Satureja hortensis as a growth promoter in broiler chickens

Rajaian, H.[1*]; Aberumandi, M.[2]; Jalaei, J.[3] and Khosravi, M.[4]

[1]Department of Basic Sciences, School of Veterinary Medicine, Shiraz University, Shiraz, Iran; [2]Graduated from School of Veterinary Medicine, Shiraz University, Shiraz, Iran; [3]Ph.D. Student in Pharmacology, Department of Basic Sciences, School of Veterinary Medicine, Shiraz University, Shiraz, Iran; [4]BSc for Veterinary Organization, Fars Province, Shiraz, Iran

[*]***Correspondence:*** *H. Rajaian, Department of Basic Sciences, School of Veterinary Medicine, Shiraz University, Shiraz, Iran. E-mail: rajaian@shirazu.ac.ir*

(Received 11 Aug 2012; revised version 8 Oct 2013; accepted 14 Oct 2013)

Summary

Satureja hortensis is a popular herb in most regions of the world with leaves used as seasoning. Evidence shows that this plant contains phenolic components such as thymol and carvacrol with a relatively wide spectrum of antimicrobial activity. This study aimed at evaluating the efficacy of *S. hortensis* plant powder as an alternative to antimicrobial growth promoters in broiler diets. The plant was bought in sufficient quantity from the district of Yasouj, Iran and was dried and ground into powder. A total of 140 unsexed 1-day-old Arbor Acers breed broiler chicks were housed and fed a starter diet up to 18 days of age. The birds were then randomly divided into two groups and reared under similar conditions. Chickens received either normal grower (from 18 to 35 days of age) and finisher (from 36 to 50 days of age) diets without *S. hortensis* (group I) or a similar diet containing one percent plant powder (group II). Statistical comparison of average body weights at various time intervals showed that chickens in group II (1930 ± 29 g, n=63) were significantly (P<0.05) heavier than the birds in the control group (1837 ± 25 g, n=62). The average body weight of males in each group (2075 ± 42 g, n=20 and 2143 ± 40 g, n=22 for groups I and II, respectively) was also greater than those of the females (1724 ± 34 g, n=42 and 1808 ± 30 g, n=41 for groups I and II, respectively). Although feed conversion ratio was slightly less in group II (1.95), it was not substantially different from that in group I (2.02). It is concluded that *S. hortensis* might be a potential growth promoter in poultry.

Key words: *Satureja hortensis*, Chickens, Growth promoter

Introduction

The genus *Satureja* is well recognized for its therapeutic values. Scientists have recently become aware of its new medicinal aspects during the last two decades. Different species of *Satureja* are famous for their analgesic, antiseptic, antimicrobial, antiviral, antioxidant, antiproliferative, antiprotozoal, antifungal, antidiarrheal, anti-inflammatory, anti-nociceptive and vasodilatory activities (Hajhashemi *et al*., 2000; Basiri *et al*., 2007; Vagionas *et al*., 2007; Razzaghi-Abyaneh *et al*., 2008; Vosough-Ghanbari *et al*., 2008; Karami-Osboo *et al*., 2010; Mihajilov-Krstev *et al*., 2010).

Based on the literature, while current data mostly highlights *in vitro* examinations, few attempts have been made towards the recognition of the clinical aspects of this genus (Momtaz and Abdollahi, 2008). Yet, this data is inconclusive and further research seems necessary to confirm traditional information and to investigate novel medicinal aspects of this genus. Within the genus *Satureja*, *S. hortensis* has so far received the most attention. The aerial parts of the plant *S. hortensis* (Summer Savory in English, Marzeh in Persian) have been widely used in foods as a flavor component and in folk and traditional medicine (Zargari, 1990; Baytop, 1997; Hajhashemi *et al*., 2000).

