Animal Health Prod and Hyg (2018) 7(1) : 558 - 562

Animal Health, Production and Hygiene

www.aduveterinaryjournal.com

Research Article

# Use of inulin and β-glucan as growth promoters in turkey chicks

Buğra Genç[1], Ahmet Ergün[2]

[1]*Department of Laboratory Animals, Faculty of Veterinary Medicine, Ondokuz Mayis University, Samsun Turkey.*

[2]*Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, Ankara University, Ankara Turkey.*

**A B S T R A C T**

**Background/Aim:** In this study, it was aimed to determine the effects of the prebiotics (β-glucan, inulin), on performance parameters of turkey chicks.

**Material and Methods:** A total of 48 male turkeys (Hybrid Converter) were used as animal material. Diet for 3 treatment groups was designed to contain β-glucan (0.014%), inulin (0.70%) and inulin + β-glucan (0.70% + 0.014%) respectively. In the group consumed β-glucan, feed conversion ratio (FCR) values were highest value. Blood serum glucose level was the highest in the 3rd group consumed inulin + β-glucan. This difference was considered as synergic effect of these two additives on the serum glucose level.

**Results and conclusion:** Although there is a synergic effect, these materials can be recommended as an alternative additives against diseases in terms of preventive medicine.

*Key words: β-glucan, immunity, inulin, performance, turkey.*

## Hindilerde inulin ve β-glukanın büyütme faktörü olarak kullanımı

**Ö Z E T**

**Özbilgi/Amaç:** Bu çalışmada prebiyotiklerin (β-glukan ve inulin) performans üzerine olan etkilerinin gösterilmesi amaçlanmıştır.

**Materyal ve Metot:** Hayvan materyali olarak toplam 48 adet erkek Hybrid Converter hindi kullanılmıştır. Deneme gurubu diyetleri sırasıyla β-glukan (0.014%), inulin (0.70%) ve inulin + β-glukan (0.70% + 0.014%) içerek şekilde dizayn edilmiş olup kontrol grubu diyetlerine her hangi bir katkı yapılmamıştır. Sadece β-glukan tüketen grupta yemden yararlanma oranının (YYO) en yüksek değerde olduğu görülmüştür. İnulin ve β-glukan tüketen 3. grupta kan serum glukoz seviyesi en yüksek değerde bulunmuş olup bu sonucun inulin ve β-glukanın sinerjik etkisine bağlı olabileceği düşünülmüştür.

**Sonuç:** Sinerjik etkilerinin olmasının yanında bu iki katkı maddesinin koruyucu hekimlik anlamında alternatif katkı olarak kullanılabileceği sonucuna varılmıştır.

*Anahtar sözcükler: β-glucan, hindi, immunite, inulin, performans.*

---

Correspondence to: Buğra Genç. Department of Laboratory Animals, Faculty of Veterinary Medicine, Ondokuz Mayis University, Samsun Turkey. bugragenc@omu.edu.tr. This article is prepared by author's doctoral thesis study.

