Performance and carcass characteristics of Japanese quail as affected by sex or mannan oligosaccharides and calcium propionate

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Abstract

The effect of sex and the supplementation of the prebiotic, mannan oligosaccharides (MOS), the acidifier, calcium propionate (CPr) or their combination in the feed of Japanese quail (*Coturnix japonica*) on their performance and carcass quality was examined in this experimentation. Three hundred, 1-day old Japanese quail were divided into four groups with three replicates each. One group that served as control received the basal diet. The three experimental diets consisted of the basal diet to which either 6 g CPr/kg, 2 g MOS/kg or both 2 g MOS/kg and 6 g CPr/kg was added. The body weight, feed consumption, feed conversion ratio (kg feed/kg weight gain) and mortality were examined at weekly intervals. At the end of the 42-day feeding period the birds were slaughtered, the carcasses were processed and the carcass weight, carcass dressing percentage and carcass part percentages were calculated. Also, the breast meat composition and its fatty acid profile were analyzed. Results showed that the female quail had a higher body and carcass weight and liver to live weight percentage, whereas they had lower carcass dressing percentage than males. The dietary addition of MOS increased body and carcass weight, whereas it decreased liver to live weight percentage and crude fat content of the breast meat. The dietary addition of CPr lowered carcass dressing percentage and ash content of the breast meat. Interactions between the two examined supplements were observed in feed consumption, feed conversion ratio and carcass weight. An interaction between MOS and sex was observed on carcass weight. It was concluded that MOS and calcium propionate can be used effectively in Japanese quail diets.

Keywords: Prebiotic, acidifier, *Coturnix japonica*, performance, meat quality, fatty acids profile
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Introduction

The inclusion of antibiotic growth promoters in the feed of farm animals has been banned in the European Union since 2006 (EU, 2005), while their use is under consideration in other countries around the world due to the potential development of antibiotic resistant bacteria (Jukes *et al*., 1956; Greko, 2001; Spais *et al*., 2001; Roe & Pillai, 2003). Consequently there has been a growing interest in the identification and evaluation of alternative feed additives that would satisfy consumers' demands and would be closer to environmentally friendly farming practices. Two categories of such additives are the prebiotics such as the mannan oligosaccharides (MOS) and the acidifiers.

The MOS, which are used as feed additives, are complex substances derived mainly from the cell walls of the yeast, *Saccharomyces cerevisiae* (Spring *et al*., 2000; Hooge, 2004; Kogan & Kocher, 2007). They comprised of proteins (12.5%), glucanes (30%), mannans (30%) and phosphoric acid. These substances, when included in the diet, adhere to pathogenic bacteria who have type-I fimbriae and consequently remove them from the gut. In addition, MOS increase the height, the uniformity and the integrity of the intestinal villi and can augment the immune response of the animal. As a result, health and performance of the animal improve (Ferket, 2004; Hooge, 2004; Ghosh *et al.*, 2007; Kogan & Kocher, 2007; Rehman *et al*., 2009).

The acidifiers, which are generally organic acids and their salts, are substances naturally occurring in animal cells, where they exert an important role in the metabolism (Kirchgessner & Roth, 1998; Lückstädt *et al*., 2004). Organic acids such as formic and propionic acid have mainly been used to sanitize animal feed. The dietary supplementation of acidifiers can modify the pH of the feed as well as the digestive tract of the animal. Also, the organic acids in their un-dissociated form are able to pass through the bacterial cell membrane into the cell, where they dissociate in H^+ ions which lowers the pH of the cell and $RCOO^-$ ions that can disrupt normal cell function and protein synthesis. The multiplication of the affected microorganisms

is less efficient, so that their population in the digestive tract is diminished (Lückstädt *et al*., 2004; Freitag, 2007; Lückstädt, 2008).

Studies concerning the use of MOS and acidifiers and especially their combined use in the Japanese quail (*Coturnix japonica*) nutrition are limited. Therefore, the first objective of the present study was to evaluate the efficiency of the dietary supplementation of MOS and the acidifier, calcium propionate (CPr), on the growth performance of Japanese quail. The second objective was to investigate whether this supplementation could have an effect on carcass quality. The third objective was to examine the interaction between sex and the above dietary treatments.

Materials and Methods

Three hundred, 1-day old Japanese quail, as hatched, were used in this study. The birds were individually weighted and assigned randomly to four treatment groups with three subgroups (replicates) of 25 birds each. All 12 subgroups were housed in separate wire suspended cages.

To meet the nutrient requirements of growing quail, a complete basal diet based on maize, soyabean meal and wheat was formulated according to Florou-Paneri (1989) and NRC (2004). Table 1 presents the ingredients and the composition of this basal diet, in powder form, which was analyzed according to AOAC (2005) for crude protein, crude fat, crude fibre, moisture and ash content. Also the calcium, total phosphorus, lysine, methionine plus cystine and metabolisable energy content were calculated from the composition of the feed ingredients, according to Novus (1992), NRC (1994) and Spais *et al*. (2002).

Table 1 Ingredients and composition of basal diet

Ingredients	g/kg
Maize	452.6
Soyabean meal	320.0
Wheat	100.0
Corn gluten meal	79.7
Calcium carbonate	14.3
Dicalcium phosphate	11.4
Soybean oil	10.8
Lysine	3.7
Vitamin and trace mineral premix*	3.5
Salt	2.1
Sodium bicarbonate	1.9
Chemical analysis	
Dry matter	914
Crude protein	238
Crude fat	28
Crude fibre	36
Ash	62
Calculated analysis	
Calcium	8.5
Total phosphorus	6.5
Lysine	13
Methionine & cystine	8.7
Metabolisable energy, MJ/kg	12.34

* Supplying per kg feed: 14000 IU vitamin A, 5000 IU vitamin D_3, 30 mg vitamin E, 13 mg vitamin K, 3 mg vitamin B_1, 8 mg vitamin B_2, 3 mg vitamin B_6, 20 μg vitamin B_{12}, 85 mg niacin, 20 mg pantothenic acid, 2 mg folic acid, 200 μg biotin, 10 mg vitamin C, 960 mg choline cloride, 100 mg Zn, 116 mg Fe, 120 mg Mg, 20 mg Cu, 0.2 mg Co, 1 mg I, 0.3 mg Se.

