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Effect of seed powder and alcoholic extract of *Peganum harmala* on growth performance, nutrient digestibility, and carcass traits in Japanese quail reared in litter and tier cage systems

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Abstract This study was carried out to investigate the effect of *Peganum harmala* seed powder (PHSP) and alcoholic *Peganum harmala* seed extract (PHSE) on growth performance, carcass parameter, and nutrient digestibility in Japanese quails reared on the litter and in tier cages. Nine hundred and sixty day-old Japanese quails were kept on the litter and in the tier cages and received a control (basal diet) and diets containing 0.2% PHSP, 0.2% PHSE, or 0.05% Maduramycin® coccidiostat. The experiment consisted of eight treatments, each with four replicates, and each replicate contained 30 quails. Statistical analysis was performed using SAS software (version 9.4) in a completely randomized design. The birds had free access to feed and water and were raised under the same climatic conditions. Body weight and feed intake were measured weekly. Final body weight, average daily gain, feed conversion ratio, and fat digestibility of quail on the litter system were 6.83%, 9.91%, 9.76% and 15.77% better than those in the tier cages. The final body weight, average daily gain, feed conversion ratio, fat and dry matter digestibility of the birds receiving *Peganum harmala* seed extract were 3.99%, 5.52%, 7.27%, 4.52% and 10.44% greater than the control treatment respectively. The data suggested that 0.2% *Peganum harmala* seed extract could be added to the diet of quails reared on the litter.

Keywords: digestibility, growth, Japanese quail, *Peganum harmala,* rearing system

Introduction

With the increasing global population, the demand for animal protein, particularly poultry meat, has risen significantly. Historically, growth-promoting antibiotics have been employed in poultry production to regulate bacterial populations, eliminate harmful intestinal bacteria, and enhance growth, thereby controlling intestinal diseases, reducing losses, and increasing production (Leeson & Summers, 2001; Applegate, 2022). However, the use of antibiotics for growth promotion in poultry has raised concerns regarding the development of antimicrobial resistance, prompting research into alternative methods to maintain poultry health and productivity (Alabio et al., 2024). Researchers and poultry industry professionals have searched for alternative compounds that not only enhance the quality and performance of animal products but are also safe for human health.

Peganum harmala is native to dry areas of Asia, the Mediterranean coast, Mexico, and the southern United States (Dang et al., 2023); however, it is also cultivated in, Iran, Australia, North Africa, and Southwest America. *Peganum harmala* fruits, which are capsules, consist of three chambers and have a width of approximately 6 to 10

mm. Initially, the fruits are green and gradually change to an orange-brown hue as they ripen. Each capsule contains over 50 tiny triangular seeds that are black-brown (Niroumand et al., 2015). In comparison to other plants that have been studied for poultry performance, *Peganum harmala* stands out due to its unique combination of alkaloids, antimicrobial and antioxidant properties, and its adaptability to harsh growing conditions. These traits make it a compelling alternative for improving poultry health, growth, and feed efficiency, all while potentially reducing reliance on synthetic chemicals or antibiotics (Arshad et al., 2008; Tanweer et al., 2012; Sharifi-Rad et al., 2021).

Peganum harmala is a medicinal plant renowned for its antibiotic properties, including antimicrobial effects. Additionally, it has the ability to enhance the functionality of the immune system (Shah et al., 2012). *Peganum harmala* seed is enriched with alkaloids such as harmine, harmaline, harmalol, vaseline, and vaspestone (Herraiz et al., 2010). *Peganum harmala* seeds are rich in carbohydrates, lipids, proteins, mineral salts, alkaloids, amino acids, and fatty acids. The predominant fatty acids include linoleic acid (61.46%), oleic acid (24.76%), and palmitic acid (7.28%). Other fatty acids present in smaller amounts are stearic acid, linolenic acid, and various saturated and unsaturated fatty acids (Mahmoudian et al., 2023). Additionally, *Peganum harmala* contains steroid substances such as β-sitosterol, cryptogenin, and lanosterol. Notably, the seeds of this plant also contain alkaloids, comprising approximately 4–6% of the seed's dry weight. These alkaloids, including harmine and harmaline, hold significant industrial and medical importance (Moloudizargari et al., 2013).

