Tikrit Journal for Agricultural Sciences (2024) 24 (3): 133-142
DOI: https://doi.org/10.25130/tjas.24.3.12

IRAQI Academic Scientific Journals
العراقية المجلات الأكاديمية العلمية
ISSN:1813-1646 (Print); 2664-0597 (Online)
Tikrit Journal for Agricultural Sciences
Journal Homepage: http://www.tjas.org
E-mail: tjas@tu.edu.iq
TJAS Tikrit Journal for Agricultural Sciences

Effect of Dietary Supplementation of Sumac Seed Powder on Meat Quality of Broiler Chicks

Mokhalad O. Hasan [1], Ahmed R. Muhaimeed [2], Adnan A. Al-Perkhdri [3], Zeiad A.Aghwan [4] , and Nyiransengimana Eugenie[5]

[1,2]*Department of Animal Production-Agriculture college-Tikrit University-salahuddin-Iraq.*
[3]*Public health, College of veterinary, University of Kirkuk, Kirkuk, Iraq*
4Halalan Thayyiban Research Centre, Universiti Islam Sultan Sharif Ali, Tutong, Negara Brunei Darussalam
[5]*Rwanda Agriculture Board- Musanze- Rwanda*

[*]*Corresponding author: E-mail*: mokhalad082@tu.edu.iq

KEY WORDS:
Sumac, Meat, Chemical, Physical Traits, Sensory Evaluation.

Received: 26/01/2024
Revision : 08/09/2024
Proofreading: 22/09/2024
Accepted: 14/09/2024
Available online: 30/09/2024

ABSTRACT

The safety of foods in terms of their sensory, chemical, physical, and human health, as well as their nutritional worth, have been recognized as having increased importance recently. The present study was carried out to examine the effects of dietary supplementation of sumac fruit powder on the meat quality of broiler chicks. A total of 135 broiler chicks (Ross 308) were randomly assigned to three dietary treatment groups, each group divided to three sub-groups of 15 birds each. The birds of T1 were fed standard diet as control group without supplementation, while the birds of T2 and T3 were fed standard diet with supplementation of 1g and 2g of sumac fruit powder/ kg feed, respectively. The results appeared improve significantly($P \leq 0.05$) of T2 and T3 compared to T1 in the percentage of cooking loss, Water Holding Capacity(WHC) also the percentages of fat and moisture as well as sensory evaluation of broilers meat. The percentage of protein and total fatty acids in broiler meat were significantly increased($P \leq 0.05$) in T2 and T3 in comparison with control treatment otherwise the dripping loss, thawing loss and ash percentage of broilers meat do not showed significant differ between treatments of study. In conclusion, dietary supplementation of sumac powder improved most of the physical and chemicals traits and all sensory evaluation of broilers meat.

تأثير إضافة مسحوق بذور السماق إلى عليقة فروج اللحم في الصفات النوعية للحم

مخلد عريبي حسن[1] ، أحمد رمضان محيميد[2]، عدنان شكور احمد البيرخدري[3] ، زيد امجد اغوان[4] و نيرنسينجيمانا يوجين

1، 2- قسم الإنتاج الحيواني-كلية الزراعة-جامعة تكريت-صلاح الدين-العراق.

3- الصحة العامة- كلية الطب البيطري- جامعة كركوك- كركوك- العراق.

4-مركز بحوث حلالاً طيباً، جامعة سلطان شريف علي الاسلامية، توتونك، نكارا بروني دار السلام.

5- مجلس زراعة راوندا- موسانز- راوندا.

