

## Effect of dietary mannan oligosaccharide with or without oregano essential oil and hop extract supplementation on the performance and slaughter characteristics of male broilers

M. Bozkurt<sup>#</sup>, K. Küçükyılmaz, A.U. Çatlı and M. Çınar

Poultry Research Institute, 09600 Erbeyli-Aydın, Turkey

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### Abstract

The effects of some alternative feed additives for antibiotic growth promoters on performance and some slaughter characteristics were examined in broilers fed wheat-soya based basal starter and finisher diets. A total of 2160 one-day-old male broiler chicks were randomly allocated to six groups with six replicate pens per treatment. The treatments were the basal diet (Control), and the basal diet supplemented with an antibiotic growth promoter (AGP); a prebiotic, mannan oligosaccharide (Bio-Mos, MOS); an essential oil of oregano (Herb-Mos Oregano, HMO); a plant extract of hop (Herb-Mos Hops, HMH) or a mixture of Herb-Mos Oregano and Herb-Mos Hops (HMOH). There were significant effects of dietary treatments on body weight and feed conversion ratio in the 0 - 21 d period, and on body weight and feed consumption in the 0 - 42 d period. The addition of all experimental additives to the diet resulted in significantly higher body weights as compared to the control treatment at both 21 and 42 days of age. Feed intakes were significantly different between the treatments at 0 - 21 d and 22 - 42 d periods, but not during the 0 - 42 d period. However, during the 0 - 21 d period the broiler chickens that received diets supplemented with AGP, MOS, HMO, HMH and HMOH had significantly better feed conversion ratios than the control group, but this pattern was not sustained during the finisher period (22 - 42 d). Mortality rate, hot carcass yield and relative weights of the small intestines, pancreas, abdominal fat and bursa of fabricius were not affected by experimental treatments. The HMH supplementation increased relative liver weight. These results showed that AGP, MOS and herbal feed additive (HMO, HMH, HMOH) supplementation to a diet provided significant advantages on broiler growth performance through a 42-d growth period. However, the combined supplementation of HMO and HMH did not exert either synergistic or additive benefits on the live performance of the broilers. These results also proved that MOS, HMO, HMH and HMOH improved broiler live performance as well as an AGP in both the starter and through the grower period. Furthermore, outstanding advantages were evidenced for the HMH treatment in particular. Therefore, the MOS, HMO, HMH and HMOH performance enhancer feed additives of natural origin may be considered as potential substitutes for AGP in broiler diets.

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**Keywords:** Antibiotic, mannan oligosaccharide, oregano essential oil, hop extract, broiler performance, slaughter characteristics

<sup>#</sup> Corresponding author. E-mail: mehmetbozkurt9@hotmail.com

### Introduction

Medical and consumer pressure and interest resulted in the systematic removal of antibiotics from animal feed in the European Union, and it was banned completely at the beginning of 2006 (Nollet, 2005; Wakeman 2005; Cervantes, 2006). Consequently, the poultry industry has been looking for substances that could replace antibiotic growth promoters (AGP) in feed (Mellor, 2000; Bach Knudsen, 2001). Various types of feed additives have been evaluated under commercial conditions and in experimental trials with the objective of achieving improved growth and the best economic return (Gill, 1999; 2001; Langhout, 2000). Mannan oligosaccharide (MOS) derived from the cell walls of *Saccharomyces cerevisia* exerts an antimicrobial mode of action by selectively binding pathogenic bacteria including *Salmonella* spp. and *Escherichia coli*, and inhibiting adhesion to enterocytes. In addition, MOS serves as an immune modulator, thus stimulating immune responses. Consequently, improving the health status of the intestinal mucosa due to feeding diets containing MOS could lead to improved growth performance, feed efficiency and liveability of broiler chickens (Spring, 1999; Shane, 2001; 2005; Ferket, 2004). Therefore, MOS as a feed additive has

replaced AGP and has also proved its efficacy in scientific experiments and large-scale field trials (Waldroup *et al.*, 2003a; b; Hooge, 2003a; b; 2004; Kocher, 2005). Recent evidence suggests that botanical feed additives could play significant roles, especially in synergistic combinations with other feed additives.