The basal diet was given to one of the groups that served as the control (Group A). The diets given to the other three groups were also based on this basal diet, but in the feed of group B an additional 6 g CPr/kg was added, in the feed of group C an additional 2 g MOS/kg was added and in the feed of group D both 6 g

CPr/kg and 2 g MOS/kg were added. The CPr supplement used was "Calcium propionate granules 99%" from Dr. Paul Lohmann, Emmerthal, Germany. The MOS supplement used was "MOS 500" from Ultra Biologics Inc., Ragaud, QC, Canada.

Feed and drinking water were offered to birds *ad libitum* and the feed consumption was recorded daily. Conventional rearing and management procedures were applied throughout the feeding period that lasted 42 days. The quail were handled according to the principles of the Greek Directorate General of Veterinary Services for the care of animals in experimentation.

All birds were individually weighted at weekly intervals. The sex of each bird was also recorded in the last three weekly measurements. The feed intake per bird per day and the feed conversion ratio (kg feed/kg weight gain, FCR) were calculated at weekly intervals. Mortality was recorded daily.

On day 42 of age, one male and one female bird from each replicate were randomly selected, weighted and slaughtered under commercial conditions. After dressing the carcass weight was measured and the dressing percentage calculated. The carcass was chilled at 1 °C for 12 h and, then it was separated into different parts, *viz.* as breast, back, neck, legs and wings, whose weight was recorded, and their percentages to carcass weight were calculated. The weight of liver and heart was also recorded and their percentages to live weight were calculated. All these parts were sealed in polyethylene bags and frozen at -20 °C for further analysis.

From the frozen breasts, the meat was separated from the bones, it was homogenized and was analyzed for crude protein, crude fat, moisture and ash according to the guidelines of AOAC (2005).

The fatty acid composition of the breast meat was also determined according to Folch *et al*. (1957) and AOAC (2005). Separation and quantification of the methyl esters of the fatty acids was carried out with a gas chromatographic system (TraceGC model K07332, ThermoFinnigan, ThermoQuest, Milan, Italy) equipped with a flame ionization detector, a model CSW 1.7 chromatography station (CSW, DataApex Ltd, Prague, Czech Republic) and a fused silica capillary column, 30 m x 0.25 mm i.d., coated with cyanopropyl polysiloxane (phase type SP-2380) with a film thickness of 0.20 μm (Supelco, Bellefonte, PA, USA). The chromatographic conditions were:

- Carrier: N_2, Flow: 1 mL/min;
- Oven: Temperature 70 °C for 0.5 min, increase 30 °C/min to 180 °C for 10 min, increase 5 °C/min to 225 °C for 10 min;
- Inlet temperature: 250 °C, detector temperature: 250 °C;
- Injection: 2 μL, with split 1/40.

The statistical analysis was performed using the General Linear Model function of the SPSS (2007) Ver. 16.0.1 statistical package (SPSS Inc., Chigaco, IL, USA). The experimentation was based on a factorial model 2 x 2 (MOS x acidifier) or 2 x 2 x 2 (MOS x acidifier x sex). The one-way analysis of variance for the four experimental groups was performed. Also, the two-way analysis of variance and three-way analysis of variance (when applicable) were performed, using as main effects the inclusion of MOS in the feed (two levels), the inclusion of CPr in the feed (two levels) and the sex of the birds (two levels, when applicable). A value of $P \leq 0.050$ was considered significant. The Levene's test was applied to test the homogeneity of the variances. Tukey's test was applied to determine statistical differences between the means.

Results and Discussion

The effect of sex and dietary supplementation of MOS and CPr on the body weight is presented in Table 2. During the six weeks of the experimentation there were no differences ($P > 0.050$) in body weight between the four groups. The addition of MOS resulted in a higher ($P \leq 0.050$) body weight on day 14 of age and on the last day of the experiment (day 42). Similar results were observed in previous studies by Guclu (2003), Parlat *et al*. (2003) and Oguz & Parlat (2004) who also observed higher body weight for birds that consumed MOS, whereas Ghosh *et al*. (2007) and Sarica *et al*. (2009) did not observe significant differences. In contrast, the addition of CPr resulted in a tendency for the birds to have lower body weights at days 28 and 35 of age. Other researchers (Sacakli *et al*., 2006; Çakir *et al*., 2008) did not find any significant difference in the body weight of birds fed acidifiers, whereas Ghosh *et al*. (2007) and Ocak *et al*. (2009) found higher body weights for birds fed acidifiers. Furthermore, the female birds had higher ($P \leq 0.010$) body weights on days 35 and 42 of age, which is to be expected since female quail are normally heavier than males (Yannakopoulos & Tserveni-Gousi, 1986; Shim, 2005). Finally, no interaction ($P > 0.050$) between the main effects was

observed, which is similar to the findings of Loddi *et al*. (2002) and Pelicano *et al*. (2004), whereas Ghosh *et al*. (2007) reported improved body weight for birds fed a combination of MOS and sodium butyrate.

Table 2 Effect of sex and dietary supplementation of MOS, CPr or their combination on body weight of Japanese quail (mean ± s.d.)

