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# EFFECT OF MANNAN OLIGOSACCHARIDES SUPPLEMENTATION ON PRODUCTIVE TRAITS, IMMUNITY, BLOOD PARAMETERS AND ANTIOXIDATIVE STATUS IN GROWING RABBITS

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**ABSTRACT**

The objective of this study was to evaluate the effect of feed additives with antibiotic Tylosin and mannan oligosaccharides (MOS) through winter and summer seasons on growth performance, carcass traits, blood hematology and biochemical traits, antioxidative status, immunological effects in V-line growing rabbits. A total of 120 male rabbits aged 6 weeks were distributed into 5 experimental groups of 12 rabbits each (control, antibiotic Tylosin 100 mg/kg and mannan oligosaccharides (MOS) at three levels 0.5, 1.0 and 1.5 %) through winter and summer of 2014. Heat stress through summer season induced the reduction in body weight, daily weight gain, FCR, DM, CP, CF, EE, NFE, DCP, TDN and carcass traits. The same trend was observed for RBC, WBCs counts, Hb, PCV, serum total protein, albumin and globulin concentration. However, serum GPT, GOT, blood urea and lipid profile were increased through summer season. Rabbits exposed to high temperature conditions during summer season resulted in non-significant effect on serum total antioxidant capacity (TAC) and significant increase in malondialdehyde (MDA). Feed additives resulted in an improvement final weight, gain, FCR and carcass traits. Addition of 0.5 % MOS resulted in more pronounced effect than antibiotic. Digestion coefficients of DM, CP, CF, EE & NFE, nitrogen balance (NB), nitrogen balance as percentage of nitrogen intake (NB/NI %) showed an increase in the group received 1.5 % MOS. Inclusion of 1.0 and 1.5% MOS in the diet significantly improved digested crude protein (DCP) in comparison with control group. Different feed additives had insignificant effect on blood hematology parameters, serum total protein, albumin and globulin concentration. GPT was insignificantly affected by different treatments, however, GOT was decreased and reached significantly by addition of 0.5 and 1.0 % MOS to the diets. Results showed that Tylosein and different levels of MOS resulted in significant increase in concentration of triglycerides in comparison with the control group. The different feed additives had numerical positive effect on TAC and this numerical effect reached significant only with the group received 0.5 % MOS in their diet. Different feed additives improved the MDA concentration. In conclusion**,** MOS as feed additives were effective to correct some of deleterious effects of high ambient temperatures on rabbit growth performance and some biological functions.

**Keywords:** mannan oligosaccharides, carcass traits, immunity, antioxidative status, V-line rabbits

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**INTRODUCTION**

Under the sub-tropical conditions of Egypt, rabbits play an important role in the economy of the farmers because of high biological value of rabbits' meat, high protein and low cholesterol and sodium (Abdel-Khalek., 2003 and Fonseca *et al.,* 2004**;** Mancini and Paci, 2021). The nutritional factors are one of the important factors that affect the economic intensive rabbit production especially during summer season. The high temperature affects negatively productive traits.

In the past, many breeders used antibiotics to increase productivity of rabbits. Nowadays, the European Union banned the use of antibiotics because of their adverse effects on health of animal and human. Utilizing natural materials is alternatively being developed. One of the natural materials is the phosphorylated mannan oligosaccharides, Bio-Mos®. It is derived from the outer cell wall of the yeast *Saccharomyces serivisae*, consist of a mannan component. The structure of the mannan resembles that of the carbohydrates. Bio-Mos® resulted in reduced mortality rate, improved feed conversion ratio (FCR) and similar daily weight gains (DWG) compared to oxytetracycline **(Fonseca *et al.,* 2004).** Both MOS and oxytetracycline induced longer villi, increased absorption area and caecal VFA's, moreover, decreased caecal pH compared to the control not medicated **(Pinheiro *et al.,* 2004).** The present study was carried out to evaluate the effect of antibiotic Tylosin and mannan oligosaccharides (MOS) on productive performance, carcass traits, blood hematology and biochemical traits, antioxidative status and immunological traits of V-Line growing rabbits through winter and summer seasons.

**Materials and Methods**

The present study was carried out at the Rabbitry Research Laboratory belonging to Animal and Fish Production Department, Faculty of Agriculture (Saba Basha), Alexandria University during the winter (January to march) and summer (July to September) of 2014. During the experimental period, minimum and maximum ambient temperatures were 13.2°C, 25.6°C in winter and 26.3°C, 38.8°C in summer, respectively. Relative humidity (RH %) averaged 61.3 and 54.4 while temperature-humidity index (THI) was 19.1 and 30.5 during the experimental period in winter and summer, respectively. The THI was calculated according to Marai *et al*. (2001).

**Management and animal feeding**

A total of 120 (60 in each season) healthy male growing V-line rabbits aged 6 weeks were used in the current experiment. Animals were distributed into 5 experimental groups of 12 rabbits each (control without any supplementation, antibiotic Tylosin 100 mg/kg and mannan oligosaccharides (MOS) at three levels 0.5, 1.0 and 1.5 %) through winter and summer. Rabbits were housed galvanized batteries (60×40×24 cm) provided with feeders and automatic drinkers. The experimental rabbits were kept under similar managerial and hygienic conditions. The rabbits were kept with a cycle of 16 h light and 8 h dark using artificial light sources. No heating was applied in the rearing pen. The experimental diets were offered to rabbits *ad libitum* in pelleted form from 6 to 12 weeks of age. The composition and calculated analysis of the basal experimental diet was presented in Table 1.