The AGPs have been replaced by a wide variety of additives extracted from herbs, spices and other plants and include essential oils, extracts, powders and dried whole parts of those botanicals. Essential oils that gained importance recently as AGP alternative natural feed additives have been extracted from aromatic plants by steam distillation, pressing or solvent extraction. Besides their well-known antimicrobial activity (Deans & Ritchie, 1987; Cowan, 1999; Hammer *et al.*, 1999; Dorman & Deans, 2000; Ultee *et al.*, 2002); many essential oils also exhibit antioxidant (Basmacıoğlu *et al.*, 2004; Botsoglou *et al.*, 2002; 2004), antifungal (Montes-Belmont & Carvajal, 1998; Shin & Lim, 2004), anticoccidial (Allen *et al.*, 1997, Evans *et al.*, 2001) and enzymatic (Platel & Sravinason, 1996; Jamroz *et al.*, 2005) activities. The beneficial effects of essential oils, particularly the essential oil of oregano, on the live performance of broilers have been shown in scientific experiments either alone (Bassett, 2000; Hertrampf, 2001; Denli *et al.*, 2004; Halle *et al.*, 2004; Çiftçi *et al.*, 2005) or in combination with other essential oils (Alçiçek *et al.*, 2003; 2004; Jamroz *et al.*, 2003; 2005; Zhang *et al.*, 2005). Furthermore, hop has been credited with numerous medicinal uses, including antibacterial activity (Stavri *et al.*, 2004). However, limited research has been performed on plant extracts, including hops, essential oils and MOS. In a preliminary study it has been demonstrated that the inclusion of ground hops into broiler diets at the rate of 0.45 kg per ton significantly improved growth rate and feed utilization in the absence of growth promoting antibiotics (Cornellison *et al.*, 2006). The positive effect of a plant extract mixture of sage, thyme and rosemary on the live performance of broilers has also been reported in an earlier study (Hernandez *et al.*, 2004). However, combining strategies may sometimes prove more beneficial than individual supplementation of feed additives. In piglets (Lückstädt *et al.*, 2005) and in broiler chickens (Zhang *et al.*, 2005), for example, essential oil-organic acid blends proved to be promising alternatives to AGPs. Therefore, the present study aimed to examine the combination of two different herbal feed additives, Herb-Mos Oregano (HMO) and Herb-Mos Hops (HMH), as novel commercial products with different modes of action to provide for a broad spectrum of growth promoters, immune stimulators, and antioxidative and digestive enhancers.

The objective of this study was not only to demonstrate the effectiveness of individual supplementation of an essential oil and a plant extract, but also to reveal possible synergistic or additive effects in terms of performance and general health of broiler chickens. It is noteworthy that, while MOS or essential oils have been studied individually as feed additives, in this study they are tested for the first time in combinations, as alternatives to AGP. Furthermore, the combined effect of an essential oil and plant extract has not been tested previously. Therefore, the aim of this study was to evaluate the ability of MOS and two plant products to stimulate broiler performance when used as supplements in broiler diets.

## Materials and Methods

Two thousand one hundred and sixty day-old male broiler chicks of a commercial strain (Ross-308) were divided randomly into six treatment groups of 360 birds each. Each treatment group was further subdivided into six replicates of sixty birds per replicate. From days 1 to 21 the birds were fed a starter diet in crumble form and from days 22 to 42 a grower diet in pellet form (Table 1). The experimental diets were as follows: 1. Basal diet, no additives (Control), 2. Basal diet + an antibiotic (AGP - avilamycin, 10 mg/kg diet); 3. Basal diet + mannan oligosaccharide (MOS - Bio-Mos<sup>®</sup>, 1 g/kg diet); 4. Basal diet + essential oil of oregano (HMO - Herb-Mos Oregano<sup>®</sup>, 1 g/kg diet); 5. Basal diet + plant extract of hops (HMH - Herb-Mos Hops<sup>®</sup>, 1 g/kg diet) and, 6. Basal diet + mixture of Herb-Mos Oregano and Herb-Mos Hops (HMOH, 1 g/kg diet). The Herb-Mos products consist of part Bio-Mos<sup>®</sup> into which either oregano essential oil or hop extract has been added. The experimental feed additives MOS, HMO, HMH, HMOH were supplied by ALLTECH (Alltech Biotechnology Centre, Ireland). The ingredient and chemical composition of the diets are presented in Table 1. The diets were isoenergetic and isonitrogenous, and contained Allzyme PT (Alltech) as xylanase. Dietary feed additives were added at the expense of sawdust. All the experimental diets were formulated to meet the minimum nutrient requirements of broilers (NRC, 1994). The experimental diets and drinking water were provided *ad libitum*. The experiment was conducted in an environmentally controlled floor pen house of commercial design. The birds were kept in 36 pens (2.4 x 1.6 m) on wood shavings as litter material. Each pen was equipped with two hanging feeders and one drinker. Bird density was 16 chicks per square meter. The lighting cycle was maintained at 23 h/d. The ambient temperature in the experimental