## Introduction

The use of probiotics and prebiotics as growth promoters in the animal nutrition field has become increasingly significant due to the increasing resistance of microorganisms to antibiotics and increase in antibiotic residues (Hill et al., 2014) in animal products. Prebiotics that interact with probiotics (Alloui et al., 2013) provide energy for themselves to grow. This allows favourable condition for microbiota to create a competitive environment against pathogens in the gut. One of the prebiotics, β-glucan, which is obtained from the yeast cell wall (Stanczuk et al., 2005) is used as a growth promoter by immunomodulator effects in poultry. This effect can be detected by a measuring the weight of spleen, antibody titres against pathogens (*S. enteritidis*) and a decreasing heterophil-to-lymphocyte ratio (Sadeghi et al., 2013). Inulin was reported (Elrayeh and Yıldız, 2012) to have had a promoter effect on the intestinal organ parts in broiler chicks. Short chain production of fatty acids also increases due to a decrease in the pH level of fatty acids within the gastrointestinal tract in animals fed with diets containing soluble and digestible oligosaccharides (Juskiewicz et al. 2006). This makes it possible to reduce pathogenic bacteria populations, to remove carcinogenic factors to prevent tumor formation, to strengthen the immune system. In a study (Iji et al. 2001) in the broilers on intestinal morphology, it was observed that increasing the height of jejunum villi caused a thicker layer of lamina propria and protective effects against pathogens. β-glucan has an important effect on the immune system. β-glucan adheres to the cell walls by macrophage, lectins, scavenger receptors, monocytes and neutrophils, NK cells and lymphocyte subpopulations. It's observed that the interaction of these receptors with β-glucan causes the immune system to function more efficiently due to the exposure of leukocytes, phagocytic activity, inflammatory cytokine activity, chemotic activity and microbial competence (Brown and Gordon, 2005). The current study is conducted to determine the effects of β-glucan and inulin on performance parameters of turkey chicks.

## Materials and methods

This research was planned and conducted according to guidelines set in the Canadian Council on Animal Care (CCAC) since CCAC was established before the Turkish Animal Experiments Central Ethics Committee.

**Experimental design:** A total of 48 male turkeys (Hybrid Converter) were used as animal material. Experimental groups comprised of 4 dietary main groups of 12 animals each. Each main group was divided into 4 subgroups. Considering the age of the animals, feed diets were formulated according to the recommendations of the NRC 1994. During the 8-week, trial feeding program was implemented with ad libitum and water. Nutrient content of diets are given in Table 1.

**Table 1**: Dry matter (DM) (%), nutrient and mineral percent (% DM), and ME (kcal/kg DM) value of the diets
**Tablo 1**: Rasyonların kuru madde (KM) (%), besin maddesi ve mineral oranları (%KM) ve ME (kcal/kg KM) değerleri.

| Week | 7-9 | | 10-12 | | 13-14 | | 15-16 | |
|---|---|---|---|---|---|---|---|---|
| Groups | Control and 1 | 2 and 3 | Control and 1 | 2 and 3 | Control and 1 | 2 and 3 | Control and 1 | 2 and 3 |
| DM (%) | 92.10 | 92.30 | 92.30 | 91.70 | 91.90 | 91.50 | 92.00 | 91.70 |
| CP (%) | 23.52 | 23.54 | 21.69 | 21.58 | 19.71 | 19.73 | 18.23 | 18.24 |
| CF (%) | 3.00 | 2.90 | 3.10 | 3.00 | 2.60 | 2.60 | 2.70 | 2.60 |
| CA (%) | 5.50 | 5.53 | 5.60 | 6.00 | 6.10 | 6.14 | 5.46 | 5.52 |
| CF (%) | 7.28 | 7.30 | 9.90 | 10.30 | 11.70 | 11.80 | 13.50 | 13.52 |
| ME (kcal/kg) | 3066 | 3080 | 3195 | 3224 | 3290 | 3307 | 3430 | 3431 |
| NFM (%) | 52.8 | 53.03 | 52.01 | 50.82 | 51.79 | 51.23 | 52.11 | 51.82 |
| Ca (%) | 1.15 | 1.12 | 1.08 | 1.10 | 1.19 | 1.20 | 1.16 | 1.15 |
| P (%) | 0.78 | 0.80 | 0.75 | 0.76 | 0.64 | 0.62 | 0.68 | 0.66 |

**Feed additives and nutrient analysis:** The additives used in this study are a semipurified chicory inulin extract containing ≥70% active inulin/DM (Ratifeed® İPE ORAFTI, Belgium) and Leucogard® (Fibona Health Products GmbH) containing 28% active β-glucan. The diet for treatment group 1 contained 0.014% β-glucan, group 2 contained 0.70% inulin, and group 3 contained 0.70% inulin + 0.014% β-glucan. The amount of the nutrients, dry matter (DM), crude ash (CA), crude protein (CP), crude fat (CF), crude fiber (CF), nitrogen free matter (NFM), calcium (Ca), total phosphorus (P) of feed materials and compound feeds used in the research was determined at the Laboratories of Ankara University according to the reported methods in AOAC 2000. Metabolizable energy (ME) level was calculated by a formula recommended in TSE 1991.