Peganum harmala seeds have been utilized for their antiparasitic and disinfectant properties since ancient times. This is attributed to the presence of beta-carboline alkaloid compounds, which confer antimicrobial, antifungal, and antiparasitic properties to these seeds (Zhu et al., 2022). Furthermore, this plant exhibits a range of beneficial properties, including anticancer, relaxing, anti-HIV, antioxidant, immune-boosting, and blood sugar-lowering effects (Hashemi et al., 2009).

The chemicals in *Peganum harmala* stimulate the digestive system and enhance the secretion of digestive enzymes, improving nutrient breakdown and absorption. Studies have shown that alkaloids such as harmaline and harmine contribute to these effects by modulating gut motility and enzyme secretion (Shamsa et al., 2008; Bukhari et al., 2017). Additionally, *P. harmala* enhances liver function, contributing to metabolic processes and nutrient utilization, which leads to improved overall performance. Research suggests that its hepatoprotective properties are linked to its antioxidant activity, reducing oxidative stress and improving liver enzyme balance (Zahra et al., 2020).

Hens raised in cages are more likely to suffer from fatty liver hemorrhagic syndrome compared to hens raised on litter (Shini et al., 2018). The liver plays a crucial role in detoxifying various substances, including drugs, and its function can be influenced by environmental factors, including the rearing system. Studies suggest that different rearing conditions, such as diet composition, exposure to environmental contaminants, and housing systems, can impact hepatic detoxification processes and overall liver health (Schiavone et al., 2018; Attia et al., 2020). Lower voluntary activity of birds in tier cages can have deleterious effects on the liver and decrease the health and performance (Kang et al., 2024).

Quails raised in tier cages tend to have lower meat quality compared to those raised on litter. On the other hand, quails raised on litter tend to have higher health problems like coccidiosis compared to those raised in the tier cages. These factors have prompted the search for a solution that can minimize the losses associated with rearing quail on litter while ensuring profitability. There is no information on the effects of *Peganum harmala* seed, as an alternative organic compound in quails reared under different production systems; therefore, this study was designed to determine if feeding *Peganum harmala* seed or extract could affect quail performance in tier cage and on litter systems.

Materials and methods

Birds and housing

The animal welfare Guideline at Shiraz University approved the experimental procedures. In this experiment, 960 mixed male and female day-old quails were randomly divided into 32 groups of 30 birds each. The quails were reared on 16 litter pens (1 m^2 each) or in 4-tier cages, each had 4 floors (0.5 m height; 1 m^2 floor space). Fresh water and mash feed were provided *ad libitum* via bell drinkers and tube feeders on the litter system and via trough feeders and nipple drinkers in tier cages. For the initial 14-day period, all experimental groups were fed by the same standard diet. From 15 to 42 days of age, the birds were fed four dietary treatments. The experiment was carried out as a 2 × 4 factorial arrangement in a completely randomized design with 4 replicates consisting of two rearing systems (litter and tier cage) and four levels of additives (zero, 0.2% *Peganum harmala* seed powder, 0.2% *Peganum harmala* seed extract, and 0.05% Maduramycin® coccidiostat). The housing conditions were implemented in accordance with the quails-specific guidelines (European Food Safety Authority, 2021).

