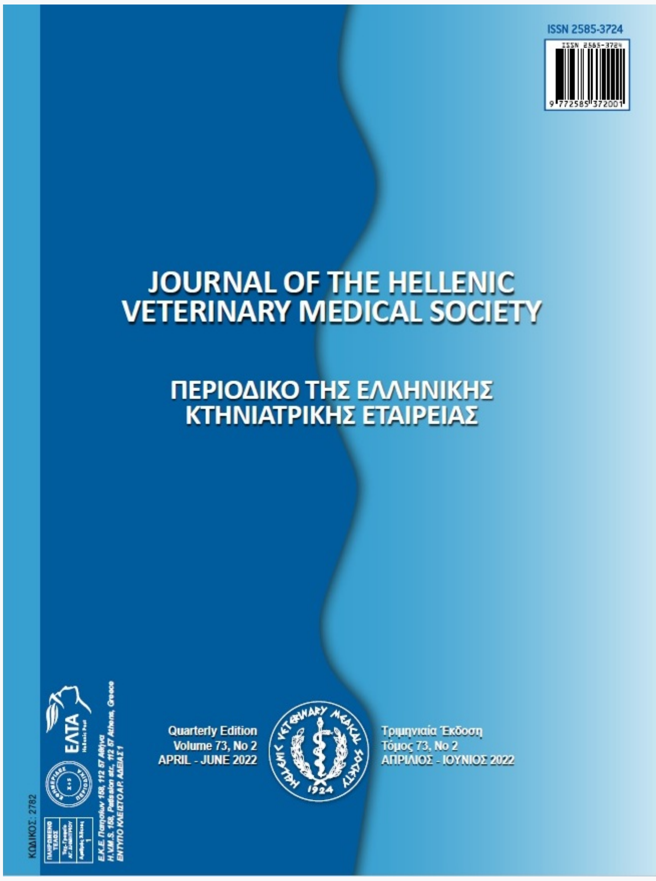
Journal of the Hellenic Veterinary Medical Society

Vol 73, No 2 (2022)



Implications of supplemental microbial phytase and essential oils (Thymus vulgaris L. and Mentha pulegium L.) on carcass traits, meat organoleptic and antioxidant status in broilers

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doi: [10.12681/jhvms.26053](https://doi.org/10.12681/jhvms.26053)

J HELLENIC VET MED SOC 2022, 73 (2): 3997-4006
ΠΕΚΕ 2022, 73 (2): 3997-4006

Research article
Ερευνητικό άρθρο

Implications of supplemental microbial phytase and essential oils (*Thymus vulgaris L. and Mentha pulegium L.*) on carcass traits, meat organoleptic and antioxidant status in broiler chickens

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ABSTRACT: This experiment was carried out to study the influence of microbial phytase and herbal essential oils (*Thymus vulgaris L and Mentha pulegium L.*) on carcass traits, meat organoleptic and antioxidant status in broilers. Three hundred and eighty-four male broilers (Ross -308) were used in factorial arrangements with eight treatments includes (0 and 200 mg/kg thyme essential oil), (0 and 200 mg/kg Mentha essential oil), (0 and 500 IU/kg microbial phytase) and 4 replicates (12 chicks per replicate) according to a completely randomized design and in three experimental periods include: starter 1 to 10 days, grower 11 to 24 days and finisher 25 to 42 days. Regarding the effects of experimental treatments on carcass traits, the use of thyme and mentha essential oils increased the percentage of abdominal fat ($P<0.05$). The use of thyme essential oil significantly increased the levels of blood superoxide dismutase (SOD) and glutathione peroxidase (GPX) ($P<0.05$). Regarding the effects of experimental treatments on meat organoleptic, the use of thyme essential oil increased the overall acceptance of chicken meat ($P<0.05$). In conclusion, the use of essential oils, although it leads to an increase in antioxidant parameters, also leads to an improvement in meat quality.

Keywords: Broiler, essential oils, antioxidant status and organoleptic.