	Body weight (g) of quail on day of age:					
	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
Quail Groups*						
Group A	19.3 ± 0.4	48.3 ± 2.0	67.8 ± 0.6	122.3 ± 3.7	154.6 ± 4.6	172.0 ± 13.4
Group B	20.3 ± 1.2	48.0 ± 1.3	63.9 ± 9.1	120.2 ± 7.5	152.3 ± 7.4	175.6 ± 21.3
Group C	19.2 ± 0.7	51.2 ± 1.4	70.6 ± 8.2	129.6 ± 8.1	160.9 ± 6.7	178.5 ± 14.0
Group D	18.8 ± 1.3	50.0 ± 1.2	66.0 ± 4.8	120.8 ± 5.4	154.2 ± 6.2	180.8 ± 14.5
P value	0.392	0.091	0.653	0.071	0.132	0.340
Effect of MOS						
0 g/kg	19.8 ± 1.0	48.2^{a} ± 1.5	65.8 ± 6.1	121.2 ± 5.7	153.4 ± 6.0	173.8^{a} ± 17.1
2 g/kg	19.0 ± 1.0	50.6^{b} ± 1.3	68.3 ± 6.5	125.2 ± 8.0	157.5 ± 7.1	179.7^{b} ± 13.7
P value	0.208	0.021	0.526	0.178	0.088	0.025
Effect of CPr						
0 g/kg	19.3 ± 0.5	49.8 ± 2.2	69.2 ± 5.4	125.9 ± 7.1	157.7 ± 6.4	175.2 ± 13.5
6 g/kg	19.6 ± 1.4	49.0 ± 1.6	65.0 ± 6.6	120.5 ± 6.2	153.2 ± 6.6	178.2 ± 17.6
P value	0.619	0.419	0.296	0.070	0.063	0.233
Effect of sex						
Male	-	-	-	121.5 ± 7.4	152.1^{a} ± 6.7	163.1^{a} ± 6.6
Female	-	-	-	124.8 ± 6.7	158.8^{b} ± 5.1	190.3^{b} ± 7.1
P value	-	-	-	0.233	0.009	0.000
Interaction (P)						
MOS x CPr	0.294	0.595	0.934	0.242	0.346	0.795
MOS x Sex	-	-	-	0.843	0.542	0.202
CPr x Sex	-	-	-	0.839	0.385	0.094
MOS x CPr x Sex	-	-	-	0.774	0.805	0.220

MOS - mannan oligosaccharides; CPr - Calcium propionate, s.d. - standard deviation.
Means within column with a superscript in common within group or effect do not differ significantly at $P \leq 0.05$.
* Groups: A = control; B = 6 g CPr/kg; C = 2 g MOS/kg; D = 6 g CPr/kg + 2 g MOS/kg.

Table 3 presents the effect of the dietary supplementation of MOS and CPr on the daily feed consumption of the growing quail. During the second and the third week of the experiment, a higher ($P \leq 0.050$) feed consumption was observed for group C compared to group B. Also, during the fourth week a higher ($P \leq 0.050$) feed consumption was observed for groups C and D compared to group B. Moreover, the addition of MOS resulted in higher ($P \leq 0.050$) feed consumptions during the second, third and fourth weeks. There is considerable variation in the results reported by other researchers, since Rosen (2007a; b) in two comparative studies reported on average lower feed consumption for birds fed MOS *vs.* controls, whereas Oguz & Parlat (2004) reported a higher feed consumption for birds fed MOS, while Ghosh *et al*. (2007) and Sarica *et al*. (2006) found no significant differences. The addition of CPr resulted in a lower ($P \leq 0.050$) feed consumption during the second and third weeks. Ao *et al*. (2009) found lower feed consumption due to the dietary supplementation of acidifiers in the feed of birds, whereas other researchers (Parlat *et al*., 2003; Sacakli *et al*., 2006; Ghosh *et al*., 2007; Çakir *et al*., 2008) did not find difference or reported (Ocak *et al*., 2009) an increase in feed consumption. Finally, interaction ($P \leq 0.010$) between MOS and CPr was observed during the fourth week, which showed that the combined addition of MOS and CPr resulted in higher feed consumption than the single addition of each substance. Brzóska *et al*. (2007) and Ghosh *et al*. (2007) found no significant interaction between MOS and acidifiers.

The results concerning the FCR are presented in Table 4. There was no difference ($P > 0.050$) in the FCR of the four groups during the six weeks of the experimentation. Neither the addition of MOS, nor the

addition of CPr resulted in any effect (P >0.050). Guclu (2003), Parlat *et al*. (2003) and Ghosh *et al*. (2007) found lower FCR for birds fed MOS. Other researchers (Sacakli *et al*., 2006; Çakir *et al*., 2008; Ocak *et al*., 2009) reported no significant difference in birds fed acidifiers, whereas Ghosh *et al*. (2007) and Senkoylu *et al*. (2007) observed lower FCR. Also, an interaction (P ≤0.050) between MOS and CPr was noticed during the fourth week which shows that the combined addition of MOS and CPr resulted in a higher FCR than the addition of each substance separately. In contrast to these findings, Pelicano *et al*. (2004), Brzóska *et al*. (2007) and Ghosh *et al*. (2007) did not find any significant interaction between MOS and acidifiers. Finally, mortality was not affected (P >0.050) throughout the experimental period in all groups.

Table 3 Effect of dietary supplementation of MOS and CPr or their combination on daily feed consumption of Japanese quail (mean ± s.d.)

	Daily feed consumption (g) on week of age:					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Quail Groups*						
Group A	3.04 ± 0.17	9.66^{ab} ± 0.36	9.64^{ab} ± 0.26	23.01^{ab} ± 0.61	13.59 ± 1.67	18.73 ± 4.09
Group B	3.16 ± 0.10	8.98^{a} ± 0.24	8.50^{a} ± 0.49	20.37^{a} ± 0.15	15.25 ± 2.16	21.05 ± 1.87
Group C	3.27 ± 0.31	10.24^{b} ± 0.65	10.27^{b} ± 0.80	23.24^{b} ± 1.63	13.98 ± 1.75	20.33 ± 2.90
Group D	3.10 ± 0.04	9.72^{ab} ± 0.16	9.28^{ab} ± 0.29	23.73^{b} ± 1.28	13.15 ± 1.31	21.96 ± 1.04
P value	0.492	0.028	0.016	0.021	0.524	0.551
Effect of MOS						
0 g/kg	3.10 ± 0.14	9.32^{a} ± 0.46	9.07^{a} ± 0.71	21.69^{a} ± 1.50	14.42 ± 1.95	19.89 ± 3.11
2 g/kg	3.19 ± 0.22	9.98^{b} ± 0.51	9.78^{b} ± 0.77	23.48^{b} ± 1.34	13.56 ± 1.45	21.14 ± 2.14
P value	0.443	0.020	0.042	0.021	0.420	0.447
Effect of CPr						
0 g/kg	3.16 ± 0.26	9.95^{a} ± 0.57	9.95^{a} ± 0.64	23.13 ± 1.11	13.78 ± 1.54	19.53 ± 3.29
6 g/kg	3.13 ± 0.08	9.35^{b} ± 0.44	8.89^{b} ± 0.56	22.05 ± 2.02	14.20 ± 1.97	21.50 ± 1.44
P value	0.833	0.029	0.007	0.123	0.688	0.246
Interaction (P)						
MOS x CPr	0.201	0.737	0.811	0.036	0.252	0.830