الخلاصة

من المسلم به في الآونة الأخيرة أن الأهمية التي أعطيت لسلامة المواد الغذائية من حيث الصفات الحسية والكيميائية والفيزيائية وصحة الإنسان، فضلا عن قيمتها الغذائية، قد تزايدت. أجريت هذه الدراسة لفحص تأثير المكملات الغذائية لمسحوق ثمار السماق على جودة اللحم لفروج اللحم. تم توزيع 153 من ذكور فروح اللحم (Ross 308) بعمر أسبوعين عشوائياً على ثلاث مجموعات غذائية، تم تقسيم كل مجموعة إلى ثلاث مجموعات فرعية تضم كل منها 15 طائراً. تم تغذية طيور T1 على علف قياسي كمجموعة سيطرة بدون مكملات، في حين تم تغذية طيور T2 و T3 على علف قياسي مع إضافة 1 جرام و 2 جرام من مسحوق ثمار السماق / كغم علف على التوالي. أظهرت النتائج تحسناً معنوياً ($P<0.05$) في T2 وT3 مقارنة مع T1 في نسبة فقدان الطهي والقدرة على الاحتفاظ بالماء وكذلك نسبة الدهن والرطوبة وكذلك التقييم الحسي للحوم فروج اللحم. ارتفعت نسبة البروتين والأحماض الدهنية الكلية في اللحوم معنويا ($P<0.05$) في T2 و T3 مقارنة بمعاملة السيطرة بينما لم تكن هناك فروق معنوية بين المعاملات في نسب الفقد بالسائل الناضح وكذلك الفقد أثناء الإذابة ونسبة الرماد في لحوم فروج اللحم. نستخلص من نتائج الدراسة أن إضافة مسحوق السماق إلى النظام الغذائي أدى إلى تحسين معظم الصفات الفيزيائية والكيميائية والتقييم الحسي في لحوم فروج اللحم.

كلمات مفتاحية: سماق، لحم، الصفات الكيميائية والفيزيائية، التقييم الحسي.

INTRODUCTION

The broiler meat is an essential source of animal protein, which is rich in protein, vitamins, and minerals. Also vitamins, poultry meat has a low content of fat and cholesterol that is considered suitable for human health compared to other edible meat (Kamil *et al.*,2021) . Consequently, broiler meat consumption has increased worldwide in recent decades, especially in developing countries (Hasan *et al.*, 2020; Choi *et al.*, 2023; Suliman *et al.*, 2023). In recent decades, researchers have tended to use medicinal plants as alternatives to antibiotics to improve the production of poultry because of their anti-inflammatory, antibacterial, antioxidant, and immune effects (Ivanova *et al.*, 2024; Kapitonova and Babich, 2024).

The sumac (*Rhus coriaria* L.) belongs to the Anacardiaceae family and is widely cultivated in tropical, subtropical, and temperate regions. It is one of the plants that has been used since ancient times to treat many diseases because it contains many active chemicals such as tannins, flavonoids, and antioxidants (Alsamri, 2021; Emir *et al.*, 2023). The sumac seed contains dry matter 88.7%, crude protein 4.3%, crude ash 4%, crude fat 19.2%, as well as it containing 95.4, 310.4 and 110.3 mg/g of ascorbic acid, total phenolic and total flavonoid, respectively(Singh, 2023). Sumac works to increase the acidity of the small intestine

as it contains organic acids, so it was commonly used to preserve food from microbial contamination and give a desired taste. Besides, the acidic media suits the beneficial bacteria but not harmful bacteria (Magnavacca *et al.*, 2022). Azizi et al. (2020) and Al-Saada et al. (2024) found that the addition of sumac seed powder had a positive effect on the productive performance, reduced the level of cholesterol in the blood of the broiler, and supported its growth and the characteristics of the carcass in addition to a significant reduction in the number of *Escherichia coli* in the small intestine, this may be interesting as it can be a natural feed alternative additive for broiler chicks.

Furthermore, Shata et al. (2017) found significant improvement in body weight, feed efficiency, and carcass traits, as well as improvement in most of the sensory evaluations for meat, such as meat color, aroma, taste, texture, and overall acceptability in cooked meat, when adding sumac powder to the diet of Japanese quail chick. Grassi et al.(2024) finding demonstrated that adding sumac to meat enhanced its sensory qualities and raised consumer interest in it. This was explained by sumac's ability to boost meat's antioxidant and functional potential; on the other hand, in both raw and cooked samples, cooking decreased the phenolic content, antioxidant activity, and oxidative stability. Since sumac contains natural antioxidants such as ascorbic acid and antibacterial agents, in addition to phenolic and flavonoid substances, which play a major role in preserving meat from rancidity and spoilage, thus enhancing the sensory qualities of lamb, therefore, the current study aimed to investigate the effects of adding sumac fruit powder to the broiler ration on the quality of meat.