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Date of initial submission: 02-06-2021
Date of acceptance: 5-03-2021

INTRODUCTION

Due to the legal prohibition on the use of antibiotics as an additive has increased the tendency to use natural compounds derived from aromatic plants in food and animal nutrition (Abd El-Ghany and Ismail, 2014; Besharati et al., 2020; Cimrin et al., 2020). Essential oils can show potentially beneficial properties such as: antiviral effects (Brochot et al., 2017), antimicrobial (Adaszyńska-Skwirzyńska and Szczerbińska, 2018; Sabo and Knezevic, 2019; Sevim et al., 2020;Abd El-Ghany, 2020), antioxidant (Chowdhury et al, 2018; Pirgozliev et al., 2019), digestibility enhancement (Zhai et al., 2018; Yang et al., 2019) and anti-parasitic (Sabuna et al., 2019; Sidiropoulou et al., 2020). Nowadays, herbal products as extracts, powder and juices are being much investigated and used by researchers in the field of food sciences and animal nutrition. This makes the world to further investigate such type of natural products for an increase in production efficiency in poultry business. Different types of phytogenic products such as mentha, garlic, anise, cinnamon, coriander, oregano, chili, pepper, rosemary, rosehip and thyme can be used as a growth promotor and gut health modulator in poultry (Criste et al., 2017). Thyme (*Thymus vulgaris*) and pennyroyal (*Mentha pulegium*) are plants of the mint family. Thyme (*Thymus vulgaris*) active constituents are thymol and carvacrol, which can affect animal metabolism and physiology. The active substances in thyme can stimulate secretion of pancreatic enzymes, thereby improving digestion efficiency and absorption of protein and other nutrients from the bird's gastrointestinal tract (Bouhtit et al., 2019). Pennyroyal (*Mentha pulegium*) is a perennial, aromatic, popular and herbaceous plant, which can reach up to half a meter in height. It has been used as an infusion, herbal tea or powder for the treatment of some diseases such as bronchitis, whooping cough, the common cold, sore throat and digestive disorders (Gülçin et al., 2020). Grigors et al. (2010) reported that the antioxidant capacity of thyme essential oil was equivalent to that of ascorbic acid. The antioxidant capacity of thyme essential oils is attributed to the thymol phenolic compounds, carvacrol and thymohydroquinone (Tabari et al., 2017; Valdivieso-Ugarte et al., 2019; Ahmadi and Jafarizadeh-Malmiri, 2020). The positive effects of phytase in poultry are documented (Farhadi et al., 2017; Roofchaei et al., 2019) and microbial phytase supplementation has been shown to increase crude protein and amino acids digestibility (Bagh-ban-Kanani et al., 2018).

Feed, as one of the influential parts, can affect the quality of poultry meat. Factors that affect meat quality are intricate and occur entire the production chain (Vašková et al., 2015; Semjon et al., 2020). Supplying poultry meat of sufficient quantity and quality to meet communal requirement is a primary goal of the broiler industry (Yadav and Jha, 2019). From a consumer perspective, poultry is a very yummy and essential element in the human diet due to its nutritional, dietetic, and sensory attributes, and its rapid culinary preparation (Vašková et al., 2018). Therefore, the objective of this study was to investigate the effects of supplemental microbial phytase and essential oils (*Thymus vulgaris* L. and Menthapulegium L.) on carcass traits, meat organoleptic and antioxidant status in broilers.

MATERIALS AND METHODS

Animals and feed

The research animal ethics committee of Islamic Azad University approved this experimental protocol (no. 2019/03-384). A total of 384 male broilers (Ross -308) were used in factorial arrangements with eight treatments includes (0 and 200 mg/kg thyme essential oil), (0 and 200 mg/kg Mentha essential oil), (0 and 500 IU/kg microbial phytase) and 4 replicates (12 chicks per replicate) according to a completely randomized design and in three experimental periods include starter 1 to 10 days, grower 11 to 24 days and finisher 25 to 42 days. The diets were formulated using the UFFDA software program to provide the advised levels of nutrients as specified for the Ross-308 broiler. Thyme and mentha essential oils were prepared from Barij Essential Oil Company (Kashan, Iran). Meri-Phyze 5000 is a microbial phytase manufactured by Meriden Animal Health in the United Kingdom. Each gram of Meri-Phyze 5000 contains at least 5000 units of phytase (FTU) enzyme.