Dietary treatments

Peganum harmala seeds were purchased from the Vakil Market, Shiraz, Iran and grounded through an electric mill. The hydro alcoholic extract of *Peganum harmala* seed was prepared using the rotary method at the Department of Horticultural Sciences, School of Agriculture, Shiraz, Iran. For the extraction process, the powdered *Peganum harmala* seeds were first placed

into a glass beaker, and then the solvent, consisting of a mixture of 96% ethanol, distilled water, and ethyl acetate, was poured onto it. The hydro alcoholic solvent was used in a quantity that completely covered the *Peganum harmala* seed powder. The resulting solution was kept in an oven at 50 degrees Celsius for 72 hours to allow the active substances to be released into the liquid phase, and then the mixture was filtered through filter paper. The filtered solution was gradually added to the Rotary Streak device several times, and then the device was turned on and the alcohol separated from the solution, resulting in a liquid. After drying, this liquid became the *Peganum harmala* seed extract (Forouzandeh et al., 2014).

The control diet, based on corn and soybeans, was formulated following the recommendation of NRC 1994. Other diets contained the basal (control) diet to which were added 0.2% *Peganum harmala* seed powder, an equal amount of *Peganum harmala* seed extract, or 0.05% Maduramycin®. The starter diet was prepared from the Rad Ard Pars Animal and Poultry Feed Factory, Shiraz, Iran. The diet quantities required for the starter and growth periods were adjusted in accordance with the dietary requirements specified for Japanese quails and using Windows User-Friendly Feed Formulation (WUFFDA) software version 1.0, as outlined in Table 1.

Table 1. Ingredients and chemical composition of Japanese quail diet in different rearing periods

	Starter (1-14 days)	Grower (15-42 days)			
Ingredients		Control	*Peganum harmala* seed extract	*Peganum harmala* seed powder	Maduramycin ® Coccidiostat
Corn grain	54.10	52.00	52.00	52.00	52.00
Soybean meal	40.30	43.75	43.75	43.75	43.75
Soybean oil	1.30	0.90	0.90	0.90	0.90
Salt	0.30	0.30	0.30	0.30	0.30
Di-calcium phosphate	1.50	1.04	1.04	1.04	1.04
Bentonite	0.50	0.00	0.00	0.00	0.00
DL- methionine	0.20	0.15	0.15	0.15	0.15
Premix[1]	0.40	0.40	0.40	0.40	0.40
Threonine	0.10	0.11	0.11	0.11	0.11
Symbisiom	0.10	0.05	0.05	0.05	0.05
Sodium bicarbonate	0.00	0.12	0.12	0.12	0.12
Oyster powder	0.20	1.18	1.18	1.18	1.18
Peganum harmala seed powder	0.00	0.00	0.00	0.20	0.00
Peganum harmala seed alcoholic Extract	0.00	0.00	0.20	0.00	0.00
Coccidiostat	0.00	0.00	0.00	0.00	0.05
Total	100	100	100	100	100
Chemical Composition					
Metabolizable energy (Mcal/kg)	2900	2900	2900	2900	2900
Crude protein (%)	24.00	24.00	24.00	24.00	24.00
Crude fiber (%)	2.85	2.85	2.85	2.85	2.85
Crude methionine (%)	0.54	0.53	0.53	0.53	0.53
Threonine (%)	1.07	1.08	1.08	1.08	1.08
Calcium (%)	0.8	0.08	0.08	0.08	0.08
Tryptophan (%)	0.36	0.36	0.36	0.36	0.36

[1]Each g of premix contains: Vitamin A, 7500 IU; Vitamin D3, 3000 IU; Vitamin E, 10 IU; Vitamin K, 2 mg; Vitamin B12, 12.5 µg; folic acid, 0.5 mg; pantothenic acid, 8 mg; pyridoxine 1.8 mg; riboflavin, 5.3 mg; thiamine, 2 mg; biotin, 0.15 mg, iodine, 1 mg; selenium, 0.15 mg; niacin, 24 mg; choline, 350 mg; copper; 6 mg; iron, 30 mg; zinc, 50 mg; manganese, 80 mg.

