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Original Article

Effects of Dietary Resveratrol and Curcumin Supplements on Meat Quality and Storage Time in Broilers

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ABSTRACT

This study was conducted in order to determine the effects of different doses of resveratrol and curcumin added to the diet of broilers on the fatty acid profile of drumstick meat, and the microbial load and physicochemical criteria in drumstick and breast meat. In the study, a total of 200 male broiler chicks at the age of one days were equally distributed into five groups. The treatments consisted of a basal diet (Control) and the treatments, which added the following amounts of additives to the basal control diet: (R250) 250 mg kg^{-1} resveratrol, (R500) 500 mg kg^{-1} resveratrol, (C250) 250 mg kg^{-1} curcumin, and (C500) 500 mg kg^{-1} curcumin. It was found that resveratrol and curcumin significantly decreased the counts of total mesophilic aerobic bacteria (TMAB) (8th day), *Lactobacillus spp.* (6th day) and *Lactococcus spp.* (8th day) in drumstick meat. In breast meat, decreases were observed in the counts of *Micrococcus/Staphylococcus* (4th day) in the C500 group, and *Enterobacteriaceae* (8th day) in the R500 and C500 groups. The TBARS value in drumstick meat decreased significantly in the R250, R500 and C500 groups on the zeroth day. Myristic acid, myristoleic acid, γ-linolenic acid, unsaturated fatty acids (ΣUFA), and medium chain fatty acids (MCFA) percentages of total fatty acids in drumstick meat were found to increase in the R250 group according to other groups. In conclusion, it was observed that resveratrol and curcumin added to the diet at variable levels affected the meat in terms of microbial and fatty acid profiles, while the effect was limited effectiveness on physicochemical parameters.

INTRODUCTION

The rapid growth of broilers, the high interest of consumers due to the low price of their quality meat, and the rapid reaction of meat to changes in dietary composition have increased the interest of researchers in producing chicken meat enriched with functional components (Kralik *et al.,* 2018). Antibiotics were commonly used in the diets of farm animals to control diseases and improve production performance for many years. However, their use in poultry feed has been prohibited in order to minimize the risk of residues in meat and prevent the development of antibiotic resistance (Ben Lagha *et al.,* 2017). Therefore, there has been an increased interest in phytochemicals contained in plants for improving the quality of animal products in animal nutrition. Either the plant itself or its extract are usually used. Plant extracts are widely used in human medicine due to their anticarcinogenic, anti-cholesterol and antihypertensive properties; and in animal feeds for their aromatic, antioxidant, antimicrobial, antiparasitic, and immunostimulant effects (Gumus *et al.,* 2017a; Gumus & Gelen, 2023).

Resveratrol (Res) is a polyphenol compound found naturally in a variety of plants, including grapes, *Polygonum cuspidatum* and peanuts (Berman

et al., 2017). Dietary resveratrol supplementation has been shown to improve antioxidant status in chickens (Yang *et al.,* 2021), and to positively affect the pH and color values of meat quality criteria, since it improves the antioxidant capacity of meat tissue in the case of many stresses (temperature, etc.), especially transport stress (Ma *et al.,* 2010). Turmeric (*Curcuma longa*), another important medicinal plant, is a perennial herb, a member of the *Zingiberacae* family, and widely used as a spice in human food (Soni *et al.,* 1997). Curcumin, dimethoxycurumin, bismethoxycurumin, (Wuthi-Udomler *et al.,* 2000) and tetrahydrosurcuminoids are the active ingredients found in turmeric (Osawa *et al.,* 1995). Derived from the roots and stems of turmeric, curcumin was observed to exhibit antioxidant (Karami *et al.,* 2011a), antiviral and antibacterial activities (Wang *et al.,* 2015). Also, Soni *et al.* (1997) reported that turmeric has protective effects in terms of aflatoxin-induced mutagenicity and hepatocarcinogenicity when used as a food additive. Curcuminoids in turmeric have a wide range of biological activity including antioxidants, antibacterial, antifungal, antiprotozoal, antiviral, anticoccidial and anti-inflammatory properties, and they suppress lipid oxidation (Masuda *et al.,* 2001). In studies conducted on broiler chickens, it has been stated that when turmeric was added to the diet at a rate of 1%, it did not adversely affect the color, pH and moisture parameters of meat (Kinati *et al.,* 2022). It was found that curcumin added to broiler diets improves meat quality by increasing the proportion of UFA in the meat (Hang *et al.,* 2018). Again, the researchers reported that the antimicrobial and anticoccidial properties of curcumin improved the quality and performance of poultry meat (Rajput *et al.,* 2014). The antioxidant capacity of meat is related to its quality. Additionally, the inclusion of certain nutrients with antioxidant function in the diet has been noted to improve the quality of poultry meat (Gumus *et al.,* 2018; Zhang *et al.,* 2018).

Some microbiological and physicochemical (a_w, pH, color values) properties are important for evaluating the quality of meat in the meat industry. One of the most important factors affecting the quality of meat is the microbial load of meat. Some microorganisms found in meat impair the quality of meat, shorten its shelf life, and pose a risk to human health (Mastromatteo *et al.,* 2010). Meat color and pH are important criteria used in the physicochemical quality of meat (Bianchi *et al.,* 2005). Water activity, another of the physical criteria, refers to the ability of muscle tissue to retain moisture, and it directly affects the taste and tenderness of the meat (Zhou *et al.,* 2010).

This study was conducted in order to determine the effects on meat quality of different doses of resveratrol and curcumin added into the diet of broilers.

MATERIALS AND METHODS

Animals, experimental design, and diet

The study design was conducted in the Faculty of Veterinary Medicine in Cumhuriyet University. A total of 200 day old male broiler chickens (*Ross 308*) constituted the material of the study. The broilers were randomly allocated to one Control group and four treatment groups (R250, R500, C250 and C500), each containing 40 broilers. Each group was randomly divided into 4 subgroups comprising 10 broilers. The animals were housed in 20 four-storey cages measuring 120×80×60 cm. While the Control group received only a basal diet, groups R250, R500, C250 and C500 were given a basal diet added with 250 mg kg^{-1} resveratrol, 500 mg kg^{-1} resveratrol, 250 mg kg^{-1} curcumin and 500 mg kg^{-1} curcumin, respectively (Table 1). Resveratrol ($C_{14}H_{12}O_3$, cas no: 501-36-0, purity grade 99.13%, Chem-Impex Int. Company, Wood Dale, IL, USA) and Curcumin ($C_{21}H_{20}O_6$, cas no: 458-37-7, purity grade 95.11%, Chem-Impex Int. Company, Wood Dale, IL, USA) were obtained from the market. Feed and water

Table 1 – Ingredients and nutrient composition of broiler starter and grower diets used in the study.

Ingredients, %	Starter (0 to 21 d)	Grower (22 to 42 d)
Maize	55.87	56.90
Soybean meal 44% CP	32.52	28.60
Gluten meal 60% CP	5.51	5.84
Soybean oil	2.00	4.82
L-lysine HCl	0.24	0.16
DL-Methionine	0.13	0.02
Limestone*	1.24	1.15
Dicalcium phosphate	1.69	1.69
Choline chloride	0.20	0.22
Common Salt	0.30	0.30
Vit-Min. Premix**	0.30	0.30
Total	100	100
Nutrient content		
Crude protein, %	22.50	19.55
Metabolizable energy (kcal/kg)	2960	3150
Crude fibre, %	3.12	3.18
Calcium, %	0.98	0.91
Phosphorous, %	0.54	0.51

*Resveratrol and curcumin have replaced limestone at the same amount in the groups which R250, R500, C250 and C500 have been included.

