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Production and hatchability of laying quails with turmeric (*Curcuma longa*) liquid in commercial diet and rearing in different sex ratios

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Abstract

An experiment was carried out to assess the optimum turmeric concentration and ideal mating ratios for Japanese quails (*Coturnix coturnix japonica*) for production performance of fertile eggs and hatchability. A total of 162 ten weeks old females and 27 males were assigned in the study. They were fed on a commercial layer quail diet containing approximately 18 % crude protein and 3000 kcal of metabolizable energy (ME)/kg and reared for 12 weeks in three mating ratios: 1:4, 1:6 and 1:8. (male: female), each replicated three times. A total of 540 selected hatching eggs per batch of incubation were collected and less than 7 days stored, then were incubated for hatching performance. Percentage of average egg production (AEP-%), feed intake (FI-g), feed conversion ratio (FCR), egg weight (EW-g), egg mass (EM-g/bird) and hatching performance were determined. It was observed that FI were the only performance production affected significantly ($P<0.001$) by feeding a commercial diet mixed with liquid turmeric. Mating ratios influence FI and FCR ($P<0.001$). Most hatching performances were affected by turmeric and sex ratios, except dead in-shell and normal quail chicks. The values of AEP (87.16%) and EM (8.42 g/bird/d) were the highest performance with 10 g/kg of turmeric. The ratio of 1:4 was the best mating ratio for local quail breed with highest records of all hatching performances significantly.

Keywords: Turmeric; Egg production; Egg weight; Fertility; Mating ratio

1 Introduction

The prohibition of using antibiotics as feed additives in farm animals have forced farmers to replace them in order to produce animal products safely for human consumption. Turmeric is one of the herbs which is popular in recent years classified as phytogenic [1, 2] with significant bioactivity as an antimicrobial [3], antioxidants and anti-inflammatory [4], anti-inflammatory ([5,6]. Turmeric improves digestive nutrition, metabolism, and prevents biliary syndrome and anorexia in humans and livestock [7,8]. Further, it stimulates secretion bile acids through the blood vessels of the liver and the activity of lipase, amylase and protease, which have an important role in metabolism and improve digestion [9]. Turmeric also improves and helps restore liver function and lowers serum triglycerides, LDL cholesterol and blood glucose levels [10,4].

Turmeric has been studied comprehensively in laying hens [11,12,13], broiler chickens [14,15,16] ducklings [17] and quails [18,19]. Research on laying hens, offering turmeric powder up to a level of 0.4% per kg of feed was not able to increase egg production and quality [13]. In broilers, providing turmeric powder 1g / kg of feed increased body weight by 15.1% and decreased abdominal fat by 0.7% [15]. In laying quail, a mixture of turmeric and curcumin improves egg production performance and albumen weight [19]. In male chickens, turmeric at a level of up to 0.50% is able to increase the concentration and motility of semen for better cement production [20]. According to Liu et al. [2020][21] addition

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of 150 mg / kg curcumin in feed increases FSH (Follicle-Stimulating Hormone). In male fowls, feeding turmeric at the level of 0.25 and 0.50% increases the concentration of semen, especially semen plasma albumin and sperm motility [22]. Thus, assigning turmeric to female and male poultry as breeder stock will be able to increase fertility and hatchability. The male and female ratio factors in quails from the study by Ipek et al. [2004][23] proved that the male to female ratio significantly affected hatchability. The mating ratio of 1: 2 and 1: 3 produces the highest fertility and hatchability of fertile eggs compared to 1: 1 or 1: 4 or 1: 5. The mating ratio does not affect embryo mortality. In contrast to Narinc et al. [2013][24] a ratio of 1: 1 produces the highest fertility in colony cages, but a ratio of 1: 2 produces the highest fertility in individual cages. No hatchability information was realized with a ratio of 1: 1 to 5 with different rearing management. Santos et al. [2015][25] argued that fertility is influenced by the body weight of male and female broiler breeders. According to Narinc et al. [2013][24] highest fertility in male to female ratios of 1: 1 (92.21%) and 1: 2 (91.18%) compared to 1: 4 and 1: 5 in the colony housing system. According to El-Sheikh et al. [2016][26] that the highest fertility in mating ratio is a ratio of 1 to 3 in single cage housing and there is an interaction between these two factors. The narrower the male to female ratio, the less efficient it is in poultry management because a large number of males will increase the cost of feed. In addition, high cannibalism occurs because quails are very active in their behave and social dominance will also occur in the population. Thus, incorporating turmeric herb not only increases production but also increases fertility. From the existing literature study, there is no information about feeding a complete diet with liquid turmeric as an additive to quail breed feed which improves its performance. Mixing liquid turmeric in drinking water is proven ineffective according to the research results reported by Sadeghi [2012][27]. However, the advantage of liquid turmeric is that it does not require drying technology which is more expensive than the liquid one. This could reduce the income of the farmers. The objective of this study was to determine the mating ratios of Japanese quails and feeding with liquid turmeric which offer the best production performance and hatchability.

