

*Original Research***Influence of Dietary Inclusion of Oil and Quercetin Supplementation on Carcass Characters and Meat Quality Attributes of Broiler Chickens****Abhishek B. Parmar^{*}, Vipul R. Patel, Sajani V. Usadadia¹, Lala M. Chaudhary², Dhruvil R. Prajapati and Arvind S. Londhe**

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Abstract

Dietary inclusion of vegetable oil, with or without quercetin was supplied to broilers for 35 days, in order to determine its influence on carcass characters and meat quality attributes. Vencobb strain of broiler chickens (n=192) were assigned in to four dietary treatment groups on 7th day of age. All the birds were supplied with corn soya-based diet as a basal feed. Group T1 served as control without any supplementation. T2 and T3 supplied with quercetin at 1 g kg⁻¹ and 33 g kg⁻¹ vegetable oil to raise 10% ME of the feed, respectively, whereas, both in combination at same dose rate were supplied in T4. At the end (42 days age) 8 birds from each respective group (2 birds per replicates) were sacrificed for carcass characters and meat quality assessment. Results revealed that dressing percentage relative to body weight was significantly differ among the dietary treatment groups, whereas % relative weight of all major organs was found comparable. Moisture % was significantly low whereas, pH and % cooking loss were comparatively high (P<0.05) in T3. CP, EE and TA content and physico-chemical composition of meat were not affected by treatments. The noteworthy (P<0.05) influence had been observed on sensory attributes of broiler meat with dietary treatments and overall palatability was improved in T1 and T2. Overall findings showed that 10% raised in ME by inclusion of oil was adversely influences the meat quality and quercetin supplementation exhibited positive impact on carcass characters and meat quality attributes of chickens.

Key words: Broilers, Carcass, Meat, Quercetin, Sensory, Vegetable Oil

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Introduction

Modern poultry production has common practice to use fat and oil for raising the energy density in poultry diets (Khatun *et al.*, 2018). Besides supplying energy, inclusion of oils results in better absorption of fat-soluble vitamins, diminishes the pulverulence, improves the palatability of feeds, increase absorption and hydrolysis of essential fatty acids furnishing lipoproteins thereby increases the efficiency of the consumed energy (Nobakht *et al.*, 2011). The source and type of dietary fat and its fatty acids composition influences on fatty acid profile and carcass quality of poultry meat (Khatun *et al.*, 2018). Assimilating the demand of consumer unsaturated fatty acids (UFA) (like ω -3 and ω -6) in poultry ration improves the meat quality (Raza *et al.*, 2016). These meats are more liable to oxidative spoilage, with retardation of meat product quality and had an unfavourable effect on consumer health (Adeyemi *et al.*, 2015). The use of dietary saturated fatty acid (SFA) are stable against the oxidative damages by lipid peroxidation and has an effective strategy to enhance the product quality with reducing spoilage and increased abdominal fat deposition (Ayad *et al.*, 2015).

However, poultry meat enriched with many nutritional properties such as low intramuscular fat and relatively high concentration of polyunsaturated fatty acids (PUFA). Oxidation by free radical is one of the primary mechanisms of quality deterioration in foods especially in meat products (Kanner, 1994). To prevent deterioration and maintain the meat quality, interest has been focussed to the use of natural antioxidants such astocopherols, carotenoids, flavonoids, phenolic acids (Yanishlieva-Maslarova *et al.*, 2001). The antioxidant from natural sources can extend shelf life, reducing lipid peroxidation and increased the acceptability and quality of meat (Fellenberg and Speisky, 2006). Quercetin (2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-4H-chromen-4-one), a flavonoid compound, belongs to the class of flavonols having a strong antioxidant potential, found ubiquitous in plant and plant food sources (Sikder *et al.*, 2014). The present experiment was designed to evaluate the influence of dietary SFA rich vegetable oil and potential of quercetin as an antioxidant supplementation on carcass characters, meat quality and sensory attributes of broiler chickens.