MOS - mannan oligosaccharides; CPr - Calcium propionate; s.d. - standard deviation.
Means within column with a superscript in common within group or effect do not differ significantly at P ≤0.05.
* Groups: A = control; B = 6 g CPr/kg; C = 2 g MOS/kg; D = 6 g CPr/kg + 2 g MOS/kg.

The growth promoter effects of MOS and acidifiers are attributed to their ability to limit the growth of potential pathogens in the digestive tract of animals (Lückstädt *et al*., 2004; Bozkurt *et al*., 2008; Lückstädt, 2008). Thus, the digestive tract remains healthy, functions more efficiently and more nutrients are available for absorption. It can, therefore, not be excluded that the beneficial effects of feed supplements might be observed under less hygienic housing conditions and/or when using a less digestible diet (Miguel *et al*., 2002; Sims *et al*., 2004; Hernández *et al*., 2006; Baurhoo *et al*., 2007; Bozkurt *et al*., 2008).

The effect of sex and supplementation of MOS and CPr in the feed of the growing quail on their carcass quality is presented in Table 5. No effect (P >0.050) was observed for the parameters measured between the four experimental groups. The addition of MOS resulted in a higher (P ≤0.010) carcass weight and lower liver percentage, but had no effect (P >0.050) on the other parameters. In similar experiments Bozkurt *et al*. (2008), Ghosh *et al*. (2008), Konca *et al*. (2009) and Sarica *et al*. (2009) reported no significant improvement in birds due to the supplementing of MOS on carcass weight, carcass dressing percentage or carcass part percentage. The birds that consumed CPr had lower (P ≤0.050) carcass dressing percentage, but the addition of CPr in the feed had no effect (P >0.050) on the other measured parameters. Ocak *et al*. (2009) reported higher carcass weights; Leeson *et al*. (2005) reported higher breast percentages, whereas Sacakli *et al*. (2006), Çakir *et al*. (2008) and Ghosh *et al*. (2008) did not report any significant difference on the carcass characteristics of birds fed acidifiers. Furthermore, the sex of the birds had a significant effect on the carcass weight and carcass dressing percentage, since the female birds had higher (P ≤0.001) carcass weight

but lower (P ≤0.001) carcass dressing percentage than males. Also, the female birds had a higher (P ≤0.001) liver percentage than the male birds. These results can be attributed to the anatomical differences between male and female birds (Yannakopoulos & Tserveni-Gousi, 1986; Shim, 2005). In addition, interaction (P ≤0.050) between MOS and CPr was observed on the carcass weight, which shows that the combined addition of MOS and CPr resulted in smaller increases of carcass weight than the single addition of MOS, compared to controls. Furthermore, interaction (P ≤0.050) between MOS and sex was observed on the carcass weight, which shows that the addition of MOS in the feed resulted in a higher increase of carcass weight for male birds than for female birds. Finally, interactions (P ≤0.050) between MOS, CPr and sex were observed on carcass weight. According to Ferket (2004), the positive effect of growth promoters on carcass quality may be attributed to the improvement of the animal's health and the more efficient utilization of the feed nutrients.

Table 4 Effect of dietary supplementation of MOS and CPr or their combination on feed conversion ratio (g feed/g gain) of Japanese quail (mean ± s.d.)

	Feed conversion ratio of quail on week of age:					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Quail Groups*						
Group A	1.64 ± 0.17	2.12 ± 0.09	2.55 ± 0.03	2.68 ± 0.03	2.74 ± 0.11	3.22 ± 0.22
Group B	1.75 ± 0.17	2.08 ± 0.05	2.59 ± 0.41	2.51 ± 0.14	2.69 ± 0.16	3.23 ± 0.16
Group C	1.80 ± 0.34	2.09 ± 0.08	2.59 ± 0.23	2.62 ± 0.03	2.72 ± 0.07	3.21 ± 0.10
Group D	1.86 ± 0.20	2.07 ± 0.06	2.59 ± 0.19	2.71 ± 0.11	2.70 ± 0.08	3.11 ± 0.15
P value	0.694	0.845	0.993	0.123	0.957	0.795
Effect of MOS						
0 g/kg	1.69 ± 0.16	2.10 ± 0.07	2.57 ± 0.26	2.60 ± 0.13	2.72 ± 0.12	3.22 ± 0.17
2 g/kg	1.83 ± 0.25	2.08 ± 0.06	2.59 ± 0.19	2.66 ± 0.09	2.71 ± 0.07	3.16 ± 0.13
P value	0.338	0.594	0.865	0.268	0.929	0.513
Effect of CPr						
0 g/kg	1.72 ± 0.26	2.10 ± 0.08	2.59 ± 0.23	2.65 ± 0.05	2.72 ± 0.07	3.21 ± 0.15
6 g/kg	1.80 ± 0.18	2.08 ± 0.05	2.59 ± 0.19	2.61 ± 0.15	2.70 ± 0.08	3.17 ± 0.15
P value	0.542	0.534	0.871	0.463	0.642	0.668
Interaction (P)						
MOS x CPr	0.831	0.784	0.869	0.042	0.812	0.563

MOS - mannan oligosaccharides; CPr - Calcium propionate; s.d.- standard deviation.
Differences between the means within column within group or effect were not significant.
* Groups: A = control; B = 6 g CPr kg; C = 2 g MOS/kg; D = 6 g CPr/kg + 2 g MOS/kg.