Data collection

The weight of quails and feed consumption were measured and feed conversion ratio was calculated on a weekly basis. To determine the amount of feed consumed by the birds in each experimental unit, the quantity of feed remaining at the end of each week was subtracted from the amount of feed provided during the week. To record the weekly weight gain, total weight of quails in each experimental unit was measured, and then calculated on *per capita* basis. A fasting period of 2 h was allowed prior to weighing. To calculate the weight gain of the birds in each experimental unit over the entire period the total weight of the unit at the beginning of the period was subtracted from the total weight of the birds at the end of period. In order to calculate the feed conversion ratio for each week or period, the average feed intake during the week or period was divided by the average daily gain of the experimental unit.

At the end of the experiment, one bird from each cage was slaughtered and the weight of the carcass, heart, liver, and lungs were calculated as a percentage of the live weight. The average final weight was calculated for each replicate. At the age of 43 days, the remaining quails were killed, and a prececal digesta sample from the last two thirds of the intestine was collected and kept at -20 degrees Celsius. Additionally, the length of the intestine was measured from the Meckel's appendix to two centimeters before the cecum.

To calculate prececal nutrient digestibility, the nutrient content of feed and ileal samples was analyzed by proximate analysis procedures (AOAC, 1995). Acid Insoluble Ash (AIA), as an internal marker, was measured in feed and digesta samples to calculate the prececal nutrient digestibility (Coca-Sinova et al*.,* 2011).

The prececal nutrient digestibility (Pc D) of dietary nutrients was calculated based on the following equation 1 (Scott et al., 1976):

Pc D = 100 - (100 × (diet nutrient / ileal nutrient) × (ileal AIA / diet AIA))

Statistical analysis

This experiment was conducted as a completely randomized design consisting of two rearing systems (litter and cages) and four diets (control, 0.2% *Peganum harmala* seed powder, 0.2% *Peganum harmala* seed extract, and 0.05% Maduramycin® coccidiostat). This resulted in eight treatments, with four replicates per treatment. The data were analyzed using SAS (2014) Statistical Software, and the treatments were compared by the Tukey's test at the five percent probability level. The statistical model was as follows:

$Y_{ijk}=\mu+A_i+B_j+AB_{ij}+\alpha_1(W_{ijk}-\bar{W}_{ijk})+e_{ijk}$

where: yijk is the k^{th} observation at the j^{th} level of factor B (rearing system) and the i^{th} level of factor A (level of supplement used), μ, the total mean, A^i, the fixed effect of the i^{th} level of factor A, B_j, the fixed effect of the j^{th} level of factor B, AB_{ij}, The interaction effect of the i^{th} level of factor A and the j^{th} level of factor B, α_1, the linear regression coefficient of the studied traits on the initial weight, W_{ijk}, the initial weight (seven days old) of quails, $\bar{W}_{ijk}$, the average initial weight of quails and e_{ijk}, was the residual of the k^{th} observations at the j^{th} level of factor B and the i^{th} level of factor A.

Results

The effect of treatments on average daily gain (ADG), final body weight (FBW), feed intake (FI) and feed conversion ratio (FCR) is shown in Table 2. Rearing quails on the litter compared to the tier cages improved the ADG, FBW, and FCR (P≤0.0001). The diet containing 0.2% *Peganum harmala* seed extract, improved ADG, FBW and FCR in comparison to the control group. Inclusion of 0.2% *Peganum harmala* seed powder in the diet improved the ADG and FCR compared the control group. The FBW of quails in *Peganum harmala* extract treatment was statistically greater than that of the birds fed with *Peganum harmala* powder. The diet supplemented with 0.2% *Peganum harmala* seed extract improved ADG, FBW and FCR in comparison to the coccidiostat treatment. The FCR of birds in 0.2% *Peganum harmala* seed powder treatment was improved in comparison to the coccidiostat treatment. The interaction effect of rearing system and diet on FCR was significant and the best FCR was observed in birds reared on the litter and fed with *Peganum harmala* seed extract treatment.