**Supplied per kg of diet: vitamin A: 10000 IU; vitamin D3: 3500 IU; vitamin E: 60 mg; vitamin K3: 3 mg; vitamin B12: 0.1 mg; Thiamine: 3 mg; Riboflavin: 6 mg; Niacin. 40 mg; Pyridoxine: 5 mg; Pantothenic acid: 11 mg; Folic acid: 1 mg; Biotin: 0.15 mg; Cholin chloride: 500 mg; Etoxycoin: 150 mg; Fe: 60 mg; Zn: 60 mg; Mn:100 mg; Cu: 10 mg; I: 1.6 mg and Se: 0.15 mg.

were supplied *ad libitum*. The ambient temperature was gradually decreased from 33 °C in the first week to 22 °C on day 14, and was then kept constant afterwards. The lighting program consisted of a continuous 23 h light. Control diets were formulated according to NRC (1994) recommendations (Table 1). The nutritional composition of the diets was determined according to the AOAC (2005).

Sample collection

After the 42 days of the feeding experiment, a total of 60 animals, with 20 animals from each group, were slaughtered in a commercial slaughterhouse according to standard commercial procedures. Prior to slaughter, the chickens were fasted for 10 h. The slaughtered animals were bled for 120 s. The feathers of the animals were plucked manually. The chicken drumsticks and breast meat were placed on polyethylene plates, covered with stretch film and stored at 4±1 °C for 10 d. Subsequently, the samples were analyzed on d 0, 2, 4, 6 and 8 for pH, a_w, and colour [L*(lightness), a*(redness), b*(yellowness)] analyses and microbial counts [TMAB, *Micrococcus/Staphylococcus spp., Enterobacteriaceae, Lactobacillus spp., Lactococcus spp., Pseudomonas spp.* and total psychrotrophic aerobic bacteria (TPAB)]. Microbiological analyses of the samples preceded the other analyses.

Meat quality analysis

Microbial load

The microbiological analyses of the samples were performed according to the method described by Baumgart *et al.* (2015). Accordingly, 25 g of the meat samples was homogenized in 225 mL of sterile Ringer's solution. Subsequently, the other solutions were prepared. Inoculations were made using the spread plate technique. The TMAB count was determined using Plate Count Agar (PCA, Merck, Darmstadt, Germany). The petri dishes were incubated under aerobic conditions at 30±1°C for 72±1 hours. The TPAB count was also determined using the Plate Count Agar (PCA, Merck, Darmstadt, Germany), and the petri dishes were incubated under aerobic conditions at 7 ± 1°C for 10 days. *Micrococcus / Staphylococcus spp.* counts were determined using Mannitol-Salt Agar (MSA, Merck, Darmstadt, Germany) and the plates were incubated under anaerobic conditions at 30±1°C for 48±1 hours. For the determination of *Enterobacteriaceae* counts, 1 ml of the appropriate dilutions was inoculated into Violet Red Bile Dextrose Agar (VRBDA, Merck, Darmstadt, Germany). The petri dishes were incubated at 30 °C under anaerobic conditions for 2 days. The plates were incubated under aerobic conditions at 30±1°C for 48±1 hours. *Lactobacillus spp.* counts were determined using MRS (de Man Rogosa and Sharpe) Agar (Merck, Darmstadt, Germany) and the plates were incubated under anaerobic conditions at 37±1°C for 48±1 hours. *Lactococcus spp.* counts were determined using M17 Agar (Merck, Darmstadt, Germany) and the plates were incubated under anaerobic conditions at 37±1°C for 48±1 hours. *Pseudomonas spp.* counts were determined using Pseudomonas Agar (Oxoid CM 0559) supplemented with CFC supplement (Oxoid SR 0103) and the plates were incubated under aerobic conditions at 25±1°C for 48±1 hours. Bacterial counts were expressed in log cfu g^{-1}.

Water activity

Water activity values were measured using an Aqualab 4TE (USA) device. Meat samples were placed in the container of the device for the reading of the a_w values.

pH

The pH values of the samples were measured as described by Gökalp *et al.* (2001). Accordingly, 10 g-portions of the homogenized samples were weighed and 100 mL of distilled water was added to each portion. Homogenization was performed for 1 minute using an Ultra-Turrax (IKA Werk T 25, Germany) homogenizer, and pH values were measured using a pH–meter (WTW Inolab, Germany).

Color measurement

The colour intensities (L*, a*, b*) of the cross sectional areas of the drumstick and breast meat samples were determined using a Minolta colorimeter (CR-200, Minolta Co, Osaka, Japan). Colour measurements were performed directly on the surface of muscle tissue by removing the skin.

Lipid peroxidation analysis (TBARS)

In order to carry out the TBARS assay, which measures the level of malondialdehyde (MDA) present in the sample, homogeneous samples of meat (about 2 g) were homogenized with 12 ml of a trichloroacetic acid (TCA) solution ((7.5% TCA, 0.1% EDTA, 0.1% propyl gallate (dissolved in 3 mL of ethanol)) for 15–20 s in an Ultra-Turrax device (T25, IKA Werk, Staufen, Germany), and then filtered through Whatman 1 filter paper. The filtrate (3 mL) was transferred to the test tube, and 3 mL of a thiobarbituric acid (TBA) (0.02 M) solution was added and then it was homogenized again.

The test tubes were subsequently kept in a water bath for 40 min at 100 °C, and then cooled in cold water for 5 min. After centrifugation (5 min at 2000 *g*), the absorbance values of the obtained liquid phase were obtained with use of a spectrophotometer (AquaMate 7000 Vis Spectrophotometer, Thermo Fisher Scientific, Waltham, MA, USA) at 530 nm. Results are given in µmol malonaldehyde kg^{-1} (Lemon, 1975).

TBARS = ((absorbance / k (0.06) x 2/1000) x 6.8) x 1000 / sample weight.

Fatty acid analysis

The meat samples were homogenized with a tissue grinder (Homogenizer HS-30E, witeg Labortechnik GmbH, Wertheim, Germany) using a pestle with polytetrafluoroethylene head (5553855 number, witeg Labortechnik GmbH, Wertheim, Germany). The grinded sample was mixed with 0.7 mL of potassium hydroxide (10 M) and 5.3 mL of methanol, and then it was incubated at 55 °C for 45 min in an incubator (Nüve FN 120, Ankara, Türkiye). Then, 0.58 mL of H_2SO_4 (10 M) was added to the mixture, vortexed, and incubated at 55 °C for 45 min again. Subsequently, 3 mL of *n*-hexane was added to the mixture and the tubes were centrifuged at 1600 *g* for 5 min (Nüve, Ankara, Türkiye) (Kara, 2023). After centrifugation, 1.5 mL of supernatant was put into polytetrafluorethylene (PTFE)/ white silicone septa blue cap vials and then analyzed in a gas chromatography device (Thermo 1300, Thermo Fisher Scientific, Waltham, MA, USA) with an automatic sampler (Thermo AI 1310, Thermo Fisher Scientific, Waltham, MA, USA). In the analysis, a column of Fatty Acid Methyl Esters (FAME) (TR-FAME, cat no: P/N 260M154P, Thermo Fisher Scientific, Waltham, MA, USA) (length: 60 m, I.D.: 0.25 mm, film: 0.25 µm, and maximum temperature of 250/260 °C) was used. The initial temperature of the column was 100 °C, which was kept for 3 min, and then it was increased to 240 °C at a rate of 4 °C/min, and kept for 10 min. The device was run at split mode, constant flow, 1 mL/min flow, 20 mL/min of split, and a 1:20 split ratio. Air flow was 350 mL/min and hydrogen – 35 mL/min. The temperature of the flame ionization detector (FID) was 260 °C (Thermo AI 1310, Thermo Fisher Scientific, Waltham, MA, USA). FAME mix (37 °C) standard solution (CL.40.13093.0001) in dichloromethane (Chem-Lab, Zedelgem, Belgium) was used for the identification of peak. Helium was used as the carrier gas. Fatty acid identification was performed by comparing and calculating the standard fatty acid peaks in the samples according to the retention time using the Xcalibur program (Kara, 2021). Saturated fatty acids (ΣSFA), ΣUFA, polyunsaturated fatty acids (ΣPUFA), monounsaturated fatty acids (ΣMUFA), MCFA (fatty acids with chains containing from 6 to 12 atoms of C), long-chain fatty acids (LCFA) (fatty acids with chains containing from 14 to 20 atoms of C) and very long-chain fatty acids (VLCFA) (fatty acids with chains containing more than 20 atoms of C) were detected.