Table 6 presents the effect of the supplementation of MOS and CPr in the feed of the growing quail on the composition of their breast meat. The crude fat content of group B was higher (P ≤0.050) than that of group D, but the crude protein, the moisture and the ash content were not affected (P >0.050). The addition of MOS resulted in a lower (P ≤0.050) crude fat percentage which is in agreement with the results of Ghosh *et al*. (2008) who found significantly lower crude fat percentage in the meat of quail fed MOS. It has been reported that dietary oligosaccharides diluted the bile salt and reduced the lipid digestibility (Maisonnier *et al.*, 2003; Ghosh *et al.*, 2008). The addition of CPr resulted in a lower (P ≤0.050) ash percentage and in a tendency for the breast meat to have a higher moisture percentage. Lessard *et al*. (1993) and Ghosh *et al*. (2008) found lower crude fat percentages for birds fed acidifiers, while Samanta *et al*. (2010) noticed

Table 5 Effect of sex and dietary supplementation of MOS, CPr or their combination on carcass characteristics of Japanese quail (mean ± s.d.)

	Carcass weight g	Carcass dressing %	Breast % of carcass	Back % of carcass	Legs % of carcass	Neck % of carcass	Wings % of carcass	Liver % of live weight	Heart % of live weight
Quail Groups*									
Group A	124.75 ± 14.62	76.37 ± 3.10	34.37 ± 3.63	27.02 ± 3.75	22.00 ± 1.30	7.58 ± 1.49	8.20 ± 1.31	2.60 ± 0.86	1.11 ± 0.21
Group B	128.15 ± 12.55	72.66 ± 3.92	34.08 ± 1.90	27.63 ± 1.56	22.67 ± 0.97	7.88 ± 0.92	7.15 ± 0.50	2.56 ± 0.60	0.97 ± 0.11
Group C	142.40 ± 10.60	77.49 ± 3.27	36.02 ± 2.66	26.67 ± 3.23	21.62 ± 1.37	7.85 ± 0.46	7.50 ± 1.39	2.07 ± 0.42	1.07 ± 0.18
Group D	131.58 ± 11.02	74.86 ± 5.49	33.92 ± 2.91	27.70 ± 2.50	21.72 ± 0.57	8.45 ± 0.41	7.67 ± 1.06	2.34 ± 0.42	1.02 ± 0.13
P value	0.106	0.223	0.568	0.909	0.369	0.448	0.453	0.427	0.468
Effect of MOS									
0 g/kg	126.45^{a} ± 13.11	74.52 ± 3.88	34.23 ± 2.77	27.33 ± 2.75	22.33 ± 1.15	7.73 ± 1.19	7.68 ± 0.10	2.58^{a} ± 0.71	1.04 ± 0.18
2 g/kg	136.99^{b} ± 11.75	76.17 ± 4.52	34.97 ± 2.87	27.18 ± 2.81	21.67 ± 1.00	8.15 ± 0.52	7.58 ± 1.18	2.21^{b} ± 0.43	1.04 ± 0.15
P value	0.005	0.198	0.535	0.902	0.199	0.246	0.855	0.047	0.904
Effect of CPr									
0 g/kg	133.58 ± 15.27	76.93^{a} ± 3.09	35.19 ± 3.16	26.84 ± 3.34	21.81 ± 1.29	7.72 ± 1.06	7.85 ± 1.34	2.34 ± 0.70	1.09 ± 0.19
6 g/kg	129.87 ± 11.40	73.76^{b} ± 4.69	34.00 ± 2.34	27.67 ± 1.99	22.19 ± 0.91	8.17 ± 0.74	7.41 ± 0.84	2.45 ± 0.50	0.99 ± 0.12
P value	0.273	0.020	0.324	0.477	0.452	0.212	0.383	0.528	0.175
Effect of sex									
Male	125.25^{a} ± 14.95	78.03^{a} ± 1.86	34.09 ± 3.16	28.18 ± 3.18	21.99 ± 1.20	7.69 ± 0.91	7.40 ± 0.90	2.05^{a} ± 0.36	1.07 ± 0.09
Female	138.19^{b} ± 7.47	72.66^{b} ± 4.23	35.10 ± 2.38	26.33 ± 1.87	22.01 ± 1.06	8.19 ± 0.91	7.86 ± 1.29	2.74^{b} ± 0.61	1.01 ± 0.21
P value	0.001	0.000	0.402	0.124	0.974	0.168	0.366	0.001	0.460
Interaction (P)									
MOS x CPr	0.045	0.666	0.449	0.856	0.577	0.671	0.235	0.369	0.534
MOS x Sex	0.030	0.818	0.231	0.227	0.818	0.399	0.727	0.076	0.683
CPr x Sex	0.052	0.307	0.611	0.402	0.843	0.197	0.678	0.301	0.222
MOS x CPr x Sex	0.033	0.948	0.311	0.477	0.645	0.086	0.752	0.072	0.847

MOS - mannan oligosaccharides; CPr - Calcium propionate; s.d. - standard deviation.
Means within column with a superscript in common within group or effect do not differ significantly at $P \leq 0.05$.
* Groups: A = control; B = 6 g CPr/kg; C = 2 g MOS/kg; D = 6 g CPr/kg + 2 g MOS/kg.

significantly higher ash percentage in their meat. Furthermore, no interaction (P >0.050) between MOS and CPr was observed. Ghosh *et al*. (2008) reported interaction between MOS and sodium butyrate on the crude fat percentage of quail meat, whereas Brzóska *et al*. (2007) did not find any significant interaction between MOS and fumaric acid.

The effect of the dietary supplementation of MOS and CPr on fatty acid composition of breast meat is presented in Table 7. No differences (P >0.050) were observed between the four experimental groups. The addition of MOS resulted in a tendency for the breast meat to have higher percentages of palmitoleic acid and monounsaturated fatty acids. The addition of CPr did not have any effect (P >0.050) on the fatty acid composition of the breast meat and no interaction (P >0.050) between the main effects was observed. According to Furuse *et al*. (1992), the fatty acid composition of the consumed feed and of the animal tissues can be modified as a result of the action of the gut microflora, because the gut microorganisms are able to hydrogenise unsaturated organic acids to more saturated ones, or even to desaturate some organic acids.