MATERIALS AND METHODS

The study was carried out following the guidelines of the research policy of the Tikrit University on animal ethics and welfare. The study was approved by the animal experimentation committee.

The birds housing, diets, and slaughtering

The study was conducted on 135-day-old broiler chicks (Ross 308) that were purchased from one of the local markets in Salah al-Din Governorate. The birds at one day old were randomly assigned to three dietary treatment groups, each group divided into three sub-groups of 15 birds each. The birds were raised in pens covered with sawdust in a semi-closed house at the animal farm of the College of Agriculture, University of Tikrit. The birds provided an ad libitum basal diet (Table 1). The following three groups were: T2 is the basal diet supplemented with 1 g of sumac fruit powder per kg of feed; T2 is the basal diet supplemented with 2 g of sumac fruit powder per kg of feed. T1 is the basal diet without supplements. According to the advice of the National Research Council, the diet was designed to satisfy nutritional needs based on body weight(NRC 1994). Upon reaching 35 days of their age, the birds were weight recorded (final weight) then slaughtered at the slaughterhouse of poultry in Agriculture College according to halal slaughter procedure, and the weight of each bird was recorded.

Table 1: The feed ingredients which were used in diets of broilers and the chemical analysis of dietary

Feed	Rations %		
	Starter	Grower	Final
Yalow corn	56.88	60	64.71
"Protein concentration 40%	5	5	5
Soybean 48%	33.68	30	25
Plant oil	1.84	2.78	3.49
Dicalcium Phosphate	1.28	1	1
CaCo3	0.77	0.8	0.5
Lysine	0.2	0.1	0.1
Methionine	0.25	0.22	0.1
Salt	0.1	0.1	0.1
*Chemical analysis			
Metabolic energy (kilocalorie/kg feed)	3000	3100	3200
Crude protein%	23	21.5	19.5
Crude fibers%	3.76	3.58	3.33
Lysine%	1.44	1.25	1.33
Methionine%	0.74	0.56	0.55
Calcium%	0.94	0.88	0.75
Phosphor%	0.46	0.41	0.39

"The Al-WAFI protein concentration consisted of: Crude protein: 40%, fat: 5%, calcium: 3.4%, phosphorus: 5.3% energy 2157 kcal/kg, fibers 3.2 %, sodium 2.4 %, chloride 4.16 %, 200000 IU/kg, lysine 3.85%, methionine 3.7%, and methionine + cysteine 4.13 % 80000 IU/kg of vitamin A 600 mg/kg of vitamin D3 60 mg/kg of tocopherol 140 mg/kg of riboflavin, 60 mg/kg of thiamin, 2 mg/kg of biotin , 800 mg/kg of niacin, 20 mg/kg of folic acid finally 50 mg/kg of vitamin K.

*The chemical compositions of the feed were calculated by the NRC (1994).

Drip loss, thawing loss, cooking loss, and water holding capacity

The meat samples collected from the breast fillet after 30 min after slaughtering were weigh recorded (W1), and then the sample was kept in a poly vacuum pack. After that, it was stored in the refrigerator at 4 °C for 24 hours. Samples were taken out of the plastic bag after a 24-hour period. The samples' surface was gently dried with tissue paper before being weighed and labeled as W2. For the 24 hours after muscle cooling, the percentage of drip loss was calculated using the following formula (Honikel, 1998):

Drip loss (%) = (W1 − W2) ÷ W1×100

When,

W1 = beginning weight

W2 = Last weight

The thawing losses of carcasses are estimated after frozen for three days, according to Nam et al. (2000). The broiler meat's cooking loss when cooked using a barbecue technique is reported to Rassmussein and Mast (1989). The water holding capacity(WHC) as determined by the press meat technique in accordance with (Grau and Hamm, 1953) as using the following formula:

WHC= meat moisture% - [(W1- W2) ÷ W1×100]

When, W2=meat weight before pressing ; W2=meat weight before pressing

Dry matter, nutrient determination

The samples of broiler meat were dried by oven to calculate the moisture percentage, and then the percentage of protein and fat as well as ash percent were estimated based on (AOAC, 2005).