Many studies have recently focused on the antibacterial and antifungal activities of the essential oils or extracts of the *Satureja* species, revealing that it has antimicrobial activities against human, food, and plant pathogens due to the presence of phenolic components such as thymol and carvacrol (Gulluce *et al*., 2003; Adiguzel *et al*., 2007). In one study, Sahin *et al*. (2003) found that essential oils and methanolic extracts of *S. hortensis* show strong inhibitory activity on wide ranges of bacteria and fungi.

Antibiotic feed additives have been used for more than half a century to enhance growth performance and to prevent diseases in livestock feeding environments (Rajaian *et al*., 2002; Naziri *et al*., 2012). However, the current trend is to look for alternatives to antibiotic feed additives due to the public concern regarding antibiotic residues in animal products and the potential evolving of antibiotic resistant bacteria. As a consequence, new commercial additives of plant origin, considered to be natural products acceptable to the consumer, have been proposed for animal produces. The chemical components of most plant essential oils are generally recognized as safe and are commonly used in the food industry (Varel, 2002). Herbs contain active substances that can improve digestion and metabolism and have antibacterial and immunostimulant activities in animals (Sabra and Metha, 1990).

Although the results of studies investigating plant extracts may contradict each other, they generally suggest that plant essential oils, or at least some of their constituents, may be used as antimicrobials in poultry production. However, for many such compounds, more research is needed on live birds to determine their usefulness. Due to its potential antimicrobial and antioxidant properties (Gulluce *et al*., 2003; Sahin *et al*., 2003; Dorman and Hiltunen, 2004), *S. hortensis* is becoming increasingly important in animal production. Therefore, the aim of the present study was to examine if *S. hortensis* had any effect on the growth of broiler chickens.

Materials and Methods

Preparing chicken rations

The plant (*S. hortensis*) was obtained in sufficient quantity from Yasouj area, southwest of Iran, and was washed and dried in shade at room temperature and then ground into a relatively uniform powder. The powder was then mixed with the proper chicken diet so that grower or finisher diets contained one percent *S. hortensis* (Table 1). It should be mentioned that whole dried plant powder was added to the diets, the analytical details of which are shown in Table 2.

Chicken rearing conditions

This experiment was carried out with 140-day-old broiler chicks (Arbor Acers breed) purchased from a local commercial hatchery, and housed in an experimental house until 50 days old. Birds were weighed and distributed in pens of 35 birds each on arrival day in order to have the best uniformity in terms of average body weight. Drinkers were cleaned, feed was distributed, and mortality was recorded daily. Birds and feeders were weighed on arrival, 9, 17, 22, 28, 32, 38, 43 and 49 days of age to determine body weight, weight gain, feed intake, and feed conversion ratio.

The starter feed was given during the first 17 days after arrival, the grower feed through the second 17 days, and the finisher feed from day 36 to 49. Feeds were replaced on the same day the birds were weighed and were offered *ad libitum* during the entire experimental period in mash form, formulated with corn and soybean meal (Table 2) according to the nutritional levels recommended by Rostagno *et al*. (2005).

Birds were randomly divided into two groups at the 18th day and reared under similar conditions. From 18 to 35 days and 36 to 49 days of age, the chickens received either normal grower/finisher diets without *S. hortensis* (group I) or a diet containing one percent plant powder (group II). Chickens were vaccinated against Newcastle disease (3 times using ocular, parenteral and oral routes of administration) and Gumboro disease (once orally) during the experiment.

Results are presented as mean ± SEM. Non-paired Student's t-tests were used to examine significant differences between the groups (P<0.05).