Materials and Methods

Ethical Approval

The present research was conducted after approval of the Institutional Animal Ethics Committee (IAEC/065-VCN-ANN-2018), College of Veterinary Science and Animal Husbandry, Navsari Agricultural University, Navsari, Gujarat, India.

Dietary Supplementation

In present experiment, quercetin was commercially procured from Sigma Aldrich Life Science (P) Ltd. The energy level was increased 10% than the recommendation (BIS, 2007) which was 3410 and 3520 Kcal

metabolizable energy (ME) per kg feed, respectively in starter and finisher phase. The ME level (Kcal/kg feed) has been raised by introducing 33 g hydrogenated vegetable oil from 7th day onward.

Experimental Diets

A total of 192-day-old broiler chicks of Vencobb-400 strain were randomly assigned into four dietary treatment groups with four replicates and 12 birds in each based on body weight. The birds were housed under deep litter system with uniform managemental practices. Nutrient requirement of birds were fulfilled as per ICAR, (2013). Birds were provided with *ad libitum* water and fed weighed quantity of basal diets with ensuring left over. Dietary treatments and pattern of supplementation are depicted as per Table 1. The ration was formulated by using listed ingredients (Table 2) following BIS, (2007) for the starter and finisher phases.

Table 1: Outline of experimental designs and treatment regimen of broiler chickens

Treatment Groups	Diet	Vegetable oil	Quercetin
I. T1 (CON)	Basal Diet	--	--
II. T2 (Q)	Basal Diet	--	1 g kg ⁻¹
III. T3(HFD)	Basal Diet	33 g	--
IV. T4 (HFD+Q)	Basal Diet	33 g	1 g kg ⁻¹

(T: Treatment; CON: Control; Q: Quercetin; HFD- High fat diet)

Carcass Characteristics

At the end of experiment (35th day), eight birds from each group (2 birds/replicate) were sacrificed by cervical dislocation as per standard protocols to study carcass characteristics. The influences of dietary treatments on dressed weight and relative weight of internal organs were estimated by using following formula.

$$\% \text{ Dressing on live body weight} = \frac{\text{Dressed carcass weight with giblet (g)}}{\text{Live body weight of bird (kg)}} \times 100$$

$$\% \text{ Relative weight of organs} = \frac{\text{Organ weight (g)}}{\text{Live body weight of bird (kg)}} \times 100$$

Meat Quality Attributes

The meat quality was evaluated through a series of parameters *viz.* chemical composition, physico-chemical properties and sensory evaluation. The breast pieces (pectoral muscle) of meat were stored at -40°C in air tight pre-labeled polythene bags to evaluate the quality attributes.

Chemical Composition

The chemical composition *viz.* moisture, dry matter, crude protein, crude fat and total ash content of meat samples were analyzed as per the standard methods (AOAC, 2002).

Table 2: Ingredients and nutrient composition of experimental diets

Ingredients (g)	Starter (8-22 days) (T1 and T2)	Finisher (23-42 days) (T1 and T2)	Starter (8-22 days) (T3 and T4)	Finisher (23-42 days) (T3 and T4)
Maize	500	500	500	500
Maize Gluten	75	52	75	52
Deoiled Rice Bran	90	100	90	100
Rice Polish	50	95	50	95
De-Oiled Soya Cake	87	50	87	50
Ground Nut Cake	90	75	90	75
Vegetable oil	-	-	33	33
Protolive	79	99	79	99
Mineral Mixture ¹	1	1	1	1
DCP	25	25	25	25
Salt	1.5	1.5	1.5	1.5
Biometh	0.3	0.3	0.3	0.3
Lysine	0.3	0.3	0.3	0.3
Toxin Binder	0.5	0.5	0.5	0.5
Choline	0.3	0.3	0.3	0.3
Meriplex	0.1	0.1	0.1	0.1
Nutrient Composition%^{**}				
Dry matter	91.21	91.79	90.42	91.14
Crude protein	23.16	20.25	22.98	20.65
Ether extract	4.49	4.43	5.95	5.88
Crude fibre	5.02	5.11	5.16	5.22
NFE	60.78	63.32	59.23	61.46
Total ash	6.55	6.89	6.68	6.79
Calcium	1.23	1.2	1.3	1.26
Phosphorus	0.58	0.62	0.58	0.62
ME*, Kcal/kg	3080.56	3185.25	3385.45	3490.31
L- Lysine**	1.22	1.31	1.45	1.36
DL-Methionine**	0.55	0.49	0.51	0.57