**Weight and Growth performance**

Individual body weight was taken weekly from 6 weeks until 12 weeks of age. Body weight gain, feed intake, and feed conversion ratio were determined.

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**Digestion trials**

At the end of experiment, 20 male rabbits were randomly taken (through winter and summer) and housed individually in metabolic cages (four rabbits from each treatment), feces and urine were collected. A preliminary period of 7 days was followed by five days for measurements of actual consumed feed and collection of feces and urine output. Representative samples of feed offered and dried feces of each rabbit were chemically analyzed for determinations of dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash according to **A.O.A.C. (2000)**. Nitrogen free extract (NFE) was determined by difference. Apparent digestion coefficient (ADC), total digestible nutrients (TDN) and digestible energy (DE) were calculated according to Cheeke *et al.* (1987).

**Blood hematological**

At the end of the trial, three rabbits were selected from each treatment group, starved of food but not water for 12 hours. 8 ml of blood sample was taken from the ear vein with a sterile syringe. 4 ml of the blood was put into a bijon bottle containing EDTA as an anticoagulant for hematological assay. The remaining 4ml of the blood sample was put into a sterile vacutainer tube without an anticoagulant for serum biochemical analysis. The hematological assay was carried out to determine erythrocyte indices such as packed cell volume (PCV), and hemoglobin (Hb) values.

Red blood cell (RBC) counts were counted on an AO Bright line hemocytometer using a light microscope at 400X magnification after diluting blood samples 200 times with a physiological saline (0.9% NaCl solution) before counting **(Natt and Herrick, 1952).** White blood cell (WBC) were counted on an AO Bright line hemocytometer using a light microscope at 100X magnification after diluting blood samples 20 times with a diluting fluid (1% acetic acid solution with a little of Leishman's stain) before counting (**Hepler, 1966**).

Differential leucocytic count was examined according to the method of **Lucky (1977).** A drop of heparinzed blood was spread on a glass slide, quickly air dried, fixed by methyl alcohol for 3- 5 min. then stained with Giemsa's stain for 20 minutes after that rinsed under slow water current and dried gently between two filter paper. Stained blood sample was examined using oil immersion lens. The percentage of each type of cells was calculated according to **Schalm *et al.* (1986).** Hemoglobin (Hb) concentration as (g/dl) was estimated by cyanomethe-moglobin method according to **Eilers (1967**). Wintrobe hematocrit tubes were used for determination of packed cell volume (PCV) as (%). Blood was centrifuged for 20 minutes on 4000 rpm, and then PCV volume was obtained by reading the packed cell volume on the graduated hematocrit tubes.

**Biochemical parameters of blood:**

Blood samples were taken from four rabbits from each group at the end of the productive experiment (at 12 weeks of age). Total protein, albumin, total lipids, cholesterol, triglycerides, low density lipoprotein, high density lipoprotein, creatinine, urea, total antioxidant capacity (TAC) and malondialdehyde were determined using the commercial kits produced by Human (Max-Planck-Ring 21-D-65205 Wiesbaden, Germany). Globulin concentration was calculated by the difference between total protein and albumin, since the fibrinogen usually comprises a negligible fraction **(Sturkie, 1986).**

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**Immunization and titration against sheep red blood cells (SRBC's)**

At week 14 of age, rabbits of all groups immunized with 0.1 ml of a 2.5% Sheep Red Blood Cells (SRBC) at 30 days after starting the dietary treatment supplementation, to measure Antibody titer against to Sheep Red Blood Cells.

The dosage of SRBC for inoculation was pre-determined by a separate trial. Antiserum to SRBC was collected 14 and 21 days' post challenge. One ml of blood with one drop of heparin was refrigerated to allow red blood cells to settle. If sedimentation was not complete, samples were centrifuged for 1 to 2 min at 3000 rpm to separate plasma and erythrocytes, and the supernatant was collected .

Briefly, 96-well plates were first filled with 50 µl of physiological saline solution in each well. Then 50 µl of antiserum was pipetted into the first well in duplicates after which 50 µl from the first well was pipetted into the second well, and so forth using an automatic pipette.

Finally, a 0.75% of SRBC solution was added to each well. Plates were incubated at 37°C for 3 hours and then examined visually for agglutination **(Wegmann and Smithies, 1966).** The agglutination titer was expressed as the log2 of the reciprocal of the highest serum dilution giving complete agglutination (**Nelson *et al*., 1997).**

**Carcass traits:**

At 12 weeks of age in each season, three rabbits were taken randomly from each treatment, fasted for 12 hrs. They were weighed, slaughtered and weighed after complete bleeding, skinned and eviscerated. The carcass weight, skin, head, liver, heart, kidneys, lungs, spleen, small intestine, and caecum weights (empty) were recorded. Although, the caecum and small intestine length were recorded.