Statistical analyses

All statistical analyses were performed using the SPSS 20.00 software (SPSS, 2011). For performance parameters, differences between the groups were determined with the one-way analysis of variance (ANOVA) test and Duncan's post-test.

Water activity, pH, TBARS, colour parameters (L*, a* and b*) and microbial counts (log cfu g^{-1}) were analysed using a general linear model:

$Yijk = \mu + di + gj + dgij + eijk$

Where Yijk = response variable, µ = population mean, di= Storage Time (0., 2., 4., 6. and 8. Days) (a_w, pH, TBARS, L*, a*, b*, microorganism)], gj = treatment group (C, R250, R500, C250 and C500), dgij = Storage Time x treatment group interaction, eijk= experimental error. The data were expressed as mean±standard error of mean (SEM). Differences were considered as significant at $p<0.05$, $p<0.01$.

RESULTS

Microbial Load

In the analysis of drumstick meat, the number of TMAB on the 8th day ($p<0.01$) and the number of *Lactobacillus spp.* on the 6th day were statistically lower than the Control group in all groups with added resveratrol and curcumin ($p<0.05$). Moreove, the number of *Lactococcus spp.* on the 8th day was statistically lower than the Control group for R500, C250 and C500 ($p<0.01$), while there was no statistical difference between the groups on other days ($p>0.05$) (Table 2). It was found that there was no statistical difference between the groups in terms of the numbers of *Micrococcus/Staphylococcus, Enterobacteriaceae, Pseudomonas spp.,* and TPAB for all days of storage ($p>0.05$) (Table 2).

In breast meat, there was a significant decrease in the numbers of *Micrococcus/Staphylococcus* in the C500 group on the 4th day, *Enterobacteriaceae* in the R500 and C500 groups on the 8th day, *Lactococcus spp*. in the R250, R500 and C500 groups on the zeroth day, and TPAB in the C250 group on the second day ($p<0.05$). There was no difference between the groups

Table 2 – Effects of dietary resveratrol and curcumin supplementation and storage time on TMAB, *Micrococcus/Staphylococcus spp., Enterobacteriaceae, Lactobacillus spp., Lactococcus spp., Pseudomonas spp.* and TPAB counts in chicken drumstick meat (log cfu g^{-1}).

Storage times, Days	Groups[1]	TMAB	*Micrococcus/ Staphylococcus*	*Enterobacteriacea*	*Lactobacillus spp.*	*Lactococcus spp.*	*Pseudomonas spp.*	TPAB
0	Cont	5.388±0.133	4.405±0.519	3.038±0.193	4.953±0.409	5.230±0.151	2.806±0.806	3.963±0.028
	R250	5.334±0.347	3.009±0.708	2.778±0.477	4.804±0.191	5.082±0.366	2.968±0.049	3.701±0.254
	R500	4.054±0.549	3.611±0.465	2.818±0.063	4.182±0.068	3.980±0.600	3.284±0.837	2.812±0.034
	C250	4.968±0.667	4.100±0.155	3.497±0.175	4.983±0.138	4.787±0.531	3.635±0.936	2.968±0.463
	C500	4.355±0.775	3.389±0.310	2.914±0.136	4.000±0.000	4.149±0.657	2.952±0.747	2.475±0.629
	p-value	0.417	0.354	0.374	0.061	0.394	0.929	0.138
2	Cont	5.667±0.412	4.724±0.008	3.747±0.367	5.212±0.367	5.290±0.290	3.544±0.590	4.895±0.050
	R250	5.334±0.535	4.697±0.299	3.224±0.525	4.929±0.327	5.333±0.500	3.562±0.283	4.333±0.129
	R500	4.569±1.064	4.218±0.104	3.447±0.243	4.923±0.174	5.024±0.231	3.389±0.043	4.889±0.235
	C250	5.548±0.151	4.597±0.643	3.524±0.109	5.031±0.709	5.487±0.573	3.576±0.496	3.797±0.106
	C500	4.151±0.151	3.616±0.662	3.078±0.036	4.032±0.731	4.185±0.230	2.887±0.632	3.817±0.817
	p-value	0.371	0.431	0.620	0.572	0.276	0.805	0.240
4	Cont	6.189±0.062[a]	5.208±0.200	3.848±0.009	5.798±0.292	5.431±0.016	4.350±0.115	5.502±0.055
	R250	5.410±0.368[a]	4.924±0.581	3.363±0.217	5.004±0.527	5.361±0.282	3.869±0.614	5.211±0.433
	R500	5.724±0.061[a]	5.060±0.019	3.374±0.772	4.943±0.244	5.309±0.275	4.183±0.001	4.989±0.290
	C250	5.661±0.184[a]	4.596±0.476	3.998±0.507	5.411±0.566	5.491±0.588	3.600±0.493	5.328±0.263
	C500	4.301±0.301[b]	3.898±0.818	3.199±0.199	4.321±0.844	4.201±0.724	3.136±0.016	4.784±0.029
	p-value	0.016	0.461	0.659	0.466	0.349	0.259	0.429
6	Cont	6.317±0.081	5.728±0.306	4.341±0.040	6.328±0.279[a]	6.143±0.009	4.818±0.040	6.174±0.206
	R250	5.900±0.423	5.402±0.209	3.500±0.801	5.172±0.372[b]	5.522±0.291	4.127±0.712	5.428±0.871
	R500	5.825±0.032	5.266±0.043	3.594±0.552	5.267±0.012[b]	5.563±0.201	4.255±0.664	5.122±0.018
	C250	5.988±0.947	5.241±0.402	4.205±0.059	5.446±0.031[b]	5.509±0.094	3.967±0.552	5.485±0.761
	C500	4.500±0.500	4.889±0.003	3.211±0.910	5.230±0.026[b]	4.509±1.207	3.472±0.171	4.958±0.024
	p-value	0.259	0.324	0.649	0.048	0.452	0.517	0.578
8	Cont	6.988±0.053[a]	5.878±0.021	4.773±0.503	6.537±0.195	6.667±0.014[a]	5.849±0.133	6.221±0.287
	R250	6.339±0.108[b]	5.599±0.083	4.234±0.572	5.486±1.023	6.342±0.184[a]	4.667±0.437	6.129±0.116
	R500	5.932±0.051[b]	5.410±0.205	3.919±0.010	5.290±0.290	5.661±0.214[b]	5.643±0.301	5.953±0.385
	C250	6.263±0.339[b]	5.618±0.130	4.303±0.798	5.707±0.202	5.781±0.128[b]	4.794±0.038	5.622±0.557
	C500	5.243±0.012[c]	5.191±0.015	3.438±0.040	5.511±0.033	5.103±0.017[c]	4.616±0.831	5.380±0.889
	p-value	0.005	0.055	0.484	0.493	0.003	0.280	0.762

All values are given as mean ± SEM, (n=12). [a-c]: Means in the same column with different superscripts differ (p<0.05). [1]Cont: basal diet alone, R250: basal diet + 250 mg kg^{-1} of resveratrol, R500: basal diet + 500 mg kg^{-1} of resveratrol, C250: basal diet + 250 mg kg^{-1} of curcumin and C500: basal diet + 500 mg kg^{-1} of curcumin. TMAB; total mesophilic aerobic bacteria, TPAB; total psychrotrophic aerobic bacteria.

for other storage times (p>0.05) (Table 3). It was found that there was no statistical difference between the groups in terms of the numbers of TMAB, *Lactococcus spp.,* and *Pseudomonas spp.* on all days of storage (p>0.05) (Table 3).