¹Tracemin CB: Each 1 kg contain–Manganese - 90 g, Zinc - 80 g, Iron - 90 g, Copper -15 g, Iodine - 2 g and Selenium - 300 mg; **calculated values

Physico-Chemical Properties

Meat samples were analyzed for their physico-chemical properties like pH, water holding capacity (Wardlaw *et al.*, 1973), tyrosine value (Strange *et al.*, 1977), thiobarbituric acid reactive substances as malondialdehyde production (Witte *et al.*, 1970) and cooking loss (Pearson and Dutson, 1994). The pH was measured using pH meter (pH Tester 30, Thermo Fisher scientific, USA). TBARS (thiobarbituric acid reactive substances) was estimated by using solvent trichloroacetic acid for extraction.

Sensory Evaluation

Meat sample (g muscle) from each was further reduced by 1.5-2.0 cm size and cooked by electric microwave oven at the temperature range of 180-200°C for 30 minutes. The cooked meat samples were

served to a panel consisting seven semi trained panelist. The products were evaluated for their appearance, color, flavor, texture, juiciness and overall palatability using a 9-point hedonic scale to anticipate the acceptability of meat products on quality bases.

Statistical Analysis

The data generated were analyzed for their statistical significance using package for the social sciences (SPSS, version 20.0 Chicago, USA). Analyzed data were used to draw interpretations and conclusions. The means were compared using Duncan's multiple range test (Duncan, 1955).

Results

Carcass Characteristics

The findings of influence of dietary oil or quercetin supplementation on carcass characters of broiler chickens are being presented in Table 3. Majority of organs relative weight were not affected on supplementation of oil, quercetin or both, however dressing per cent were significantly affected with dietary treatments. Quercetin supplementation (T2) revealed higher dressing percentage, followed by T4, T3 and low in unsupplemented group (T1). The % relative weight of large intestine was high in T1 ($P < 0.05$), which were similar to T2 and T4, while low in T3. The weight of the whole sell cuts like neck, back, thigh, breast, drumstick and wing were not influenced ($P > 0.05$) by supplementing either oil or quercetin or inclusion of both together in birds.

Meat Quality Attributes

Chemical Composition

Results for chemical composition of breast meat of broilers supplemented with oil or quercetin are shown in Table 3. The moisture and dry matter percent were significantly influenced by the dietary treatments. The moisture level was significant improved in T2 and T1, while poor in T3. Intermediate level of moisture was observed in T4 groups. The other proximate components of meat were not affected with either oil or quercetin in broilers. However, apparently higher EE was found in T3 groups.

Physico- Chemical Composition

The findings pertaining to influencing effect of oil or quercetin or both on physicochemical compositions was mentioned in Table 3. The pH of meat sample significantly affected with dietary treatments. However, other physico-chemical characters namely water holding capacity, tyrosine and thiobarbituric acid reactive substances values were not influenced ($P > 0.05$) by supplementation. Cooking loss was noticed greater ($P < 0.05$) in T3 and found low in T2 and T4 groups.

Sensory Evaluation

The effects of oil with or without quercetin on sensory evaluation of meat are displayed in Table 3. The dietary treatments have significant influenced on all the sensory characters except color of cooked meat. All sensory attributes in T1 and T2 groups were scored highest ($P < 0.05$) than the T3 and T4.