Carcass quality

At the end of the experimental period, on the 42nd day, two birds per replicate were selected and were slaughtered to determine carcass traits. The percent of the carcass was determined by comparing spleen weight, abdominal fat, intestine, gizzard, liver, bursa of Fabricius, breast, thigh, back, and neck weights to corresponding carcass weights. To determine the organoleptic properties, including meat color, they were randomly measured in four positions on the surface of each half of the pectoralis muscle (right half), and the mean values of color per muscle were calculated according to Zhuang and Savage (2009) method by the

Table 1. Nutritional contents of diets fed to broilers during the starter, growing and finishing periods

	Starter period (1 to 10 days of age)	Growing period (11 to 24 days of age	Finishing period (25 to 42 days of age)
Corn	47.75	54.93	56.75
Soybean meal	44.50	37.90	36.71
oil	3.26	3.39	3.05
powder of bone	2.26	2.18	1.87
Oyster powder	0.29	0.29	0.33
Salt	0.46	0.47	0.42
Vitamin supplement *	0.25	0.25	0.25
Mineral supplement *	0.25	0.25	0.25
DL-methionine	0.37	0.34	0.38
Metabolic energy (kcal / kg)	3000	3000	3000
Crude protein (%)	27.50	20.95	20.64
Calcium (%)	1.05	0.88	0.80
Usable phosphorus (%)	0.50	0.43	0.39
Sodium (%)	0.32	0.21	0.19
Lysine (%)	1.67	1.26	1.23
Methionine + cysteine (%)	1.18	0.99	0.85
Trepitophan (%)	0.35	0.28	0.28

*Provides per kg of diet:trans-retinol 3784 mg, cholecalciferol 125mg,-tocopherol acetate 100 mg, vitamin K33 mg, vitamin B12 mg, vitamin B25 mg, vitamin B64 mg, vitamin B12 0017 mg, niacin 40 mg, folic acid 18 mg,D-biotin 015 mg, calcium D-pantothenate 15 mg, Mn 100 mg,Fe 80 mg, Zn 80 mg, Cu 8 mg, I 2 mg, Co 05 mg, Se 015 mg.

colorimetric device. A *, b *, and L * indicate redness, yellowness, and brightness of the meat, respectively.

Antioxidant status

At the age of 42, the antioxidant status and lipid peroxidation level were determined, blood samples were taken from the wing vein of two chickens from each replicate in order to take their serum samples. After blood sampling, the chickens were slaughtered, and 2 g was taken from their livers and kept at -20 ° C with the serum samples until analysis. Total serum antioxidant capacity (TAC.S) and malondialdehyde level (MDA) were determined. After homogenizing in buffer solution (1.15% potassium chloride, pH 7.4), liver samples were centrifuged at 4 ° C for 15 minutes at 5000 rpm, and from the supernatant obtained to measure the activity of GPX and SOD, as well as MDA levels, were used. Glutathione peroxidase was determined using RANDOX kits (Germany) according to the manufacturer's instruction. Superoxide dismutase activity was assayed by the Winterbourn et al. (1975) method. The level of MDA, which is an indicator of lipid peroxidation, was measured in the serum and liver tissue of broilers.

Organoleptic properties of meat

The meat samples (from the right half of the pectoralis muscle) were then cooked at 170 ° C after being placed in an aluminum foil in an electric oven for 39-45 minutes, depending on the weight of the meat samples. Pieces of meat were prepared without adding spices and fat to prevent overlapping the chicken meat taste. The cooked samples were immediately cut into 12 pieces and presented to the panel members at random. The traits evaluated in the experiment were odor, taste, crispness, juiciness, and general acceptability. No information on meat or experimental treatments and working methods was provided to panel members. Respondent members were instructed to complete the evaluation form immediately after eating the meat samples according to their decision. A five-point scale was used, which is 1 to the lowest taste, juiciness, and crispness and 5 to the highest score compared to these indicators (Cross et al, 1986).