house was maintained at 32 °C during the first week and gradually decreased by 3 °C in the second and third weeks, and was fixed at 22 °C thereafter. Chicks were vaccinated via their drinking water against Infectious Bursal Disease, New Castle Disease (HB1) and La sota at days 14, 21 and 28, respectively. During the 42 d experimental period, the growth of broilers was evaluated by recording body weight gain, feed intake, feed conversion ratio and mortality. Birds were weighed individually at 1, 21 and 42 d of age. Feed intakes per pen were recorded at 21 and 42 d of age. The feed conversion ratio (FCR) was calculated as feed consumed per unit of body weight gain and was adjusted for weight of chicks at first day and bird mortality. FCR was determined at the end of the 21 days, and the 42-day experimental periods. Mortality was recorded daily and was used to adjust the total number of birds to determine the total feed intake per bird. At the end of the experiment (at d 42), 18 birds whose body weights were close to the group average were selected from each of the replicate groups of each treatment. These birds were slaughtered by severing the bronchial vein to determine some measurements of carcass yield, selected internal organs, abdominal fat pad and bursa of fabricius. The weights of selected internal organs (liver, pancreas and small intestines), abdominal pad weight and bursa of fabricius were measured individually. The weights of these internal organs were expressed as percentages of live body weight. The hot carcass yields were calculated as percentages of the preslaughter live body weight of broiler chickens. Standard techniques of the proximate analysis were used to determine the nutrient concentrations in the diets (Naumann & Bassler, 1993). The experimental diets were also analysed for starch, sugar, total calcium and phosphorus according to analytical methods described by Naumann & Bassler (1993). The metabolisable energy content of the diets was calculated based on chemical composition (Anonymous, 1991). The data obtained from this study were analyzed statistically using the General Linear Models procedure of SAS (1991). Significant differences between treatment means were separated using Duncan's multiple range test with a 5% probability.

**Table 1** The ingredients and chemical composition of the basal starter and grower diets (as fed)

Ingredients (g/kg)	Starter diet	Grower diet	Chemical composition of basal diet (g/kg)		
			Starter diet	Grower diet	
Wheat	525.1	573.1	Dry matter	893.9	896.0
Soyabean meal (48%)	118.0	102.4	Crude protein	232.0	214.0
Full-fat soyabean	300.0	250.0	Crude fat	79.1	94.1
Soya oil	14.3	35.2	Crude fibre	40.7	39.8
Dicalcium phosphate	17.0	16.3	Crude ash	69.3	66.1
Ground limestone	10.2	9.45	Starch	332.2	338.2
Salt	2.50	2.50	Sugar	36.4	37.5
L-Lysine HCL	1.66	1.05	Calcium	9.47	8.78
DL-methionine	3.74	2.50	Phosphorus (total)	6.76	6.44
Vitamin premix <sup>1</sup>	2.50	2.50	Calculated composition (g/kg)		
Mineral premix <sup>2</sup>	1.00	1.00	Available phosphorus	4.7	4.4
Anticoccidial <sup>3</sup>	1.00	1.00	Lysine	14.0	12.0
Antioxidant	1.00	1.00	Methionine	7.0	5.5
Allzyme PT <sup>4</sup>	1.00	1.00	Methionine+cysteine	11.0	9.2
Sawdust	1.00	1.00	Linoleic acid	38.7	45.1
Total	1000	1000	Metabolisable energy (MJ/kg)	13.16	13.49

<sup>1</sup> Supplied per kg of diet: 12000 IU vitamin A; 1500 IU vitamin D<sub>3</sub>; 30 mg vitamin E; 5 mg vitamin K<sub>3</sub>; 3 mg vitamin B<sub>1</sub>; 6 mg vitamin B<sub>2</sub>; 5 mg vitamin B<sub>6</sub>; 0.03 mg vitamin B<sub>12</sub>; 40 mg nicotine amid; 10 mg calcium-D-pantothenate; 0.75 mg folic acid; 0.075 mg D-biotin; 375 mg choline chloride.