Table 3: Influence of dietary oil with or without quercetin on carcass characteristics (% relative weight) of broiler chickens

% Relative Weight	Treatment Groups				SEM
	T1	T2	T3	T4	
Dressing	57.40 ^c ±0.82	65.34 ^a ±0.74	60.62 ^b ±0.64	62.31 ^{ab} ±0.78	0.61
Head	2.74 ±0.08	2.71 ±0.06	2.76 ±0.08	2.67 ±0.08	0.03
Legs	4.81 ±0.18	4.53 ±0.11	4.59 ±0.09	4.96 ±0.13	0.07
Gizzard	1.49 ±0.11	1.55 ±0.12	1.20 ±0.10	1.45 ±0.11	0.05
Large intestine	2.01 ^a ±0.11	1.92 ^{ab} ±0.09	1.34 ^b ±0.33	1.78 ^{ab} ±0.10	0.43
Small intestine	1.35 ±0.34	1.43 ±0.33	1.39 ±0.37	1.39 ±0.35	0.16
Heart	0.60 ±0.03	0.63 ±0.02	0.61 ±0.01	0.61 ±0.03	0.01
Pancreas	0.17 ±0.01	0.18 ±0.01	0.15 ±0.00	0.17 ±0.08	0
Neck	4.48 ±0.22	4.61 ±0.16	4.28 ±0.14	4.67 ±0.14	0.09
Back	6.62 ±0.33	6.76 ±0.17	6.38 ±0.24	6.91 ±0.27	0.12
Thigh	10.38 ±0.55	10.68 ±0.43	10.12 ±0.33	10.81 ±0.45	0.22
Breast	22.17 ±0.1.19	22.93 ±0.71	21.47 ±0.77	23.22 ±0.99	0.46
Drumstick	10.15 ±0.47	10.63 ±0.314	9.99 ±0.35	10.92 ±0.51	0.21
Wing	12.02 ±0.55	11.69 ±0.41	11.03 ±0.36	12.05 ±0.52	0.23

^{ab}Means with different superscript in a row differ significantly ($P < 0.05$); T1= Control; T2= Quercetin (1g kg⁻¹ feed); T3=33 g kg⁻¹ Vegetable oil; T4=33 g kg⁻¹ Vegetable oil + Quercetin (1g kg⁻¹ feed)

Discussion

Carcass characters were not significantly influenced by the dietary treatment except relative dressing percent and large intestine. Dressing % was increased ($P < 0.05$) in quercetin supplemented group (T2 and T4), which might be due to apparent increase in relative weight of internal organs. Similar response was observed by Soomro *et al.* (2016) who found significant differences in values of carcass weight and dressing percentage of broiler fed varying level of dietary fat from different sources. Findings of relative weight of breast and leg were consistence with Zhang *et al.* (2013), who supplemented varying level of olive oil to broilers. In same trend, Ayed *et al.* (2015) reported comparable (%) relative weight of thigh, heart and gizzard on supplementation of either soybean or palm oil in broilers. Similarly, Somade *et al.* (2016) found comparable finding on relative weight of heart in broiler on supplementation of quercetin with sodium azide (SAZ) induced extra hepatic oxidative stress in rat. However, Nobakht *et al.* (2011) reported significant effect of different level and oil sources on relative weight of gizzard.

Many researchers revealed that polyphenolic compound from varying sources like *Moriga olifera*, grape seed, *Allium sativum*, *Allium cepa*, *Zingiber officinal* having potential to improved dressing percent of broiler carcass (Arslan *et al.*, 2017 and Abu Hafsa and Ibrahim, 2018). Contradictory of present finding,

Goliomytis *et al.* (2014) reported that higher relative weight of heart while rest of the internal organ like liver, spleen and fat pad were found similar in chickens supplied with quercetin. They suggested that increased % relative heart weight might be due to the exhibition analogues effect of quercetin on cardiovascular function.