**Performance findings and blood analysis:** Body weight (BW), body weight gain (BWG), feed conversion rate (FCR) and feed intake (FI) values were determined weekly. Blood samples (1 ml) were taken from the subclavian vein of 2 animals in each subgroup by syringe containing 2 mg EDTA at the beginning and end of the trial. The leukocyte count in this study was calculated as reported in Konuk (1981)'s study. Animals were immunized by Hitchner B1(Intervet, Netherlands) spray against New Castle disease at 7 and 12 week olds. Levels of specific antibodies formed against Newcastle disease (ND) and maternal antibodies were detected by the hemaglutination inhibition test (Allan and Gough, 1974). Analyses of total cholesterol and total triglyceride levels were conducted using the spectrofotometric method by specific kits (GLOBE Diagnostics S.r.İ.İtaly GD034000 - GD081500). Glucose levels were determined with an autoanalyzer (Abbott Alcyon 300, USA). For statistical analyses SPSS 10.0.1 for Windows One-way ANOVA programme were used. Duncan's multiple range test was used for P-values ($P < 0.05$).

## Results

**Table 3:** Mean (± SE) feed conversion ratio (feed intake (kg)/weight gain (kg)) of the groups weekly
**Tablo 3:**Grupların haftalık ortalama (± SE)yemden yararlanma oranları(yem tüketimi(kg)/canlı ağırlık kazncı (kg)).

| Week | Experimental Groups | | | | |
|---|---|---|---|---|---|
| | Control | 1 β-glucan | 2 Inulin | 3 β-glucan+ Inulin | P –value* |
| 1 | 1.83 ± 0.09 | 1.80 ± 0.03 | 1.75 ± 0.04 | 1.72 ± 0.05 | 0.585 |
| 2 | 1.93 ± 0.02 | 2.13 ± 0.13 | 1.97 ± 0.07 | 2.09 ± 0.08 | 0.376 |
| 3 | 1.91 ± 0.01 | 2.07 ± 0.04 | 1.99 ± 0.09 | 2.10 ± 0.10 | 0.323 |
| 4 | 2.55 ± 0.13 | 2.47 ± 0.15 | 2.33 ± 0.16 | 2.41 ± 0.13 | 0.759 |
| 5 | 1.93 ± 0.10 $^{b}$ | 2.37 ± 0.05 $^{a}$ | 2.02 ± 0.13 $^{b}$ | 2.22 ± 0.11 $^{ab}$ | 0.048 |
| 6 | 2.75 ± 0.04 | 3.01 ± 0,11 | 2.85 ± 0.07 | 3.00 ± 0.14 | 0.272 |
| 7 | 2.64 ± 0.02 | 3.27 ± 0.37 | 3.01 ± 0.33 | 3.08 ± 0.08 | 0.400 |
| 8 | 2.88 ± 0.12 | 3.71 ± 0.66 | 3.03 ± 0.21 | 3.08 ± 0.27 | 0.460 |
| 1-8 | 2.31 ± 0.01 $^{b}$ | 2.56 ± 0.07 $^{a}$ | 2.35 ± 0.05 $^{b}$ | 2.44 ± 0.05 $^{ab}$ | 0.035 |

a,b : Differences are statistically significant: (p<0.05); n= 4

**Table 4.** Mean (± SE) body weight (BW) (g), hot carcass weight (HCW) (g) and hot carcass yield (HCY) (%).
**Tablo 4.** Ortalama (± SE)canlı ağırlık (CA)(g), sıcak karkas ağırlığı (g) ve sıcak karkas verimi (%).