**Statistical analysis:**

Two-way analysis of variance was conducted using General Linear Models Procedure of SAS program (1997) with two seasons and 5 feed additives. The statistical model as follows:

$Y_{ijk}=\mu+ S_i + T_j +(ST_{ij})+e_{ijk}$

Where:

$Y_{ijk}$= the observation of the $k^{th}$ individual;

$\mu$= the overall mean;

$S_i$= the fixed effect of $i^{th}$ season, i=1-2;

$T_j$= the fixed effect of $j^{th}$ treatment, j=1-5;

$(ST_{ij})$= the interaction between season and treatment;

$e_{ijk}$= random error.

The differences among the groups were subjected using Duncan' s Multiple Range-test **(Duncan, 1955).**

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**Table 1: Ingredients and chemical composition of experimental diets**

| **Ingredients** | **Control** | **Tylosin 100 mg/kg** | **MOS 0.5%** | **MOS 1%** | **MOS 1.5 %** |
|---|---|---|---|---|---|
| Yellow corn | 19 | 19 | 19 | 19 | 19 |
| Wheat bran | 11 | 10.99 | 10.5 | 10 | 9.5 |
| Barley | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 |
| Clover hay | 33 | 33 | 33 | 33 | 33 |
| Soy bean meal (44%CP) | 15 | 15 | 15 | 15 | 15 |
| Molasses | 3 | 3 | 3 | 3 | 3 |
| DI-calcium phosphate | 1 | 1 | 1 | 1 | 1 |
| L-lysine | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| DI- Methionine | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Premix | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| MOS | - | - | 0.5 | 1 | 1.5 |
| Tylosin | - | 0.01 | - | - | - |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Chemical analysis:** | | | | | |
| Dry matter (DM) | 94.11 | 94.01 | 92.89 | 92.36 | 92.36 |
| Organic matter (OM) | 89.96 | 89.76 | 91.91 | 91.41 | 91.47 |
| Crude protein (CP) | 17.03 | 17.00 | 17.61 | 17.51 | 17.13 |
| Ether extract (EE) | 2.67 | 2.70 | 2.54 | 2.69 | 2.51 |
| Crude fiber (CF) | 11.97 | 11.90 | 11.07 | 11.19 | 11.12 |
| Nitrogen free extract (NFE) | 58.29 | 58.16 | 60.69 | 60.02 | 60.71 |

*Each kg of vitamin and mineral mixture contained: Vit A.2000.000 IU; E 10mg; B1 400 mg; B2 1200mg; B6 400mg; B12 10 mg; D3 180000 IU; Colin chloride 240 mg; Pantothenic acid 400 mg; Niacin 1000mg; Folic acid 1000 mg; Biotin 40 mg; Manganese 1700 mg; Zinc 1400 mg; Iron 15 mg; Copper 600 mg; Selenium 20 mg; Iodine 40 mg and Magnesium 8000 mg

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**RESULTS and DISCUSSION**

**Productive traits:**

Table 2 showed the average live body weight, daily weight gain, feed intake and FCR of rabbits as affected by different seasons and feed additives.

Season had highly significant effect on all studied traits except FCR. The decrease in daily gain through summer season reached to 8.3 % in comparison with winter season. Such effect was accompanied with a parallel effect on feed intake. The decline in live body weight observed in summer season is in agreement with those reported by **Ayyat *et al.* (2002) and Marai *et al.* (1994).** They concluded that poor growth performance of rabbits under heat stress may have been a result of the decrease in feed intake. High environmental temperature stimulates the thermal receptors to transmit suppressive nerve impulses to the appetite center in the hypothalamus causing the decrease in feed consumption (**Marai *et al.,* 1994**). This may lead to less protein biosynthesis and/or less fat deposition, leading to lower body gain.

Irrespective of season, body weight of rabbits was significantly ($P \leq 0.01$) affected by the different feed additives, where adding Tylocein, MOS at 0.5, 1.0 and 1.5 % resulted in significant increase in final body weight by 9.7, 14.5, 10.9 and 13.7 %, respectively, in comparison with control group. The results showed that addition of 0.5% MOS resulted in more pronounced effect than antibiotic and other treatments. The same trend was observed for daily gain of rabbits in favour of 5% Mos. Through the experimental period (6-12 weeks) the superiority ranged from 17.2- 24.5 % than control group. **Kim *et al.* (2011)** reported that the antibiotic avilamycin, FOS 0.25, and MOS 0.05 groups showed significantly greater overall body weight gains than did birds in the MOS 0.025 treatment group, and body weight gain in this group was greater than gain in the FOS 0.5 and control groups.

Irrespective of feed additives, the results showed that feed conversion ratio insignificantly affected by season. When the effect of seasons was over looked, the results showed significant ($P \leq 0.01$) effect of different feed additives through the whole experimental period. Feed additives showed significant ($P \leq 0.01$) improvement in feed conversion ratio in comparison with control. **Fonseca *et al.* (2004)** demonstrated that providing Bio-Mos®, resulted in improved feed conversion ratio (FCR) and daily weight gains (DWG) compared to oxytetracycline. They attributed their to that Bio-Mos® induced longer villi and increased absorption area compared to the control not medicated (**Pinheiro *et al.,* 2004**). Certain types of oligosaccharides might be a potential alternative of antibiotics in enhancing animal growth and improving the intestinal microbiota **(Patterson and Burkholder, 2003).** The supplementation with oligosaccharides, such as yeast manano-oligosaccharides and yeast β-glucans have been used to improve growth performance and immunity in young rabbits **(El-Abed *et al.,* 2015).**

The interaction effect due to seasons and feed additives was recorded ($P \leq 0.01$) for body weight, daily weight gain and FCR and significant ($P<0.05$) for feed intake. Generally, the results showed that MOS at 0.5 and 1.5% levels recorded the highest values of final body weight, daily weight gain, feed intake and FCR.