Water holding capacity, pH, color and tenderness are crucial for the culinary value and technological properties of chicken meat (Nissen and Young, 2006). The pH value plays a vital role for maintaining the meat keeping quality and that directly relay on muscle energy metabolism balance (Li *et al.*, 2017). In present study, the pH of breast muscle was significantly differ among dietary treatments, however, the values of pH were within the range of 5.5 to 6.5 suggested by Mir *et al.* (2017). Increasing in meat pH on supplementation of oil was also noticed by Zaki *et al.* (2018). In agreement with present study, quercetin supplementation did not showed any influence on meat pH, TBARS level and cooking loss in broilers (Goliomytis *et al.*, 2015). Inconsistence to present findings, Tasdelen and Ceylan, (2017) and Kalakuntla *et al.* (2017) reported significantly increase TBARS level in breast muscle on vegetable oil supplementation in broilers, which might be due to the increased lipid peroxidation for sack of higher dietary oil supplementation in the muscles. The cooking loss was found highest in the T3 group that might associate with the changes in meat pH.

Contrary, to present results, supplementation of polyphenols (hesperidine shows significance improvement in TBARS value of stored broiler meat (Simitzis *et al.*, 2011). Flavanols supplementation to broilers reduces the malondialdehyde level while did not exert any significant changes in meat pH and cooking loss (Goliomytis *et al.*, 2015) which was inconsistence to present findings. This positive effect on malondialdehyde level might be attributed to strong antioxidant potential and accumulation of its metabolites in body tissues (Goliomytis *et al.*, 2014). Changes in the water content of meat ensuring alterations in the key quality attribute such as color and texture (Ali *et al.*, 2015). Similar to present result of meat chemical composition, Dorra *et al.* (2014) found non-significant effects on proximate composition, however, contrary results with non-significant alteration were noted for moisture (%) with inclusion of frying oil the diet of broilers. Similar effect on dry matter content (Ayad *et al.*, 2015) and breast meat protein content (Kalakuntla *et al.*, 2017) was observed with oil supplementation in broilers. Increased dietary fat resulting in to elevation in amount of energy consumed by the chickens (Ayad *et al.*, 2015). The apparently higher fat content in T3 group might be due to the possible widening of calorie: protein ratio and high SFA content of vegetable oil this study.

Significant changes in sensory attributes under present study were might be the reflection of alteration in moisture content of meat. It indicated that supplementation of oil was influencing on physio-chemical and sensory parameters (Kalakuntla *et al.*, 2017). The inclusion of oil or quercetin had found significant influence on all the sensory characters excluding color of cooked meat. Improvement in sensory score in

T2 might be the flavor enhancing effects of quercetin and presence of its metabolites in the tissues (Li *et al.*, 2016).

Table 4: Influence of dietary oil with or without quercetin on meat quality attributes of broiler chickens

Attributes	Treatment Groups				SEM
	T1	T2	T3	T4	
Chemical composition					
MO (%)	74.10 ^a ±0.48	74.23 ^a ±0.73	71.66 ^b ±0.94	72.79 ^{ab} ±0.85	0.41
DM (%)	25.89 ^b ±0.48	25.76 ^b ±0.73	28.33 ^a ±0.94	27.20 ^{ab} ±0.85	0.41
CP (%)	22.42±0.64	23.16±0.66	23.05±0.39	23.74±0.59	0.29
EE (%)	4.47±0.12	4.56±0.08	4.70±0.13	4.60±0.11	0.05
TA (%)	2.99±0.28	2.98±0.18	3.57±0.18	3.43±0.23	0.11
Physico-chemical composition					
pH	5.58 ^b ±0.12	5.80 ^{ab} ±0.14	6.04 ^a ±0.10	5.80 ^{ab} ±0.01	0.06
WHC (%)	94.41±0.12	94.20±0.14	94.12±0.10	94.24±0.08	0.05
Tyrosine value	22.42±0.64	23.16±0.66	23.05±0.39	23.74±0.59	0.29
TBARS (mg 100-1)	0.61±0.09	0.55±0.11	0.67±0.17	0.60±0.07	0.05
Cooking loss (%)	22.99 ^{ab} ±0.28	22.90 ^b ±0.18	23.57 ^a ±0.18	22.67 ^b ±0.20	0.11
Sensory attributes					
Appearance	7.75 ^{ab} ±0.25	8.12 ^a ±0.29	7.00 ^{ab} ±0.37	7.37 ^b ±0.74	0.16
Color	7.25±0.25	7.50±0.26	7.50±0.32	7.87±0.29	0.14
Flavor	7.75 ^a ±0.25	8.12 ^a ±0.29	6.75 ^b ±0.31	6.50 ^b ±0.37	0.19
Juiciness	6.37 ^b ±0.49	8.25 ^a ±0.31	5.62 ^b ±0.32	5.87 ^b ±0.29	0.28
Texture	6.12 ^b ±0.29	7.50 ^a ±0.32	6.12 ^b ±0.39	6.25 ^b ±0.52	0.24
Overall palatability	7.25 ^b ±0.25	8.25 ^a ±0.25	6.62 ^b ±0.74	6.62 ^b ±0.46	0.21