| Items | Experimental Groups | | | | |
|---|---|---|---|---|---|
| | Control | 1 β-glucan | 2 Inulin | 3 β-glucan+Inulin | *P* –value* |
| BW | 9965 ± 223.69 | 9918 ± 208.64 | 9910 ± 669.57 | 9925 ± 319.83 | 0.999 |
| HCW | 7922 ± 209,60 | 7875 ± 114.61 | 7782 ± 301.93 | 7746 ± 283.38 | 0.950 |
| HCY | 79.48 ± 0,681 | 79.43 ± 0.528 | 78.50 ± 0.577 | 78.02 ± 0.397 | 0.224 |

2

Differences are not statistically significant (P>0.05) n=4

After completion of the eight weeks of this study, our findings indicate that there were no significant differences among the experimental groups 1, 2 and 3 in terms of BW (P>0.05) (Table 2).

During the fifth week of the study FCR rates were found to be statistically significant (P<0.05) among the groups (Table 3).

The highest FCR rate (2.56) was found in the first group which was treated with β-glucan. There was no significant difference (P>0.05) in carcass weight (Table 4), on the of white blood cells (WBC) count and leukocytes (P>0.05) (Table 5).

The highest serum glucose values were found in the third group of turkeys which consumed β-glucan and inulin together (P<0.05) (Table 6).

Serum triglyceride and cholesterol levels and antibody levels (Table 6) caused by vaccination against Newcastle disease did not significantly affect (P> 0.05) the groups.

**Discussion**

Researchers (Sturkie, 1986; Yusrizal and Chen, 2003) reported that the added 1.00% rate of oligofructose and inulin to the diet had no effect on the performance of male broilers while an increase in body weight in females was significant (P<0.05). This confirms that the prebiotic effect mechanism is influenced by gender difference. Our results also indicate an adverse effect (Sturkie, 1986) of 0.1% inulin on body weight in the control group. The reason for the difference in the activity of inulin such as fructooligosaccharides used in diets can be explained by specific work activity and quality (Yusrizal and Chen, 2003) of the inulin. MOS, FOS and inulin did not affect the BWG in turkey diets when added at the level of 0.4% (Juskiewicz, 2006). However, in the same study (Juskiewicz, 2006) it was demonstrated that the highest body weight gain was in the group consumed FOS (799.00 g) and the lowest level of in the group that consumed inulin (753.00 g). These results are similar to the findings in our research. In a study (Saleimanesh et al., 2006) performed in chicks fed with probiotic, prebiotic and symbiotics according to the results, none of the additives had any significant effect (P>0.05) on performance parameters. As it was reported in similar studies, using prebiotics have no significant effect on daily feed intake and carcass quality (Sojoudi et al., 2006). On the other hand, Falaki et al.(2011) reported that symbiotic had a significant effect on body weight gain (P>0.05). Nevertheless it was reported (Saleimanesh et al., 2016) that the effectiveness of prebiotics on the humoral immune response is superior to symbiotic. Prebiotic additives shows immunomodulatory and growth promoter effect under stressful conditions (Midilli et al., 2008). In a study (Keser et al., 2012), which reflects the results of our work, β-glucan did not significantly affect (P>0.05) the performance parameters compared to that of the control group. These values were similar when zinc, chitosan, oligosaccharide were added to the diets. The cholesterol-lowering effect of β-glucan was shown in monogastric laboratory animals (Bilal et al., 2012). However, longer period time is required in poultry to see the effects as the animals were slaughtered for marketing processes. β-glucan was reported (Bilal et al., 2012) to reduce LDL cholesterol and triglyceride levels without affecting the HDL cholesterol and triglyceride in rats that consumed a diet containing added fat and β-glucan. This leads β-glucan to enable livers to synthesize on cholesterol and it has a protective effect against atherosclerosis. Huyghebaert et al. (Huyghebaert et al., 2011) infers that prebiotics mechanism and effectiveness define their nature, type and characteristics. For instance, FOS are effective on bifidobacteria and MOS are on *E. coli* and *Salmonella spp*.. When considered from this point of view, the real effect of a growth promoter should be detected based on certain parameters. Although there are no significant statistical differences in our study, it was determined that β-glucan increases feed consumption. Due to the fact that the effects of the prebiotics on the performance criteria are unclear, similar results were

