAT QUALITY, AND FOOTPAD DERMATITIS IN BROILER CHICKENS

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Master Thesis

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We, the jury members, certify that the contents and form of the master thesis titled "Influence of Dietary Graded Levels of Commercial Herbal Extract Blend Supplementation on Growth Performance, Meat Quality, and Footpad Dermatitis in Broiler Chickens" prepared by Umair AHSAN student at Department of Animal Nutrition and Nutritional Diseases, Institute of Health Sciences, Adnan Menderes University, Aydın, Republic of Turkey.

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This thesis accepted by the above mentioned jury has been approved on ……….. in session No. ……….. of Institute of Health Sciences vide No. ……….. in accordance with the relevant provisions of Postgraduate Education and Examination Regulations of Adnan Menderes University.

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CONTENTS

ABBREVIATIONS

a*	Redness of meat
ANOVA	Analysis of variance
b*	Yellowness of meat
BW	Body weight
cP	Centipoise
FCR	Feed conversion ratio
FPD	Footpad dermatitis
L*	Lightness of meat
NSPs	Non-starch polysaccharides
PFAs	Phytogenic feed additives
WHC	Water holding capacity

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ÖZET

ETLİK PİLİÇ RASYONLARINA FARKLI DÜZEYLERDE TİCARİ BİTKİSEL EKSTRAKT KARIŞIMI EKLENMESİNİN PERFORMANS, ET KALİTESİ VE AYAK TABANI YANGISI ÜZERİNE ETKİLERİ

AHSAN U. Adnan Menderes Üniversitesi Sağlık Bilimleri Enstitüsü Hayvan Besleme ve Beslenme Hastalıkları Programı Yüksek Lisans Tezi, Aydın, 2016.

Bu çalışma, etlik piliç rasyonlarına farklı düzeylerde katılan fitojenik yem katkı maddesinin (PFA) performans, et kalitesi ve ayak tabanı yangısı üzerine olan etkileri araştırılması amacı ile gerçekleştirilmiştir. Çalışmada toplam 480 adet günlük erkek etlik civciv (ROSS 308) her birinde sekiz alt grup (on beşer civcivden oluşan) bulunan dört deneme grubuna ayrılmıştır. Denemede basal rasyon (katkı içermeyen) başlangıç, büyüme ve bitirme dönemlerine uygun şekilde hazırlanmıştır. Deneme gruplarının rasyonlarına sırası ile 100 mg/kg (PFA100), 125 mg/kg (PFA125) ve 150 mg/kg (PFA150) düzeyinde PFA katkısı yapılmıştır. Çalışma sonunda (42. gün) her alt gruptan bir adet piliç kesilerek, et kalitesi parametrelerinden pH, renk (L*, a*, b*), su tutma kapasitesi ve pişirme kaybı kesim anında, kesim sonrası 24 ve 72. saatlerde incelenmiştir. Bağırsak viskozitesi ve altlık nem düzeyi ölçümleri çalışma sonunda yapılmıştır. Çalışmanın 21 ve 42. günlerinde piliçlerin tamamı ayak tabanı yangıları oluşumu ve şiddeti yönünden skorlanmıştır. Denemenin hiç bir döneminde yem tüketimi, canlı ağırlık ve yemden yararlanma oranı bakımında gruplar arasında farklılık gözlenmemiştir. Rasyona PFA katılmasının kesim anında ve kesim sonrası 24. saatte et kalitesi üzerine önemli etkisi olmamıştır. PFA katkısının bağırsak viskozitesi ve altlık nem düzeyine etkisi olmadığı gibi ayak tabanı yangılarının görülme sıklığı ve şiddeti üzerine de etkisi bulunamamıştır. Çalışmada PFA'nin yem tüketimi, canlı ağırlık artışı ve yemden yararlanma oranı üzerine etki göstermemesi başlıca kanatlı rasyonlarına katılan bu ekstraktların bitkiden bitkiye aktif biyomoleküllerinin konsantrasyonu bakımından değişkenlik gösterebilmesi ve kanatlı rasyonlarında buna bağlı ekstraktların etkin dozunun uygulanamaması gibi birçok etmenden kaynaklanabilmektedir. Katkının hiçbir düzeyi büyüme performansı, et kalitesi ve ayak tabanı yangıları üzerine olumlu bir etki gösterememesine karşın etlik piliçlerin beslenmesinde bu bileşiklerin optimum karışımlarının kullanım dozlarının belirlenebilmesi için daha fazla sayıda araştırmaya gereksinim vardır.

Anahtar kelimeler: Ayak tabanı yangısı, et kalitesi, etlik piliç, fitojenik yem katkısı, performans

ABSTRACT

INFLUENCE OF DIETARY GRADED LEVELS OF COMMERCIAL HERBAL EXTRACT BLEND SUPPLEMENTATION ON GROWTH PERFORMANCE, MEAT QUALITY AND FOOTPAD DERMATITIS IN BROILER CHICKENS

AHSAN U. Adnan Menderes University, Institute of Health Sciences, Animal Nutrition and Nutritional Diseases Program Master Thesis, Aydın, 2016.

The current study was conducted to evaluate the effect of graded dietary levels of a phytogenic feed additive (PFA) on growth performance, meat quality, and footpad dermatitis (FPD) in broilers. Four hundred eighty, one-day-old male broiler (Ross 308) were assigned to four experimental groups, each consisting of 8 replicate pens (15 chicks per each replicate pen). Corn-soybean meal based basal diet was formulated for starter, grower, and finisher, fed to the control group (without supplementation). Basal diets were supplemented with PFA at 100 mg/kg (PFA100), 125 mg/kg (PFA125), and 150 mg/kg (PFA150) levels, respectively. One bird was slaughtered from each pen at the end of experiment. Meat quality parameters including pH, color (L*, a*, b*), drip loss, and cooking loss were measured on d 42 at slaughter, 24-h and 72-h post-slaughter, respectively. Intestinal viscosity and litter moisture were measured on d 42. All the birds were subjected to FPD scoring on d 21 and 42 of the experiment. Feed intake, BW gain, and feed conversion ratio (FCR) were not different among the dietary treatments throughout the study. Dietary PFA supplementation had no significant effect on meat quality of broilers at slaughtering and 24-h post-slaughter. Dietary PFA supplementation did not affect the intestinal viscosity, litter moisture, and FPD score in broilers. It can be hypothesized that the inability of PFAs to enhance the feed intake, BW gain, and FCR corresponds to many factors primarily due to the variations in the concentration of active biomolecules among the individual plants that leads to the failure to attain the exact inclusion level in the poultry diets. Although none of the addition levels were helpful in improving the growth performance, meat quality, and in decreasing the FPD score, more research is needed to set the optimum dietary levels of blending these compounds for their prospective use in broiler nutrition.