Table 1: Feed constituents of various diets ($g\ kg^1$)

Composition	Feed		
	Starter[1]	Grower[2]	Finisher[3]
Corn	646	370	360
Soybean	260	250	235
Wheat	-	300	338
Fish powder	70	45	30
Meat powder	6.5	5	5.5
Sodium chloride	-	1.5	1.3
Sea shell	7.5	6	7.5
Dicalcium phosphate	8.5	11	11
Methionine	1	1.25	1.25
Lysine	-	-	0.2
Vitamin E	0.5	0.25	0.25
Plant powder	0	10	10

[1] From the second to the end of 17th day. [2] From 18th to the end of 35th day. [3] From 36th up to 49th day

Results

Composition and feed analysis of diets and the dried plant are shown in Tables 1 and 2. Average body weights of chickens in each group are illustrated in Table 3. The average weight of chickens on arrival day (day 2) was 53.3 ± 0.3 g. The average weight at the end of the beginner stage (day 18) was about 420 g. The average weights of chickens in group II were generally greater than those in group I. The differences were significant (P<0.05) except for their weights at the 38th day (Table 3). At slaughter time (day 49), average live body weights were 1837 and 1930 g for groups I and II, respectively (Table 3). Male chickens were heavier (P<0.01) than females and their average weights were determined to be 2075 vs. 1724 g in group I and 2143 vs. 1808 g in group II (Table 4). Mortality rate was

Table 2: Feed analysis (%) of dried plant powder and various diets fed to chickens

Feed	Parameter					
	Crude protein	Crude fat	Crude fiber	Dry matter	Calcium	Phosphorous
Dried *S. hortensis* powder	7.2 ± 1.1*	2.5 ± 0.9	25.3 ± 3.4	98.1 ± 1.2	0.65 ± 0.23	0.09 ± 0.04
Starter	22.8 ± 1.5	3.8 ± 0.4	3.7 ± 0.5	90.0 ± 2.1	1.0 ± 0.21	0.81 ± 0.27
Grower	24.0 ± 1.4	3.0 ± 0.4	3.6 ± 0.5	88.1 ± 1.8	0.63 ± 0.11	0.57 ± 0.09
Finisher	21.5 ± 1.3	2.8 ± 0.3	3.5 ± 0.4	87.5 ± 2.0	0.21 ± 0.07	0.45 ± 0.07

* Mean±SD (n=3)

Table 3: Live body weights (g) of chickens in different groups at various time intervals (days)

Age (days)	Group I[1]	GroupII[1]
2	53.3 ± 0.3[2] (n=140)	
9	175.1 ± 1.2 (n=137)	
17	418.2 ± 2.7 (n=133)	
22	561 ± 7 (n=67)	612 ± 6* (n=66)

28	777 ± 10 (n=65)	822 ± 11* (n=63)
32	974 ± 15 (n=64)	1018 ± 17* (n=63)
38	1378 ± 24 (n=63)	1432 ± 25 (n=63)
43	1663 ± 27 (n=63)	1767 ± 29* (n=63)
49	1837 ± 25 (n=62)	1930 ± 29* (n=63)

[1] Group I, control; group II, received 1% *S. hortensis* in the grower and finisher diets (see text for details). [2] Mean±SEM. * Statistically different compared with group I (P<0.05)

Table 4: Live body weights (g) of male and female chickens and FCR values in the control and experiment groups at the time of slaughter (49-day-old)

Group I[1]		Group II[1]	
Male	Female	Male	Female
2075 ± 42[2] (n=20)	1724 ± 34* (n=42)	2143 ± 40** (n=22)	1808 ± 30** (n=41)
FCR[3]= 2.02		FCR= 1.95	

[1] Group I, control; group II, received 1% *S. hortensis* in grower and finisher diets (see text for details). [2] Mean±SEM. [3] Feed conversion ratio was obtained from dividing total weight of feed intake during rearing period by total live body weights of chickens on day 49. * Statistically different (* P<0.01, compared with males; ** P<0.05, compared with the birds of the same sex in the other group)

about 5% during the beginner period. For the rest of the rearing period, mortality rates were recorded to be about 7% in group I and 3% in group II (Table 3). Feed conversion ratios (FCR) in groups I and II were calculated to be around 2.02 and 1.95, respectively.