**Table 5.** Mean (±SE) WBC* (×$10^3$ /$mm^3$) and leucocyte type (%) at start and end of trial
**Tablo 5:** Araştırma başı ve sonu ortalama (± SE)akyuvar (×$10^3$ /$mm^3$) ve lökosit tipi (%) değerleri

| Items | Control | 1 β-glucan | 2 Inulin | 3 β -glucan+Inulin | P –value* |
|---|---|---|---|---|---|
| Experimental Groups (Trial start) | | | | | |
| WBC (x $10^3$ /$mm^3$) | 32.50 ± 3.40 | 34.00 ± 2.50 | 32.75 ± 3.63 | 28.50 ± 2.59 | 0.634 |
| Leucocyte type | | | | | |
| Lymphocyte (%) | 50.25 ± 1.75 | 50.5 ± 1.19 | 50.50 ± 1.84 | 47.75 ± 2.13 | 0.642 |
| Heterophil (%) | 41.50 ± 2.36 | 41.50 ± 1.04 | 43.75 ± 1.88 | 42.75 ± 2.05 | 0.805 |
| Eosinophile (%) | 0.75 ± 0.25 | 1.00 ± 0.57 | 0.25 ± 0.25 | 1.75 ± 0.25 | 0.073 |
| Basophil(%) | 2.25 ± 0.75 | 3.50 ± 0.28 | 1.75 ± 0.25 | 3.25 ± 0.47 | 0.078 |
| Monocyte (%) | 5.25 ± 0.47 | 3.50 ± 0.86 | 3.75 ± 0.75 | 4.50 ± 0.28 | 0.255 |
| Experimental Groups (End of trial) | | | | | |
| WBC* (x $10^3$ /$mm^3$) | 33.00 ± 5.04 | 36.00 ± 3.31 | 30.50 ± 4.51 | 28.50 ± 5.54 | 0.703 |
| Leucocyte type | | | | | |
| Lymphocyte (%) | 51.75 ± 2.13 | 49.25 ± 1.54 | 50.00 ± 1.77 | 48.00 ± 0.91 | 0.471 |
| Heterophil (%) | 40.50 ± 2.10 | 41.00 ± 1.35 | 44.25 ± 1.88 | 43.50 ± 0.50 | 0.305 |
| Eosinophile (%) | 0.50 ± 0.20 | 0.75 ± 0.47 | 0.25 ± 0.25 | 1.00 ± 0.40 | 0.533 |
| Basophil (%) | 2.00 ± 0.40 | 3.50 ± 0.64 | 1.50 ± 0.57 | 2.75 ± 0.47 | 0.053 |
| Monocyte (%) | 5.25 ± 0.62 | 5.50 ± 1.04 | 4.00 ± 0.70 | 5.00 ± 0.70 | 0.571 |

*WBC: White blood cell.
**Differences are not statistically significant (P>0.05); n=4