^{ab}Means with different superscript in a row differ significantly ($P < 0.05$); T1= Control; T2= Quercetin (1g kg⁻¹ feed); T3=10% Vegetable oil; T4=10% Vegetable oil + Quercetin (1g kg⁻¹ feed), moisture; MO, dry matter; DM, crude protein; CP, ether extract; EE and total ash; TA., water holding capacity; WHC, thiobarbituric acid reactive substances; TBARS.

Consistence effect was noted by Takahashi *et al.* (2012) who reported significant effect on sensory characters like flavor, sweetness and taste in broilers supplemented with arachidonic acid enriched oil (AAO). Similar effect ($P > 0.05$) on sensory attributes of meat with quercetin supplementation to broilers was observed by Jang *et al.* (2011). Contrary to present findings significant influence on juiciness, flavor, oxidized flavor and acceptability of breast meat samples were observed by Kirkpinar *et al.* (2014) with dietary oregano and garlic oils supplementation.

Conclusion

Dietary inclusion of oil with or without quercetin does not exerted significant influence on carcass characters. The oil inclusion had significantly reduced moisture level in meat, although overall either quercetin or oil supplementation did not affect the chemical composition of meat of broilers. Supplementation of oil without quercetin has showed increased the meat pH and cooking loss. The sensory

attributes have found adverse influence with higher dietary oil supplementation whereas quercetin incorporation improved it.