Physicochemical Criteria

It was found that there was no statistical difference between the groups on all days of storage in terms of the values of L*, a* and b* of the color parameters in drumstick meat and a_w value (p>0.05) (Table 4). The pH value in the drumstick meat was observed to significantly decrease only on the 8th day in all groups with added resveratrol and curcumin (p<0.05), while there was no difference between the groups on the other days (p>0.05) (Table 4). The TBARS value in drumstick meat was determined to significantly decrease in the R250, R500 and C500 groups on the zeroth day (p<0.01), significantly increasing only in the C250 group on the 4th day (p<0.05), and was similar on the other days in all groups (p>0.05) (Figure 1).

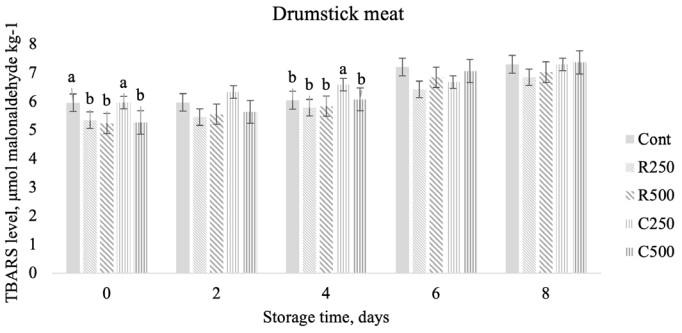

Figure 1 – Effect of diet and storage time on the TBARS level in drumstick meat of broilers fed diets supplemented with different doses of resveratrol and curcumin. Diet - Cont: basal diet alone, R250: basal diet + 250 mg kg^{-1} of resveratrol, R500: basal diet + 500 mg kg^{-1} of resveratrol, C250: basal diet + 250 mg kg^{-1} of curcumin and C500: basal diet + 500 mg kg^{-1} of curcumin. TBARS – thiobarbituric acid reactive substances. a-b – bars with different letters within each storage time are significantly different at p<0.01

Table 3 – Effects of dietary resveratrol and curcumin supplementation and storage time on TMAB, *Micrococcus/Staphylococcus spp., Enterobacteriaceae, Lactobacillus spp., Lactococcus spp., Pseudomonas spp*. and TPAB counts in chicken breast meat (log cfu g^{-1}).

Storage times, Days	Groups[1]	TMAB	*Micrococcus/ Staphylococcus*	*Enterobacteriacea*	*Lactobacillus spp.*	*Lactococcus spp.*	*Pseudomonas spp.*	TPAB
0	Cont	4.801±0.102	4.369±0.046	3.201±0.055	4.724±0.016^{a}	4.611±0.196	2.624±0.132	3.774±0.058
	R250	4.481±0.448	2.756±0.057	2.690±0.088	3.841±0.062^{bc}	4.634±0.236	3.146±0.301	2.638±0.492
	R500	3.797±0.894	3.540±0.540	3.060±0.019	3.753±0.151^{bc}	3.656±0.957	2.582±0.134	2.997±0.465
	C250	4.116±0.331	3.500±0.459	2.465±0.234	4.319±0.173^{ab}	4.493±0.151	2.550±0.596	2.011±0.165
	C500	3.752±0.711	2.651±0.048	2.521±0.521	3.349±0.349^{c}	3.557±0.557	1.962±0.485	2.287±0.111
	p-value	0.666	0.059	0.307	0.022	0.458	0.404	0.060
2	Cont	4.818±0.165	4.388±0.274	3.488±0.447	4.661±0.184	5.491±0.014	3.050±0.205	4.305±0.263^{ab}
	R250	4.628±0.151	4.042±0.162	3.239±0.062	4.151±0.151	4.765±0.561	3.296±0.420	4.781±0.158^{a}
	R500	4.540±0.239	3.552±0.061	3.247±0.469	4.060±0.759	4.492±0.170	3.028±0.171	3.772±0.073^{bc}
	C250	4.602±0.602	3.796±0.318	3.652±0.096	4.619±0.239	4.452±0.151	2.578±0.464	3.303±0.189^{c}
	C500	4.000±0.000	2.759±0.759	2.892±0.613	3.681±0.681	4.027±1.027	2.245±0.768	4.516±0.118^{a}
	p-value	0.483	0.181	0.731	0.609	0.473	0.553	0.009
4	Cont	5.837±0.066	4.766±0.368^{a}	3.846±0.233	5.136±0.095	4.889±0.190	3.970±0.151	5.049±0.085
	R250	5.194±0.513	4.481±0.251^{a}	3.389±0.389	4.455±0.309	4.778±0.125	3.309±0.577	4.894±0.282
	R500	4.858±0.256	3.972±0.028^{ab}	3.398±0.017	4.653±0.000	4.799±0.007	3.437±0.095	5.203±0.139
	C250	4.724±0.423	4.021±0.322^{ab}	3.815±0.162	4.628±0.327	4.486±0.230	2.906±0.094	4.371±0.593
	C500	4.301±0.301	3.230±0.026^{b}	3.275±1.098	4.021±0.021	4.239±0.460	2.699±0.699	4.651±0.349
	p-value	0.149	0.043	0.901	0.087	0.430	0.350	0.512
6	Cont	6.171±0.171	4.915±0.500	3.796±0.381	5.940±0.065	6.026±0.053	4.595±0.197	5.596±0.575
	R250	5.377±0.423	4.937±0.381	3.528±0.063	4.669±0.493	5.203±0.522	3.671±0.630	4.996±0.151
	R500	5.661±0.890	4.318±0.062	3.400±0.555	4.690±0.213	5.332±0.010	3.703±0.527	5.244±0.057
	C250	4.938±0.239	4.490±0.235	4.255±0.024	5.145±0.031	4.748±0.243	3.253±0.349	5.047±0.685
	C500	6.319±0.186	3.275±0.496	3.255±0.024	4.849±0.548	5.591±0.011	3.212±0.186	4.913±0.223
	p-value	0.334	0.113	0.286	0.187	0.109	0.270	0.786
8	Cont	6.753±0.151	5.321±0.228	5.071±0.179^{a}	5.957±0.043	6.109±0.067	5.391±0.136	6.068±0.046
	R250	5.646±0.500	5.144±0.412	4.078±0.036^{abc}	4.716±0.239	5.599±0.298	3.763±0.383	5.130±0.016
	R500	5.645±0.531	4.196±0.552	3.517±0.040^{bc}	4.690±0.213	5.413±0.681	4.898±0.483	5.720±0.322
	C250	5.351±0.120	4.691±0.468	4.512±0.007^{ab}	5.217±0.013	4.773±0.569	3.898±0.407	5.056±0.375
	C500	6.342±0.020	3.908±0.021	3.301±0.585^{c}	5.410±0.524	4.613±0.011	3.446±1.145	5.260±0.012
	p-value	0.134	0.178	0.029	0.093	0.213	0.263	0.088

All values are given as mean ± SEM, (n=12). $^{a-c}$: Means in the same column with different superscripts differ (p<0.05). [1]Cont: basal diet alone, R250: basal diet + 250 mg kg^{-1} of resveratrol, R500: basal diet + 500 mg kg^{-1} of resveratrol, C250: basal diet + 250 mg kg^{-1} of curcumin and C500: basal diet + 500 mg kg^{-1} of curcumin. TMAB; total mesophilic aerobic bacteria, TPAB; total psychrotrophic aerobic bacteria.