Key words: Broiler, footpad dermatitis, meat quality, performance, phytogenic feed additive

1. INTRODUCTION

1.1. Necessity of Feed Additives

World population is increasing day by day and it has been projected to reach 9.6 billion by the year 2050. To meet the requirement of sustainable animal protein for human at a least cost, scientists are working to overcome the challenges by improving the animal production by different scientific approaches. However, the cost of feeding for animals is relatively high and animal nutritionists are focusing their research on efficient feed production for livestock. To minimize the cost of feed with proper nutritional value, several supplements are commonly used as feed additives. The antibiotics have been used at sub-therapeutic levels in poultry production for more than 50 years in order to achieve better growth through maintaining the relatively stable gut ecosystem (Huyghebaert et al., 2011). The use of antibiotics remained in practice until they questioned for growing concerns towards resistance to antibiotics in chickens (Kabir, 2009) and lowered efficacy of antibiotics used in human medicine (Dibner and Richards, 2005). Possibly, the irrational use of antibiotics has resulted in the emergence of new pathogens, some of them prompted from animals during the last 25 years. Most of the pathogens causing illness in humans have been reported to cross species barrier from animals (Ahsan et al., 2016). The use of antimicrobials as growth promoters is, therefore, being discouraged by public. The European Union banned the use of in-feed antibiotic growth promoters in 2006 (Vesna et al., 2007) which resulted in the development of potential alternatives to antibiotics in animal nutrition (Karaskova et al., 2015). In practice, the alternatives to antibiotics must possess the same beneficial properties. Recent attempts have been made in search of such an alternative that includes different commercial feed additives belonging to different classes (Das et al., 2012). Recently, phytogenic feed additives (PFAs) have attracted the attention of most of the researchers due to their prospective characteristic features to spare the use of antibiotic growth promoters in poultry nutrition (Puvaca et al., 2013). These PFAs, commonly used as plant extracts or essential oils, have been tested in different animal species like ruminants and non-ruminants especially in swine and poultry nutrition (Karaskova et al., 2015).

2. REVIEW OF LITERATURE

2.1. PFAs and Bioactive Molecules

The botanical products, also known as PFAs, are widely used in animal nutrition these days. It is a general perception that different herbs and spices are the sources of different chemical substances that are useful in animal production. According to Yitbarek (2015), commonly used PFAs belong to different groups, for instance, herbs (plants that are flowering, non-persistent, and non-woody), spices (herbs or parts of the herbs used to develop taste and flavor in food), essential oils (plant extracts obtained by water or alcoholic distillation), or oleoresins (extracts derived from non-aqueous solvent). Essential oils are also commonly used in poultry nutrition that are odoriferous plants' secondary metabolites that have higher biological functions in comparison with raw materials from which it is derived (Yitbarek, 2015). It consists of two main compounds, terpenoids and phenylpropanes (Lee et al., 2004). These phytogenic compounds possess many bioactive molecules such as anethole, allicin, allyl-isothiocyanate, cineole, carvacrol, capsaicin, linalool, piperine, and thymol that have beneficial effects such as antimicrobial and antioxidant properties (Ruberto et al., 2002; Burt, 2004; Puvaca, 2008; Windisch et al., 2008; Puvaca et al., 2013). These bioactive molecules of PFAs have beneficial effects on poultry health and growth performance (Yang et al., 2009; Applegate et al., 2010; Hippenstiel et al., 2011). The efficacy of PFAs depends on the variety of factors including composition, level of application to the diet, genetics, total nutrition, and feed composition (Puvaca et al., 2013). The variety of composition of PFAs may have both positive and negative effects on the live performance of broilers (Buchanan et al., 2008). The total composition of active molecules may vary depending on the use of different plant parts such as seeds, leaf, wood, or bark (Yitbarek, 2015). The list of commonly used herbs and spices, usable parts of phytogenic plants, their active molecules, and functions in poultry are presented in the Table 1 and 2, respectively.

Table 1. Some phytogenic plants with their bioactive molecules and functions for poultry and other animals (Yitbarek, 2015)

Plant	Photogenic Parts	Active Biomolecules	Major Functions
		Aromatic spices	
Nutmeg	Seed	Sabinene	Digestion stimulant, antidiarrhoeic
Cinnamon	Bark	Cimetaldehyde	Appetite and digestion stimulant, antiseptic
Cloves	Cloves	Eugenol	Appetite and digestion stimulant, antiseptic
Cardamom	Seed	Cineol	Appetite and digestion stimulant,
Coriander	Leaves, seed	Linalol	Digestion stimulant
Cumin	Seed	Cuminaldehyde	Digestive, carminative, galactagogue
Anise	Fruit	Anethol	Digestive, carminative, galactagogue
Celery	Fruits, leaves	Phtalides	Appetite and digestion stimulant
Parsley	Leaves	Apiol	Appetite and digestion stimulant, antiseptic
Fenugreek	Seed	Trigonelline	Appetite stimulant
		Pungent spices	
Capsicum	Fruit	Capsaicin	Digestion stimulant
Pepper	Fruit	Piperine	Digestion stimulant
Horsradish	Root	Ally izotiocianat	Appetite stimulant
Mustard	Seed	Ally izotiocianat	Digestion stimulant
Ginger	Rizom	Zingerone	Gastric stimulant
Garlic	Bulb	Allicin	Digestion stimulant, antiseptic
		Herbs	
Rosemary	Leaves	Cineol	Digestion stimulant, antiseptic, antioxidant
Thyme	Whole plant	Thymol	Digestion stimulant, antiseptic, antioxidant
Sage	Leaves	Cineol	Digestion stimulant, antiseptic, carminatives
Laurel	Leaves	Cineol	Appetite and digestion stimulant, antiseptic
Mint	Leaves	Menthol	Appetite and digestion stimulant, antiseptic

Table 2. Phytogenic additives commonly used in poultry nutrition (Yitbarek, 2015)

Herb/Spices	Latin Name	Plant Family	Bioactive Molecules
Oregano	*Oreganum vulgare*	Labiateae	Carvacrol, thymol
Thyme	*Thymus vulgare*	Labiateae	Thymol, carvacrol
Garlic	*Allium sativum L.*	Alliaceae, Liliaceae	Daillyldisulfide, allin, alliciin
Horseradish	*Armoracia rusticana*	Brassicaceae	Ally-isothiocyanate
Chili, Cayenne pepper	*Capsicum frutescens*	Solanaceae	Capsaicin
Peppermint	*Mentha piperita*	Labiateae	Menthol, carvacrol
Cinnamon	*Cinnamomum cassia*	Lauraceae	Cinnamaldehyde
Anise	*Pimpinella anisum*	Apiaceae, Umbelliferae	Anethol

2.2. Chemical Composition of PFAs

The PFAs have beneficial effects on animal nutrition thus they are now being used as supplements or feed additives in livestock feed industry. The chemical composition as well as mode of action of PFAs are different from each other due to the content of active biomolecules (Table 1). The chemical composition varies mainly due to the different factors including location or origin, plant species, growth stage, harvesting time, soil type, climate and stress condition, cultivation, fertilization, and irrigation level (Daferera et al., 2003). Although there is quite a bit variation regarding the chemical composition of these products, an example chemical composition of different phytogenic herb and spices have been summarized in Table 3.