Discussion

Growth promoter feed additives have been included in poultry diets to promote growth, protect health and maximize the genetic potential of modern broiler chickens, turkeys and layer hybrids for several decades. Of these, antibiotics have been used at sub-therapeutic doses in animal feed, including poultry diets, for over five decades to prevent disease, promote growth, and feed conversion efficiency (Rosen, 1996; Engberg *et al*., 2000). Antibiotics exert their effect by stabilizing the intestinal microbial flora, thereby preventing proliferation of specific intestinal pathogens (Shane, 2005). Today, the non-prescription use of antibiotics in poultry feeds has been eliminated or severely limited in many countries because of concerns related to the development of antibiotic-resistant human pathogenic bacteria and legislative actions to limit their use in many others.

Phytogenic feed additives comprise a wide variety of herbs and spices. The assumption that phytogenic compounds might improve the palatability of feed has not yet been confirmed by choice-feeding studies. Plant active principles are chemical compounds present in the entire plant or in its specific parts conferring to them therapeutic activity or beneficial effects (Martins *et al*., 2000). These substances have low molecular weight and are derived from the plants' secondary metabolism, including glycosides, alkaloids, terpenoids, saponins, mucilages, flavonoids, and essential oils (Martins *et al*., 2000; Huyghebaert, 2003). These compounds are produced by plants to defend them against external factors such as physiological stress, environmental factors, and protection against predators and pathogens (Huyghebaert, 2003).

According to Kohlert *et al*. (2000), most active principles of plant extracts are absorbed in the intestine by enterocytes, and readily metabolized by the body. Products of this metabolism are transformed into polar compounds by conjugation with glucoronate and excreted in the urine. As the active compounds are readily metabolized and have short half-lives, the risk of tissue accumulation is probably minimal (Kohlert *et al*., 2000).

Although numerous studies have demonstrated *in vitro* antioxidative and antimicrobial efficacy, respective experimental *in vivo* evidence is still quite limited and the mechanisms involved are still widely unknown (Derwich *et al*., 2010). The same applies to the supposition that phytogenic compounds may specifically enhance activities of digestive enzymes and nutrient absorption (Bandoniene *et al*., 2002). Nevertheless, a limited number of experimental comparisons of phytogenic feed additives with antibiotics and organic acids have suggested similar effects on the gut, such as reduced bacterial colony counts, fewer fermentation products (including ammonia and biogenic amines), less activity of the gut-associated lymphatic system, and a greater pre-cecal nutrient digestion, probably reflecting an overall improved gut equilibrium (Alcicek *et al*., 2004). In addition, some phytogenic compounds seem to promote intestinal mucus production. Such effects may explain a considerable number of practical studies with swine and poultry reporting improved production performance after providing phytogenic feed additives. Generally, available evidence indicates that phytogenic feed additives may add to the set of non-antibiotic growth promoters for use in livestock, such as organic acids and probiotics. However, a systematic approach toward the efficacy and safety of phytogenic compounds used as feed additives is still missing; hence, further investigation on the *in vivo* action of the active principles and their effects are required. In addition, significant improvement of animal performance must be shown before plant extracts are effectively adopted in animal nutrition. Previous studies suggest, for example, that herbs, spices, and extracts of various plants have appetizing and digestion stimulation properties and antimicrobial effects (Alcicek *et al*., 2004; Zhang *et al*., 2005). The improvement in feed efficiency achieved with essential oil mixtures could be attributed to their positive effects on nutrient digestibility, as reported by Hernandez *et al*. (2004) and Jamroz *et al*. (2005).

The genus *Satureja* contains about 200 species of aromatic herbs and shrubs, largely distributed in areas stretching from the Mediterranean region to Europe, West Asia, North Africa, the Canary Islands, and South

America (Momtaz and Abdollahi, 2010). Plenty of studies verify the antioxidant activity of *Satureja* subspecies. Antioxidants are compounds which inhibit or delay the oxidation of other molecules by inhibiting the initiation or propagation of oxidizing chain reactions. Recently, the consumption of natural antioxidants that occur in higher plants has increased because of the side effects of synthetic ones (Bakkali *et al*., 2008).