Table 2. Effect of rearing system and seed powder and alcoholic extract of *Peganum harmala* on average daily gain (ADG), final body weight (FBW), feed conversion ratio (FCR) and feed intake (FI) in Japanese quails

	FI (g)	ADG (g)	FBW (g)	FCR
Rearing system (Main effect)				
Cage	22.47	5.35	221.41	4.20
Litter	22.28	5.88	236.53	3.79
SEM[1]	0.55	0.17	4.93	0.24
P-value	0.36	<0.0001	<0.0001	<0.0001
Type of feed (Main effect)				
Control	22.62	5.48^{c}	225.48^{b}	4.13^{a}
Peganum harmala seed extract	22.33	5.80^{a}	234.86^{a}	3.85^{b}
Peganum harmala seed powder	21.72	5.63^{ab}	229.38^{b}	3.86^{b}
Coccidiostat	23.02	5.55^{bc}	226.16^{b}	4.15^{a}
SEM[1]	0.44	0.31	8.54	0.30
P-value	0.27	0.0055	0.0007	0.0046
Interaction of rearing system and feed type				
Cage × Control	23.20	5.24	218.67	4.43^{a}
Cage × *Peganum harmala* seed extract	21.67	5.56	228.18	3.90^{bc}
Cage × *Peganum harmala* seed powder	21.60	5.32	220.80	4.06^{b}
Cage × Coccidiostat	23.42	5.29	217.97	4.43^{a}
Litter × Control	21.89	5.72	232.29	3.83^{bc}
Litter × *Peganum harmala* seed extract	21.78	5.95	241.54	3.66^{c}
Litter × *Peganum harmala* seed powder	22.96	6.03	237.95	3.81^{bc}
Litter × Coccidiostat	22.53	5.81	234.35	3.88^{bc}
SEM[1]	0.15	0.13	3.16	0.18
P-value	0.45	0.70	0.72	0.05

[a, b:] Within column, means with common superscript (s) are not different (P>0.05).
[1]SEM: Standard Error of the Mean.

The effect of treatments on prececal nutrient digestibility is shown in Table 3. Rearing on the litter compared to the tier cage increased crude fat digestibility (P≤0.0001). feeding 0.2% *Peganum harmala* seed extract compared to the control and coccidiostat treatments improved crude fat digestibility (P<0.0001). Feeding the diet supplemented with 0.2% *Peganum harmala* seed extract improved the dry matter (P≤0.0001) and crude fat (P<0.0001) digestibility in comparison to 0.2% *Peganum harmala* seed powder. Coccidiostat supplementation improved the dry matter

digestibility compared to supplementation of the diet with 0.2% *Peganum harmala* seed powder. The interaction effect of the rearing system and diet was only significant for fat digestibility and the greatest digestibility was observed in litter × *Peganum harmala* seed extract combination.

Rearing on the litter increased the heart weight percentage but decreased the liver weight percentage in compared to the tire cage system (Table 4). The effect of diet supplements and interaction effect of treatments on heart weight was significant. The greatest heart weight was observed in the birds that were reared on the litter and received coccidiostat (significant interaction effect).

Table 3. Effect of rearing system and seed powder and alcoholic extract of *Peganum harmala* on dry matter (DM), crude protein (CP), and fat digestibility in Japanese quails

	Prececal nutrient digestibility (%)		
Rearing system (Main effect)	DM	CP	Fat
Cage	79.65	78.48	64.22
Litter	77.55	76.65	74.35
SEM[1]	7.02	7.07	16.79
P-value	0.21	0.25	<0.0001
Type of feed (Main effect)			
Control	80.40^{ab}	79.47	69.98^{b}
0.2% *Peganum harmala* seed extract	89.77^{a}	68.89	73.29^{a}
0.2% *Peganum harmala* seed powder	79.10^{b}	77.50	68.89^{b}
Coccidiostat	85.19^{a}	84.40	69.12^{b}
SEM[1]	3.74	3.02	17.31
P-value	<0.0001	<0.09	0.0008
Interaction of rearing system and feed type			
Cage × Control	81.71	79.67	60.02^{c}
Cage × *Peganum harmala* seed extract	71.73	70.88	63.80^{bc}
Cage × *Peganum harmala* seed powder	79.10	77.60	77.94^{ab}
Cage × Coccidiostat	86.06	85.78	77.43^{ab}
Litter × Control	79.10	79.28	61.73^{bc}
Litter × *Peganum harmala* seed extract	67.81	66.90	79.58^{a}
Litter × *Peganum harmala* seed powder	79.10	77.40	69.85^{b}
Litter × Coccidiostat	84.32	83.02	60.80^{c}
SEM[1]	3.18	2.69	11.50
P-value	0.84	0.78	0.05