Table 6 Effect of dietary supplementation of MOS and CPr or their combination on carcass breast meat composition of Japanese quail (mean ± s.d.)

	Carcass breast meat			
	Crude protein g/kg	Crude fat g/kg	Moisture g/kg	Ash g/kg
Quail Groups*				
Group A	219 ± 4	31^{ab} ± 17	719 ± 11	15 ± 1
Group B	213 ± 3	46^{a} ± 14	731 ± 9	14 ± 1
Group C	218 ± 11	23^{ab} ± 3	725 ± 14	15 ± 2
Group D	212 ± 4	13^{b} ± 2	735 ± 3	14 ± 0
P value	0.498	0.041	0.298	0.218
Effect of MOS				
0 g/kg	216 ± 4	38^{a} ± 16	725 ± 11	15 ± 1
2 g/kg	215 ± 8	18^{b} ± 6	730 ± 11	15 ± 1
P value	0.672	0.015	0.419	0.970
Effect of CPr				
0 g/kg	218 ± 8	27 ± 12	722 ± 12	15^{a} ± 1
6 g/kg	212 ± 3	29 ± 20	733 ± 6	14^{b} ± 1
P value	0.160	0.722	0.095	0.050
Interaction (P)				
MOS x CPr	0.985	0.093	0.813	0.655

MOS - mannan oligosaccharides; CPr - Calcium propionate; s.d. - standard deviation.
Means within column with a superscript in common within group or effect do not differ significantly at P ≤0.05.
* Groups: A = control; B = 6 g CPr/kg; C = 2 g MOS/kg; D = 6 g CPr/kg + 2 g MOS/kg.

Conclusions

The sex of the quail affected the results, since the female quail had a higher (P ≤0.001) body and carcass weight and liver to live weight percentage, whereas they had lower (P ≤0.001) carcass dressing percentages. The dietary addition of MOS increased body (P ≤0.050) and carcass (P ≤0.010) weight, whereas it decreased (P ≤0.050) liver to live weight percentage and crude fat content of the breast meat. Moreover, the dietary addition of CPr lowered (P ≤0.050) carcass dressing percentage and ash content of the breast meat. Interaction (P ≤0.050) between the two examined supplements was observed on feed consumption, FCR and carcass weight. Interaction (P ≤0.050) between MOS and sex was observed on carcass weight.

Table 7 Effect of dietary supplementation of MOS and CPr or their combination on fatty acid composition of the breast meat of Japanese quail (mean ± s.d.)

	Myristic acid C14:0 %*	Palmitic acid C16:0 %*	Palmitoleic acid C16:1 %*	Stearic acid C18:0 %*	Oleic acid C18:1 %*	Linoleic acid C18:2 %*	Linolenic acid C18:3 %*	Erucic acid C22:1 %*	Total SFA %*	Total MUFA %*	Total PUFA %*
Quail Groups**											
Group A	5.54 ± 2.58	18.69 ± 1.03	5.16 ± 1.77	9.83 ± 2.95	31.95 ± 5.56	22.52 ± 0.60	1.36 ± 0.12	4.94 ± 1.65	34.05 ± 4.49	42.08 ± 5.00	23.87 ± 0.66
Group B	2.56 ± 0.97	19.56 ± 1.23	4.86 ± 1.15	7.99 ± 0.38	36.03 ± 1.39	24.58 ± 4.06	1.52 ± 0.27	2.86 ± 1.02	30.14 ± 1.28	43.76 ± 3.09	26.10 ± 4.33
Group C	4.53 ± 1.99	17.73 ± 0.85	7.11 ± 1.22	7.87 ± 1.83	35.27 ± 4.02	21.64 ± 0.72	1.45 ± 0.17	4.41 ± 1.88	30.12 ± 2.97	46.78 ± 3.31	23.09 ± 0.61
Group D	3.20 ± 1.90	18.30 ± 1.28	6.07 ± 0.98	7.62 ± 1.03	37.39 ± 1.74	22.07 ± 1.99	1.30 ± 0.10	4.07 ± 1.39	29.11 ± 1.04	47.52 ± 0.91	23.37 ± 1.89
P value	0.230	0.301	0.233	0.469	0.359	0.461	0.453	0.438	0.225	0.246	0.454
Effect of MOS											
0 g/kg	4.06 ± 2.38	19.13 ± 1.12	5.02 ± 1.35	8.91 ± 2.13	33.99 ± 4.26	23.55 ± 2.83	1.44 ± 0.21	3.90 ± 1.68	32.09 ± 3.65	42.92 ± 3.83	24.99 ± 3.03
2 g/kg	3.86 ± 1.51	18.01 ± 1.02	6.59 ± 1.14	7.74 ± 1.33	36.33 ± 3.00	21.86 ± 1.36	1.37 ± 0.15	4.24 ± 1.49	29.62 ± 2.07	47.15 ± 2.21	23.23 ± 1.27
P value	0.848	0.122	0.074	0.298	0.294	0.241	0.536	0.713	0.166	0.063	0.242
Effect of CPr											
0 g/kg	5.03 ± 2.13	18.21 ± 1.00	6.15 ± 1.71	8.85 ± 2.44	33.61 ± 4.70	22.08 ± 0.76	1.40 ± 0.15	4.68 ± 1.61	32.09 ± 4.03	44.43 ± 4.59	23.48 ± 0.71
6 g/kg	2.89 ± 0.80	18.93 ± 1.32	5.46 ± 1.16	7.80 ± 0.72	36.71 ± 1.59	23.32 ± 3.17	1.41 ± 0.22	3.47 ± 1.28	29.63 ± 1.19	45.64 ± 2.90	24.73 ± 3.34
P value	0.064	0.292	0.396	0.350	0.175	0.378	0.955	0.206	0.169	0.556	0.394
Interaction (P)											
MOS x CPr	0.440	0.818	0.649	0.473	0.650	0.557	0.153	0.351	0.398	0.817	0.501

MOS - mannan oligosaccharides; CPr - Calcium propionate; s.d. - standard deviation; SFA - Saturated fatty acids; MUFA - Monounsaturated fatty acids; PUFA - Polyunsaturated fatty acids.