**Digestibility coefficients of nutrients, nutritive values and nitrogen balance:**

Irrespective of feed additives, the results in Table (3) showed that digestibility coefficients of dry matter (DM), crude protein (CP), crude fiber (CF), Ether extract (EE) and nitrogen free extract (NFE) were significantly affected by season; however, organic matter was insignificantly affected. Digestion coefficients of DM, CP, CF, EE and NFE were significantly ($P \leq 0.01$) deteriorated through high temperature summer conditions in

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comparison with winter time, which reflected on daily body weight. However, through summer, the result showed that rabbits given 0.5 and 1.5 % MOS in their diet recorded the highest values for DM, OM, CP, CF and NFE and Tylocein and 1% MOS recorded the highest values for CF, while the highest values for EE were found in the groups had 0.5 and 1.5 % in their diet. **Marai *et al.* (2001)** reported that digestibility coefficients declined due to heat stress by 7.9% in dry matter, 8.1% in crude protein and 1.0% in crude fiber. While **El-Gamal (2002)** showed that the ambient temperature had no significant effects on digestibility coefficient of all nutrients, but the digestibility of ether extract was better under high temperature but, it decreased digestibility of crude fiber.

Irrespective of seasons, the results showed that digestibility coefficients of dry matter (DM) showed significant improvement due to different supplementations. This improvement effect reached significant only in the group received 1 and 1.5 % MOS containing diet. Supplementation of MOS increased the length of ileal villi and possible a result of reduction in microbial counts, which also detected in fattening rabbits **(Mourão *et al.* 2006).**

Concerning the nutritive values, results showed that seasons had significant ($P < 0.01$) effect on total digestible nutrients (TDN) and digested crude protein (DCP). These values decreased through summer by 2.3 and 9.2 % in comparison with winter, respectively. Also, the results showed that including 1.0 and 1.5% MOS in the diet significantly improved DCP in comparison with control group, however, TDN was insignificantly affected by the different experimental groups. The best values of DCP % and TDN were recorded in the group received 1.5 % MOS in their diet through the winter seasons.

Data in Table 4 concerning the nitrogen utilization illustrated that during summer, nitrogen intake, fecal nitrogen, digested nitrogen were significantly ($P \leq 0.01$) decreased while urine nitrogen significantly increased. Also, nitrogen balance and nitrogen balance as percentage of nitrogen intake were significantly ($P \leq 0.01$) decreased. It is worthy to note that nitrogen intake, fecal nitrogen and digested nitrogen were insignificantly affected by different treatments in comparison with control group. However, urine nitrogen was decreased with different feed additives and reached significant ($P \leq 0.05$) effect only with addition of 0.5 % MOS in the diet in comparison with control group. The different feed additives resulted in significantly ($P \leq 0.01$) increase in the nitrogen balance (NB) and nitrogen balance as percentage of nitrogen intake (NB/NI %).

Different seasons and feed additives had significant interaction effect on nitrogen intake, fecal nitrogen, digested nitrogen, urine nitrogen, NB and NB/NI %. The best values of NB and NB/NI % were recorded in the groups given all feed additives through winter time.

**Blood hematological parameters and biochemical constituents:**

The results of the blood parameters are tabulated in Table 5. The overall means of RBC, WBC counts, Hb and PCV reduced during summer season. The results may be due to the heat stress through summer. **Ashour (2001)** and **Gad *et al.* (1995)** found that hematological parameters were highest in winter and were lowest in summer. They reported that the drop is responsive trial to reduce oxygen intake, thus reducing metabolic heat production under this hot condition. The decreases in oxygen intake are important for animals to keep heat balance (**Solouma, 1999**). **Comito *et al.* (2007)** reported that thermal panting could decrease hemoglobin synthesis. In terms of dietary treatments effect, no differences in the blood parameters were detected between the five treatments.

Serum total protein, albumin and globulin concentration values were significantly ($P \leq 0.01$) decreased through the summer season. However, albumin/globulin ratio was increased through summer season in

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comparison with winter season. **El-Gindy (2006)** found the same findings for rabbits' does kept under normal temperature and those reared under high temperature. **El-Masry and Habeeb (1989)** and **Habeeb *et al.* (1993)** illustrated that the significant decline in total protein with rising temperature seems to be due to dilution of plasma proteins caused by the increase in water consumed and decrease of protein synthesis as a result of depression of anabolic hormonal secretion**.**

Total protein, albumin and globulin means did not significantly affected by feed additives. **Ismail *et al.* (2004)** found that insignificant (P<0.05) differences were observed in plasma total protein, albumin, globulin and albumin/globulin ratio were achieved by NZW rabbits fed Bio-Mos (1.0 and 1.5 g/kg diet) as compared to rabbits fed low level (0.5 g/kg diet) and control. Blood serum total protein has a particular importance in maintaining plasma volume. This importance is due to the fact that total protein in plasma generates a colloid osmotic pressure, which controls the flow of water between blood and interstitial fluids **(Harper *et al.,* 1977)**. Also, **Haider *et al.* (2010)** reported that proteins are playing role in intracellular buffers within the body tissues to provide a reserve buffering capacity. This indicates that the different feed additives used in the present study did not have a deleterious effect on acid base balance.