[a, b:] Within column, means with common superscript (s) are not different (P>0.05).
[1]SEM: Standard Error of the Mean.

Table 4. Effect of rearing system and seed powder and alcoholic extract of *Peganum harmala* on carcass parameters (percent of live body weight) and carcass weight (g) in Japanese quails

	Carcass parameters				
Rearing system (Main effect)	Lung	Liver	Heart	Carcass percentage	Carcass weight
Cage	0.79	3.07	0.73	59.86	143.37
Litter	0.84	2.64	0.81	143.37	147.33
SEM[1]	0.07	0.39	0.11	2.15	12.80
P-value	0.09	0.005	0.04	0.18	0.34
Type of feed (Main effect)					
Control	0.84	2.74	0.72	60.62	141.85
Peganum harmala seed extract	0.78	2.99	0.77	61.64	155.80
Peganum harmala seed powder	0.81	2.85	0.81	59.29	141.63
Coccidiostat	0.84	2.84	0.77	59.98	142.11
SEM[1]	0.07	0.45	0.11	2.10	11.53
P-value	0.41	0.65	0.46	0.19	0.056
Interaction effect of rearing system and feed type					
Cage × Control	0.82	2.96	0.70^{c}	59.55	135.12
Cage × *Peganum harmala* seed extract	0.77	2.99	0.70^{c}	60.87	151.99
Cage × *Peganum harmala* seed powder	0.76	3.14	0.83^{ab}	58.92	139.15
Cage × Coccidiostat	0.83	3.19	0.68^{c}	60.10	147.20
Litter × Control	0.87	2.52	0.74^{bc}	61.70	148.57
Litter × *Peganum harmala* seed extract	0.80	2.99	0.84^{ab}	62.42	159.62
Litter × *Peganum harmala* seed powder	0.86	2.57	0.79^{b}	59.65	144.11
Litter × Coccidiostat	0.85	2.48	0.86^{a}	59.86	137.03
SEM[1]	0.07	0.38	0.01	2.008	10.01
P-value	0.75	0.32	0.04	0.20	0.23

[a, b:] Within column, means with common superscript (s) are not different (P>0.05).
[1]SEM: Standard Error of the Mean.

Discussion

A significant negative effect on average daily gain (ADG), final Body weight (FBW), and feed conversion ratio (FCR) was recorded in the quails reared in cages. Previous studies reported that the FCR in poultry is influenced by a variety of factors. For instance, when

birds experience stress and excessive competition for feed and space, rapid eating can affect natural digestion and feed consumption (Wang and Cui, 2011). In previous researches, broiler rearing in tier cages increased the behavior of cannibalism due to the lack of sufficient space, lack of proper ventilation, as well as lack of access to clean water and balanced diet (Bist et al., 2023). The incidence of breast blisters and leg abnormalities in broilers were significantly greater in tier cage systems compared to litter system (Wang et al., 2015). Broiler chickens housed in cages exhibit a higher prevalence of gait problems and leg abnormalities compared to those raised on the floor. Additionally, footpad dermatitis is a common issue in poultry, characterized by inflamed feet and lesions, which can be exacerbated by restrictive housing conditions (van den Oever et al.,2020).