2 Material and methods

2.1 Animal and experimental management

The experimental study was conducted to examine the productive performance of laying Japanese quail when feeding a commercial diet mixed with liquid turmeric herb was assigned. The study was carried out at the teaching farm of Faculty of Animal Science, Mataram University, Indonesia. A total of 162 twelve –weeks-old local female and 27 male Japanese quails (*Coturnix coturnix Japonica*) were arranged in a completely randomized design. The treatments included factorial combinations of three liquid turmeric concentration and three mating ratios. The birds were randomly allocated to the three dietary treatments, which were replicated three times. The three different turmeric concentrations in diets were: 10 g/kg (Low Concentration: -LC), 15 g/kg (Medium Concentration: -MC) and 20 g/kg (High Concentration – HC). A commercial layer quail feed containing 18% crude protein and 3000 kcal/kg metabolizable energy was used. The ratios of natural mating were: 1: 4, 1: 6 and 1: 8 respectively as the determination of this ratio is based on the results of research on Japanese quails [28] and on laying ducks [29]. The density of one quail was 0.31, 0.28 and 0.25 m^2/bird per square meter of floor area for mating ratios of 1:4, 1:6 and 1:8 respectively. The experiment was carried out for 12 wks.

2.2 Preparing liquid turmeric

Liquid turmeric was prepared from fresh turmeric purchased from the local market, then the skin was removed, washed, blended and watered according to treatments. Squeezed, the mixed water was taken to be sprayed into the commercial layer quail diet. The low, medium and high concentration level are meant that 5 g/kg (0.5%), 10 g/kg (1%) or 20 g/kg (2%) calculated on dried matter basis. Chemical analysis of fresh turmeric according to AOAC [2005][30]

2.3 Experimental incubation

A simple and conventional incubation was applied for measuring hatchability performance. Three small incubators with approximately capacity of 900 quail eggs were used and hatching eggs were collected starting at the 3th week of experimental period. A total of 540 eggs were allotted to three incubators. Prior to incubation, the eggs have stored at room temperature (80% relative humidity and cleaned using a soft tissue and then set in the incubators for hatching. The temperature and relative humidity of the incubator were maintained between 38 to 39˚C and 70 to75% respectively. The turning of the egg was applied 3 times a day with 8 hour intervals. To determine fertility, dead in-germ and dead in-shell, candling was made on the day 3^{th,} 8th and 15th respectively according to Pedroso et al. [2006][31]. We followed the definition of abnormal quail chicks as stated by Joseph and Moran [2005][32] and Rashid *et al*. [2009][33] that blindness, exposed navels, small in size (low post-hatching weight), defect in shape and other abnormalities were culled. The hatching process was replicated in three times. Percentage of fertility and hatchability were calculated using the formula: fertility = number of fertile eggs/total eggs set x 100%; hatchability (fertile egg basis) or HF = number of hatched quails/number of fertile eggs x 100%; hatchability (egg set basis) or HS = number of hatched

quails/number of eggs set x100%; dead in-germ or DG = number of dead embryo/number of eggs set x 100%; dead in-shell or DS = number of dead quails in shell /number of egg sets x 100%; then normal quail chicks = number of normal quail chicks/number of hatched quail chicks x 100%. This former was saleable

2.4 Measurements

The production performances were determined as follows. Feed intake (g) was calculated by subtracting feed residue weights from feeders from the total feed. Egg production (%) was recorded daily and was calculated on weekly basis of cumulative production. Egg weight (g) was documented on individual egg basis. Egg mass (g) was calculated by multiplying average egg weight and egg production percentage. Feed conversion ratio (FCR) was calculated by dividing the total of feed consumed with the total egg mass. Body weight at the beginning and end of the study was recorded.