Table 3. Chemical composition of phytogenic herbs and spices (Yitbarek, 2015)

Herbs/Spices	DM[1] (%)	EE[1] (%)	CP[1] (%)	CF[1] (%)	Ash[1] (%)	NFE[1] (%)
Organo	88	0.6	10.8	12.9	0.9	62.8
Garlic	96	0.7	15.3	2.1	4.1	73.2
Cress	97	23.2	24.2	11.9	7.1	30.7
Mustard	96	38.5	25.4	6.4	4.3	21.2
Black cumin	97	31.9	20.6	10.4	4.5	30
Fenugreek	92	4.5	12.9	13.1	4.2	57.5
Black pepper	95	5.3	25.5	23.6	3.6	37.4
Clover	92	16.6	6.9	11.5	6	51.3
Ginger	94	5.4	8.6	3.3	6.3	63
Ansi	94	1.38	12.9	20.9	0.8	58

[1]DM: Dry matter; EE: Ether extract; CP: Crude protein; CF: Crude fiber; NFE: Nitrogen free extract

2.3. Beneficial Effects of PFAs

The nutritional benefits of PFAs include the improvement in the performance of birds through better feed conversion ratio (FCR; Jamroz and Kamel, 2002; Windisch et al., 2008; Hong et al., 2012), improved daily weight gain (Ciftci et al., 2005), better digestibility of fat, protein, calcium, and phosphorus (Amad et al., 2011; Mountzouris et al., 2011), and improved apparent total digestibility of crude protein (Hernandez et al., 2004). In addition, the dietary supplementation of PFAs may stimulate the blood circulation and digestive enzyme production, and reduce the load of pathogenic bacteria (Brenes and Roura, 2010; Reisinger et al., 2011). The biological effects of PFAs largely depend on the interaction of intestinal microbiota with the PFAs. It is very important to reveal this particular interaction for a better understanding of the nutritional benefits, however, the mode of action still remains ambiguous. The activity of digestive enzymes in the small intestine may be enhanced by lowering the gut microbial activity (Windisch et al., 2008). Hammer et al. (1999) reported that the efficacy of herbal essential oils is always very low due to the inclusion level of these essential oils mostly being lower than the effective does found in *in vitro* studies (0.03 to 2% (v/v)). Some studies have reported positive effects of essential oils on pathogenic microbiota in the intestine of broilers (Jamroz et al., 2003; Mitsch et al., 2004; McReynolds et al., 2009).

Similarly, Aksit et al. (2006) reported a decrease in the microbial load in carcasses of broilers following the consumption of dietary essential oils. In addition, dietary PFAs supplementation has been reported to improve the intestinal morphology and functioning, secretion of intestinal enzymes and bile acids, all of which might help to maintain a healthy intestinal environment (Platel and Srinivasan., 2000; Williams and Losa, 2001; Nazeer et al., 2002; Lee et al., 2003a; 2003b; 2003c; Jang et al., 2004; Chrubasik et al., 2005; Jamroz et al., 2006; Reisinger et al., 2011). Studies also suggested that PFA could protect the intestinal cells and other tissues from the oxidative damage which might have related to their potent antioxidative properties (Cuppett and Hall, 1998, Craig, 1999; Nakatani, 2000; Wei and Shibamoto, 2007). A detailed review underlining the effects of PFAs on the performance, meat quality, and footpad lesions of broilers is given below.

2.3.1. Broiler Performance

Influence of different PFAs on productive performance of broilers has been an unresolved question so far due to the varying results obtained in different studies. Some studies have reported that PFAs do not affect the live performance of broiler birds. Botsoglu et al. (2002) and Lee et al. (2004) showed that the supplementing the 100 and 50 mg/kg (respectively) oregano essential oil in wheat/soybean meal-based diets posed no significant effect on body weight (BW) and FCR of Cobb broilers. Likewise, there was a negative correlation between the broiler growth performance and dietary supplementation of commercial PFAs containing 2% capsicum oleoresin, 3% cinnamaldehyde, and 5% carvacrol supplements (Muhl and Liebert, 2007).

Some studies have reported negative effects of PFAs on the performance of broiler birds. Maize-soybean meal-based diets supplemented with commercial phytogenic preparation, cinnamaldehyde, and thymol at 100 mg/kg showed negative effect on growth performance of broilers (Lee et al., 2003c). The supplementation of essential oil and the oregano herb also reduced the average feed intake and BW gain in Ross 308 broilers (Puvaca et al., 2013). Similarly, Hernandez et al. (2004) found the same effect with wheat-corn-soyabean meal-based diet supplemented with 5000 and 200 mg/kg of oregano herb. Cross et al. (2003) stated the negative effect on body weight gain by feeding a dosage of 5 g/kg of thyme essential oil. Abildgaard et al. (2010) reported a decrease in BW gain following the supplementation of 100 or 200 mg/kg CRINA® in broiler diets in a 25 d feeding study.

Tiihonen et al. (2010) found 5% improvement in BW gain of broilers through dietary supplementation of 5 mg/kg cinnamaldehyde and 15 mg/kg thymol. Mostly, the literature findings highlight that PFAs had no influence on broiler live performance including BW, BW gain, feed intake, and FCR at the age of 21 days (Fascina et al., 2012). This finding is a bit similar with other findings regarding the performance of broiler chickens (Fukayama et al., 2005; Toledo et al., 2007; Rizzo et al., 2010; Kumar et al., 2010).