Fatty acid determination

The concentrations of meat fatty acids in meat samples were estimated at the Department of Research and Technology in Baghdad using a gas chromatography device Japanese Shimadzu (GC–2010) after extracting the fat from the meat samples carcass by using hexane with a Soxhlet extractor according to(Zhang *et al.*,2015).

Sensory evaluation

Samples from breast muscle were cut into cubes about 3 cm^3, sprinkled with little normal salt, and then placed in the electric oven at 165 °C for about 15 minutes (O'Sullivan, 2017). And its amount is found in the flavor, juiciness, tenderness, and general acceptability of meat so he sensory evaluation of cooked meat samples was conducted by professors in the college who have experience in sensory evaluation and gave grades from 1 to 7 according to the sensory scale mentioned by (Yusop *et al.,* 2009).

Statistical analysis

A completely randomized design (CRD) was used for every variable measured in the study; the animal served as the study unit. With a 95% confidence level, the data were statistically analyzed using the Statistical Analysis System (SAS) package Version 9.2 software (SAS, 2010). The significance of variance between the means of the parameters for experimental studies using the Duncan multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

From the results shown in Table 2, there were no significant differences in drip loss and thawing loss among the treatments, while the cooking loss and water holding capacity showed significant improvement ($P \leq 0.05$) in T2 and T3 in comparison with the control treatment (T1). This result is agreed with Sadallah and Alhaji (2021). The decreased water holding capacity and cooking loss are due to the sumac seed's containment of phenolic compounds, which function as antioxidants and support the stability and protection of meat and fat cells' cellular structures as well as the defense of fluid and sarcoplasmic components in the cell membranes surrounding muscle fibers against oxidative damage brought on by the production of free radicals that rupture these membranes, increasing the muscles' ability to detect water and minimizing fluid loss during cooking (Arora *et al.,* 2000).

Table 2: Effect of sumac powder on physical traits of broilers meat

Traits %	Treatments		
	First	Second	Third
Drip loss	0.50 ± 0.13	0.84 ± 0.13	0.71 ± 0.16
Thawing loss	1.72 ± 0.11	2.01 ± 0.07	1.67 ± 0.20
Water Holding Capacity	44.75b ± 0.14	48.12 a± 1.08	47.20 a± 0.47
Cook loss	27.36 a ± 0.22	23.03 b ± 0.93	25.16 b ± 0.12

-First treatment was basal feed; second and Third treatments basal feed with adding (1 kg of feed containing 1 and 2 grams of sumac powder, respectively.
- The various letters in the same raw indicate significant treatment variations (P≤0.05).

The results of Table 3 show a significant increase (P≤0.05) in T2 and T3 compared to the control group in the percentage of meat protein, but these treatments showed a significant decrease (P≤0.05) compared to the control group in the percentage of oil and moister in broilers meat. No significant differences in ash percentage have been shown among all treatment groups. These results are in agreement with the findings of Sharbati et al. (2015) and Ahmadian et al. (2020). The increase in protein content in the meat of carcasses fed sumac seed powder is due to its containment of flavonoids and phenolic compounds that have a role in protecting meat proteins from changing their nature, reducing the oxidation process, suppressing free radicals, and thus protecting cell membranes from rupture (Botsoglou *et al.,* 2003; Levental *et al.,* 2016). Also, the flavonoids function similarly to steroid hormones in terms of structure and action, boosting metabolism rates through the production and support of structural proteins that help the body build muscle mass and other tissues (Sturkie, 2000). The notable drop in the proportion of fat in the carcasses of birds fed sumac seeds is a result of an increase in fatty acid content, particularly linoleic fatty acid, which acts to increase metabolic processes, oxidize fats, and reduce the proportion of fat in the tissues (West and others, 1998). Furthermore, there exists an inverse correlation between the percentage of fat and moisture in broiler meat, which could account for the rise in the meat's moisture content (Al-Fayadh *et al.,* 2011).