Results in Table (7) showed that serum GPT and GOT were significantly increased through summer season. This increase showing a stressful condition. The decrease in the concentration of aforementioned enzymes through the winter reflects better liver function (**Abou-Egla *et al.,* 2001** and **El-Saieh, 2014).**

Irrespective of seasons, the results showed that GPT concentration was insignificantly affected by different feed additives in comparison with the control group, however, GOT was decreased and reached significantly (P ≤ 0.05) only by addition of 0.5 and 1.0 % MOS to the diets. These results mean that MOS hadn't deleterious effect on liver function. **Attia *et al.* (2014)** reported that MOS supplementation to growing rabbits diet resulted in decreasing plasma AST and ALP in comparison with control. **Shahba (2011)** found that MOS did not affect liver morphology. Also, **Ismail *et al.* (2004)** reported insignificant differences were observed in plasma ALT and AST concentrations were achieved by NZW rabbits fed Bio-Mos (1.0 and1.5 g/kg diet) as compared to rabbits fed low level (0.5 g/kg diet) and control.

Regarding to the effect of season, it was noticed that total lipids, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL) and triglycerides were significantly (P ≤ 0.01) increased in blood serum of rabbits exposed to high temperature through summer season in comparison with the rabbits reared under normal temperature through the Egyptian winter time. The ratio of HDL/LDL was significantly decreased through summer in comparison with winter. The increase in lipid profile through heat stress conditions in summer showing a stressful condition. **El-Gindy (2006)** reported that total lipid and total cholesterol of adult rabbit does reared under high temperature were higher than those reared under either medium or normal temperature. More recently, **Asal (2013)** showed that blood plasma total lipids and triglycerides were significantly increased in rabbit bucks due to exposure to heat stress in summer season compared to winter.

In addition, the results indicated that feed additives insignificantly affected total lipids, HDL, LDL and the ratio HDL/LDL, while total cholesterol and triglycerides were significantly affected. Addition of MOS at level 0.5 g/kg diet resulted in significant elevation of total cholesterol in comparison with control or 1.0 and 1.5 MOS g/kg diet. However, Tylosein had insignificant effect on cholesterol concentration as compared with control group. **Ismail *et al.* (2004)** showed significant (P ≤ 0.05) differences were observed in plasma cholesterol levels by NZW rabbits fed Bio-Mos (1.0 and 1.5 g/kg diet) as compared to rabbits fed low level (0.5 g/kg resulted in significant increase in concentration of triglycerides in diet) and control. **Grela *et al.*** (2006) found that FOS supplementation

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resulted in a significant decrease in plasma total lipid and total cholesterol of growing rabbits. **Radwan and Abdel-Khalek (2007)** showed a significant decreasing effect ($P \leq 0.05$) in both plasma total lipids and cholesterol with supplementing NZW rabbits with growth promoters (lactic acid, acetic acid, GOS® and MOS®). Also, **Attia *et al.* (2014)** reported that MOS supplementation to growing rabbits diet resulted in decreasing plasma total cholesterol and total lipids in comparison with control.

**Total antioxidant capacity (TAC) and malondialdehyde (MDA):**

Results of total antioxidant capacity (TAC) and malondialdehyde (MDA) are illustrated in Table (6). It is clear to note that rabbits exposed to high temperature conditions during summer season resulted in non-significant effect on serum total antioxidant capacity (TAC) and significant increase in malondialdehyde (MDA). In addition, feed additives had numerical positive effect on TAC and this numerical effect reached significant only with the group received 0.5% MOS in their diet in comparison with control group. The best value was found in the group had 1 % MOS in their diet in comparison with the other feed additives.

When the effect of different feed additives was overlooked, the results showed that Vitamin C itself plays important roles in cellular anti-oxidant defenses, not only by reacting with all oxygen species through formation of dehydroascorbyl, a particular inert radical, but also by transferring radical equivalents from lipid phases to the aqueous compartment. In complement, ascorbate participates in the regeneration of reduced glutathione from the oxidized form in the cytoplasm and allows tocopherol regeneration through a non-enzymatic reaction (**Ciftci *et al.*, 2005**). Heat stress leads to the cell membrane (**Luadicina and Marnett, 1990**), destroying membrane integrity during stress. Heat stress stimulates lipid peroxidation as a consequence of increased free radical generation. The increase in lipid peroxidation decreases antioxidant levels such as vitamin C and vitamin E in tissues **(Tatli Seven *et al.*, 2008).**

**Shahba (2011)** demonstrated that plasma total antioxidant capacity (TAC) significantly increased of MOS supplemented-group compared to inulin and ZnB groups in growing V-line rabbits. Also, **Zeweil *et al.* (2016)** reported significant decrease in seminal plasma MDA concentration, while significant increase in seminal plasma TAC due to MOS supplementation in comparison with the control group in male rabbits.

Interaction effect due to different treatments was recorded on TAC and MDA values. The best value of TAC was recorded in the group given 0.5 % MOS through summer season, while the lowest value was recorded in control group through summer. On the other hand, the lowest value of MDA was found in the group received 1 % MOS through the summer season, while the highest values were observed in the control and Tylosin fed group. The different treatments had insignificant effect on TAC and MDA through winter.