The L value among the color parameters in breast meat was observed to decrease on the zeroth day in the R500 and C250 groups (p<0.01) (Table 5). The a value among the color parameters was observed to increase on the second day in the R500 group (p<0.05), decrease in the C250 and C500 groups on the fourth day and in the C250 group on the 8th day; while the b value was determined to decrease on the 6th day in the C250 group (p<0.05) (Table 5). The pH value in breast meat was observed to significantly decrease only on the 6th day in the C250 group (p<0.05), while there was no difference between the groups on the other days (p>0.05) (Table 5). The TBARS value for breast meat was found to increase significantly in the C250 group on the 8th day (p<0.01), while there was no difference between the groups on the other days (p>0.05) (Figure 2).

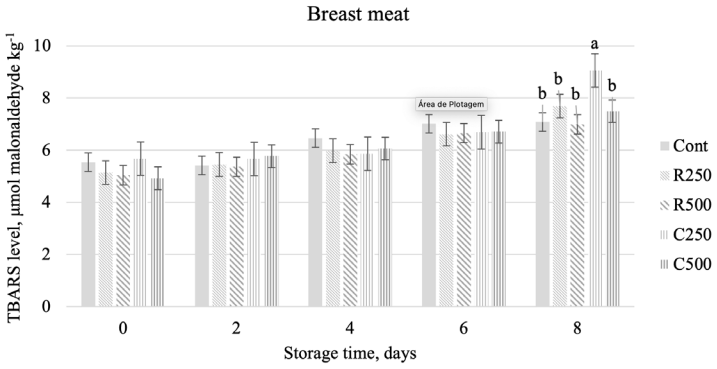

Figure 2 – Effect of diet and storage time on the TBARS level of breast meat of broilers fed diets supplemented with different doses of resveratrol and curcumin. Diet - Cont: basal diet alone, R250: basal diet + 250 mg kg-1 of resveratrol, R500: basal diet + 500 mg kg-1 of resveratrol, C250: basal diet + 250 mg kg-1 of curcumin and C500: basal diet + 500 mg kg-1 of curcumin. TBARS – thiobarbituric acid reactive substances. a-b – bars with different letters within each storage time are significantly different at p<0.01

Table 4 – Effects of dietary resveratrol and curcumin supplementation and storage period on colour parameters (L*, a* and b*), a_w, and pH in chicken drumstick meat.

Storage times, Days	Groups[1]	L	a	b	pH	a_w
0	Cont	59.550±1.642	6.968±1.232	5.683±1.437	6.460±0.040	0.995±0.001
	R250	61.633±1.998	6.453±0.755	6.380±1.212	6.215±0.175	0.995±0.003
	R500	58.313±3.201	6.700±0.456	7.265±0.891	6.230±0.160	0.994±0.000
	C250	54.440±2.106	7.103±1.334	3.340±1.100	6.155±0.185	0.991±0.003
	C500	56.313±2.454	4.890±0.735	5.215±1.173	6.325±0.015	0.995±0.001
	p-value	0.274	0.508	0.235	0.589	0.622
2	Cont	52.993±2.165	6.200±0.724	9.008±1.180	6.135±0.035	0.995±0.002
	R250	57.078±2.145	6.458±0.392	10.825±0.595	6.130±0.030	0.995±0.000
	R500	56.783±1.581	7.295±0.749	5.978±1.158	6.425±0.105	0.994±0.002
	C250	67.040±9.908	5.763±1.018	5.330±1.430	6.165±0.165	0.996±0.003
	C500	63.420±0.546	5.993±0.897	7.625±2.885	6.145±0.145	0.994±0.002
	p-value	0.267	0.690	0.170	0.382	0.899
4	Cont	53.245±2.192	7.240±0.459	7.233±1.295	6.535±0.045[a]	0.996±0.003
	R250	58.845±1.555	5.613±0.855	10.195±1.292	6.105±0.105[b]	0.997±0.000
	R500	59.973±0.592	7.885±0.856	5.793±1.125	6.325±0.075[ab]	0.992±0.003
	C250	59.425±2.504	9.320±1.746	10.183±1.813	6.135±0.015[b]	0.993±0.003
	C500	55.015±2.924	6.575±1.140	6.433±0.270	6.490±0.080[a]	0.992±0.002
	p-value	0.147	0.221	0.068	0.023	0.584
6	Cont	54.595±2.046	6.833±0.850	10.363±1.304	6.120±0.020	0.993±0.003
	R250	49.628±1.425	5.640±0.994	9.570±0.745	6.365±0.065	0.992±0.004
	R500	56.035±1.766	5.055±0.702	12.355±0.523	6.430±0.170	0.990±0.004
	C250	57.378±3.486	6.770±0.705	7.310±1.098	6.270±0.030	0.991±0.003
	C500	58.703±0.858	4.548±0.475	10.305±2.427	6.240±0.080	0.986±0.000
	p-value	0.067	0.187	0.199	0.277	0.592
8	Cont	54.250±2.129	6.485±1.130	8.948±1.574	6.855±0.115[a]	0.994±0.002
	R250	55.735±2.428	4.920±1.166	8.408±0.608	6.130±0.120[b]	0.990±0.000
	R500	55.740±3.031	5.523±1.641	8.065±1.296	6.340±0.010[b]	0.996±0.003
	C250	56.213±3.961	5.368±0.933	8.193±1.242	6.380±0.090[b]	0.990±0.003
	C500	54.033±2.033	7.210±0.994	8.838±0.742	6.355±0.065[b]	0.991±0.004
	p-value	0.972	0.669	0.975	0.017	0.621

All values are given as mean ± SEM, (n=12). [a-b]: Means in the same column with different superscripts differ ($p<0.05$). [1]Cont: basal diet alone, R250: basal diet + 250 mg kg^{-1} of resveratrol, R500: basal diet + 500 mg kg^{-1} of resveratrol, C250: basal diet + 250 mg kg^{-1} of curcumin and C500: basal diet + 500 mg kg^{-1} of curcumin. L*: lightness, a*: redness, b*: yellowness, a_w:water activity.

Fatty Acid Profile

The values obtained in the analysis made in terms of fatty acid percentages of total fatty acids in drumstick meat are given in Table 6. Table 6 shows that capric acid, myristic acid, myristoleic acid, γ-linolenic acid, ΣUFA and MCFA percentages of total fatty acids in the R250 group increased ($p<0.01$), while lauric acid, myristic acid, and pentadecanoic acid levels in the C250 group and heneicosanoic acid and ΣSFA levels in the R250 group decreased ($p<0.01$). ΣMUFA, ΣPUFA, n-3, n-6, n-9, n-3/n-6, LCFA, VLCFA and other fatty acid percentages of total fatty acids (stearic acid, palmitic acid, oleic acid, linoleic acid, and arachidonic acid) were found to be statistically similar in all groups ($p>0.05$) (Table 6).

DISCUSSION

Curcumin and resveratrol obtained from turmeric stems and root (*Curcuma longa linn*) are used as feed additives in livestock as coloring, flavoring and antioxidant agents (Abd El-Hack *et al.,* 2021; Jin *et al.,* 2021a; Salah *et al.,* 2021). The important biological properties present in these herbal additives make them a potential substitute for antibiotics in animal feed. Microorganism load, pH, meat color and a_w parameters are usually used for determining meat quality (Purwanti *et al.,* 2019; Jin *et al.,* 2021a). The main factors affecting consumer decisions when purchasing meat and related products are the appearance, smell and structural characteristics of meat. Meat gets spoiled depending on the number of bacteria on the surface of the product, the ratio of the protein and carbohydrate decomposers of the existing bacteria, and the amount of water activity on the surface, when the temperature of the environment allows these bacteria to multiply (Gumus *et al.,* 2017b).