Statistical analyses

Statistical analysis of the data was performed using the GLM procedure of SAS software (9.2) (Palangi and Macit, 2019). The statistical model of the project was as follows:

$$Y_{ijkl} = \mu + A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} ++ \varepsilon_{ijkl}$$

where: Y_{ijkl}= a dependent variable, μ = overall mean, A_i = the effect of Thyme essential oil, B_j = the effect of Mentha essential oil, C_k = the effect of microbial phytase, AB_{ij} = the interaction of thyme and mint essential oils, AC_{ik} = the interaction of Thyme essential oil and microbial phytase, BC_{jk} = the interaction of Mentha essential oil and microbial phytase; ABC_{ijk} = the interaction of Thyme, Mentha essential oils and phytase and ε_{ijkl} = the residual deviation of the observation from the effects in the model. Tukey's test at the 5% level of probability was used to compare means.

RESULTS

Carcass quality

The effects of dietary supplementation essential oils (thyme and mentha) and microbial phytase on the carcass quality of chickens are shown in Table 2. The use of thyme and mentha essential oils increased the percentage of abdominal fat in chickens ($P<0.05$). However, other carcass quality parameters in experimental broilers were not significantly different from control ($P >0.05$).

Antioxidant status

The effects of dietary supplementation essential oils (Thyme and Mentha) and microbial phytase on the antioxidant status of chickens are shown in Table 3. The use of thyme essential oil significantly increased the levels of SOD and GPX in chickens ($P <0.05$). However, other antioxidant parameters in experimental broilers were not significantly different from control ($P >0.05$).

Organoleptic properties of meat

The effects of dietary supplementation essential oils (thyme and mentha) and microbial phytase on meat organoleptic properties of chickens are shown in Table 4. The use of thyme essential oil increased the overall acceptance of chicken meat ($P <0.05$). However, other organoleptic properties of meat in experimental broilers were not significantly different from control ($P >0.05$).

DISCUSSION

Carcass quality

These results were contradicted with the findings of Sadeghi et al. (2012) and Shirzadegan et al. (2014), who reported that the essential oils did not affect liver weight and abdominal fat. It seems that because these medicinal plants, in addition to having high antimicrobial and antioxidant properties, have antifungal properties, stimulate appetite, increase the digestibility of nutrients and feed consumption, and improve the condition of the gastrointestinal tract. By adding these substances, the digestibility of nutrients (Aydin et al, 2010) and increases the energy released from the diet and excess energy is stored in the ventricular area in the form of fat in the animal. Baghban-Kanani et al. (2020) stated that difference in bird performance fed diets with phytase supplement may be due to a number of factors including phytase source, feed ingredients, and dietary characteristics. In this study, microbial phytase had no significant effect on carcass quality, resulting in differences in feed ingredients.

Antioxidant status

Considering that GPX and MDA enzymes are part of the body's first line of defense against free radicals (Ghobadi et al., 2017) and total antioxidant capacity is also an indicator of anti-radical, enzymatic, and non-enzymatic antioxidant activity (Banerjee et al., 2017; Akpro et al., 2019). Therefore, according to the results obtained from the liver's parameters, it can be said that the use of thyme essential oil has improved and strengthened the antioxidant status in the liver and serum of broilers. As the antioxidant status improves, the level of MDA (which is an indicator of lipid peroxidation in the body) decreased (Bai et al., 2019; Hamidi et al., 2021). Antioxidant activities of essential oils such as thyme and oregano have been reported in various studies (Han et al., 2017; Sakkas and Papadopoulou, 2017; Cao et al., 2018).Traditionally, it is considered that the excessive reactive oxygen species (ROS) can be removed or reduced by antioxidant enzymes such as GPX and SOD. The enhanced ROS generation can lead to oxidative damages and decrease antioxidant enzymes activities (Pan et al., 2021).