Table3: Effect of sumac powder on chemical traits of broilers meat

Traits %	Treatments		
	First	Second	Third
Protein	17.50b±0.29	21.30 a ± 0.38	20.20 a ± 0.31
Oil	7.80a±0.29	5.71 c ± 0.21	6.70 b ± 0.23
Ash	1.90±0.17	2.01 ± 0.31	1.85 ± 0.08
moisture	72.70a±0.15	71.01 b ± 0.28	71.30 b ± 0.14

-First treatment was basal feed; second and Third treatments basal feed with adding (1 kg of feed containing 1 and 2 grams of sumac powder, respectively.
- The various letters in the same raw indicate significant treatment variations (P≤0.05).

The results in Table 4 show a significant increase (P≤0.05) in T2 and T3 compared with the control group in the percentage of fatty acids such as linoleic, linolenic, stearic, oleic and finally palmitic. Furthermore, the percentage of all aforementioned fatty acids in T3 is increased significantly (P≤0.05)

compared with other treatment groups. This result is in agreement with Kishawy et al. (2019). The cause of the rising fatty acid concentrations in meat is the release of these acids from their locations in muscle fat as a result of the lipase enzyme's activity and the fatty acids' tendency to self-oxidize (St *et al.*, 1996).

The results shown in Table 5 demonstrated a significant increase (P≤0.05) in T2 and T3 compared with the control treatment in all sensory evaluations of broiler meat, such as flavor, juiciness, texture, and overall acceptability. These results are supported by the findings of Shata et al. (2017). The improvement in the panel taste of meat of birds fed with dietary supplementation of sumac is due to the role of the active compounds such as tannins, flavonoids, and phenolic compounds that have a great effect on the protection of meat proteins and which contribute to improving the palatability, tenderness, and juiciness traits because of improved water holding capacity and low loss during cooking and kept moisture in meat as shown in Tables 2 and 3 (Jasim and Omar, 2013). These compounds also act as bacteria that change the natural properties of poultry meat that cause spoilage, and these compounds have anti-oxidation properties through their strong effectiveness in inhibiting lipid oxidation, similar to the action of vitamin E, which protects the low-density lipoprotein LDL from oxidation and its role in maintaining the inhibitory enzymes for oxidation (Ooi *et al.*, 2006); phenolic compounds present in food; and flavorings provide protection for meat proteins and protect their cell membranes from some changes in their nature that limit or delay the oxidation process (Jiang and Xiong, 2016).

Table 4: Effect of sumac powder in meat fatty acids of broiler chicks

Traits %	Treatments		
	First	Second	Third
Linoleic Acid	0.009 c ± 0.001	0.116 b ± 0.003	0.303 a ± 0.003
Linolenic Acid	0.001 c ± 0.001	0.005 b ± 0.001	0.015 a ± 0.003
Stearic Acid	0.015 c ± 0.002	0.154 b ± 0.003	0.606 a± 0.003
Oleic Acid	1.140 c ± 0.144	3.543 b ± 0.178	5.458 a ± 0.180
Palmitic Acid	1.135 c ± 0.032	4.194 b ± 0.105	6.513 a ± 0.059

-First treatment was basal feed; second and Third treatments basal feed with adding (1 kg of feed containing 1 and 2 grams of sumac powder, respectively.
- The various letters in the same raw indicate significant treatment variations (P≤0.05).