reported in other studies (Stanczuk et al., 2005; Chae et al., 2006). In a study by Chae et al. (6), feed consumption and FCR was significantly higher in the group which had 0.03% level of β-glucan added to their diet, which is in compliance with our results. According to a report by Juskkiewicz et al. (2006), the use of these supplements in doses of 0.40% in turkey diets did not affect the FCR levels. On the contrary, Yusrizal and Chen's study (2003) found out that 1.00% inulin rate increased the carcass weight of the female broilers more than the males, this stated that there is dissimilarity between sexes. This supports the hypothesis (Sturkie, 1986) which states that the sensitivity of females against feeds rich in sugar and feed additives is higher. Our results indicate that inulin causes lower value of serum glucose when used alone. However, when used with β-glucan, the effect is the opposite. This case can be explained unknown effects of fructan derivatives on serum glucose metabolism. According to the results obtained from our study, there was no effect of both additives on antibody levels, leukocytes formula and white blood cell count. Lack of these immunological responses can be attributed lack of animal exposure to diseases, and also frequency of blood sampling times. Owing to its similar conclusions, another doctoral thesis study (Elrayeh and Yıldız, 2012) supports our study. Due to the fact that β-glucan and inulin have various effects because they are obtained from different sources; by taking the specifications of the animal material, further studies are required to be made on the gastrointestinal microbiota. As a result, it can be stated that more studies are required to be conducted by using various types of additives like symbiotics at different levels on different breeds and sexes of animal material for the study parameters.

**Table 6:** Mean (± SE) total blood serum cholesterol, triglyceride, glucose values (mg/dl), anticorps levels (log2) through the vaccinations against New Castle disease
**Tablo 6:** Ortalama (± SE)toplam kan serum kolesterol, trigliserit, glukoz değerleri (mg/dl), ve new Castle aşısına karşın antikor seviyeleri (log2)

| Items | Control | 1 β-glucan | 2 Inulin | 3 β-glucan+Inulin | *P*-value* |
|---|---|---|---|---|---|
| | Experimental Groups | | | | |
| Total cholesterol | 166.87 ± 4.78 | 174.42 ± 14.90 | 167.25 ± 3.85 | 169.00 ± 1.73 | 0.905 |
| Total Triglyceride | 41.80 ± 7.74 | 36.27 ± 6.05 | 39.17 ± 4.10 | 42.55 ± 1.84 | 0.841 |
| Glucose | 289.75 ± 13.86 $^{ab}$ | 267.00 ± 9.58 $^{b}$ | 261.25 ± 5.03 $^{b}$ | 305.75 ± 10.37 $^{a}$ | 0.033 |
| Maternal | 8.00 ± 0.40 | 8.50 ± 0.28 | 7.75 ± 0.25 | 8.50 ± 1.04 | 0.754 |
| 4th week | 5.75 ± 0.75 | 5.92 ± 0.31 | 6.65 ± 0.85 | 6.05 ± 0.06 | 0.729 |
| 8th week | 5.75 ± 0.47 | 6.50 ± 0.50 | 6.75 ± 0.75 | 7.32 ± 0.62 | 0.354 |

a,b : Mean value in a row with different superscripts differs significantly: (P<0.05); n=4
Serum triglyceride and cholesterol levels and antibody levels (Table 6) caused by vaccination against Newcastle disease did not significantly affect (P> 0.05) the groups.

**Acknowledgements**

This article is derived from Phd. thesis of corresponding author. The authors gratefully acknowledge to Mrs. Terrin Day for proofreading and to Mrs. Müberra Genç M.Sc. due to the scientific contribution in every phase of the study.

**References**

Allan WH, Gough RE (1974): A standard haemagglutination inhibition test for Newcastle disease. Comparison of macro and micro methods. Vet. Rec. 95: 120-123.

Alloui MN, Szczurek W, Świątkiewicz S (2013): The usefulness of prebiotics and probiotics in modern poultry nutrition. Ann. Anim. Sci. 1: 17–32.

AOAC (2000): Offical Methods of Analysis of AOAC. International. 1th ed. AOAC International, Maryland, USA.

Bilal T, Gürsel FE, Ateş A, Keser O (2012):Effects of dietary β-glucan on serum lipids and performance indices in rats fed a diet enriched with cholesterol. Pak Vet J. 32: 97

Brown GD, Gordon S (2003): Fungal beta-glucans and mammalian immunity. Immunity.19: 311-315.

Chae BJ, Lohakare JD, Moon WK, Lee SL, Park YH, Hahn TW (2006): Effects of supplementation of β-glucan on the growth performance and immunity in broilers. Research in Veterinary Science. 80: 291-298.