Organoleptic properties of meat

Taste is considered a major factor in the marketing of broilers. Flavor-related amino acids (valine, isoleucine, leucine, phenylalanine, arginine, proline, and methionine) are related to the tangy flavor in meat (Ali et al., 2019; Lengkidworraphiph at et al., 2020). This shows that the used essential oils affect the amino acid profiles and improve the taste of the meat. Adding plant essential oils to poultry diets can have a positive effect on some physiological characteristics, carcass quality, as well as the quality of stored meat (Dávila-Ramírez et al., 2020; Ashour et al., 2020). Herbal additives are also used as a substitute for synthetic antioxidants due to their antioxidant properties, and while maintaining the quality

Table 2. Effects of adding essential oils (thyme and mentha) and microbial phytase on the carcass quality of broilers

effects			Back and neck	Breast	Thigh	Bursa of fabricius	Spleen	Liver	Gizzard	Intestine	Abdominal fat
Main effects											
Thyme											
0			26.7450	32.9662	26.8906	0.1743	0.1356	2.5575	2.3450	7.3175	1.7962[b]
200			27.2575	32.4043	26.5606	0.1756	0.1556	2.7500	2.4575	7.3868	2.1300[a]
SEM			0.2360	0.3516	0.4813	0.0115	0.0072	0.0642	0.0672	0.1815	0.0825
p-value			0.1377	0.2697	0.6322	0.9398	0.0630	0.0865	0.2483	0.7893	0.0087
mentha											
0			26.8943	33.1325	26.3975	0.1693	0.1493	2.5275	2.3962	7.2531	1.8031[b]
200			27.1081	32.2381	27.0537	0.1806	0.1418	2.8100	2.4062	7.4512	2.1231[a]
SEM			0.2360	0.3516	0.4813	0.0115	0.0072	0.0642	0.0672	0.1815	0.0825
p-value			0.5280	0.0847	0.3446	0.4989	0.4717	0.0048	0.9171	0.4479	0.0114
Microbial phytase											
0			27.1375	32.9412	26.2106	0.1768	0.1425	2.6525	2.4106	7.2106	1.9056
500			26.8650	32.4293	27.2406	0.1731	0.1487	2.6850	2.3918	7.4937	2.0206
SEM			0.2360	0.3516	0.4813	0.0115	0.0072	0.0642	0.0672	0.1815	0.0825
p-value			0.4223	0.3136	0.1433	0.8209	0.5480	0.7239	0.8453	0.2811	0.3347
Interactions											
Thyme × mentha											
0	0		26.7375	33.54	26.7925	0.1750	0.1462	2.4650	2.3362	6.9462	1.6162
0	200		26.7525	32.3925	26.9887	0.1737	0.1250	2.7100	2.3537	7.6887	1.9762
200	0		27.0512	32.7250	26.0025	0.1637	0.1525	2.59	2.4562	7.56	1.99
200	200		27.4637	32.0837	27.1187	0.1875	0.1587	2.91	2.4587	7.2137	2.27
SEM			0.3337	0.4973	0.6807	0.0163	0.0102	0.0909	0.0950	0.2567	0.1168
p-value			0.5571	0.6154	0.5057	0.4530	0.1926	0.6837	0.9378	0.0445	0.7350
Thyme × phytase											
0	0		27.0975	32.9925	26.7850	0.1725	0.1325	2.6037	2.3362	7.1912	1.6612
0	500		26.3925	32.94	26.9962	0.1762	0.1387	2.5712	2.3537	7.4437	1.9312
200	0		27.1775	32.89	25.6363	0.1812	0.1525	2.7012	2.4850	7.23	2.15
200	200		27.3375	31.9187	27.4850	0.17	0.1587	2.7987	2.43	7.5437	2.11
SEM			0.3337	0.4973	0.6807	0.0163	0.0102	0.0909	0.0950	0.2567	0.1168
p-value			0.2074	0.3648	0.2408	0.6513	1	0.4816	0.7064	0.9061	0.1970
mentha × phytase											
0	0		27.1025	33.06	26.2062	0.1687	0.1462	2.4587	2.4175	7.0962	1.8162
0	500		26.6862	33.2050	26.5887	0.17	0.1525	2.5962	2.3750	7.41	1.79
200	0		27.1725	32.8225	26.2150	0.1850	0.1387	2.8462	2.4037	7.3250	1.9950
200	500		27.0437	31.6537	27.8925	0.1762	0.1450	2.7737	2.4087	7.5775	2.2512
SEM			0.3337	0.4973	0.6807	0.0163	0.0102	0.0909	0.0950	02567	0.1168
p-value			0.6705	0.1990	0.3510	0.7629	1	0.2595	0.8049	0.9061	0.2383
effects											
Thyme	mentha	phytase									
0	0	0	27.0575	32.7725	26.8250	0.1750	0.1450	2.4425	2.3250	7.0225	1.6050
200	0	0	27.1475	33.3475	25.5875	0.1625	0.1475	2.4750	2.51	7.17	2.0275
0	200	0	27.1375	33.2125	26.7450	0.17	0.12	2.7650	2.3475	7.36	1.7175
0	0	500	26.4175	34.3075	26.76	0.1750	0.1475	2.4875	2.3475	6.87	1.6275
200	200	0	27.2075	32.4325	25.6850	0.20	0.1575	2.9275	2.46	7.29	2.2725
200	0	500	26.9550	32.1025	26.4175	0.1650	0.1575	2.7050	2.4025	7.95	1.9525
0	200	500	26.3675	31.5725	27.2325	0.1775	0.13	2.6550	2.36	8.0175	2.2350
200	200	500	27.72	31.7350	28.5525	0.1750	0.16	2.8925	2.4575	7.1375	2.2675
SEM			0.4720	0.7032	0.9626	0.0231	0.0145	0.1285	0.1344	0.3631	0.1651
p-value			0.5376	0.0735	0.5905	0.5983	0.7179	0.7649	0.7650	0.1027	0.3721