There is an important relationship between the microbial load of meat and its quality. Some

Table 5 – Effects of dietary resveratrol and curcumin supplementation and storage period on colour parameters (L*, a* and b*), a_w, and pH in chicken breast meat.

Storage times, Days	Groups[1]	L	a	b	pH	a_w
0	Cont	56.400±0.800[a]	7.278±0.324	6.185±0.322	6.040±0.130	0.993±0.001
	R250	54.305±1.413[ab]	7.783±1.561	8.135±0.583	5.925±0.085	0.992±0.001
	R500	50.585±1.810[bc]	9.383±0.172	8.603±1.547	5.895±0.005	0.993±0.001
	C250	48.248±1.127[c]	9.503±1.506	8.080±0.675	5.815±0.015	0.992±0.003
	C500	52.900±1.382[ab]	6.638±1.075	10.110±0.692	5.805±0.075	0.991±0.002
	p-value	0.006	0.294	0.077	0.325	0.893
2	Cont	55.220±1.732	5.848±1.118[bc]	8.145±1.020[c]	5.785±0.085	0.995±0.004
	R250	52.805±0.808	8.610±0.562[a]	9.775±1.232[bc]	5.855±0.055	0.994±0.001
	R500	51.758±0.431	7.820±1.136[ab]	8.700±0.544[c]	5.900±0.150	0.993±0.004
	C250	54.133±1.217	4.635±0.624[c]	13.283±1.072[a]	5.700±0.010	0.997±0.000
	C500	55.833±1.728	5.360±0.452[bc]	11.910±1.015[ab]	5.815±0.055	0.992±0.002
	p-value	0.212	0.019	0.012	0.575	0.690
4	Cont	54.850±1.273	7.560±0.760[a]	9.088±1.259	6.230±0.260	0.996±0.001[a]
	R250	53.413±1.219	7.665±0.751[a]	11.140±0.878	5.905±0.035	0.998±0.001[a]
	R500	51.343±0.346	8.135±1.092[a]	9.748±1.037	5.945±0.035	0.996±0.002[a]
	C250	52.038±1.258	4.393±0.144[b]	12.393±0.486	5.935±0.045	0.995±0.002[a]
	C500	52.315±0.761	4.838±0.489[b]	10.293±1.571	5.870±0.040	0.988±0.002[b]
	p-value	0.193	0.004	0.300	0.351	0.050
6	Cont	56.290±1.482	6.170±0.219	10.878±0.650[ab]	5.930±0.030[a]	0.994±0.003
	R250	57.103±2.555	5.653±0.445	7.898±0.887[b]	5.900±0.020[a]	0.994±0.001
	R500	52.663±0.541	5.668±0.598	10.208±1.056[b]	5.910±0.030[a]	0.993±0.001
	C250	55.348±0.614	5.270±0.392	10.818±0.587[ab]	5.720±0.000[b]	0.994±0.001
	C500	53.738±1.671	4.283±0.581	13.353±1.282[a]	5.850±0.040[a]	0.987±0.002
	p-value	0.294	0.109	0.015	0.015	0.100
8	Cont	52.418±2.431	6.743±1.227[a]	7.033±0.592[b]	5.935±0.095	0.996±0.001
	R250	52.043±2.872	6.758±0.938[a]	10.520±0.918[a]	5.830±0.050	0.991±0.003
	R500	54.565±1.207	5.000±0.561[ab]	10.963±0.579[a]	5.910±0.060	0.995±0.001
	C250	57.568±1.424	3.003±0.707[b]	10.990±0.832[a]	5.755±0.055	0.988±0.001
	C500	56.715±1.569	4.213±0.450[ab]	11.078±1.416[a]	5.815±0.015	0.996±0.001
	p-value	0.244	0.023	0.031	0.339	0.059

All values are given as mean ± SEM, (n=12). [a-c]: Means in the same column with different superscripts differ ($p<0.05$). [1]Cont: basal diet alone, R250: basal diet + 250 mg kg^{-1} of resveratrol, R500: basal diet + 500 mg kg^{-1} of resveratrol, C250: basal diet + 250 mg kg^{-1} of curcumin and C500: basal diet + 500 mg kg^{-1} of curcumin. L*: lightness, a*: redness, b*: yellowness, a_w:water activity.

microorganisms present in meat decrease the quality of meat, shorten its shelf life and pose a risk to human health (Ozbilgin *et al.,* 2021). It is known that the microbial load in meat increases in direct proportion to the duration of the storage period (Gumus *et al.,* 2018). Antimicrobial substances in meat are very important to preserve it. In this context, this study investigated the relationship between supplements in the diet and concentrations of TMAB, TPAB, *Enterobacteriaceae, Lactobacillus spp., Lactococcus spp., Micrococcus / Staphylococcus* and storage time. Insausti *et al.* (2001) reported that 6-8 log CFU g^{-1} is an acceptable microbial limit for the total number of bacteria in meat. The current study observed an increase in the number of bacteria with an extension of the storage period, while these values did not exceed the upper limit for all bacteria species (8 log CFU g^{-1} on the 8th day). In drumstick meat, the number of TMAB on the 8th day and the number of *Lactobacillus spp.* on the 6th day were statistically lower than the Control group in all groups with added resveratrol and curcumin. Moreover, the number of *Lactococcus spp.* on the 8th day was statistically lower than the Control group in the R500, C250 and C500 groups. Similarly, curcumin was reported to have antibacterial activity on gram-negative bacteria (E. coli) (de Oliveira *et al.,* 2018). Additionally, when fucoxanthine, a similarly effective natural additive, was added to the broiler diet, the numbers of *Staphylococcus spp.* and TMAB in breast and drumstick meat significantly decreased on the 5th and 6th days (Gumus *et al.,* 2018). In their study on quails, Ozbilgin *et al.* (2021) found that hesperidin added to the diet significantly decreased the number of TMAB on the 11th day. In addition to these findings, however, it was also reported that the addition of turmeric at a dose of 4 g kg^{-1} to the diet did not affect

Table 6 – Effect of resveratrol and curcumin addition to the diet on fatty acid profile of broiler drumstick meat, g 100 g^{-1}.