<sup>2</sup> Supplied per kg of diet: 80 mg Mn; 40 mg Fe; 60 mg Zn; 5 mg Cu; 0.5 mg I; 0.2 mg Co; 0.15 mg Se.

<sup>3</sup> Provided 70 mg Narasin per kg of diet.

<sup>4</sup> Xylanase based enzyme preparation.

## Results and Discussion

The effects of the experimental feed additives on body weight, feed intake, feed conversion ratio and mortality of broiler chickens are presented in Table 2. A significant growth promoting effect was observed from all feed additives. The AGP, MOS, HMO, HMH and HMOH supplementation to the diet increased body weight of broiler chickens both at 21 and 42 days of age compared to the control ( $P < 0.01$ ). Contrary to that pattern, no differences ( $P > 0.05$ ) were observed between the treatments during the finisher period (22 to 42 d). Birds receiving the diet containing HMH exhibited the highest body weight both at three and six weeks of age. Dietary supplementation of AGP, MOS, HMO, HMH and HMOH enhanced the body weight of 21-d old chickens in relation to the control birds by 18.9, 16.7, 20.2, 23.5 and 21.8%, respectively. A similar pattern was observed at 42 days with improvements of 5.2, 4.9, 4.4, 7.1 and 6.2%, respectively. Despite the exceptional growth rate of 2.54 kg for the control treatment at 42 days of age, supplementation with the feed additives enhanced final body weight by at least 4%. It is worth noting that the growth promoting effect of the HMH treatment for both 21-d and 42-d body weights was greater than those of the other experimental treatments, both alone and combined with HMO.

**Table 2** Body weight, feed intake, feed conversion ratio and mortality of broilers given either AGP, MOS, HMO, HMH or HMOH added diets

Experimental period (d) and parameter	Treatments						s.e.m.	P
	Control	AGP	MOS	HMO	HMH	HMOH		
Body weight (g)								
21 d	767 <sup>c</sup>	912 <sup>cd</sup>	895 <sup>d</sup>	922 <sup>bc</sup>	947 <sup>a</sup>	934 <sup>ab</sup>	6.60	0.0001
42 d	2543 <sup>c</sup>	2674 <sup>ab</sup>	2667 <sup>b</sup>	2656 <sup>b</sup>	2723 <sup>a</sup>	2700 <sup>ab</sup>	18.28	0.0001
22 – 42 d	1776	1762	1772	1734	1776	1766	16.49	0.6943
Feed intake (g)								
0 – 21 d	1271	1311	1311	1288	1309	1298	15.06	0.3847
22 – 42 d	3607 <sup>b</sup>	3769 <sup>a</sup>	3763 <sup>a</sup>	3734 <sup>ab</sup>	3831 <sup>a</sup>	3831 <sup>a</sup>	30.23	0.0496
0 – 42 d	4878 <sup>b</sup>	5080 <sup>a</sup>	5074 <sup>a</sup>	5022 <sup>ab</sup>	5140 <sup>a</sup>	5129 <sup>a</sup>	63.26	0.0701
Feed conversion (g feed/g gain)								
0 – 21 d	1.772 <sup>a</sup>	1.515 <sup>bc</sup>	1.545 <sup>b</sup>	1.471 <sup>c</sup>	1.457 <sup>c</sup>	1.462 <sup>c</sup>	0.02	0.0001
22 – 42 d	2.031 <sup>b</sup>	2.139 <sup>a</sup>	2.123 <sup>a</sup>	2.153 <sup>a</sup>	2.157 <sup>a</sup>	2.169 <sup>a</sup>	0.01	0.0010
0 – 42 d	1.954	1.934	1.935	1.924	1.919	1.933	0.01	0.2855
Mortality (%)								
0 – 21 d	0.28	2.25	3.38	2.54	2.25	1.69	0.72	0.1017
0 – 42 d	1.69	2.54	4.51	3.38	3.71	2.54	0.85	0.2247

<sup>a-c</sup> Means with in row different superscript differ at  $P < 0.05$ ; s.e.m. – standard error of mean.

AGP - antibiotic growth promoters; MOS - Bio-Mos; HMO - Herb-Mos Oregano; HMH - Herb-Mos Hops; HMOH - Herb-Mos Oregano plus Herb-Mos Hops.