References

1. Abu Hafsa, S. H. and Ibrahim, S. A. (2018). Effect of dietary polyphenol-rich grape seed on growth performance, antioxidant capacity and ileal microflora in broiler chicks. *Journal of Animal Physiology and Animal Nutrition*, 102: 268-275.
2. Adeyemi, K. D., Sabow, A. B., Shittu, R. M., Karim, R. and Sazili, A. Q. (2015). Influence of dietary canola oil and palm oil blend and refrigerated storage on fatty acids, myofibrillar proteins, chemical composition, antioxidant profile and quality attributes of semimembranosus muscle in goats. *Journal of Animal Science and Biotechnology*, 6:51.
3. Ali, S., Zhang, W., Rajput, N., Khan, M. A., Li, C. B. and Zhou, G. H. (2015). Effect of multiple freeze-thaw cycles on the quality of chicken breast meat. *Food Chemistry*, 173: 808-814.
4. AOAC. (2002). Official method of analysis. Revision 1 Arlington. VA: Association of Official Analytical Chemists, Inc.
5. Arslan M, Haq, A. U., Ashraf, M., Iqbal, J. and Mund, M. D. (2017). Effect of turmeric (*Curcuma longa*) supplementation on growth performance, immune response, carcass characteristics and cholesterol profile in broilers. *Veterinaria*, 66 (1).
6. Ayed, H. B., Attia, H. and Ennouri, M. (2015). Effect of oil supplemented diet on growth performance and meat quality of broiler chickens. *Advanced Techniques in Biology & Medicine*, 4:1.
7. BIS. (2007). Indian Standard: Poultry feed specifications, 5th revision, Bureau of Indian Standards, New Delhi
8. Dorra, T. M., Hamady, G. A. A. and Abdel-Moneim, M. A. (2014). The use of recovered frying oil in broiler chicken diets: effect on performance, meat quality and blood parameters. *Research Journal of Animal, Veterinary and Fishery Sciences*, 2(3), 11-15.
9. Duncan, D. B. (1955). Multiple ranges and multiple F' test. *Biometrics*, 11(1): 1-42.
10. Fellenberg, M. A. and Speisky, H. (2006). Antioxidants: their effects on broiler oxidative stress and its meat oxidative stability. *World's Poultry Science Journal*, 62: 53-70.
11. Goliomytis, M., Kartsonas, N., Charismiadou, M. A., Symeon, G. K., Simitzis, P. E. and Deligeorgis S. G. (2015). The influence of naringin or hesperidin dietary supplementation on broiler meat quality and oxidative stability. *Plos One*, 10 (10): 879-884
12. Goliomytis, M., Tsourekis, D., Simitzis, P. E., Charismiadou, M. A., Hager-Theodorides, A. L. and Deligeorgis, S. G. (2014). The effects of quercetin dietary supplementation on broiler growth performance, meat quality, and oxidative stability. *Poultry Science*, 93: 1957-1962.
13. ICAR (2013). Nutrient requirements of poultry. Third edition, Indian Council of Agricultural research, New Delhi.
14. Jang, A., Srinivasan, P., Lee, N. Y., Song, H. P., Lee, J. W. and Lee, M. (2008). Antioxidative potential of raw breast meat from broiler chicks fed a dietary medicinal herb extract mix. *Poultry Science*, 87(11): 2382-2389.
15. Kalakuntla, S., Nagireddy, N. K., Panda, A. K., Jatoth, N., Thirunahari, R. and Vangoor, R. R. (2017). Effect of dietary incorporation of n-3 PUFA polyunsaturated fatty acids rich oil sources on fatty acid profile, keeping quality and sensory attributes of broiler chicken meat. *Animal Nutrition*, 3(4): 386-391. DOI: 10.1016/j.aninu.2017.08.001
16. Kanner, J. (1994). Oxidative processes in meat and meat products: Quality implications. *Meat Science*, 36: 169-189.
17. Khatun, J., Loh, T. C., Akit, H., Foo, H. L. and Mohamad, R. (2018). Influence of different sources of oil on performance, meat quality, gut morphology, ileal digestibility and serum lipid profile in broilers. *Journal of Applied Animal Research*, 2018; 46(1): 479-485.