**Carcass traits:**

Results tabulated in Table (7) showed that carcass weight and dressing percentage significantly ($P \leq 0.01$) recorded the lowest values in summer season in comparison with winter. However, skin, heart, kidney, lungs, small intestine and caecum percentages were insignificantly affected.

Feed additives had significant ($P<0.01$) effect on carcass weight, dressing percentage, liver and cecum %. The highest significant ($P \leq 0.01$) values were noticed in the groups given different levels of MOS in comparison with control and Tylosin fed group. Also, the results showed insignificant effect due to antibiotic on dressing percentage, liver and cecum % in comparison with control. However, it was observed that the different feed additives had significant ($P \leq 0.01$) effect on liver percentage. Addition of antibiotic Tylosin to the diet resulted in significant increase in liver percentage in comparison with MOS fed groups. However, the results were

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insignificant in comparison with control group. Cecum percent was decreased in the groups given 0.5 and 1.0 % MOS in comparison with control.

It could be concluded that MOS as feed additives had effective to correct some of deleterious effects of high ambient temperatures on rabbit growth performance and some biological functions.

Table 2 Effect of season and feeding treatment on body weight, daily gain and FCR in rabbits

| | Initial weight (g) | Final weight (g) | Daily Gain (g) | Feed intake (g) | FCR |
|---|---|---|---|---|---|
| **Season** | | | | | |
| Winter | 726.73[a] | 1941.52[a] | 28.92[a] | 104.80[a] | 3.65 |
| Summer | 682.94[b] | 1797.24[b] | 26.53[b] | 93.15[b] | 3.56 |
| **Treatment** | | | | | |
| control | 703.23 | 1702.83[c] | 23.80[b] | 94.52[b] | 4.00[a] |
| Tylocein | 696.67 | 1868.53[b] | 27.90[a] | 96.11[b] | 3.47[b] |
| 0.5% Mos | 706.27 | 1950.10[a] | 29.62[a] | 102.51[a] | 3.47[b] |
| 1% Mos | 707.80 | 1888.60[ab] | 28.12[a] | 102.56[a] | 3.69[ab] |
| 1.5% Mos | 710.23 | 1936.83[ab] | 29.21[a] | 99.15[ab] | 3.39[b] |
| **SEM** | | | | | |
| ***P* value** | | | | | |
| Season (S) | 0.0009 | 0.0001 | 0.0005 | 0.0001 | 0.4428 |
| Treatment (T) | 0.9710 | 0.0001 | 0.0001 | 0.0199 | 0.0094 |
| S*T | 0.2043 | 0.0001 | 0.0001 | 0.0001 | 0.039 |

SEM: standard error of the mean. FCR= feed conversion ratio

[a, b] Values in columns with different letters differ significantly ($P < 0.05$).

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Table 3 Effect of season and feeding treatment on digestibility coefficients of nutrient and nutritive values in growing rabbits

| | Digestion coefficients of nutrient | | | | | | Nutritive values | |
|---|---|---|---|---|---|---|---|---|
| | DM | OM | CP | CF | EE | NFE | DCP (%) | TDN (%) |
| **Season** | | | | | | | | |
| Winter | 71.85[a] | 72.14 | 75.76[a] | 29.04[a] | 80.78[a] | 72.03[a] | 13.66[a] | 72.16[a] |
| Summer | 69.83[b] | 71.46 | 72.26[b] | 26.98[b] | 77.16[b] | 71.10[b] | 12.40[b] | 70.51[b] |
| **Treatment** | | | | | | | | |
| control | 70.23[b] | 70.61[b] | 73.26 | 27.27 | 77.94 | 71.25 | 12.66[b] | 70.93 |
| Tylocein | 70.91[ab] | 71.48[ab] | 74.04 | 28.04 | 79.17 | 71.47 | 13.03[ab] | 71.59 |
| 0.5% Mos | 70.68[ab] | 71.89[ab] | 74.40 | 28.21 | 79.35 | 71.61 | 13.00[ab] | 71.83 |
| 1% Mos | 71.25[a] | 72.25[ab] | 74.33 | 28.76 | 79.65 | 71.43 | 13.17[a] | 71.14 |
| 1.5% Mos | 71.11[a] | 72.77[a] | 74.03 | 27.77 | 78.74 | 72.08 | 13.30[a] | 71.18 |
| **SEM** | *1.21* | *2.68* | *1.80* | *2.41* | *3.66* | *1.27* | *0.72* | *2.25* |
| ***P* value** | | | | | | | | |
| Season (S) | 0.0001 | 0.2125 | 0.0001 | 0.0001 | 0.0001 | 0.0007 | 0.0001 | 0.0008 |
| Treatment (T) | 0.0925 | 0.0378 | 0.3053 | 0.4071 | 0.6248 | 0.3241 | 0.0571 | 0.7166 |
| S*T | 0.0001 | 0.0341 | 0.0001 | 0.0106 | 0.0005 | 0.0340 | 0.0001 | 0.0482 |

SEM: standard error of the mean.

[a, b] Values in columns with different letters differ significantly (P < 0.05).