Parameters	Groups[1]					*p*-value
	Cont	R250	R500	C250	C500	
Caprylic Acid (C8:0)	0.00±0.00	0.02±0.01	0.01±0.00	0.00±0.00	0.02±0.01	0.078
Capric Acid (C10:0)	0.02±0.00^{bc}	0.05±0.01^{a}	0.01±0.00^{c}	0.02±0.00^{c}	0.03±0.01^{ab}	<0.001
Undecanoic Acid (C11:0)	0.00±0.00^{b}	0.01±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	<0.001
Lauric Acid (C12:0)	0.10±0.02^{ab}	0.14±0.02^{a}	0.06±0.00^{bc}	0.05±0.00^{c}	0.10±0.02^{ab}	0.001
Tridecanoic Acid (C13:0)	0.00±0.00	0.03±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.426
Myristic Acid (C14:0)	0.60±0.06^{b}	0.81±0.05^{a}	0.48±0.02^{bc}	0.41±0.02^{c}	0.60±0.07^{b}	<0.001
Myristoleic Acid (C14:1)	0.12±0.02^{bc}	0.23±0.03^{a}	0.09±0.01^{c}	0.08±0.01^{c}	0.18±0.04^{ab}	0.001
Pentadecanoic Acid (C15:0)	0.33±0.06^{ab}	0.42±0.07^{a}	0.25±0.03^{bc}	0.17±0.01^{c}	0.48±0.06^{a}	0.002
Palmitic Acid (C16:0)	21.88±0.64	20.74±0.45	22.25±0.48	22.16±0.25	21.00±0.20	0.065
Palmitoleic Acid (C16:1)	4.12±0.65	4.71±0.33	3.71±0.43	3.55±0.23	4.58±0.68	0.395
Heptadecanoic Acid (C17:0)	0.12±0.01	0.14±0.01	0.12±0.01	0.12±0.00	0.13±0.01	0.370
Heptadecenoic Acid (C17:1)	0.05±0.01	0.02±0.01	0.04±0.00	0.04±0.00	0.04±0.00	0.245
Stearic Acid (C18:0)	9.86±1.51	6.47±0.78	9.02±0.73	10.12±0.22	8.52±1.28	0.115
Elaidic Acid (C18:1n9t)	0.02±0.01	0.00±0.00	0.03±0.01	0.03±0.00	0.01±0.01	0.078
Oleic Acid (C18:1n9c)	30.78±1.67	30.73±1.31	28.57±0.74	28.47±0.70	30.49±2.11	0.598
Linolelaidic Acid (C18:2n6t)	0.00±0.00	0.04±0.04	0.00±0.00	0.00±0.00	0.00±0.00	0.426
Linoleic Acid (C18:2n6c)	24.64±1.27	28.96±1.57	26.20±0.79	26.68±0.33	26.31±1.18	0.134
Eicosanoic acid (C20:0)	0.09±0.02	0.14±0.03	0.10±0.02	0.09±0.01	0.16±0.04	0.127
γ-Linolenic Acid (C18:3 n6)	1.00±0.14^{b}	1.48±0.09^{a}	0.93±0.06^{b}	0.93±0.03^{b}	1.13±0.13^{b}	0.003
Eicoenioic Acid (C20:1)	0.08±0.02	0.07±0.03	0.04±0.01	0.06±0.00	0.06±0.02	0.642
α-Linolenic Acid (C18:3n3)	0.33±0.05	0.28±0.05	0.26±0.02	0.26±0.01	0.25±0.03	0.469
Heneicosanoic Acid (C21:0)	0.27±0.04^{a}	0.15±0.01^{b}	0.33±0.04^{a}	0.32±0.04^{a}	0.21±0.05^{ab}	0.012
Eicosadienoic Acid (C20:2)	0.10±0.02	0.03±0.01	0.10±0.01	0.10±0.01	0.10±0.05	0.227
Beheric Acid (C22:0) 4%	0.36±0.12	0.24±0.10	0.64±0.05	0.56±0.06	0.47±0.15	0.082
Eicosatrienoic Acid (C20:3 n6)	0.08±0.02	0.07±0.02	0.09±0.01	0.08±0.01	0.07±0.03	0.862
Arachidonic Acid (C20:4 n6)	3.84±0.71	2.53±0.62	5.38±0.73	4.79±0.45	4.12±1.24	0.152
Tricosanoic Acid (C23:0)	0.14±0.04	0.13±0.03	0.10±0.02	0.06±0.00	0.07±0.01	0.157
Docosadienoic Acid (C22:2)	0.03±0.01	0.07±0.03	0.02±0.01	0.01±0.00	0.03±0.01	0.077
Lignoceric Acid (C24:0)	0.02±0.00	0.04±0.02	0.01±0.01	0.00±0.00	0.02±0.01	0.272
Eicosapentaenoic Acid (C20:5 n3)	0.44±0.07	0.31±0.03	0.62±0.10	0.48±0.05	0.40±0.12	0.146
Docosahexaenoic Acid (C22:6 n3)	0.52±0.10	0.87±0.22	0.51±0.09	0.39±0.04	0.39±0.10	0.067
ΣSFA	33.78±1.25^{a}	29.49±0.98^{b}	33.36±0.61^{a}	34.05±0.16^{a}	31.82±1.43^{ab}	0.019
ΣUFA	66.20±1.25^{b}	70.50±0.99^{a}	66.62±0.60^{b}	65.93±0.16^{b}	68.18±1.42^{ab}	0.018
ΣMUFA	35.23±1.96	35.88±1.29	32.51±1.10	32.23±0.86	35.39±2.64	0.405
ΣPUFA	30.97±1.53	34.63±2.11	34.11±1.10	33.70±0.84	32.79±1.93	0.520
w-3	1.30±0.16	1.46±0.23	1.39±0.19	1.12±0.07	1.03±0.21	0.445
w-6	29.68±1.60	33.17±2.17	32.73±1.00	32.58±0.77	31.76±1.78	0.538
w-9	30.99±1.67	31.03±1.32	28.73±0.75	28.63±0.71	30.74±2.14	0.568
w-3/w-6	0.05±0.01	0.05±0.01	0.04±0.00	0.03±0.00	0.03±0.01	0.280
MCFA (6-12 C)	0.12±0.02^{bc}	0.21±0.03^{a}	0.08±0.00^{c}	0.06±0.00^{c}	0.16±0.03^{ab}	<0.001
LCFA (14-20 C)	98.47±0.13	98.17±0.35	98.27±0.21	98.58±0.12	98.62±0.29	0.617
VLCFA (>20 C)	1.40±0.14	1.60±0.32	1.64±0.21	1.35±0.12	1.22±0.32	0.708

All values are given as mean ± SEM, (n=8). a-c: Means in the same line with different superscripts differ (p<0.05). 1Cont: basal diet alone, R250: basal diet + 250 mg kg-1 of resveratrol, R500: basal diet + 500 mg kg-1 of resveratrol, C250: basal diet + 250 mg kg-1 of curcumin and C500: basal diet + 500 mg kg-1 of curcumin. MUFA: Monounsaturated fatty acid, PUFA: Polyunsaturated fatty acid, w-3: Omega-3 fatty acid, w-6: Omega-6 fatty acid, w-9: Omega-9 fatty acid, LCFA: long chain fatty acids; MCFA: medium chain fatty acids; SFA: saturated fatty acids; UFA: unsaturated fatty acids; VLCFA: very long chain fatty acids.

the total number of bacteria in thigh meat in a study conducted in broilers (Kyakma *et al.,* 2022).

Lipid oxidation of meat and meat products is a common occurrence in the post-mortem period. MDA is a biomarker that can be evaluated using TBARS values and is a secondary product of lipid oxidation (Jin *et al.,* 2021b). Studies reported that the addition of antioxidants such as curcumin (Jin *et al.,* 2021b) and resveratrol inhibited lipid and protein oxidation (Yang *et al.,* 2021). Similarly, Karami *et al.* (2011) found that 0.5% turmeric powder added to the diet of goats reduced the MDA content of the meat stored at +4 °C on the zeroth, 7th and 14th days. In a study conducted in ducks, it was reported that the addition

of curcumin at doses of 300, 400 and 500 mg kg^{-1} to the diet significantly reduced the TBARS value in breast meat (Jin *et al.,* 2021b). Similarly, curcumin added to broiler diets was reported to reduce the level of MDA in serum (Abd El-Hack *et al.,* 2021). This study determined that the TBARS value in drumstick meat decreased significantly in the R250, R500 and C500 groups on the zeroth day. In studies conducted in broilers, 400 mg kg^{-1} of resveratrol (Zhang *et al.,* 2018) and 40 mg kg^{-1} of curcumin added to the diet were observed to reduce the amount of MDA in breast meat (Galli *et al.,* 2020). Contrary to these findings, it was also reported that the addition of turmeric at a dose of 4 g kg^{-1} to the diet did not affect the number of MDA bacteria in thigh meat in a study conducted in broilers (Kyakma *et al.,* 2022).