Table 5: Effect of sumac powder on sensory evaluation of broiler meat

Traits %	Treatments		
	First	Second	Third
Flavor	4.04 ± 0.16 b	5.50 ± 0.34 a	5.30 a ± 0.33
Juiciness	4.10 ± 0.10 b	5.50 ± 0.30 a	5.40 a ± 0.27
Tenderness	4.60 ± 0.16 b	5.80 ± 0.20 a	5.30 a ± 0.21
Overall acceptability	4.60 ± 0.26 b	5.90 ± 0.23 a	5.60 a ± 0.34
Flavor	4.04 ± 0.16 b	5.50 ± 0.34 a	5.30 a ± 0.33

-First treatment was basal feed; second and Third treatments basal feed with adding (1 kg of feed containing 1 and 2 grams of sumac powder, respectively.
- The various letters in the same raw indicate significant treatment variations (P≤0.05).

CONCLUSION

The study's findings that adding sumac fruit powder to the diet enhanced the majority of meat's chemical and physical characteristics as well as every sensory evaluation. However the treatments had no influence on the meat's ash, thawing loss, or drip loss which this study noted. The addition of 2 g/kg feed of sumac powder (T3) to the broiler chicks diet considerably raised the amount of fatty acids in the meat.

CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

ACKNOWLEDGMENT

The authors express their gratitude to the entire staff of Tikrit University's Department of Animal Production in the College of Agriculture for their invaluable technical assistance throughout the study's execution.

REFERENCES

Ahmadian, A., Seidavi, A., and Phillips, C. J. (2020). Growth, carcass composition, haematology and immunity of broilers supplemented with sumac berries (*Rhus coriaria* l.) and thyme (*Thymus vulgaris*). *Animals*, 10(3), 513.

Al-Fayadh, Hamdy A., Saad A. Naji and Nadia N. Al-Hajo. (2011). Poultry meat technology. 2nd Edition. Aldaar University for publishing and printing. Baghdad University. Iraq.

Al-Saada, Q., Al-Nasseri, A. N., Hasan, M. O., & Taha, M. W. (2024, February). Effect of Rhus coriaria L. on performance productive, physiological and carcass characteristics of broiler chicks. In IOP Conference Series: Earth and Environmental Science (Vol. 1302, No. 1, p. 012053). IOP Publishing.

Alsamri, H., Athamneh, K., Pintus, G., Eid, A. H., and Iratni, R. (2021). Pharmacological and Antioxidant Activities of *Rhus coriaria* L.(Sumac). Antioxidants, 10(1), 73.

AOAC. Association Official Analytical Chemists. (2005). Official methods of analysis. (18th Ed.). Gaithersburg, Maryland, USA.

Arora,A.M.,G. Nair, and G.M. Stasburg. (2000). Structure activity relationships for antioxidant activates of series of Flavonoids. *Journal Free Radical Biology Medicine*. 24:1355-1363.

Azizi, M., Passantino, G., Akter, Y., Javandel, F., Seidavi, A., Bahar, B., and Tufarelli, V. (2020). Effect of sumac (*Rhus coriaria* L.) seed powderon growth, carcass traits, blood parameters, immune system and selected ileal microorganisms of broilers. *Veterinaria Italiana*, 56(3), 185-192.

Botsoglou, N.A., Grigoropoulou,S.H., Botsoglou,E., Govaris, A., and Papageorgiou,G. (2003). The effects of dietary oregano essential oil and α-tocopheryl acetate on lipid oxidation in raw and cooked turkey during refrigerated storage. *Meat Science*, 65(3), 1193-1200.

Choi, J., Kong, B., Bowker, B. C., Zhuang, H., & Kim, W. K. (2023). Nutritional strategies to improve meat quality and composition in the challenging conditions of broiler production: a review. *Animals*, *13*(8), 1386.

Duncan, D. B. (1955). Multiple ranges and multiple F test. Biometric, CABI Publishing, Wallingford, UK. P. 1- 42.

Emir, A. A., Yildiz, E., Aydogdu, Y. and Sumnu, G. (2023). Active films based on Faba bean (*Vicia faba* L.) flour incorporated with Sumac (*Rhus coriaria*): Assessment of antioxidant and antimicrobial performances of packaging for shelf life of chick breast. *Food and Bioprocess Technology*, 16(2), 327-341.