Elrayeh AS, Yıldız G (2012): Effects of inulin and β-glucan supplementation in broiler diets on growth performance, serum cholesterol, intestinal length, and immune system. Turk. J. Vet. Anim. Sci. 36: 388-394.

Falaki M, Shams SM, Dastar B, Zerehdaran S (2011): Effects of different levels of probiotic and prebiotic on performance and carcass characteristics of broiler chickens. Journal of Animal and Veterinary Advances. 10: 378–384.

Hill C, Guarner FR, Gibson GR, Merenstein DJ, Pot B, Morelli L, Canani RB, Flint HJ, Salminen S, Calder PC Sanders ME (2014): Expert consensus document. The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. Nat. Rev. Gastroenterol. Hepatol. 11: 506– 514.

Huyghebaert G, Ducatelle RF, Immerseel FV (2011): An update on alternatives to antimicrobial growth promoters for broilers Vet. J. 187: 182–188.

Iji PA, Saki A, Tivey DR (2001): Intestinal structure and function of broiler chickens on diet supplemented with a mannan oligosaccharide. J. Sci. Food Agric. 81: 1186

Juskiewicz J, Zdunczyk Z, Jankowsky J, Krol B (2006): Caecal metabolism in young turkeys fed diets supplemented with oligosaccharides. Arch. Geflügelk. 66: 206

Keser O, Bilal T, Kutay HC, Abas I, Eseceli H (2012): Effects of chitosan oligosaccharide and/or beta-glucan supplementation to diets containing organic zinc on performance and some blood indices in broilers. Pak Vet J. 32: 15-19.

Konuk T (1981). Pratik Fizyoloji. 2nd Ed. A.Ü. Vet. Fak. Yayınları, Ankara.

Midilli M, Alp M, Kocabaglı N, Muglali OH, Turan N, Yılmaz H, Cakır S (2008). Effect of dietary probiotic and prebiotic supplementation on growth, performance and serum IgG concentration of broilers. South African Journal of Animal Science. 38: 21–27.

NRC (1994): Nutrient Requirements of Poultry. Ninth Revised Edition.

Sadeghi AS, Mohammadi A, Shawrang P, Aminafshar M (2013): Immune responses to dietary inclusion of prebiotic-based mannan-oligosaccharide and ß-glucan in broiler chicks challenged with Salmonella enteritidis. J Vet. Anim. Sci. 37: 206–213.

Salehimanesh A, Roostaei M, Mehr A (2016): Effect of dietary probiotic, prebiotic and symbiotic supplementation on performance, immune responses, intestinal morphology and bacterial populations in broilers. J Anim Physiol Anim Nutr. 100: 694-700.

Sojoudi MR, Dadashbeiki M, Bouyeh M (2012): Effect of different levels of prebiotics TechnoMos On carcass characteristics of broiler chickens. Journal of Basic and Applied Scientific Research. 2: 6778–6794.

SPSS for Windows (1999). Release 10.0.1, SPSS (Inc, Chicago, II, USA).

Stanczuk J, Zdunczyk Z, Juskiewicz J, Jankowsky J (2005): Indices of response of young turkeys to diets containing mannanoligosaccharide or inulin. Veterinarija IR Zootecnika. 31: 98-101.

Stier H, Ebbeskotte V, Gruenwald J (2014): Immune-modulatory effects of dietary yeast beta-1,3/1,6-D-glucan. Nutr. J. 13: 38.

Sturkie PD (1986): Avian physiology. 4th ed. Springer-Verlag New York, NY.

TSE (1991): Animal feeds-metabolic (convertible) energy determination (chemical method). TSI No: 9610. Turkish Standards Institute, Ankara, Turkey.

Yusrizal SN, Chen TC (2003): Effect of adding chicory fructans in feed on broiler growth performance, serum cholesterol and intestinal length. Int. J. Poult. Sci. 2: 214