Color is a very important feature in consumers decisions, and it is very important that the unique color of the meat does not deteriorate during shelf life. It is known that the myoglobin and hemoglobin pigments, which make up the natural color of meat, are highly sensitive to oxidation (Gumus *et al.,* 2017b). This study found that adding curcumin and resveratrol to the diet did not affect the color parameters in drumstick meat, while the a value in breast meat increased on the second day in the R500 group, but decreased on the 4th day in the C250 and C500 groups, and on the 8th day in the C250 group. Similar to our results, in a study conducted in broilers, 400 mg kg^{-1} of resveratrol added to the diet did not affect postmortem color parameters (L, a and b) at 45 minutes, and the a and b values at 24 hours, but significantly reduced the L value at 24 hours (Zhang *et al.,* 2018). In another study conducted in broilers, it was reported that curcumin added to the diet did not affect the L, a and b values in meat (Abd El-Hack *et al.,* 2021). In their study conducted in broilers, Galli *et al.* (2020) found that the addition of 40 mg kg^{-1} of curcumin to the diet did not affect the L and a values color values in breast meat, while it increased the b value. Another study conducted in ducks reported that the addition of curcumin at doses of 300, 400 and 500 mg kg^{-1} to the diet did not affect the L, a and b values for the color parameters of breast meat at 15 minutes after slaughter; the L value decreased in the groups with added curcumin at doses of 400 and 500 mg kg^{-1} at 24 hours; the a value increased in the group with added curcumin at dose of 500 mg kg^{-1}; and the b value was similar in all groups (Jin *et al.,* 2021b). Kyakma *et al.* (2022), on the other hand, reported that the 4 g kg^{-1} dose of turmeric added to broiler diets increased color values such as L, a and b in thigh meat, contrary to the information above. The findings obtained in this study and other literature information shows that the effect of resveratrol and curcumin additives on meat color was variable.

Water activity refers to the ability of muscle tissue to retain moisture. It directly affects the taste and tenderness of the meat (Zhou *et al.,* 2010). It was stated that the integrity of muscle cell membranes should not be disturbed in order to keep this criterion within normal limits, otherwise the fluid inside the cell leaves it and the quality of meat is negatively affected (Stanley & Parkin, 1991). It was stated that when the membrane integrity of muscle cells is lost, the hydroxyl group in the chemical structures of alcohol groups contained in phenolic compounds can be a good barrier due to the fact that it has less affinity for water (Amariei *et al.,* 2016). It was reported that curcumin supplementation ensures cell membrane integrity by increasing antioxidant capacity and improves meat quality of broilers by increasing water holding capacity (Wang *et al.,* 2015). This study showed that the contributions of resveratrol and curcumin to the diet did not have a significant impact on the a_w value in drumstick and breast meat. Similar to these findings, in a study conducted in broilers, it was stated that the addition of 40 mg kg^{-1} curcumin to the diet did not affect the water holding capacity of breast meat (Galli *et al.,* 2020). Similarly, it was reported that 300 mg kg^{-1} of curcumin added to the diet of broilers did not affect the water holding capacity of breast meat (Rajput *et al.,* 2014). Contrary to these results, however, there are studies that report that curcumin increased the moisture level in meat (Abd El-Hack *et al.,* 2021), or that the addition of turmeric at a dose of 4 g kg^{-1} to broiler diets reduces the water holding capacity of thigh meat (Kyakma *et al.,* 2022).

Meat quality is also assessed by pH and cutting force. The pH value is an important indicator for assessing meat quality, as it affects the cutting force of the muscle, its water holding capacity, and lactic acid content. It was reported that due to the rapid decrease in the pH of meat during rigor mortis (death stiffness), there is an abnormal temperature increase, denaturation occurs in proteins, and as a result, the quality of meat in broilers is negatively affected (Gumus *et al.,* 2018). In this study, the pH value of drumstick meat significantly decreased on the 8th day in all groups with added resveratrol and curcumin, the pH value of breast meat significantly decreased on the 6th day in the C250 group, and there was no difference between

the groups on the other days. Similar to these results, studies conducted in broilers showed that 400 mg kg^{-1} of resveratrol added to the diet did not affect the postmortem pH levels at 45 minutes and 24 hours in breast meat (Zhang *et al.,* 2018), and turmeric extract at doses of 100, 200 and 300 mg kg^{-1} did not affect the postmortem pH levels of breast and drumstick meat at 45 minutes and 24 hours (Wang *et al.,* 2015). In other studies conducted in broilers, it was also reported that the addition of 40 mg kg^{-1} of curcumin to the diet did not affect the pH of breast meat (Galli *et al.,* 2020). Similarly, 300 mg/kg of curcumin added to the diet of broilers did not affect postmortem pH levels at 3 hours (Rajput *et al.,* 2014). In a study conducted on ducks, it was observed that 300 and 400 mg kg^{-1} resveratrol additives had no effect on pH levels at 15 minutes and 24 hours, but resveratrol at a dose of 500 mg/kg significantly increased pH levels at both times (Jin *et al.,* 2021a). Kyakma *et al.* (2022), on the other hand, conducted a study on broilers that reported the addition of turmeric at a dose of 4 g kg^{-1} to the diet to reduce pH levels in thigh meat.

Over the past quarter century, interest in meat products that have beneficial effects on human health has increased. Therefore, broiler meat, with its superior content of unsaturated fatty acids, is also in demand (Salah *et al.,* 2021). Saturated fatty acids, especially stearic, lignoceric, palmitic and myristic acids, are often considered harmful to health due to their hypercholesterolemic properties (Ozbilgin *et al.,* 2021). This study determined that myristoleic acid, γ-linolenic acid, ΣUFA in general and MCFA levels increased in the R250 group, while saturated fatty acids such as lauric acid and myristic acid increased in the C250 group and ΣSFA levels decreased in the R250 group. These results show that the additives tend to improve the quality of meat in terms of fatty acid content. Similar to these results, a study on broilers determined that adding curcumin at 100 mg kg^{-1} to the diet significantly decreased the SFA levels, and significantly improved ΣMUFA (myristoleic, palmitoleic and oleic) and ΣPUFA (linoleic, oleic, linoleic and eicosapentaenoic) levels in breast (myristic and palmitic) and drumstick (palmitic and stearic) muscles (Salah *et al.,* 2021). Hang *et al.* (2018) suggested that broiler diets enriched with curcuminoids at 20 mg kg^{-1} increased the levels of linoleic acid and total n-6 ΣPUFA in the pectoral muscles. Similarly, in the study conducted by Daneshyar *et al.* (2011), it was reported that the addition of turmeric powder (0.75%) to broiler diets reduced saturated fatty acids in the drumstick muscles. Contrary to these findings, it has also been stated that the supplementation of curcuminoids to the diet did not change the levels of saturated fatty acids in the breast and thigh muscles of Korat chickens (Hang *et al.,* 2018). Looking at the findings in the current study and other similar studies, it can be said that the inclusion of curcumin in the broiler diet positively restores PUFA and MUFA levels in the meat.

CONCLUSION

It is concluded that resveratrol and curcumin added to broiler diets at 250 and 500 mg kg^{-1} doses positively affected the meat in terms of microbial and fatty acid profile, increasing the shelf life quality of chicken meat and increasing its ΣUFA content. Also, resveratrol added to the diet at doses of 250 mg kg^{-1} positively affected ΣUFA. Thus, it can be concluded that the addition of resveratrol and curcumin to the diet can both affect the shelf-life quality of broiler meat and have a health-promoting effect by increasing ΣUFA contens, which, in turn, can increase consumer interest in broiler meat.

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CONFLICT OF INTEREST

The authors declare no competing interests.

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ERRATUM

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