Although PFAs have shown negative effects on broiler performance, some scientific findings illustrate the positive effect on the performance of broilers at different growth phases. Jamroz et al. (2005) reported an improvement in the live performance of male Hubbard broilers by supplementation of wheat/barley/soybean meal or corn/soybean meal-based diets with 100 mg/kg of plant extract containing capsicum oleoresin, cinnamaldehyde, and carvacrol. Spernakova et al. (2007) reported an increase in BW gain of broilers in response to dietary 500 mg/kg rosemary powder. Settle et al. (2014) also found significantly higher body weight gain during starter period following the inclusion of dietary PFAs. Use of dietary garlic essential oil (Kumar and Berwal, 1998) and garlic powder (Lewis et al., 2003) improved the growth performance of chickens. Lippens et al. (2005) noticed that dietary plant extracts supplementation improved the growth of chicken compared to other dietary phytogenic supplements like citrus, oregano, cayenne pepper, cinnamon, and thyme extracts. Diets supplemented with 1 g/kg of essential oil of thyme had significant positive effect on BW gain of broilers. Another study showed an improved BW gain in broilers (approximately 6%) with the supplementation 5 g/kg thyme herb in comparison with the control diet (Toghyani et al., 2010). Similar results were also observed by Mohamed and Abbas (2009) but with the supplementation of 1 g/kg of fennel. Therefore, the efficacy of PFAs in broilers largely depends on the inclusion level in feed, and on growth period of broilers (Mountzouris et al., 2011). The variety of phytogenic compounds possesses diversity of active biomolecules which leads the variable findings. The improvements of feed conversion ratio interacts with different ages when feeding with PFAs. There are numerous scientific findings reporting the improvement of feed conversion ratio in response to dietary PFAs supplementation, after 7 d of age (Ciftci et al., 2005); 14 d of age (Giannenas et al., 2003); between 14 to 21 and 28 to 35 day of age (Hernandez et al., 2004); between 21 to 41 day of age (Jamroz et al., 2005); and between 29 to 42 day of age (Mountzouris et al., 2011; Fascina et al., 2012). It can be concluded that a variety of factors are involved such as basic ingredients, hygienic state, environmental factors, quality of the phytogenic products that trigger the broilers' performance (Windisch et al., 2008; Ocak et al., 2008; Jang et al., 2004; Botsoglou et al., 2002).

2.3.2. Meat Quality

Park et al. (2014) showed that dietary *Saposhnikovia divaricata*, *Lonicera japonica* and *Chelidonium mejus* extracts inhibited the oxidation of lipid and protein in broiler meat by exhibiting antioxidant activity that resulted in improved shelf life and meat quality. Some phytogenic compounds such as rosemary and sage extracts, oregano oil, oregano rosemary powder, and garlic powder have the potential to reduce the oxidative properties or delaying of lipid peroxidation (Young et al., 2003; Spernakova et al., 2007; Stanacev et al., 2011; Lopez-Bote et al., 1998). It is widely accepted that PFAs have antimicrobial and antioxidant functions that contribute to microbiological safety of food during storage either in the raw or cooked meat (Soltan et al., 2008). This might be due to fact that PFAs reduce the load of pathogens in the intestine, and promote a balanced healthy gut ecosystem that contribute to the reduction of carcass contamination during slaughter. Stanacev and Puvaca (2011) found positive effect of PFAs in broiler diet that positively affected the quality and safety of the chicken meat. Kaneko et al. (2001) described green tea extract inclusion to broiler diet may have an improving effect on live performance and lean meat production. Related findings also established by Sarker et al. (2010) who described 0.5% green tea extracts containing broiler diet had positive role in growth performance and meat composition. Addition of herbal extracts in broiler diet not only improves the immunity but also increases the carcass quality and meat quality during storage (Cross et al., 2007). Li et al. (2015) reported that PFAs in broiler diet improve the breast meat without any adverse effect on meat quality. There are some factors such as meat color and pH value, which may affect the quality of the meat and its derivatives, thereby may alter the consumer acceptance (Carpenter et al., 2007). Herawati and Marjuki (2011) found red ginger fed to broilers slightly improved the meat pH value than control. The green tea extract supplementation to broiler diet at 0.1 g/kg level resulted in lower pH value and lighter breast meat than other treated and control groups (Erener et al., 2011). Ali et al. (2008) stated that higher pH value in broiler meat is due to glycogen depletion, which usually occurred during stress or activity prior to slaughter. However, some scientific findings illustrated there was no significant improvement of carcass weight and meat pH value by dietary phytogenic compounds (Hernandez et al., 2004; Cabuk et al., 2006; Demir et al., 2008; Amad et al., 2011; Kırkpınar et al., 2011; Cho et al., 2014). The dietary supplementation of *Saposhnikovia divaricata*, *Lonicera japonica* and *Chelidonium mejus* extracts had no significant impact on meat quality and composition such as pH, color, water holding capacity, and fatty acid concentration (Park et al., 2014).

2.4. Aim of the Project

The different functions of PFA investigated so far in poultry diets have presented an unclear situation possibly due to the differences in proper plant selection, active ingredient, and dietary inclusion levels. In spite of paying a considerable attention towards using the different combinations of plant extracts in poultry diets, the results have presented a distorted depiction in terms of their efficacy. To date, there has been no report describing the possible effect of different dietary PFA levels on meat quality and footpad dermatitis lesions in broilers. In addition, a possible effect of dietary PFA through the already speculated mechanisms by others on intestinal morphology and functions may help reduce the footpad dermatitis (FPD) in broilers. We speculated that PFAs might help decrease the FPD by lowering the intestinal viscosity. Therefore, we designed the present study to evaluate the effect of varying levels of PFAs on live performance, meat quality, and FPD in broiler chickens.

3. MATERIALS AND METHODS

The present study was carried out at the Poultry Research Unit of Adnan Menderes University, Aydın, Turkey. The ethical committee approved the study through letter No. 64583101/2015/128.

3.1. Birds and Management

Four hundred eighty male Ross-308 day-old broiler chicks were purchased from a local commercial hatchery (Egetav Tavukçuluk San. ve Tic. A.Ş., İzmir, Turkey). Average weight of a chick ranged between 40 to 46 g (43±3 g). The experimental rooms were thoroughly cleaned and fumigated 10 days before starting the experiment. The rooms were heated to a constant temperature of 32 ºC before the arrival of chicks. The chicks were randomly placed in 32 replicate pens of four experimental groups/treatments (8 replicate pens per treatment; 15 chicks per pen). Each bird was provided a floor space of 0.07 m^2. One feeder and three nipple drinkers were installed in each pen. Floor feeders and tube feeders were used for feeding birds from days 0 to 10 and 11 to 42, respectively. The trial lasted for 42 days. Each pen had a 6 to 8 cm deep layer of wood shavings as a bedding material. *Ad libitum* access to feed and water was ensured throughout the experiment. Continuous lighting (24-h) was provided. No fluorescence light was used during the day time. Dark period of the day was illuminated by using the fluorescence light. The birds were maintained at 32ºC in the first week. A temperature of 0.5 ºC per day was reduced after the first week until a constant temperature of 24 ºC was achieved. The birds were visited four times a day and the mortality was recorded if any.

3.2. Diets and Treatments

Basal diet based on corn/soybean meal was formulated (Table 4) for broilers according to the recommendations by Aviagen (2014) for Ross 308 broiler for starter (d 0-10), grower (d 11-24), and finisher (d 25-42). The basal diet was fed to one of the four experimental groups designated as control group. The other dietary treatments were obtained by supplementing the basal diet with phytogenic product at 100 mg/kg (PFA100), 125 mg/kg (PFA125), and 150 mg/kg (PFA150).The phytogenic product used in this study was a unique blend of herbs, essential oils, and functional flavors in a powdery form characterized by menthol and anethole (BIOMIN Holding GmbH, Getzersdorf, Austria). The product comprised of cinnamon, cumin, peppermint oil, garlic oil, anise oil, fennel oil, and carrier.