Means with different letters in each column have a significant difference (P <0.05).

Table 3. Effects of adding essential oils (thyme and mentha) and microbial phytase on the antioxidant status of broilers

effects			TAC. S	MDA. S[1]	GPX.L	SOD.L	MDA.L[2]
Main effects							
Thyme							
0			1.6875	4.7812	2.6918[b]	15.4193[b]	1.13
200			1.7025	4.8687	2.9750[a]	17.0781[a]	1.2875
SEM			0.1203	0.3897	0.0990	0.4055	0.0617
p-value			0.9305	0.8752	0.0546	0.0080	0.0837
mentha							
0			1.6175	4.7687	2.92	16.3275	1.1875
200			1.7725	4.8812	2.7468	16.17	1.23
SEM			0.1203	0.3897	0.0990	0.4055	0.0617
p-value			0.3713	0.84	0.2287	0.7859	0.6307
Microbial phytase							
0			1.7425	4.6187	2.6987	16.1418	1.15
500			1.6475	5.0312	2.9681	16.3556	1.2675
SEM			0.1203	0.3897	0.0990	0.4055	0.0617
p-value			0.5817	0.4615	0.0665	0.7126	0.1908
Interactions							
Thyme × mentha							
0	0		1.6062	4.7750	2.7275	15.3112	1.05
0	200		1.7687	4.7875	2.6562	15.5275	1.21
200	0		1.6287	4.7625	3.1125	17.3437	1.3250
200	200		1.7762	4.9750	2.8375	16.8125	1.25
SEM			0.1701	0.5511	0.1401	0.5734	0.0872
p-value			0.9652	0.8576	0.4743	0.5208	0.1908
Thyme × phytase							
0	0		1.7675	4.6875	2.59	14.9375	1.05
0	500		1.6075	4.8750	2.7937	15.9012	1.21
200	0		1.7175	4.55	2.8075	17.3462	1.25
200	500		1.6875	5.1875	3.1425	16.81	1.32
SEM			0.1701	0.5511	0.1401	0.5734	0.0872
p-value			0.7058	0.6867	0.6438	0.2033	0.6307
mentha × phytase							
0	0		1.7425	4.6375	2.8712	16.56	1.1625
0	500		1.4925	4.90	2.9687	16.0950	1.2125
200	0		1.7425	4.60	2.5262	15.7237	1.1375
200	500		1.8025	5.1625	2.9675	16.6162	1.3225
SEM			0.1701	0.5511	0.1401	0.5734	0.0872
p-value			0.3713	0.7878	0.2319	0.2482	0.4446
effects							
Thyme	mentha	phytase					
0	0	0	1.7225	4.95	2.6250	1463.50	0.90[d]
200	0	0	1.7625	4.3250	3.1175	18.4850	1.4250[a]
0	200	0	1.8125	4.4250	2.5550	15.24	1.20[b]
0	0	500	1.49	4.60	2.83	15.9875	1.20[b]
200	200	0	1.6725	4.7750	2.4975	16.2075	1.0750[c]
200	0	500	1.4950	5.20	3.1075	16.2025	1.2250[b]
0	200	500	1.7250	5.15	2.7575	15.8150	1.22[b]
200	200	500	1.88	5.1750	3.1775	17.4175	1.4250[a]
SEM			0.2406	0.7794	0.1981	0.8110	0.1234
p-value			0.632	0.4888	0.2287	0.0750	0.0258