Differences between means within group or effect were not significant.

* Individual fatty acids expressed as percentage of total fatty acids.

** Groups: A = control; B = 6 g CPr/kg; C = 2 g MOS/kg; D = 6 g CPr/kg + 2 g MOS/kg.

References

Ao, T., Cantor, A.H., Pescatore, A.J., Ford, M.J., Pierce, J.L. & Dawson, K.A., 2009. Effect of enzyme supplementation and acidification of diets on nutrient digestibility and growth performance of broiler chicks. Poult. Sci. 88, 111-117.

AOAC, 2005. Official Methods of Analysis. (18th ed.). Ed. Horwitz, W., Association of Analytical Chemists, AOAC International, Arlington Virginia, USA.

Baurhoo, B., Phillip, L. & Ruiz-Feria, C.A., 2007. Effects of purified lignin and mannan oligosaccharides on intestinal integrity and microbial populations in the ceca and litter of broiler chickens. Poult. Sci. 86, 1070-1078.

Bozkurt, M., Küçükyilmaz, K., Çatli, A.U., & Çinar, M., 2008. Growth performance and slaughter characteristics of broiler chickens fed with antibiotic, mannan oligosaccharide and dextran oligosaccharide supplemented diets. Int. J. Poult. Sci. 7, 969-977.

Brzóska, F., Buluchevskij, S., Stecka, K. & Śliwiński, B., 2007. The effects of lactic acid bacteria and mannan oligosaccharide, with or without fumaric acid, on chicken performance, slaughter yield and digestive tract microflora. J. Anim. Feed Sci. 16, 241-251.

Çakir, S., Midilli, M., Erol, H., Şimsek, N., Çinar, M., Altintas, A., Alp, H., Altintas, L., Cengiz, Ö. & Antalyali, A., 2008. Use of combined probiotic-prebiotic, organic acid and avilamycin in diets of Japanese quails. Revue Med. Vet. 159 (11), 565-569.

EU, 2005. Ban on antibiotics as growth promoters in animal feed enters into effect. IP/05/1687, 22/December/2005. European Union. http:// europa.eu/ rapid/ pressReleasesAction.do? reference=IP/05/1687 &format=HTML &aged=0 &language=EN &guiLanguage=en [accessed January 2010].

Ferket, P.R., 2004. Alternatives to antibiotics in poultry production: responses, practical experience and recommendations. Nutritional biotechnology in the feed and food industries: Proc. Alltech's 20th Annual Symposium, Kentucky, USA. pp. 56-67.

Florou-Paneri, P., 1989. Nutritional Requirements of the Quail. Aristotle University Press, Aristotle University of Thessaloniki, Greece (in Greek).

Folch, J., Lees, M. & Sloane Stanley, G.H., 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226, 497-509.

Freitag, M., 2007. Organic acids and salts promote performance and health in animal husbandry. In: Acidifiers in Animal Nutrition. Ed. Lückstädt, C., Nottingham University Press, UK.

Furuse, M., Murai, A. & Okumura, J., 1992. Gut microflora can modify fatty acid composition in liver and egg yolk lipids of laying Japanese quail. Comp. Biochem. Physiol. 103A, 569-571.

Ghosh, H.K., Halder, G., Samanta, G., Paul, S.K. & Pyne, S.K., 2007. Effect of dietary supplementation of organic acid and mannan oligosaccharide on the performance and gut health of Japanese quail (Coturnix coturnix japonica). Asian J. Poult. Sci. 1(1), 1-7.

Ghosh, H.K., Halder, G., Samanta, G. & Koley, S., 2008. Effect of dietary supplementation of organic acid and mannan oligosaccharide on the plasma minerals and carcass traits of Japanese quail (Coturnix coturnix japonica). Res. J. Vet. Sci. 1, 44-49.

Greko, C., 2001. Safety aspects on non-use of antimicrobials as growth promoters. In: Gut Environment of Pigs. Eds Piva, A., Bach Knudsen, K.E. & Lindberg, J.E., Nottingham University Press, Nottingham, UK. pp. 219-230.

Guclu, B.K., 2003. The effect of mannanoligosaccharide on fattening performance of quails. Indian Vet. J. 80 (10), 1018-1021.

Hernández, R.H., García, V., Madrid, J., Orengo, J., Catalá, P. & Megías, M.D., 2006. Effect of formic acid on performance digestibility, intestinal histomorphology and plasma metabolite levels of broiler chickens. Br. Poult. Sci. 47, 50-56.

Hooge, D., 2004. Meta-analysis of broiler chicken pen trials evaluating dietary mannan oligosaccharide, 1993-2003. Int. J. Poult. Sci. 3, 163-174.

Jukes, T.H., Hill, D.C. & Branion, H.D., 1956. Effect of feeding antibiotics on the intestinal tract of the chick. Poult. Sci. 35, 716-723.

Kirchgessner, M. & Roth, F.X., 1988. Nutritive effects of organic acids in piglet rearing and pig fattening. Ubersichten zur Tierernahrung 16, 93-108.

Kogan, G. & Kocher, A., 2007. Role of yeast cell wall polysaccharides in pig nutrition and health protection. Livest. Sci. 109, 161-165.

Konca, Y., Kirkpinar, F. & Mert, S., 2009. Effects of mannan-oligosaccharides and live yeast in diets on the carcass, cut yields, meat composition and colour of finishing turkeys. Asian-Australas. J. Anim. Sci. 22, 550-556.

Leeson, S., Namkung, H., Antongiovanni, M. & Lee, E.H., 2005. Effect of butyric acid on the performance and carcass yield of broiler chickens. Poult. Sci. 84, 1418-1422.

Lessard, P., Lefrancois, M.R. & Bernier, J.F., 1993. Dietary addition of cellular metabolic intermediates and carcass fat deposition in broilers. Poult. Sci. 72, 535-545.