The antimicrobial activity of *Satureja* spp. was first reported during the 1950s, when it was found that the inhibitory effect of this savory plant was probably due to its high thymol and carvarcol content, which are among the most efficient herbal antibacterial agents known (Oussalah *et al*., 2006).

The plant oil's mechanism of action is probably related to the outer membrane disintegrating properties of thymol and carvacrol (Helander *et al*., 1998). In the literature, some investigations suggest that these compounds penetrate the cell and interfere with cellular metabolism (Marino *et al*., 1999). Other studies indicate that they disturb the structure of the cellular membrane and react with enzyme active sites or act as an H^+ carrier, depleting adenosine triphosphate pool (Farag *et al*., 1989; Ultee *et al*., 2002).

Statistical comparisons of average body weights between the control (group I) and experiment (group II) groups showed that birds in group II were significantly ($P<0.05$) heavier than the control birds. Considering the data in Table 2 and the fact that only 1% plant powder was used and the diets were very close in terms of energy and nitrogen contents, these substitutions might not have caused a profound difference on the chickens' performances. At the time of slaughter, a cost effective difference of about 100 g was observed among the control and experimental groups. In other words, the addition of only 1% plant powder to the diet of broiler chickens increased net profits by about 5%. Performance traits of broiler chickens including body weight, feed intake, feed conversion ratio and livability illustrate that the substitution of the control by the alternative diet resulted in significantly higher body weight at various stages of the chickens' life up to slaughter time, while there was no major difference in overall feed intake.

In our previous study (Rajaian *et al*., 2006), the beneficial effects of *Berberis vulgaris* root powder was reported, but it was highlighted that recommending the use of this root as a feed additive may not be practical, particularly where the plant is scarce. However, since *S. hortensis* is abundant and relatively cheap in the region, no shortage applies to the use of this plant as an herbal additive for chicken diet. In conclusion, results of the present study revealed that *S. hortensis* is useful as a feed additive to promote growth in broiler chickens.

Acknowledgements

Financial support by the Natural Antimicrobials Center of Excellence (NACE) and Entrepreneurship Center of Shiraz University is greatly appreciated. We are also grateful to Dr. Dadras for his kind scientific advice.

References

Adiguzel, A; Ozer, H; Kilic, H and Cetin, B (2007). Screening of antimicrobial activity of essential oil and methanol extract of *Satureja hortensis* on foodborne bacteria and fungi. Cze. J. Food Sci., 25: 81-89.

Alcicek, A; Bozkurt, M and Cabuk, M (2004). The effects of a mixture of herbal essential oil, an organic acid or a probiotic on broiler performance. South Afr. J. Anim. Sci., 34: 217-222.

Bakkali, F; Averbeck, S; Averbeck, D and Idaomar, M (2008). Biological effects of essential oils. Rev. Food Chem. Toxicol., 46: 446-475.

Bandoniene, D; Venskutonıs, PR; Gruzdıene, D and Murkovıc, M (2002). Antioxidative activity of sage (*Salvia officinalis* L.), savory (*Satureja hortensis* L.) and borage (*Borago officinalis* L.) extracts in rapeseed oil. Eur. J. Lipid Sci. Technol., 104: 286-292.

Basiri, S; Esmaily, H; Vosough-Ghanbari, S; Mohammadirad, A; Yasa, N and Abdollahi, M (2007). Improvement by *Satureja khuzestanica* essential oil of malathion-induced red blood cells pesticide. Biochem. Physiol., 89: 124-129.

Baytop, T (1997). Turkce Bitki Adlari Sozlugu (A dictionary of vernacular names of wild plants of Turkey), Ankara, Publication of the Turk Dil Kurumu (The Turkish Language Society). No.: 578.