2.5 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) following the General Linear Model (GLM) procedure of SPSS version 16 [2009][34]. The differences between the means of groups were identified by the test of Duncan's at 5% significant level.

3 Results and discussion

3.1 Production performance

The effects of different turmeric concentration and mating ratios on production performance are presented in Table 1. Feed intake was influenced ($P<0.001$) by liquid turmeric concentration. Low liquid turmeric concentration (LC) increases feed intake with better feed conversion than MC and HC. The higher the concentration of turmeric, the lower the feed consumption. In other words, a linier reduction in feed intake was found with increasing turmeric concentration into laying quail diets from 5 to 20 g/kg. This is because high concentrations affect the palatability. Turmeric 10 g/kg (LC) feed (in dried matter basis) increased feed intake by 5.0 g per bird per day compared to 15 g/kg (MC) concentration and 2.5 g higher than HC. This natural additive has been founded to affect the digestive tract worked more efficiently. As a result, it would have been emptied earlier and feed consumption will have been promoted [9] Working with layer chickens, Park et al [2012][35] found turmeric powder up to 0.5% did not effect on feed intake. Hassan [2016][11] observed inclusion turmeric powder into laying hens up to 4% did not affect the aroma, the palatability and the appetite of the birds. The results are almost similar with the findings of Kafi et al. [2018] [16] and Ekine et al.[2020][36] who worked with broilers. It have been observed previously by Durrani et al. [2006][37] that significantly lower feed intake of broilers with turmeric supplementation. They also showed that 5g/kg (0.5%) turmeric with the lowest feed intake and the highest weight gain offered the best improved feed efficiency. Thus, the level of turmeric will be effective on feed intake when the palatability is not changed. This efficiency could also be related to the ability of turmeric restrain and reduce the growing and colonization of various pathogenic and non-pathogenic species of bacteria as reported by Nascimento et al. [2019][38]. They found that turmeric increased intestinal crypt depth in the duodenum which indicated the recovery of digestive tract when the birds were attacked by bacteria.

As for sex ratio effect, this study observed, there was no differences in egg production, egg weight and egg mass were noticed due to turmeric liquid supplemented to laying quail hen diet from 1 to 2% g/kg of feed although LC offered the highest egg production (87.16%) and egg mass production (8.42 g/bird/d). However, the ratios of 1:4 and 1:8 offered the higher feed intake very significantly ($P<0.001$) by 11.3 and 9.6 g/bird respectively than the ratio of 1:6. However, the ratio of 1:6 was better feed utilization than 1:4 and 1:8 groups during the study. This relates to the higher egg production ($P=0.135$) and lower feed intake ($P<0.001$) in 1:6 mating ratio. Effect of sex ratio on egg production traits in this study found no significant differences at sex ratios from 4 to 8 females to 1 male. In contrary to earlier reported by Khalil et al. [2011][39] in Japanese quail and showed decreasing sex ratio (1:6 or 1:8) resulted in reducing laying rate compared to higher sex ratio (1:2 or 1:4). These results are in agreement with Haghighi et al. [2016] [40] who work with broiler breeders found male fowl have no effect on egg production

The total egg production was 82.32%; 86.19% and 84.46% for sex ratios 1:4, 1:6 and 1:8 (male :female) respectively and was not affected by mating ratios ($P=0.437$). The interaction effects between turmeric concentration of diet and sex ratio were not significant for all parameters of production performance.