Loddi, M.M., Nakaghi, L.S.O., Edens, F., Tucci, F.M., Hannas M.I., Moraes V.M.B. & Ariki, J., 2002. Effect of mannanoligosaccharide and organic acids on intestinal morphology integrity of broilers evaluated by scanning electron microscopy. Proc. 11th European Poultry Science Conference, Bremen, Germany. pp. 121.

Lückstädt, C., 2008. The use of acidifiers in fish nutrition. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, CAB International. 3, 44.

Lückstädt, C., Senkoylu, N., Akyurek, H. & Agma, A., 2004. Acidifier - a modern alternative for antibiotic free feeding in livestock production, with special focus on broiler production. Veterinarija Ir Zootechnika 27 (49), 91-93.

Maisonnier, S., Gomez, J., Bree, A., Berri, C., Baeza, E. & Carre, B., 2003. Effects of microflora status, dietary bile salts and guar gum on lipid digestibility, intestinal bile salts, and histomorphology in broiler chickens. Poult. Sci. 82, 805-814.

Miguel, J.C., Rodrogies-Zas, S.L. & Pettigrew, J.E., 2002. Practical effects of Bio-Mos in nursery diets: A meta-analysis. In: Biotechnology in the Feed and Food Industries. Eds Lyons, T.P. & Jacques, K.A., Proc. 13th Annual Symp. Nottingham University Press, Nottingham, UK. pp. 425-434.

Novus, 1992. Raw Material Compedium, First Edition. Novus, Brussels, Belgium.

NRC, 1994. Nutrient Requirements of Poultry. (9th rev.). National Research Council, National Academy Press, Washington, D.C., USA.

Ocak, N., Erener, G., Altop, A. & Kop, C., 2009. Effect of malic acid on performance and some digestive tract traits of Japanese quails. J. Poult. Sci. 46, 25-29.

Oguz, H. & Parlat, S.S., 2004. Effects of dietary mannanoligosaccharide on performance of Japanese quail affected by aflatoxicosis. S. Afr. J. Anim. Sci. 34, 144-148.

Parlat, S.S., Yildiz, A.O. & Yazgan, O., 2003. Effect of dietary addition of probiotics (mannanoligosaccharides) or antibiotics (virginiamycin) on performance of Japanese quail (Coturnix coturnix japonica). Proc. Balkan Animal Science Conference, Bucharest, Romania.

Pelicano, E.R.L., Souza, P.A., Souza, H.B.A., Leonel, F.R., Zeola, N.M.B.L. & Boiago, M.M., 2004. Productive traits of broiler chickens fed diets containing different growth promoters. Braz. J. Poult. Sci. 6, 177-182.

Rehman, H., Vahjen, W., Kohl-Parisini, A., Ijaz, A. & Zentek, J., 2009. Influence of fermentable carbohydrates on the intestinal bacteria and enteropathogens in broilers. Wrld's Poult. Sci. J. 65, 75-89.

Roe, M.T. & Pillai, S.D., 2003. Monitoring and identifying antibiotic resistance in bacteria. Poult. Sci. 82, 622-626.

Rosen, G.D., 2007a. Holo-analysis of the efficacy of Bio-Mos® in broiler nutrition. Br. Poult. Sci. 48, 21-26.

Rosen, G.D., 2007b. Holo-analysis of the efficacy of Bio-Mos® in turkey nutrition. Br. Poult. Sci. 48, 27-32.

Sacakli, P., Sehu, A., Ergun, A., Genc, B. & Selcuk, Z., 2006. The effect of phytase and organic acid on growth performance, carcass yield and tibia ash in quails fed diets with low levels of non-phytate phosphorus. Asian-Australas. J. Anim. Sci. 19, 198-202.

Samanta, S., Haldar, S. & Ghosh, T.K., 2010. Comparative efficacy of and organic acid blend and bacitracin methylene disalicylate as growth promoters in broiler chickens: Effects on performance, gut histology, and small intestinal milieu. Vet. Med. Int. 2010, Article ID 645150.

Sarica, S., Corduk, M., Yarim, G.F., Yenisehirli, G. & Karatas U., 2009. Effects of novel feed additives in wheat based diets on performance, carcass and intestinal tract characteristics of quail. S. Afr. J. Anim. Sci. 39, 144-157.

Senkoylu, N., Samli, H.E., Kanter, M. & Agma, A., 2007. Influence of a combination of formic and propionic acids added to wheat- and barley-based diets on the performance and gut histomorphology of broiler chickens. Acta Vet. Hung. 55, 479-490.

Shim, K.F., 2005. The Nutrition and Management of Japanese (Coturnix) quail in the Tropics. http://www.thatquailplace.com/quail/coturn1.htm [accessed January 2010].

Sims, M.D., Dawson, K.A., Newman, K.E., Spring, P. & Hooge, D.M., 2004. Effects of dietary mannan oligosaccharide, bacitracin methylene disalicylate, or both on the live performance and intestinal microbiology of turkeys. Poult. Sci. 83, 1148-1154.

Spais, A.B., Florou-Paneri, P. & Christaki, E., 2001. The Bases of Mammal and Bird Nutrition. Ekdoseis Sighroni Paideia. Thessaloniki, Greece. (in Greek).

Spais, A.B., Florou-Paneri, P. & Christaki, E., 2002. Animal Feeds and Diets. ISBN: 960-357-055-9. Ekdoseis Sighroni Paideia. Thessaloniki, Greece. (in Greek).

Spring, P., Wenk, C., Dawson, K.A. & Newman, K.E., 2000. The effects of dietary mannanoligosaccharides on cecal parameters and the concentration of enteric bacteria in the ceca of Salmonella-challenged broiler chicks. Poult. Sci. 79, 205-211.

SPSS, 2007. SPSS 16.0.1 for Windows. SPSS Inc., Chicago, IL, USA. http://www.spss.com [accessed January 2010].

Yannakopoulos, A.L. & Tserveni-Gousi, A.S., 1986. Carcass characteristics of Japanese quail at 42 days of age. Br. Poult. Sci. 27, 123-127.