Means with different letters in each column have a significant difference ($P < 0.05$).

[1]MDA level on blood samples

[2]MDA level on liver samples

Table 4. Effects of adding essential oils (thyme and mentha) and microbial phytase on organoleptic properties of meat in broilers

effects			Acceptance	Crisp	Flavor	Hydration	Smell	b	a	L
Main effects										
Thyme										
0			3.03375	3.0512	2.9425	3.1775	2.9812^{b}	10.7143^{b}	3.8837^{a}	51.4737^{b}
200			3.7937	3.0275	3.4818	3.5206	3.5131^{a}	12.5368^{a}	2.9650^{b}	53.3618^{a}
SEM			0.1691	0.2319	0.2441	0.1778	0.1587	0.2859	0.0897	0.2856
p-value			0.1615	0.9429	0.1314	0.1852	0.0262	0.0001	<0.0001	<0.0001
mentha										
0			3.0643	2.8781	3.0362	3.1850	3.1850	11.2443	3.7106^{a}	51.8468^{b}
200			3.3487	3.2006	3.3881	3.5131	3.3093	12.0068	3.1381^{b}	52.9887^{a}
SEM			0.1691	0.2319	0.2441	0.1778	0.1587	0.2859	0.0897	0.2856
p-value			0.2463	0.3353	0.3183	0.2044	0.5846	0.0715	<0.0001	0.0093
Microbial phytase										
0			3.1018	3.0681	3.0600	3.2475	3.0593	10.9687^{b}	3.7062^{a}	52.2475
500			3.3112	3.0106	3.3643	3.4506	3.4350	12.2825^{a}	3.1425^{b}	52.5851
SEM			0.1691	0.2319	0.2441	0.1778	0.1587	0.2859	0.0897	0.2856
p-value			0.3902	0.8623	0.3868	0.4273	0.1072	0.0034	0.0002	0.4075
Interactions										
Thyme × mentha										
0	0		2.7178	2.7287	2.5912	2.8725	2.70	10.2262	4.5437^{a}	50.5412
0	200		3.3487	3.3737	3.2937	3.4825	3.2625	11.2025	3.2337^{b}	52.4062
200	0		3.4100	3.0275	3.4812	3.4975	3.67	12.2625	2.8775^{c}	53.1525
200	200		3.3487	3.0275	3.4825	3.5437	3.3562	12.8112	3.0525^{b}	53.5712
SEM			0.2392	0.3279	0.3452	0.2515	0.2244	0.4043	0.1268	0.4040
p-value			0.1615	0.3353	0.3200	0.2735	0.0627	0.6019	<0.0001	0.0861
Thyme × phytase										
0	0		2.8962	3.0925	2.7162	3.1375	2.6525	9.0650	4.5050^{a}	50.8187
0	500		3.1712	3.01	3.1687	3.2175	3.31	12.3627	3.2625^{b}	52.1287
200	0		3.3075	3.0437	3.4037	3.3575	3.4662	12.8725	2.9075^{c}	53.6762
200	500		3.4512	3.0112	3.56	3.6837	3.56	12.2012	3.0225^{bc}	53.0475
SEM			0.2392	0.3279	0.3452	0.2515	0.2244	0.4043	0.1268	0.4040
p-value			0.7862	0.9399	0.6718	0.6289	0.2213	<0.0001	<0.0001	0.0246
mentha × phytase										
0	0		2.9487	3.0437	2.7012	3.0750	3.0125	10.7525	4.1712^{a}	51.7162
0	500		3.1800	2.7125	3.3712	3.2950	3.3575	11.7362	3.2500^{b}	51.9775
200	0		3.2550	3.0925	3.4187	3.4200	3.1062	11.1850	3.2412^{b}	52.7787
200	500		3.4425	3.3087	3.3575	3.6062	3.5125	12.8287	3.0350^{b}	53.1987
SEM			0.2392	0.3279	0.3452	0.2515	0.2244	0.4043	0.1268	0.4040
p-value			0.9279	0.4121	0.3002	0.9471	0.8926	0.4224	0.0095	0.8459
effects										
Thyme	mentha	phytase								
0	0	0	2.5325	2.9350	2.0925	2.7775	2.34	8.0375	5.8125^{a}	49.3525
200	0	0	3.3650	3.1525	3.31	3.3725	3.6850	13.4675	2.5300^{c}	54.0800
0	200	0	3.2600	3.25	3.34	3.4975	2.9650	10.0925	3.1975^{b}	52.2850
0	0	500	2.9050	2.5225	3.09	2.9675	3.06	12.4150	3.2750^{b}	51.7300
200	200	0	3.25	2.9350	3.4975	3.4325	3.2475	12.2775	3.2850^{b}	53.2725
200	0	500	3.4550	2.9025	3.6525	3.6225	3.6550	11.0575	3.2250^{b}	52.2250
0	200	500	3.4375	3.4975	3.2475	3.4675	3.56	12.3125	3.2500^{b}	52.5275
200	200	500	3.4475	3.12	3.4675	3.7450	3.4650	13.3450	2.8200^{c}	53.8700
SEM			0.3383	0.4638	0.4883	0.3557	0.3174	0.9864	0.1794	0.9215
p-value			0.7547	0.8653	0.6082	0.7145	0.6819	0.5718	<0.0001	0.5713