Table 4 Effect of season and feeding treatment on nitrogen balance.

| | N intake (NI) (g) | Fecal N (g | Digested N (g) | Urine N (g) | NB (g) | NB/NI% |
|---|---|---|---|---|---|---|
| **Season** | | | | | | |
| Winter | 3.21[a] | 0.73[a] | 2.48[a] | 0.90[b] | 1.58[a] | 49.26[a] |
| Summer | 2.63[b] | 0.48[b] | 1.86[b] | 1.04[a] | 1.11[b] | 42.21[b] |
| **Treatment** | | | | | | |
| control | 2.84 | 0.62[ab] | 2.09 | 1.07[a] | 1.16[b] | 40.64[b] |
| Tylocein | 2.95 | 0.63[a] | 2.22 | 0.94[ab] | 1.37[a] | 46.02[a] |
| 0.5% Mos | 2.94 | 0.63[a] | 2.17 | 0.90[b] | 1.41[a] | 47.27[a] |
| 1% Mos | 2.91 | 0.58[ab] | 2.19 | 0.99[ab] | 1.34[a] | 45.86[a] |
| 1.5% Mos | 2.95 | 0.56[b] | 2.16 | 0.94[ab] | 1.45[a] | 48.89[a] |
| **SEM** | *0.15* | *0.08* | *0.21* | *0.20* | *0.21* | *14.28* |
| ***P* value** | | | | | | |
| Season (S) | 0.0001 | 0.0001 | 0.0001 | 0.0009 | 0.0001 | 0.0001 |
| Treatment (T) | 0.1927 | 0.0261 | 0.6287 | 0.0566 | 0.0010 | 0.0044 |
| S*T | 0.0001 | 0.0001 | 0.0001 | 0.0202 | 0.0001 | 0.0001 |

SEM: standard error of the mean.

[a, b] Values in columns with different letters differ significantly (P < 0.05).

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**Table 5 Effect of season and feeding treatment on blood heamatological parameters.**

| | RBC ($10^6$/mm$^3$) | WBC ($10^3$/mm$^3$) | Hb mg/dl | PCV % | Total protein g/dl | Albumin g/dl | Globulin g/dl | Alb/Glo ratio |
|---|---|---|---|---|---|---|---|---|
| **Season** | | | | | | | | |
| Winter | 4.97$^a$ | 7.18$^a$ | 14.96$^a$ | 45.87$^a$ | 7.43$^a$ | 4.74$^a$ | 2.69$^a$ | 1.77$^b$ |
| Summer | 3.51$^b$ | 6.00$^b$ | 10.66$^b$ | 32.51$^b$ | 5.76$^b$ | 3.93$^b$ | 1.83$^b$ | 2.21$^a$ |
| **Treatment** | | | | | | | | |
| control | 4.13 | 6.92 | 13.35 | 39.32 | 6.51 | 4.32 | 2.19 | 2.06 |
| Tylocein | 4.27 | 6.58 | 12.73 | 39.26 | 6.31 | 4.21 | 2.10 | 1.97 |
| 0.5% Mos | 4.14 | 6.70 | 12.20 | 38.27 | 6.80 | 4.42 | 2.38 | 1.98 |
| 1% Mos | 4.36 | 6.66 | 12.98 | 39.78 | 6.71 | 4.33 | 2.39 | 1.93 |
| 1.5% Mos | 4.29 | 6.11 | 12.78 | 39.33 | 6.67 | 4.41 | 2.26 | 2.00 |
| **SEM** | *0.443* | *1.094* | *0.973* | *2.594* | *0.586* | *0.337* | *0.410* | *0.330* |
| ***P* value** | | | | | | | | |
| Season (S) | 0.0001 | 0.0040 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0006 |
| Treatment (T) | 0.859 | 0.753 | 0.340 | 0.883 | 0.607 | 0.806 | 0.6910 | 0.9741 |
| S*T | 0.0001 | 0.0500 | 0.0001 | 0.000 | 0.0001 | 0.0001 | 0.0004 | 0.0441 |

SEM: standard error of the mean.

$^{a, b}$ Values in columns with different letters differ significantly ($P < 0.05$).

Table 6 Effect of season and feeding treatment on blood biochemistry and antioxidant profile in rabbits.