Table 1 Productive performance of laying quails as influenced by varying levels of turmeric in the ration and sex ratios from 10 to 22 wks. of age

	Feed intake (g/bird/day)	Egg production (%)	FCR (g of feed/g of egg mass)	Egg weight (g/egg)	Egg mass production (g/bird/day)
Turmeric levels (g/kg))					
LC (10)	45.6[a]	87.16	4.891	10.69	8.42
MC (15)	43.1[b]	84.68	4.919	10.77	7.73
HC (20)	40.6[c]	81.14	4.668	10.80	7.93
SEM	0.889	2.21	0.161	0.375	0.241
Sex ratio (SR)					
1 : 4	47.4[a]	82.32	5.316a	10.78	8.20
1 : 6	36.1[b]	86.19	3.992b	10.71	7.94
1 : 8	45.7[a]	84.46	5.170a	10.77	7.95
SEM	0.889	3.011	0.166	0.375	0.245
Turmeric concentration x sex ratio interaction					
LC (10) -1 : 4	52.2	88.63	5.349	9.83	8.76
LC (10) -1 : 6	38.3	86.86	4.155	9.28	8.32
LC (10) -1 : 8	46.4	85.98	5.167	9.07	8.18
MC (15)-1 : 4	46.6	81.06	5.313	8.75	7.73
MC (15)-1 : 6	36.5	87.37	4.069	9.11	7.76
MC (15)-1 : 8	46.3	85.60	5.373	8.80	7.71
HC (20)-1 : 4	43.5	77.27	5.285	8.52	8.09
HC (20)-1 : 6	33.7	84.34	3.752	9.08	7.73
HC (20)-1 : 8	44.6	81.81	4.967	9.09	7.97
SEM	1.748	3.688	0.426	0.086	0.345
Probability					
Turmeric level	<.001	0.135	0.489	0.249	0.058
Sex ratio	<.000	0.437	<.000	0.871	0.485
Turmeric x SR	0.227	0.726	0.944	0.539	0.950

a-b means with different superscript within column turmeric concentration and sex ratios differed significantly (P<0.0001); LC : Low concentrate ; MC : Medium concentrate ; HC : High concentrate ; SEM- Standard Error of Means.1:4 (male: female)

3.2 Hatching performance

The hatching performance (fertility, hatchability, dead in-germ, dead in- shell and normal chicks) of local quails as influenced by liquid turmeric concentration and sex ratios and their interactions is presented in Table 2. Turmeric levels affect hatching performance except egg weight and egg mass weight. Sex ratios affect all performance, and its interaction affects fertility only.

Records of embryonic mortality (DG-25.3%) and dead in-shell (DS-6.08%) were least (P<0.05) in 1:4 mating ratio group (Table 2). In other words, the mating ratio of 1:4 showed the best hatching performance in this study.

Table 2 Hatching performance of laying quails as influenced by different concentration of turmeric liquid in the ration and mating ratios

Item	F	HF	HS	DG	DS	NC
	%					
Turmeric levels (g/kg)						
LC (10)	91.29[a]	72.76[b]	66.66[b]	33.3[b]	6.600	90.54
MC (15)	91.85[a]	75.89[a]	69.81[a]	30.1[c]	7.071	90.62
HC (20)	88.88[b]	69.02[c]	61.66[c]	38.3[a]	7.517	88.88
SEM	0.466	0.727	0.842	0.842	0.603	0.868
Sex ratio (SR)						
1 : 4	94.62[a]	78.82[a]	74.63[a]	25.3[c]	6.082[c]	92.23[a]
1 : 6	90.92[b]	74.33[b]	67.59[b]	32.4[b]	6.323[b]	91.48[b]
1 : 8	86.48[c]	64.51[c]	55.93[c]	44.1[a]	8.782[a]	86.33[c]
SEM	0.466	0.727	0.063	0.842	0.603	0.868
Turmeric x sex ratio interaction						
LC (10) -1 : 4	95.55	80.19[b]	76.66[b]	23.3[h]	4.08	94.86
LC (10) -1 : 6	91.11	74.39[e]	67.77[e]	32.2[e]	6.10	91.78
LC (10) -1 : 8	87.22	63.70[h]	55.55[h]	44.4[b]	9.61	84.97
MC (15) -1: 4	95.00	81.87[a]	77.77[a]	22.2[i]	7.02	91.42
MC(15) -1 : 6	91.67	74.55[c]	68.33[d]	31.6[f]	5.45	92.68
MC (15)-1 : 8	88.88	71.24[g]	63.33[g]	36.6[c]	8.73	87.76
HC (20) -1 : 4	93.33	74.50[d]	69.44[c]	30.5[g]	7.14	90.40
HC (20) -1 : 6	90.00	74.06[f]	66.66[f]	33.3[d]	7.41	89.99
HC (20) -1 : 8	83.33	58.60[i]	48.89[i]	51.1[a]	8.00	86.26
SEM	0.808	0.060	0.842	1.458	0.109	0.097
Probability						
Turmeric level	<.001	<0.000	<.0001	<0.000	0.571	0.303
Sex ratio	<.0001	<0.000	<.0001	<0.000	<0.009	<.0001
Turmeric x SR	0.124	<0.002	<0.005	<0.005	0.166	0.269