Means with different letters in each column have a significant difference (P <0.05).

of meat, they have no adverse effects on the product and the environment (Pateiro et al., 2018; Hashemi et al., 2020). Lipid oxidation also plays a role in determining the final pH and total pigment concentration and, consequently, the color of the meat in the muscle (Kılıç et al., 2018; Domínguez et al., 2019). Plant essential oils with their antioxidant properties reduce the lipid oxidation of stored meat (Aminzare et al., 2019). They can also affect *in vivo* antioxidant systems such as vitamin E, superoxide dismutase, and glutathione peroxidase (Diniz do Nascimento et al., 2020; Sharma et al., 2020). Therefore, the observed variation in the amount of redness and yellowness in meat can be attributed to the antioxidant effect of essential oils in meat. The rate of discoloration in fresh meat is related to the rate of pigment oxidation, oxygen consumption, and the effectiveness of the meth myoglobin regenerative system (Buzrul, 2017; Khan et al., 2018; Flores et al., 2020).

CONCLUSIONS

The use of thyme essential oil increased the overall acceptance of chicken meat. Our results showed that essential oil influences chicken meat antioxidant properties. Moreover, it affected the smell, b and L parts of the meat. Use of thyme essential oil in broiler ration is recommended.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationship that could influence the work reported in this paper.

ACKNOWLEDGMENTS

The article was extracted from the Ph.D. thesis prepared by Eslam Ghalandari, under supervision of Prof. Alireza Safamehr and Prof. Ali Nobakht. The authors wish to express their sincere gratitude to Dr. Valiollah Palangi for his valuable cooperation in the English edition.

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