| | SGPT u/l | SGOT u/l | Urea mg/dl | Creatinine mg/dl | T. lipids mg/dl | Cholesterol mg/dl | HDL mg/dl | LDL mg/dl | HDL/ LDL | Triglycerides mg/dl | TAC | MDA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Season (S)** | | | | | | | | | | | | |
| Winter | 21.44$^b$ | 22.11$^b$ | 52.66$^b$ | 1.46 | 159.36$^b$ | 49.91$^b$ | 29.37$^b$ | 16.84$^b$ | 1.95$^a$ | 35.90$^b$ | 1.195 | 12.40$^b$ |
| Summer | 25.44$^a$ | 35.42$^a$ | 61.18$^a$ | 1.48 | 231.32$^a$ | 68.99$^a$ | 40.12$^a$ | 55.01$^a$ | 0.73$^b$ | 69.75$^a$ | 1.194 | 13.42$^a$ |
| **Treatment (T)** | | | | | | | | | | | | |
| control | 23.5 | 31.41$^a$ | 59.97$^a$ | 1.55 | 198.49 | 57.49$^b$ | 34.64 | 36.44 | 1.3 | 49.00$^c$ | 1.081$^b$ | 14.11$^a$ |
| Tylocein | 22.55 | 29.79$^{ab}$ | 61.21$^a$ | 1.56 | 201.43 | 60.03$^{ab}$ | 35.28 | 36.73 | 1.38 | 50.69$^{ab}$ | 1.297$^a$ | 13.62$^a$ |
| 0.5% Mos | 22.5 | 27.43$^b$ | 51.52$^b$ | 1.39 | 189.04 | 63.98$^a$ | 34.24 | 35.76 | 1.45 | 55.90$^a$ | 1.167$^{ab}$ | 12.60$^b$ |
| 1% Mos | 24.1 | 27.14$^b$ | 55.31$^{ab}$ | 1.44 | 191.24 | 59.02$^b$ | 34.83 | 35.23 | 1.32 | 55.22$^a$ | 1.214$^{ab}$ | 11.93$^c$ |
| 1.5% Mos | 24.54 | 28.06$^{ab}$ | 56.58$^{ab}$ | 1.4 | 196.49 | 56.28$^b$ | 34.73 | 35.52 | 1.23 | 53.31$^{ab}$ | 1.214$^{ab}$ | 12.32$^{bc}$ |
| **SEM** | *4.95* | *3.05* | *5.61* | *0.14* | *11.34* | *3.53* | *1.68* | *3.44* | *0.46* | *3.27* | *0.134* | *0.33* |
| ***P* value** | | | | | | | | | | | | |
| S | 0.0322 | 0.0001 | 0.0008 | 0.7977 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.9939 | 0.0001 |
| T | 0.9346 | 0.0545 | 0.0089 | 0.1502 | 0.2823 | 0.0056 | 0.8637 | 0.9281 | 0.9355 | 0.0018 | 0.039 | 0.0001 |
| S*T | 0.3475 | 0.0001 | 0.0158 | 0.5302 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.049 | 0.0001 |

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TAC = Total antioxidant capacity mm/L ; MDA = Malondialdehyde nmol/ml

SEM: standard error of the mean.

[a, b] Values in columns with different letters differ significantly (P < 0.05).

Table 7 Effect of season and feeding treatment on carcass traits.

| | Carcass weight | Dressing % | Skin (%) | Head (%) | Liver (%) | Heart (%) | Kidney (%) | Lung (%) | Spleen (%) | Cecum (%) | Cecum length (cm) | Small Intestine (%) | Small Intestine length(cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Season (S)** | | | | | | | | | | | | | |
| Winter | 982.16[a] | 51.60[a] | 15.78 | 6.22[b] | 3.21[b] | 0.39 | 0.81 | 0.662 | 0.084[b] | 1.56 | 31.72 | 3.54 | 273 |
| Summer | 880. 49[b] | 49.90[b] | 16.13 | 7.49[a] | 3.96[a] | 0.42 | 0.75 | 0.687 | 0.132[a] | 1.75 | 31.2 | 3.65 | 268.64 |
| **Treatment (T)** | | | | | | | | | | | | | |
| control | 868.22[b] | 49.81[b] | 15.97 | 7.28 | 3.69[ab] | 0.34 | 0.85 | 0.716 | 0.106 | 1.81[a] | 31.6 | 3.74 | 278.3 |
| Tylocein | 894.64[b] | 49.64[b] | 15.89 | 6.81 | 3.92[a] | 0.41 | 0.82 | 0.608 | 0.106 | 1.74[ab] | 32.2 | 3.53 | 271.2 |
| 0.5% Mos | 976.10[a] | 51.22[a] | 16.19 | 6.49 | 3.29[b] | 0.41 | 0.74 | 0.658 | 0.114 | 1.57[b] | 31.4 | 3.53 | 266.7 |
| 1% Mos | 954.50[a] | 51.79[a] | 15.38 | 6.79 | 3.48[b] | 0.39 | 0.78 | 0.678 | 0.103 | 1.43[b] | 30 | 3.56 | 260.9 |
| 1.5% Mos | 962.18[a] | 51.33[a] | 16.34 | 6.89 | 3.55[b] | 0.41 | 0.73 | 0.715 | 0.112 | 1.73[a] | 32.1 | 3.61 | 277 .00 |
| **SEM** | *46.48* | *1.71* | *2.22* | *0.89* | *0.89* | *0.12* | *0.18* | *0.15* | *0.05* | *0.4* | *7.82* | *1.2* | *40.02* |
| ***P* value** | | | | | | | | | | | | | |
| S | 0.0001 | 0.0001 | 0.4312 | 0.0001 | 0.0002 | 0.2655 | 0.0957 | 0.402 | 0.0001 | 0.0228 | 0.7413 | 0.6634 | 0.589 |
| T | 0.0001 | 0.0001 | 0.7087 | 0.1151 | 0.244 | 0.862 | 0.1746 | 0.1433 | 0.9658 | 0.032 | 0.9053 | 0.9789 | 0.6273 |
| S*T | 0.0001 | 0.0001 | 0.264 | 0.0001 | 0.0083 | 0.9424 | 0.2291 | 0.0405 | 0.0189 | 0.0179 | 0.9747 | 0.9884 | 0.6386 |

SEM: standard error of the mean.

[a, b] Values in columns with different letters differ significantly (P < 0.05).

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