Table 4. Ingredient and nutrient composition of basal diet

Ingredients	**Starter**	**Grower**	**Finisher**
		%	
Corn	55.63	56.15	59.00
Soybean meal	37.50	36.00	33.50
Vegetable oil	2.50	4.15	4.25
Limestone	0.89	0.85	0.80
Dicalcium phosphate	2.30	2.00	1.73
Salt	0.35	0.35	0.35
DL-Methionine	0.37	0.25	0.12
L-Lysine sulphate	0.21	-	-
Vitamin-mineral premix[1]	0.25	0.25	0.25
Nutrient Composition (calculated)			
Crude protein	21.75	20.89	19.92
Metabolizable energy (Kcal/kg)	2910	3029	3070
Crude fiber	3.47	3.39	3.3
Crude ash	5.70	5.33	4.95
Calcium	0.97	0.88	0.79
Available phosphorus	0.54	0.48	0.43
Digestible lysine	1.17	1.02	0.96
Digestible methionine	0.66	0.54	0.40

[1]Vitamin and mineral premix (per kg of diet): retinol acetate, 1706 mg; cholecalciferol, 41 mg; DL-α-tocopherol, 27 mg; menadione, 0.99 mg; cobalamin, 0.015 mg; folic acid, 0.8 mg: D-pantothenic acid, 15 mg; riboflavin, 5.4 mg; niacin, 45 mg; thiamine, 2.7 mg; D-biotin, 0.07 mg; pyridoxine, 5.3 mg; manganese, 90 mg; zinc, 83 mg; iron, 121 mg; copper, 12 mg; iodine, 0.5 mg; selenium, 0.3 mg

3.3. Growth Performance

BW and feed intake were recorded (per pen) weekly using an electrical balance (minimum accuracy ± 1 g). BW gain was calculated. FCR was calculated by dividing the feed intake by BW gain for the respective periods. Feed intake, BW, BW gain, and FCR were reported weekly (see tables 5, 6, 7, and 8) and for the periods 1-21 days, 22-42 days, and 1-42 days. FCR was adjusted by adding the body weight of dead bird in the pen weight.

3.4. Slaughtering of Birds

At 42 day of the experiment, one bird from each pen was randomly selected and slaughtered by cutting the jugular vein, in a pre-cleaned slaughter room. The feathers were removed and intestines were exposed. The samples of digesta were collected aseptically for the measurements of intestinal viscosity. The carcasses were collected for the measurement of meat quality parameters.

3.5. Meat Quality

The indicators of meat quality were measured at slaughtering, and 24-h and 72-h post-slaughter. In order to measure the meat quality parameters 24-h and 72-h post-slaughter, approximately 100 g of breast meat (pectoralis major) was collected after slaughter from each carcass in labeled plastic bags. The meat samples were stored at -18 ºC in a deep freezer (Bosch, Germany) until further analysis.

3.5.1. Measurement of Breast pH

Breast pH was measured at slaughter, and 24-h and 72-h post-slaughter. A waterproof pH meter (Model HI 9124, pH/Temperature meter, Hanna, Italy) was used after calibration at pH 4 and 7, according to the direct method previously described by Liu and Zhou (2013). Approximately 2 to 2.5 cm deep pH probe was implanted into the breast muscle avoiding the contact with the bone. Three readings were taken at different points of the pectoralis major muscle.

3.5.2. Measurement of Meat Color

Meat color was also recorded at slaughter, and 24-h and 72-h post-slaughter. A chromameter (Minolta CR400; Konica Minolta Sensing Inc., Osaka, Japan) was used to measure the color of the breast meat. The color of each breast meat sample was expressed according to the values of lightness (L*), redness (a*), and yellowness (b*) previously described by the International Commission on Illumination (CIE).

3.5.3. Water Holding Capacity

Water holding capacity (WHC) was measured in terms of two different values namely drip loss and cooking loss according to the procedure of Honikel (1998). These values are influenced by the storage time of meat. Therefore, these values were measured 24-h and 72-h post-slaughter.

3.5.3.1. Drip loss

Almost 50 g meat sample from the breast was individually vacuum-packed and kept at 4ºC for 24-h. Samples were dried by patting on a paper towel. The samples were weighed again after the drying. Following equation was used to calculate the drip loss percentage of the breast meat samples:

$$\text{Drip loss \%} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.5.3.2. Cooking loss

Almost 50 g sample from the breast muscle was allowed to thaw at room temperature. The sample was transferred to a preheated water bath at 80 ºC. After 20 minutes, the sample was taken out of the water bath and allowed to cool. Samples were dried by patting on a paper towel without squeezing. The dried samples were weighed again. Following equation was used to calculate the cooking loss percentage of the breast meat samples:

$$\text{Cooking loss \%} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.6. Intestinal Viscosity

The viscosity of intestinal contents (digesta) of broilers slaughtered on day 42 was measured. The samples of intestinal contents were collected from the anterior (duodenum and jejunum), and posterior (ileum) portions of the intestinal tract in separate micro-centrifuge tubes assuming the Meckel's diverticulum as a benchmark. Approximately 1.5 g of intestinal contents was collected from each bird and centrifuged at 12700 × g for 5 minutes. Supernatant was collected and stored at 4 ºC until analysis. Viscosity of each samples was measured using a Brookfield DV-E digital viscometer (Model Cone and Plate LVDV-E, Brookfield Engineering Laboratories Inc., Middleboro, MA.) according to the technique described by Bedford and Classen (1993). Viscosity was measured in centipoise (cP).

3.7. Litter Moisture

Approximately 100 g litter sample was collected from each pen in plastic bags at the end of the experiment. The litter samples were labelled accordingly. The sample was collected from different places (from the corner, near the feeder, and under the nipple drinkers) within each pen so as to make a representative sample. The samples were stored at 4 ºC until analysis. A known quantity of each sample was dried at 65 ºC for 24 hours. The samples were again weighed after drying. Following equation was used to calculate moisture percentage in each litter sample:

$$\text{Moisture (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.8. Scoring of Footpad Dermatitis Lesions

The incidence and severity of FPD was evaluated on days 21 and 42 of age by observing all the birds. A visual FPD scoring system was used described by Bilgili et al. (2006). One of the three values was assigned to each lesion based on the following criteria:

0 = Foot pads with no lesions, intact dermal ridges within the central plantar foot pad surface, with or without discoloration

1 = Foot pads with mild lesions, dermal ridges not intact within center, round to oval ulcer on the central plantar foot pad surface, rough lesion surface with a small tag of crust <7.5 mm in diameter

2 = Foot pads with severe lesions, large brown discolored ulcers of >7.5 mm in diameter

3.9. Statistical Analysis

The data were statistically analyzed using one-way analysis of variance (ANOVA) in a completely randomized design to evaluate the effect of different levels of PFA on various parameters of broilers in a completely randomized design. The data were tested for normality using Shapiro-Wilk's test. Non-normalized traits were normalized using logarithmic or square root transformation. The data obtained for each parameter were analyzed in a statistical software package (SPSS Version 17.0; SPSS Inc., Chicago, IL, USA). Means were compared using Tukey's post-hoc test. The confidence interval was set at 95% (*P* <0.05). The results were presented as Mean $\pm$ SEM.