The improved body weight gain of broilers receiving a diet with added HMO in this study agreed with results reported by Alçiçek *et al.* (2003; 2004). They reported that birds fed on the mixture of six different essential oils extracted from herbs growing in Turkey had significantly better body weights than those fed the basal diet and also diets containing an antibiotic, a probiotic and an organic acid. Likewise, Basset (2000) found that the supplementation of oregano essential oil through the drinking water (150 mL/1000 L) increased the body weight of broilers by 4%. Furthermore, some authors reported a growth promoting mode of action of essential oils in quail (Denli *et al.*, 2004) and broilers (Jamroz *et al.*, 2003; Halle *et al.*, 2004; Çiftçi *et al.*, 2005). Contrary to this, some earlier investigations indicated that essential oils or oil combinations did not improve body weight gain. Botsoglou *et al.* (2002) and Papageorgiou *et al.* (2003) found that dietary supplementation of essential oils derived from oregano at levels of 50 or 100 mg/kg to

chickens and to turkeys (200 mg/kg) did not exhibit a growth promoter effect. Similar results were obtained by Basmacıoğlu *et al.* (2004) who included oregano oils at two levels, 150 mg/kg diet and 300 mg/kg diet. Zhang *et al.* (2005) also reported that the supplementation of a mixture of essential oils from oregano, cinnamon, thyme and capsicum had no positive effect on the 42-d growth performance broiler. However, during the past decade the growth promoting effect of dietary MOS supplementation on broiler chickens has been demonstrated in numerous works which were conducted under different management conditions comprising different breeds, diet compositions, experimental periods, vaccination programmes and inclusion levels (Kumprecht *et al.*, 1997; Sims & Sefton, 1999; Shafey *et al.*, 2001; Hooge *et al.*, 2003b; Bozkurt *et al.*, 2005a; b).

There are a few reports on the performance of broilers receiving the hop extract as a performance enhancer feed additive. In one of the few, it was demonstrated that the addition of 50 g/ton of antibiotic (penicillin) and ground hops at 0.45 kg per ton significantly increased the 14 d, 35 d and 42 d body weights of male broilers (Cornelison *et al.*, 2006). On the other hand, there are some recent reports on the dietary effect of some other plant extracts. No significant differences on body weight gain of broilers were observed when thyme powder (Sarica *et al.*, 2005) and a blend of extracts of sage, thyme and rosemary (Hernandez *et al.*, 2004) were added to a diet.

The AGP improved the body weight and feed efficiency of broilers in comparison with the control. All herbal additive treatments and MOS fed to broilers gave a live performance similar to that of the AGP (avilamycin) under the conditions of our experiment. The result of this study also confirmed that the combined package of MOS and essential oil of oregano (HMO) or hop extract (HMH) can perform as an AGP in both the starter period and for the entire growth period of broiler chickens. An enhancing effect of antimicrobial feed additive (AGP) in combination with MOS on broiler 49-d growth performance was also proven by Hooge *et al.* (2003b). These authors reported that MOS alone improved live performance of broilers equivalent to antibiotics and demonstrated an additive effect when combined with antibiotics.

No differences in feed intake were observed between diets from 0 to 21 d of age ( $P > 0.05$ ). However, at 42 d of age the voluntary feed intakes of birds fed AGP, MOS, HMH and HMOH added diets were significantly higher than that of the control birds. This suggests that during the finisher period from 22 to 42 d of age all the experimental feed additives stimulated feed consumption significantly compared to the control treatment (Table 2). However, the vast majority of studies on dietary essential oil supplementation did not find any stimulating or depressive effect of oils on voluntary feed intake of broiler chickens. Noteworthy, variations related to the source and active components of essential oils, breed and age of the birds, management conditions, and ingredient and nutrient composition of the experimental diets did not affect the feed intake of birds in any of the studies (Hernandez *et al.*, 2004; Basmacıoğlu *et al.*, 2004; Botsoglou *et al.*, 2004; Zhang *et al.*, 2005). The observed trend of herbal feed additives on feed consumption of broilers in our study agrees with those earlier reports only for the starter period, but differs from the grower and whole experimental periods due to the appetite stimulating effect. A similar stimulating effect on cumulative feed intake of an essential oil combination with significant performance improvements was reported by Alçiçek *et al.* (2004). Noteworthy, contrary to the results of these studies, two workers recently indicated that the oregano essential oil added to diets depressed cumulative feed intake of broilers at the same level, 147 g for Halle *et al.* (2004) and 150 g for Çabuk *et al.* (2006), despite significantly improved weight gains and feed efficiencies. On the other hand, hop extract (HMH) led to an over-consumption of the feed under our experimental conditions; conversely, the ground hops did not stimulate feed consumption of broilers as was formerly determined by Cornelison *et al.* (2006).