Derwich, E; Benziane, Z; Manar, A; Boukir, A and Taouil, R (2010). Phytochemical analysis and *in vitro* antibacterial activity of the essential oil of *Origanum vulgare* from Morrocco. Am.-Eurasian J. Sci. Res., 5: 120-129.

Dorman, HJD and Hiltunen, R (2004). Fe (III) reductive and free radical-scavengering properties of Summer Savory (*Satureja hortensis* L.) extract and sub fractions. Food Chem., 88: 193-199.

Engberg, RM; Hedemann, MS; Leser, TD and Jensen, BB (2000). Effect of zinc bacitracin and salinomycin on intestinal microflora and performance of broilers. Poult. Sci., 79: 1311-1319.

Farag, RS; Daw, ZY; Hewedi, FM and El-Baroty, GSA (1989). Antimicrobial activity of some Egyptian spice essential oils. J. Food Protect., 52: 665-667.

Gulluce, M; Sokmen, M; Daferera, D; Agar, G; Ozkan, H; Kartal, N; Polissiou, M; Sokmen, A and Sahin, F (2003). *In vitro* antibacterial, antifungal, and antioxidant activities of the essential oil and methanol extracts of herbal parts and callus cultures of *Satureja hortensis* L. J. Agric. Food Chem., 51: 3958-3965.

Hajhashemi, V; Sadraei, H; Ghaadi, AR and Mohseni, M (2000). Antispasmodic and antidiarrheal effects of *Satureja hortensis* L. essential oil. J. Ethnopharm., 71: 187-192.

Helander, IM; Alakomi, HL; Latva-Kala, K; Pol, I; Smid, EJ; Gorris, LGM and von Wright, A (1998). Characterization of the action selected essential oil components on gram-negative bacteria. J. Agric. Food Chem., 46: 3590-3595.

Hernandez, F; Madrid, J; Garcia, V; Orengo, J and Megias, MD (2004). Influence of two plant extracts on broiler performance, digestibility, and digestive organ size. Poult. Sci., 83: 169-174.

Huyghebaert, G (2003). Replacement of antibiotics in poultry.

In: *The proceedings of the Eastern Nutrition Conference*. Quebec, Canada, PP: 1-23.

Jamroz, D; Orda, J; Kamel, C; Wiliczkiewicz, A; Werteckl, T; Orda, J and Sukorupinska, J (2005). Use of active substances of plant origin in chicken diets based on maize and locally grown cereals. Br. Poult. Sci., 46: 485-493.

Karami-Osboo, R; Khodaverdi, M and Ali-Akbari, F (2010). Antibacterial effect of effective compounds of *Satureja hortensis* and *Thymus vulgaris* essential oils against *Erwinia amylovora*. J. Agric. Sci. Technol., 12: 35-45.

Kohlert, C; Van Rensen, I; Marz, R; Schindler, G; Graefe, EU and Veit, M (2000). Bioavailability and pharmacokinetics of natural volatile terpenes in animal and humans. Plant. Medic., 66: 495-505.

Marino, M; Bersani, C and Comi, G (1999). Antimicrobial activity of the essential oils of *Thymus vulgaris* L. measured using a bio-epidemiometric method. J. Food Protect., 62: 1017-1023.

Martins, ER; Castro, DM; Castellani, DC and Dias, JE (2000). *Plantas medicinais viçosa: editora UFV*. Universidade Federal de Viçosa. P: 220.

Mihajilov-Krstev, T; Radnovic, D; Kitic, D; Stojanovic-Radic, Z and Zlatkovic, B (2010). Antimicrobial activity of *Satureja hortensis* L. essential oil against pathogenic microbial strains. Arch. Biol. Sci. Belgrade. 62: 159-166.

Momtaz, S and Abdollahi, M (2008). A systemic review of the biological activities of *Satureja* L. species. Pharmacol. Online. 2: 34-54.