4. RESULTS

In the present study, there was no significant effect of different levels of PFA on BW gain, feed intake, and FCR of broiler at any phase of growth (Figure 1).

Similarly, meat quality parameters such as lightness, redness, yellowness, pH, drip loss, and cooking loss were not different among the treatments at slaughtering and 24-h post-slaughter (Table 9 and 10). However, lightness of the meat 72-h post-slaughter was significant ($P<0.05$) in broilers fed diets with PFA100 compared to those fed PFA125 (Table 11).

Intestinal viscosity and litter moisture were non-significant among the treatments at day 42 of the experiment (Table 12).

The dietary inclusion of PFAs had no significant effect on the incidence and severity of FPD in broilers at days 21 and 42 of the experiment (Table 13).

Table 5. Weekly body weight (BW) of broiler chickens (g) fed different levels of PFAs (n=8)

Treatments[1]	Days						
	1	7	14	21	28	35	42
Control	43.10±0.18	188±2.74	540±4.02	1099±10.0	1770±10.5^{b}	2365±26.0	2966±33.7
PFA100	42.90±0.76	194±1.32	555±5.04	1135±10.6	1795±5.20^{ab}	2422±20.3	3019±24.3
PFA125	43.12±0.21	194±1.19	542±4.97	1122±11.5	1775±11.1^{ab}	2443±17.5	2964±31.2
PFA150	43.01±0.20	192±1.39	548±3.59	1115±9.4	1810±12.0^{a}	2408±31.9	2989±27.3
Probability	0.88	0.06	0.09	0.13	0.03	0.16	0.53

^{a,b}Means bearing different superscripts within the same column differ significantly ($P<0.05$)

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 6. Weekly body weight (BW) gain of broiler chickens (g) fed different levels of PFAs (n=8)

Treatments[1]	Days					
	7	14	21	28	35	42
Control	145±2.77	352±3.02	559±8.10	671±12.3	595±29.7	601±18.7
PFA100	151±1.33	361±4.68	579±13.9	661±10.3	627±22.7	597±21.6
PFA125	151±1.12	348±5.26	580±9.87	652±17.6	669±16.5	521±31.7
PFA150	149±1.43	356±2.86	567±8.17	695±7.93	598±26.3	581±27.4
Probability	0.06	0.17	0.42	0.11	0.14	0.12

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 7. Weekly feed consumption (g day^{-1}) of broilers fed different levels of PFAs (n=8)

Treatments[1]	Weeks					
	1	2	3	4	5	6
Control	160±1.73	450±5.75	767±9.41	1090±12.6	1297±11.2	1351±30.1
PFA100	159±2.50	450±3.87	779±5.82	1143±21.9	1309±16.7	1304±39.9
PFA125	158±1.91	443±5.17	756±5.14	1085±11.7	1319±21.5	1226±27.5
PFA150	159±2.51	447±4.32	766±7.53	1109±17.3	1353±30.5	1260±41.0
Probability	0.95	0.68	0.17	0.08	0.30	0.09

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 8. Weekly feed conversion ratio of broilers fed different levels of PFAs (n=8)

Treatments[1]	Weeks					
	1	2	3	4	5	6
Control	1.11±0.02	1.28±0.02	1.37±0.02	1.63±0.03	2.22±0.11	2.26±0.05
PFA100	1.05±0.02	1.25±0.02	1.35±0.02	1.73±0.04	2.11±0.08	2.21±0.11
PFA125	1.05±0.01	1.27±0.03	1.31±0.02	1.67±0.04	1.98±0.06	2.42±0.16
PFA150	1.07±0.02	1.26±0.01	1.35±0.02	1.60±0.02	2.29±0.09	2.19±0.09
Probability	0.08	0.66	0.19	0.06	0.08	0.47

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 9. Lightness (L*), redness (a*), yellowness (b*), and pH of meat of broilers at slaughter fed different levels of PFAs (n=8)

Treatments[1]	(L*)	(a*)	(b*)	pH
Control	49.40±1.90	5.15±0.65	1.28±0.56	6.06±0.10
PFA100	51.41±0.41	5.72±0.57	1.80±0.45	6.20±0.10
PFA125	50.98±0.79	4.64±0.34	1.47±0.99	6.10±0.09
PFA150	50.41±0.43	3.84±0.35	2.56±1.46	6.02±0.12
Probability	0.585	0.164	0.826	0.662

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 10. Lightness (L*), redness (a*), yellowness (b*), pH, drip loss, and cooking loss of meat of broilers 24-h post-slaughter fed different levels of PFAs (n=8)

Treatments[1]	(L*)	(a*)	(b*)	pH	Drip loss (%)	Cooking loss (%)
Control	56.51±0.79	2.11±0.52	4.61±0.58	5.66±0.03	12.93±0.94	30.92±1.78
PFA100	58.60±1.09	1.70±0.46	4.50±0.58	5.61±0.02	12.31±0.76	27.82±1.92
PFA125	53.53±1.25	1.72±0.41	4.80±0.74	5.67±0.03	12.15±1.51	28.77±0.94
PFA150	56.80±2.18	1.84±0.47	5.56±0.84	5.65±0.03	13.10±1.04	29.30±0.99
Probability	0.114	0.918	0.700	0.465	0.915	0.521

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 11. Lightness (L*), redness (a*), yellowness (b*), pH, drip loss, and cooking loss of meat of broilers 72-h post-slaughter fed different levels of PFAs (n=8)

Treatments[1]	**(L*)**	**(a*)**	**(b*)**	**pH**	**Drip loss (%)**	**Cooking loss (%)**
Control	55.75±0.91[ab]	1.71+0.52	5.78±0.36	5.70±0.04	15.68±2.53	29.05±0.92
PFA100	57.79±1.01[a]	1.53+0.37	6.05±0.95	5.61±0.03	12.87±0.75	28.89±0.90
PFA125	52.62±1.01[b]	1.31+0.46	5.60±1.03	5.80±0.13	11.44±0.51	26.37±0.42
PFA150	54.94±1.12[ab]	2.10+0.63	6.10±0.94	5.64±0.03	11.25±0.69	28.03±0.64
Probability	0.012	0.735	0.974	0.252	0.113	0.064