a-i means with different superscript within column turmeric concentration and sex ratios differed significantly P<0.0001); LC: Low concentration ; MC : Medium concentration ; HC : High concentration; F : Fertility; HF: Hatchability (fertile egg basis); HS : Hatchability (egg set basis); DG: Dead in-germ; DS: Dead in-shell; NC : Normal quails; SEM- Standard Error of Means

It was revealed that LC and MC diets showed 2.41% and 2.97% higher fertility than HP diet (P<0.001). Hatching records of DS and NC were higher in MC and HC than LC although these were statistically not significant. The highest percentage of fertility (91.85%) and hatchability rate (75.89%) were recorded at feeding MC turmeric liquid diet or at mating ratio of 1:4. Lower fertility with higher mating ratios may be possible due to preferential mating behaviors [41]. In this study, as it is indicated in Table 2, both hatchability (HF and HS) were improved by decreasing the number of males in the mating ratio. These results support the finding of Ayoola et al. [2017][28] who investigated the effect of mating ratio on the hatching characteristics of Japanese quails. Similar finding was reported by Indarsih et al. [2019][29] who investigated in local laying ducks. They found an improvement in fertility of mating ratio 1:4 by about 4.3% and 10.4% compared to sex ratios of 1: 5 and 1:6 respectively. HF and HS of sex ratio of 1: 4 were improved by 2.2% and 10.1% and by 9.5% and 20.7% compared to sex ratios of 1: 5 and 1: 6 respectively. The study was also consistent with those of Narinc et al. [2013][24], who noted that the percentage fertility increased with decreasing mating ratios However,

these results are contradictory to the study reported by Haghighi et al. [2016][40] in broiler breeders. They investigated the effect of three mating ratios (1M : 13.3F, 1M: 11.6F and 1M: 10.5F) in a deep litter system. It was concluded that increasing the sex ratio improved hatchability as a result of more frequent sexual interactions of males and females. Thus, it seems that the effect of sex ratios on hatching performance will be different, and was affected by type of poultry and housing system. Razee et al. [2016][42] provided evidence to show that rearing system had significant impact on the performances (body weight, feed intake and feed conversion) of growing Japanese quails. In addition, cage system was better than litter system due to their active behaviors. For the males, in general there is positive correlation between body weight and semen quality [43] Although we did not weigh the birds, the high feed intake shown in the mating ratio of 1:4 (Table 1), we can assume to correlate between the higher body weight with the testicular weight. And the success rate of mating was depended on the number of aggressive males. However, more and over aggressive males leads to the failure in mating process and this is the biggest problem in keeping quails, usually many male quails cause stress and aggressive pecking due to the struggle for one female [44].

4 Conclusion

This study revealed that 10 g of turmeric /kg of feed supplementation in quail diet showed the highest values of AEP (87.16%) and EM (8.42 g/bird/d). The ratio of 1:4 was the best mating ratio for local quail breed with highest records of all hatching performances significantly. .

Compliance with ethical standards

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Disclosure of conflict of interest

The authors of the paper declare that they have no conflict of interest.

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