Furthermore, improved performance in poultry raised on the litter system may be also attributed to the enhanced nutrient digestion. In the present study, rearing on the litter increased crude fat digestibility compared to tier cage system. The reduction in nutrient digestibility in tier cage can be attributed to the type of rearing system and the equipment used (Wang & Cui, 2011), which leads to reduced fat digestibility in quails due to lower activity in tier cages.

The rearing system had a significant effect on the weight of internal organs, specifically the heart and liver. The litter rearing system resulted in the greatest heart weight, while the cage rearing system led to the greatest liver weight. The greater weight of heart in litter system may the consequence of greater bird activity leading to better health condition and increased availability of oxygen and nutrients for growth. The positive effects of physical activity on the health and development of the cardiovascular system have been reported (Lavie et al., 2015). On the other hand, lower activity of birds in tier cage system may cause the greater liver weight by greater fat deposition and fatty liver syndrome in quails and lowered the health condition and less growth performance. Hens raised in cages were more likely to suffer from fatty liver hemorrhagic syndrome compared to hens raised on litter (Shini et al., 2018). Studies suggest that different rearing conditions, such as diet composition, exposure to environmental contaminants, and housing systems, can impact hepatic detoxification processes and overall liver health (Schiavone et al., 2018; Attia et al., 2020). Free-range and organic rearing systems, for instance, have been associated with improved antioxidant capacity and reduced oxidative stress in the liver compared to conventional systems (Surai & Fisinin, 2016). Decreased voluntary activity in tier cages can greatly cause metabolic diseases of the liver and decrease the health and performance (Kang et al., 2024).

Average daily gain, FBW and FCR in *Peganum harmala* seed extract treatment, and ADG and FCR in *Peganum harmala* seed powder treatment were significantly greater than the control treatment. The reason for the improvement in ADG, FBW and FCR in birds fed with the *Peganum harmala* seed extract and powder can be due to its chemical components. *Peganum harmala* plant contains alkaloids, steroids, flavonoids, anthraquinones, amino acids, and polysaccharides compounds with antibiotic properties (Dang et al., 2023). The chemicals in *Peganum harmala* stimulate the digestive system and enhance the secretion of digestive enzymes, improving nutrient breakdown and absorption. They enhance liver function, contributing to metabolic processes and nutrient utilization and improved overall performance (Forouzandeh et al*.,* 2014).

In the present study, the type of feed additives had a significant effect on the digestibility of dry matter, and fat. Previous researches showed that chemical constituents in medicinal plants possess antioxidant properties and enhance the feed digestion and nutrient absorption (Bidar et al; 2018; Khattak et al; 2014). Digestive system is expected to be the primary site of action for herbal additives, and any alterations in the intestinal environment can impact the digestion and absorption of nutrients. The substances present in medicinal plants possess a stimulating effect on enhancing the secretion of digestive juices from organs such as the liver and pancreas, thereby improving the digestibility of feed (Hernández et al*.,* 2004). Plant metabolites in *Peganum harmala* seed extract can have beneficial chemical and physiological effects on the digestive system of chickens. These effects are believed to stabilize the intestinal microflora, which in turn can influence the intermediate nutrient metabolism (Jamroz et al., 2003). The improvement in FCR and growth performance can be attributed to several factors, including enhanced nutrient digestibility. It is reasonable to assume that the inclusion of *Peganum harmala* seed powder and extract in the diet would impact the abundance and composition of microbes and enzymes in the digestive tract, and consequently improve the growth performance of quails.

Conclusions

The litter rearing system significantly increased the growth performance in Japanese quails. Furthermore, the use of litter *versus* tier cages had a significant effect on fat digestibility, with higher digestibility in the litter rearing system. *Peganum harmala* seed extract, in particular, showed the greatest DWG, FBW, the best FCR and fat digestibility. Considering the positive effects of *Peganum harmala* seed extract on growth performance and nutrient digestibility, addition of *Peganum harmala* seed extract in quail feed can be recommended as a natural antibiotic especially in litter rearing system.

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