18. Kirkpinar, F., Unlu, H. B., Serdaroglu, M. and Turp, G. Y. (2014). Effects of dietary oregano and garlic essential oils on carcass characteristics, meat composition, colour, pH and sensory quality of broiler meat. *British Poultry Science*, 55(2): 157-166.
19. Li, Y., Yao, J., Han, C., Yang, J., Chaudhry, M. T., Wang, S., Liu, H. and Yin, Y. (2016). Quercetin, Inflammation and Immunity. *Nutrients*, 2 (3): 167.
20. Li, Y., Yu, C., Li, J., Zhang, L., Gao, F. and Zhou, G. (2017). Effects of dietary energy sources on early post-mortem muscle metabolism of finishing pigs. *Asian-Australasian Journal of Animal Sciences*, 30(12): 1764-1772.
21. Luna, A., Labaque, M. C., Zygadlo, J. A. and Marin, R. H. (2010). Effects of thymol and carvacrol feed supplementation on lipid oxidation in broiler meat. *Poultry Science*, 89: 366-370.
22. Mir, N. A., Rafiq, A., Kumar, F., Singh, V. and Shukla, V. (2017). Determinants of broiler chicken meat quality and factors affecting them: a review. *Journal of Food Science and Technology*, 54(10): 2997-3009.
23. Nissen, P. M. and Young, J. F. (2006). Creatinine monohydrate and glucose supplementation to slow- and fast-growing chickens changes the post mortem pH in pectoralis major. *Poultry Science*, 85(6): 1038-1044. <http://dx.doi.org/10.1093/ps/85.6.1038>
24. Nobakht, A., Norany, J. and Safamehr, A. R. (2011). The effects of different amounts of Menthapulegium L. (pennyroyal) on performance, carcass traits, hematological and blood biochemical parameters of broilers. *Journal of Medicinal Plant Research*, 5: 3763-3768.
25. Pearson, A. M. and Dutson, T. R. (1994). Quality attributes and their measurement in meat, poultry and fish products. *Advances in Meat Research*. Blackie Academic and Professional, UK.9-12.
26. Raza, T., Chand, N., Khan, R. U., Shahid, M. S. and Abudabos, A. M. (2016). Improving the fatty acid profile in egg yolk through the use of hempseed (*Cannabis sativa*), ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) in the diet of Hy-Line White Leghorns. *Archive of Animal Breeding*, 68:183-190.
27. Sikder, K., Das, N., Kesh, B. S. and Dey, S. (2014). Quercetin and β -sitosterol prevent high fat diet induced dyslipidemia and hepatotoxicity in swine albino mice. *Indian Journal of experimental Biology*, 52: 60-66.
28. Simitzis, P. E., Symeon, G. K., Charismiadou, M. A., Ayoutanti, A. G. and Deligeorgis, S. G. (2011). The effects of dietary hesperidin supplementation on broiler performance and chicken meat characteristics. *Canadian Journal of Animal Science*, 91: 275-282.
29. Simopoulos, A. P. (2000). Human requirement for n-3 polyunsaturated fatty acids. *Poultry Science*, 79: 961-970.
30. Somade, T. O., Olorode, S. K., Olaniyan, T. O. and Faokunla, O. (2016). Quercetin, a polyphenolic phytochemical prevents sodium azide-induced extra-hepatic oxidative stress in rats. *Cogent Biology*, 2: 795-798.
31. Soomro, R. N., Yao, J., Hu, R., Memon, A., Abbasi, I. H. R., Arain, M. A., Siyal, F. A., Soomro, S. A., Abro, M. R. and Soomro, A. A. (2016). Effects of dietary fat supplementation on hematology and growth trait in broiler chickens. *Advances in Animal and Veterinary Sciences*, 4(10): 518-526.
32. Strange, E. D., Benedict, R. C., Smith, J. L. and Swift, G. E. (1977). Evaluation of rapid tests for monitoring alteration in meat quality during storage. *Intact Meat. Journal of Food Protection*, 40: 843-847.
33. Takahashi, H., Rikimaru, K., Kiyohara, R. and Yamaguchi, S. (2012). Effect of arachidonic acid-enriched oil diet supplementation on the taste of broiler meat. *Asian-Australasian Journal of Animal Science*, 25(6): 845 - 851.
34. Tasdelen, E. O. and Ceylan, N. (2017). Effects of dietary inclusion of oil sources with or without vitamin E on body composition and meat oxidation level in broilers. *Revista Brasileira de Ciencia Avicola (Brazilian Journal of Poultry Science)*, 19: 103-116.
35. Wardlaw, F. B., McCaskill, L. H. and Acton, J. C. (1977). Effect of post-mortem muscle changes on poultry meat loaf properties. *Journal of Food Science*, 38: 421-423.

36. Witte, V. C., Krause, G. F. and Bailey, M. E. (2013). A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *Journal of Food Sciences*, 35: 582-585.
37. Yanishlieva-Maslarova, N. N. and Heinonen, M. (2001). Sources of natural antioxidants. In Pokorny J, Yanishlieva N, and Gordon M. (Eds.), *Antioxidants in food* Boca Raton: CRC Press. Pp.210-249.
38. Zaki, E. F., El Faham, A. I. and Nematallah, G. M. (2018). Fatty acids profile and quality characteristics of broiler chicken meat fed different dietary oil sources with some additives. *International Journal of Health, Animal science and Food safety*, 5: 40-50.
39. Zhang, Z. F., Zhou, T. X. and Kim, I. H. (2013). Effects of dietary olive oil on growth performance, carcass parameters, serum characteristics, and fatty acid composition of breast and drumstick meat in broilers. *Asian-Australasian Journal of Animal Sciences*, 26(3): 416-422.