All feed additives improved the feed conversion ratio during the 0 to 21 d starter period ( $P < 0.01$ ) compared with the control, but not over the entire 0 to 42 d period. In fact, the control birds exhibited a better ( $P < 0.05$ ) FCR than the additive treatments during this period. Obviously, excessive feed consumption during the finisher period led to such a pattern even though all experimental treatments achieved similar body weight gains. The FCR of birds fed the HMO, HMH and HMOH added diets was significantly better than those of AGP and MOS added diets for the first 21 d of the experiment. Evidently, during the starter period the birds fed the diets containing the additives converted feed to body weight gain more efficiently ( $P < 0.01$ ) than the controls, but this was not sustained until the end of the experiment. Herbal additives fed to broilers led to better growth performance and feed efficiency than that of the control treatment, results that agree with those of Alçiçek *et al.* (2003; 2004) and Çabuk *et al.* (2006) who observed significant improvements on FCR in 42-d-old broilers fed a diet supplemented with the same herbal essential oil

mixture (Herbromix<sup>®</sup>) containing oil of oregano, laurel leaf oil, sage leaf oil, myrtle leaf oil, fennel seed oil and citrus peel oil.

A number of reports has also provided evidence of the enhancement of FCRs through the dietary addition of carvacrol (Lee *et al.*, 2003) and a mixture of essential oils including oregano, cinnamon, thyme and capsicum (Zhang *et al.*, 2005). Significant improvements in FCR of broilers at 35 d of age were reported by Halle *et al.* (2004) who added oregano oil ranging from 0.1 g/kg to 1.0 g/kg to a diet. In agreement with the results of the present study, Cornelison *et al.* (2006) indicated that the addition of ground hops at 0.45 kg per ton feed also resulted in significant improvements in FCR and feed efficiency at all ages when compared to the negative control. Contrary to these findings, it was reported that dietary supplementation of essential oils (Basmacıoğlu *et al.*, 2004; Botsoglou *et al.*, 2004; Hernandez *et al.*, 2004; Lee *et al.*, 2004a; b), thyme powder (Sarica *et al.*, 2005), Chinese herb medicine formulation (Guo *et al.*, 2004) and plant extracts (Hernandez *et al.*, 2004) had no beneficial effects on FCR of broiler chickens even if the gender and age of bird, diet composition and nutrient density, active components and constituents of herbs were differentiated for the experiments. The lack of response of experimental feed additives on feed efficiency at a significant level at 42 d of age was attributed to the dietary use of a commercial enzyme preparation (Allyzme PT-Alltech<sup>®</sup>) with a xylanase activity for wheat-based poultry diets. Therefore, the wheat-based dietary suppression on growth performance of broiler chickens might have been partially overcome by the inclusion of exogenous enzyme preparation to the diet. Antimicrobial and enzymatic activities of both might have reached peak levels in synergism, particularly in the starter period, when the endogenous enzyme activity of young birds was not effective enough. Thus, in the starter period the synergistic mode of action of enzymes with AGP, MOS, oregano essential oil and hop extract might have led to superior feed efficiencies compared to that of the control treatment. From another point of view, it could be suggested that dietary inclusion of an exogenous enzyme preparation in combination with herbal products at the recommended doses did not induce any adverse effect on the overall performance of broiler chickens.

Similar to the findings of this study, a beneficial effect on the feed conversion ratio has been reported frequently when broiler chickens were fed diets supplemented with MOS (Kumprecht *et al.*, 1997; Sims & Sefton, 1999; Shafey *et al.*, 2001; Ceylan *et al.*, 2003; Hooge *et al.*, 2003b; Hooge, 2004; Bozkurt *et al.*, 2005b). On the other hand, the results obtained in our study are in contrast to those of Engberg *et al.* (2000), Van Compenhout *et al.* (2001) and Sarica *et al.* (2005) who found no significant effect on voluntary feed intake and FCR when AGP was added into a wheat-based broiler diet. In fact, dietary inclusion of MOS and AGP resulted in intermediate feed conversion ratios between the control and herbal additives during the starter period in this study.