[a,b]Means bearing different superscripts within the same column differ significantly ($P<0.05$)
[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

Table 12. Intestinal viscosity (cP) and litter moisture (%) of broilers fed different levels of PFAs (n=8)

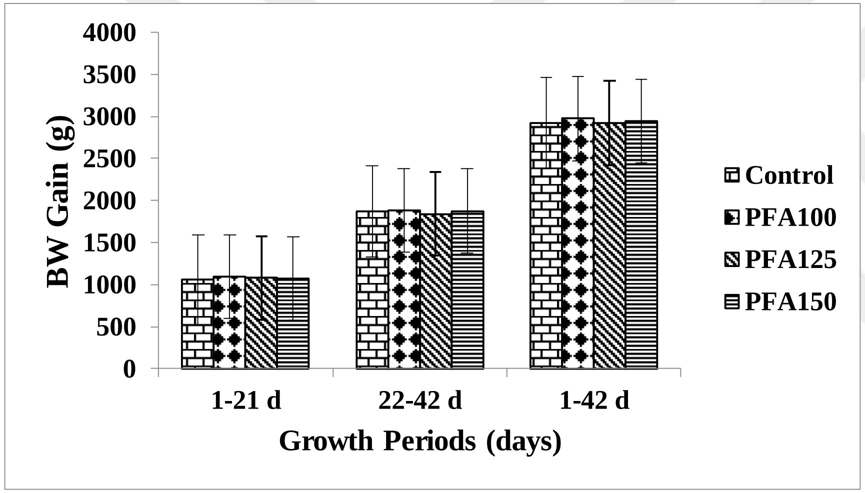
Treatments[1]	**Intestinal viscosity (cP)**		**Litter moisture (%)**
	Anterior	**Posterior**	
Control	1.49±0.08	1.63±0.14	1.50±0.07
PFA100	1.47±0.13	1.48±0.09	1.48±0.07
PFA125	1.54±0.14	1.54±0.07	1.54±0.08
PFA150	1.41±0.08	1.47±0.08	1.45±0.06
Probability	0.91	0.66	0.84

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA

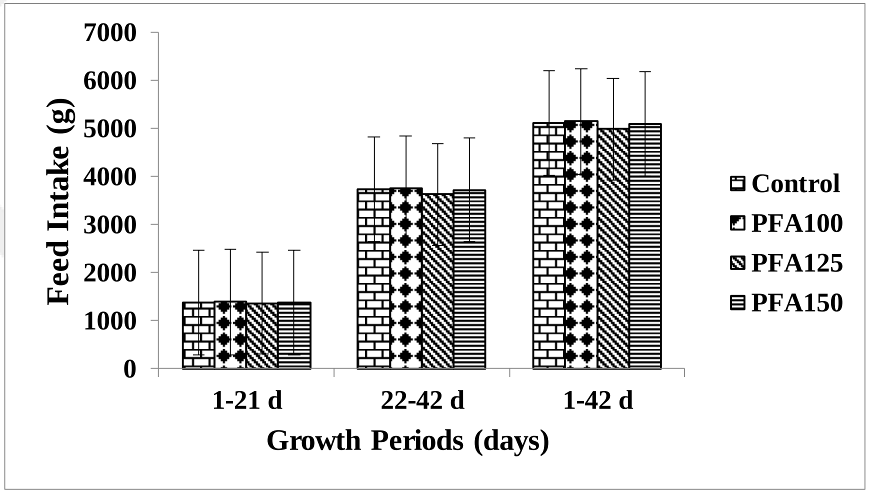
Table 13. Incidence and severity of footpad dermatitis (FPD) score of broilers (at days 21 and 42) fed different levels of PFAs

Treatments[1]	Day 21				Day 42			
	0	1	2	T[2]	0	1	2	T[2]
Control	20.54±4.46	46.72±1.78	32.75±4.28	79.46±4.46	32.96±5.56	47.21±4.43	19.83±6.00	67.04±5.56
PFA100	31.20±9.08	39.65±5.48	29.15±9.73	68.80±9.08	39.78±9.15	35.10±4.40	25.13±7.09	60.22±9.15
PFA125	23.82±6.98	44.78±4.75	28.77±4.76	73.55±6.76	39.19±7.23	44.46±4.37	16.35±7.68	60.81±7.23
PFA150	28.57±6.63	42.32±4.10	29.11±6.40	71.43±6.63	36.13±8.72	43.00±5.33	20.88±8.57	63.87±8.72
Probability	0.708	0.675	0.970	0.734	0.921	0.310	0.868	0.921

[1]Control: 0 mg/kg PFA; PFA100: 100 mg/kg PFA; PFA125: 125 mg/kg PFA; PFA150: 150 mg/kg PFA
[2]T = Total FPD lesion comprising of score 1 and 2



(A)



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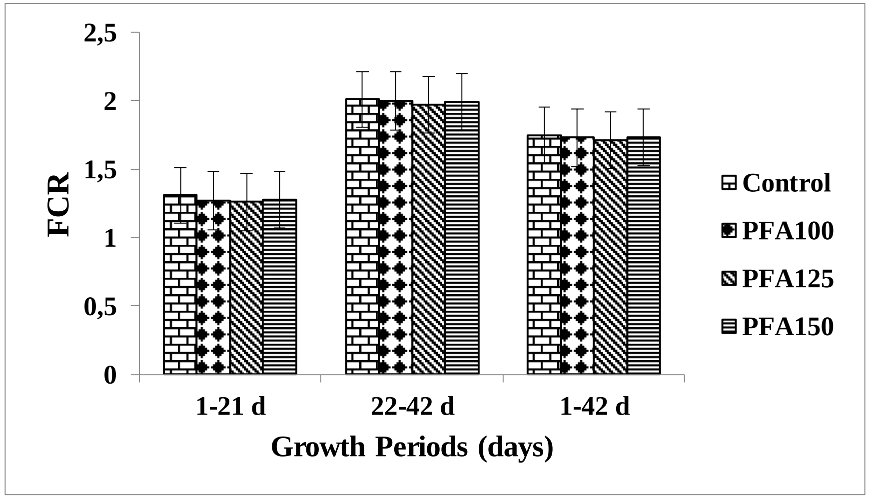

(C)

Figure 1. (A) BW gain (g), (B) Feed intake (g), and (C) FCR of broilers fed different levels of PFAs

5. DISCUSSION

Phytogenic products are considered beneficial in monogastric nutrition in order to improve live performance and meat quality. However, previous studies revealed inconsistent results in terms of growth performance and other bodily parameters. Moreover, very little data is available on the possible effects of dietary PFA on the meat quality and footpad lesions of broilers. Therefore, the present study was conducted to evaluate the effect of different levels of dietary PFA on performance, meat quality, and FPD in broilers.