Momtaz, S and Abdollahi, M (2010). An update on pharmacology of *Satureja* species; from antioxidant, antimicrobial, antidiabetes and antihyperlipidemic to reproductive stimulation. Int. J. Pharmacol., 6: 454-461.

Naziri, Z; Rajaian, H and Firouzi, R (2012). Antibacterial effects of Iranian native sour and sweet pomegranate (*Punica granatum*) peel extracts against various pathogenic bacteria. Iranian J. Vet. Res., 13: 282-288.

Oussalah, M; Caillet, S; Saucier, L and Lacroix, M (2006). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: *E. coli* o157:H7, *Salmonella typhimurium*, *Staphylococcus aureus* and *Listeria monocytogenes*. Food Cont., 18: 414-420.

Rajaian, H; Haghkhah, M and Toranjipoor, H (2002). Antibacterial effect of *Berberis vulgaris*. (In Persian). Iranian J. Vet. Res., 3: 175-178.

Rajaian, H; Jalaee, J and Aghajani, M (2006). Effect of *Berberis vulgaris* on weight gain in broilers. Int. J. Poult. Sci., 5: 395-397.

Razzaghi-Abyaneh, M; Shams-Ghahfarokhi, M; Yoshinari, T; Rezaee, MB; Jaimand, K; Nagasawa, H and Sakuda, S (2008). Inhibitory effect of *Satureja hortensis* L. essential oil on growth and aflatoxin production by *Aspergillus parasiticus*. Int. J. Food Microbiol., 123: 228-233.

Rosen, GD (1996). Pronutrient antibiotic replacement standards discussed. Feed Stuffs. 75: 11-13.

Rostagno, HS; Albino, LFT; Donzele, JL; Gomez, PC; Ferreira, AS; Oliveira, RF and Lopes, DC (2005). *Tabelas brasileiras para aves a suinos: composicao de alimentos e exigencies nutricionais*. 2nd Edn., Vol. 2, Vicosa Departamento de Zootecnia Univerdidade Federal de Vicosa. P: 186.

Sabra, KL and Metha, TJ (1990). A comparative study on additive of livol (herbal growth promoter) and some chemical growth promoters in the diets of broiler chickens. Ind. J. Anim. Product. Manage., 6: 115-118.

Sahin, F; Karaman, J; Gulluce, M; Oguteu, H; Sengul, M; Adıguzel, S; Ozturk, S and Kotan, R (2003). Evaluation of antimicrobial activities of *Satureja hortensis* L. J. Ethnopharmacol., 87: 61-65.

Shane, S (2005). Antibiotic alternative in turkey production. World Poult., 19: 14-15.

Ultee, A; Bennicnk, MHJ and Moexelaar, R (2002). The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen *Bacillus cereus*. Appl. Environ. Microbiol., 68: 1561-1568.

Vagionas, K; Graikou, K; Ngassapa, O; Runyoro, D and Chinou, I (2007). Composition and antimicrobial activity of the essential oils of three *Satureja* species growing in Tanz. Food Chem., 103: 319-332.

Varel, VH (2002). Livestock manure odor abatement with plant-derived oils and nitrogen conservation with urease inhibitors: a review. J. Anim. Sci., 80: 1-7.

Vosough-Ghanbari, S; Rahimi, R; Kharabaf, S; Zeinali, S and Mohammadirad, A (2008). Effects of *Satureja khuzestanica* on serum glucose, lipids and markers of oxidative stress type 2 diabetes mellitus: a double-blind randomized controlled trial. Evid. Based Complement Alternat. Med., 7: 465-470.

Zargari, A (1990). *Medic plants* (In Persian), Vol. 4, Tehran, Tehran University Press. PP: 325-328.

Zhang, KY; Yan, F; Keen, CA and Waldroup, PW (2005). Evaluation of micro-encapsulated essential oils and organic acids in diets for broiler chickens. Int. J. Poult. Sci., 4: 612-619.