At 21 and 42 days of age, the mortality of birds was not affected by dietary treatments. In fact, beneficial effects of feed grade antibiotics and MOS on the overall health status of the broilers have been reported previously (Visek, 1978; Henry *et al.*, 1986; Spring, 1999; Engberg *et al.*, 2000; Shane, 2001; Ferket, 2004; Hooge, 2004). Several recent studies also noted beneficial effects of essential oils in preventing problems with coccidiosis (Allen *et al.*, 1997; Evans *et al.*, 2001), necrotic enteritis (Mitsch *et al.*, 2004) and intestinal colonisation of *E. coli* and *Salmonella typhimurium* (Helander *et al.*, 1998). However, recently published studies have indicated that the supplementation of essential oils to the diet did not improve the liveability of birds when compared to unsupplemented control treatment. The lack of response of herbal feed additives including essential oils on the broiler liveability in those studies were attributed to clean, hygienic and unstressed housing conditions (Lee *et al.*, 2003; Basmacıoğlu *et al.*, 2004; Guo *et al.*, 2004; Sarica *et al.*, 2005). Contrary to those conclusions, AGP, MOS and herbal feed additive treatments could not provide a decrease in mortality in male birds even though they were reared under stocking density stress (43 kg live weight per m<sup>2</sup> floor space).

The effects of the dietary additives on carcass yield and the relative weights of the small intestines, liver, pancreas, abdominal fat pad and bursa of fabricius are presented in Table 3. These slaughter characteristics were not influenced statistically by any of the dietary treatments ( $P > 0.05$ ). However, it is of note that the relative liver weight of chickens receiving the HMOH diets was numerically higher than those of the other treatments. A similar observation was reported by Debersac *et al.* (2001) who indicated that a plant extract from rosemary enhanced hepatic metabolism, and hence increased relative liver weight in rats. In contrast to our results, Alçiçek *et al.* (2003; 2004) observed an improvement on carcass yield of broilers when supplemented with an essential oil combination in a broiler diet. In agreement with the results of our

**Table 3** Mean carcass yield and relative weight of some internal organs, abdominal fat and bursa of fabricius of broilers fed with AGP, MOS, HMO, HMH and HMOH supplemented diets

Organ weight, %	Control	AGP	MOS	HMO	HMH	HMOH	s.e.m.	P
Slaughter weight (g)	2630	2655	2647	2653	2631	2646	17.57	0.8673
Carcass yield	77.29	76.26	77.31	76.74	76.95	77.98	0.49	0.2406
Small intestines	3.13	3.39	2.98	3.10	3.04	3.17	0.12	0.3139
Liver	224	2.23	2.27	2.36	2.31	2.54	0.07	0.0640
Pancreas	0.28	0.28	0.29	0.29	0.31	0.30	0.01	0.4882
Abdominal fat	1.54	1.19	1.40	1.23	1.46	1.59	0.12	0.1615
Bursa of fabricius	0.20	0.17	0.19	0.17	0.16	0.18	0.01	0.6913

AGP - antibiotic growth promoters; MOS - Bio-Mos; HMO - Herb-Mos Oregano; HMH - Herb-Mos Hops; HMOH - Herb-Mos Oregano plus Herb-Mos Hops.

study, Basmacıoğlu *et al.* (2004) and Sarica *et al.* (2005) found no beneficial effect of dietary supplementation of oregano essential oil and thyme powder, respectively, on the carcass yield of broiler chickens. Besides, a thinning effect on the intestinal wall of birds was induced by the antimicrobial activity of antibiotics (Henry *et al.*, 1986), an experimental blend of MOS and organic acids (Bozkurt *et al.*, 2005b) and essential oils (Alçiçek *et al.*, 2004; Jamroz *et al.*, 2005). However, this was not measured in the present study.

## Conclusion

A dietary addition of feed additives as performance enhancers significantly improved broiler growth performance in comparison with the control, and this was associated with an increase in voluntary feed intake. Dietary supplementation of the essential oil of oregano (HMO) and hop extract (HMH) provided a significant improvement on body weight gain of broiler chickens when supplemented to the diet individually, but this improvement could not be enhanced through synergistic or additive mechanisms in terms of a combined inclusion (HMOH). Herbal feed additives when used in conjunction with MOS may act as gut environment stabilizers and provide synergism, thus maximizing the growth rate and feed efficiency without negatively affecting carcass yield and principal internal organ weights. As a consequence, data derived from this study suggest that the feed additive MOS, either alone or combined with the essential oil of oregano and hop extract, have the potential to replace growth promoting antibiotics in the production of broilers.

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