The present study showed that BW gain, feed intake, and FCR of broilers were not statistically different among the treatments. These results are no different than those reported by Botsoglu et al. (2002) and Lee et al. (2004) who found that dietary supplementation of oregano essential oil (100 and 50 mg/kg, respectively) did not affect the broilers' performance. Likewise, some other studies reported no effect of dietary PFAs on the performance of broilers (Fukayama et al., 2005; Toledo et al., 2007; Kumar et al., 2010; Rizzo et al., 2010; Fascina et al., 2012). In contrast, some studies have reported negative effects of dietary PFAs on the performance of broilers (Cross et al., 2003, Lee et al., 2003a; 2003b; 2003c; Hernandez et al., 2004; Abildgaard et al., 2010; Puvaca et al., 2013). However, some other studies showed that dietary PFAs supplementation improved the performance of broilers. Jamroz et al. (2005) reported that the inclusion of 100 mg PFAs (containing carvacrol, cinnamaldehyde, and capsicum oleoresin) per kg of the diet improved the performance of broilers. Spernakova et al. (2007) reported similar findings in broilers fed rosemary powder at 500 mg/kg of the diet. Fortification of broiler diet with a blend of phytogenic extracts at 1 g/kg also increased the BW gain and enhanced the performance (Lippens et al., 2005). Similarly, the dietary supplementation of 1 g/kg thyme essential oil (Cross et al., 2007) and 5 g/kg thyme herb (Toghyani et al., 2010) improved the performance of broilers. The actual mechanism of action by which PFAs improve the performance of broilers is not known, however, it may be due to the stabilization of feed components, improvement of the gut environment, concentration of enviable microflora or by the continuous stimulation of pancreatic and the digestives enzymes (Windisch et al., 2008). However, the variation in the results of the present study compared to previous studies may be due to the difference in a number of factors. The variation in the efficacy of PFAs may arise due to the difference in the selection of plants that possess various active biomolecules. In addition, the use of different parts of the plants may influence the results as well as the variations in the effectiveness of PFAs supplemented to the poultry diets. Moreover, it is more likely that the concentration of the active biomolecules varies greatly among the plants in addition to the parts of the plants used that lead towards an inconsistency in the concentration of the biomolecules in PFAs. Among the other factors, the harvesting season, application methods, geographical origin, phytogenic production process, age of poultry, and environmental conditions can all contribute to inconsistent results. Additionally, the inclusion level of PFAs may play an important role. Most of the studies have used the mixture of different plant extracts, essential oil, herbs, and spices. Only fewer studies have emphasized the use of individual plant or its extracts. The quantity of the active biomolecules in an individual plant has been an unsolved question. This implies that the exact inclusion level cannot be reached until the quantification of active biomolecules in the individual plant is not accomplished in order to determine the effective level of application in poultry diets. Among the other factors, the composition of the diet as well as the genetic potential of the broilers also determine the efficacy of PFAs.

It is a general perception that the pre-slaughter stress conditions greatly deteriorate the meat quality such as color, pH, drip loss, and cooking loss. PFAs are believed to possess antioxidative properties that protect the cellular function in the intestine and other body tissues (Cuppett and Hall, 1998; Craig, 1999; Nakatani 2000; Wei and Shibamoto, 2007). The antioxidative properties of PFAs may help the broilers overcome the stress conditions. Therefore, dietary PFAs may improve the meat quality of the chicken. However, in the present study, there was no significant effect of different levels dietary PFAs on the meat quality of broilers compared to the control. These findings are consistent with those of Li et al (2015) who reported that different levels of a commercial phytogenic product (0.5 and 1 g/kg in diet) had no effect on the pH, color, water holding capacity, and drip loss of meat of broilers in comparison with those fed control diet. In the present study, dietary PFAs at 100 mg/kg significantly improved the lightness of meat of broilers 72-h post-slaughter compared to broilers fed 125 mg/kg PFAs. However, it seems to occur by chance as the reciprocal effect on the other meat color measurements such as yellowness and redness was not significant.

There is no report available describing the effect of PFAs on intestinal viscosity, litter moisture, and incidence and severity of FPD in poultry. Therefore, the results of the present study cannot be explained in the light of literature available. Intestinal viscosity of broilers depends on feed composition. Diets fed to the broilers, in the present study, consisted of corn and soybean. Soybean meal contains considerable amount of soluble and insoluble non-starch polysaccharides (NSPs) (Choct, 1997). An increase in the concentration of soluble NSPs generally increases the intestinal viscosity. This happens due to reduced nutrient digestion and absorption (Choct and Annison, 1990), consequently altering the gut physiology and intestinal ecosystem (Angkanaporn et al., 1994). Higher intestinal viscosity increases the litter moisture as the droppings become stickier. The droppings are caustic in nature, and prolonged adhesion of the droppings to the epidermis of paws elicits irritation. This results in the corrosion of epidermis and keratin layers of the paws causing a pathologic condition named FPD (Shepherd and Fairchild, 2010). PFAs are known to improve the nutrient digestibility (Amad et al., 2011, Mountzouris et al., 2011) that may, in turn, decrease the intestinal viscosity and litter moisture eventually. In the present study, it was expected that the PFAs supplementation at different levels in broiler diets would reduce the intestinal viscosity of the broilers resulting in lowered litter moisture, and FPD incidence and severity. However, it seems that these events did not occur in the present study. The possible explanation is that the basal diets were similar in all the treatments so did the intestinal viscosity, litter moisture, and FPD score. In addition, the minimum concentration of active biomolecule to show its possible effect on intestinal viscosity, litter moisture, and incidence and severity of FPD is questionable.

6. CONCLUSIONS

The results of the present study suggest that varying inclusion levels of dietary PFAs in corn-soy based broiler diets neither improves nor declines the growth performance. Moreover, the chicken meat quality, intestinal viscosity, litter moisture, and incidence and severity of FPD in broilers is not influenced by dietary PFAs addition in the current study. The efficacy of PFAs is governed by a number of factors, and therefore, the use of PFAs in poultry diets should be paid attention only after careful considerations. The concentration of active biomolecules and the inclusion level is the key determining factor for growth performance and other goals of rearing the poultry birds. Hence, the inclusion level of PFAs in poultry diets may be different for different goals such as for maximal BW, maximal feed efficiency, and disease prevention etc. PFAs are used in broiler diets due to the potential properties possessed by the bioactive molecules of herbs or spices. Although none of the addition levels were helpful in improving the growth performance, meat quality, and in decreasing the FPD score, more research is needed to set the optimum dietary levels of blending these compounds for their prospective use in broiler nutrition.

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ACADEMIC PUBLICATIONS

Journal Articles

- **Ahsan U,** Kamran Z, Raza I, Ahmad S, Babar W, Riaz MH, Iqbal Z. Role of selenium in male reproduction – a review. Animal Reproduction Science 2014, 146(1-2), 55-62.

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