Grassi, G., Di Gregorio, P., Rando, A., & Perna, A. M. (2024). Quality and sensorial evaluation of beef burgers added with Sicilian sumac (*Rhus coriaria* L). *Heliyon*, *10*(5).

Grau, R. and Hamm, R. (1953). Eine einfache Methode zur Bestimmung der Wasser bindung im Muskel. *Naturwissenschaften*,40:29-30.

Hasan, M. O., Hasan, T. K., and Naji, S. A. H. (2020, August). Effect of adding pumpkin and flax oil to diets on the meats physical and chemical traits of broilers. In IOP Conference Series: *Earth and Environmental Science*, 553(1):012009.

Honikel, K. O. (1998). Reference method for the assessment of physical characteristics of meat. Meat Science, 49:447-457.

Ivanova, S., Sukhikh, S., Popov, A., Shishko, O., Nikonov, I., Kapitonova, E. & Babich, O. (2024). Medicinal plants: a source of phytobiotics for the feed additives. *Journal of Agriculture and Food Research*, 101172.

Jasim, M. A. and Y. M. Omar. (2013). Manufacture fish balls product and studying the bacterial changes on frozen storage. *Kufa Journal for Agricultural Sciences*, 5(1), 353-372.

Jiang, J., and Xiong, Y. L. (2016). Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: A review. *Meat science*, 120, 107-117.

Kapitonova E. and Babich, O. (2024). Medicinal plants: a source of phytobiotics for the feed additives. *Journal of Agriculture and Food Research*, 101172.

Kamil, Y. M., Katab, T., & Mohammed, A. B. M. (2021, May). Effect of Supplementing laying Japanese quail (*Coturnix coturnix* japonica) diets with Amla and Green Tea Extracts on the Product Performance and Biochemical Parameters. In *IOP Conference Series: Earth and Environmental Science* (Vol. 761, No. 1, p. 012109). IOP Publishing.

Kishawy, A. T., Amer, S. A., Abd El-Hack, M. E., Saadeldin, I. M., and Swelum, A. A. (2019). The impact of dietary linseed oil and pomegranate peel extract on broiler growth, carcass traits, serum lipid profile, and meat fatty acid, phenol, and flavonoid contents. *Asian-Australasian journal of animal sciences*, 32(8), 1161.1171.

Levental K.R., Lorent J.H., Lin X., Skinkle A.D, Surma M.A, Stockenbojer E.A., Gorfe A.A, and Levental I. (2016). Polyunsaturated lipids regulate membrane domain stability by tuning membrane order. *Biophysical Journal*.,110(8),1800-1810.

Magnavacca, A., Pozzoli, C., & Sangiovanni, E. (2022). The Nutraceutical Properties of Sumac (*Rhus coriaria* L.) against Gastritis: Antibacterial and Anti-Inflammatory Activities in Gastric Epithelial Cells Infected with H. pylori. *Nutrients*, *14*(9), 1757.

Nam,J., H.Park., C.K.Songa, D.G.Kim, Y.H.Moon and I.C.Jung. (2000). Effect of freezing and re-freezing treatment on chick meat quality. *Journal food Sciences*, 20(1), 222-229.

NRC. (1994). Nutrient Requirements of Poultry. 9th Rev. Ed. National Academy Pres., Washington DC., USA.

O'Sullivan MG. 2017. A handbook for sensory and consumer driven new product development: innovative technologies for the food and beverage industry. Sawston, UK: Woodhead Publishing; pp. 39-57.

Ooi, L .S .,Y .Li ,S .L .Kam , H.Wang, E .Y. Wong and V .E .Ooi .(2006). Antimicrobial activities of cinnamon oil and cinnamaldehyde from the Chinse medicinal herb cinnamon blume .*International Journal Food microbiology*, 107(2),180-5.

Rassmussein,A.L. and M.G.Mast. (1989). Effect of Feed withdrawal on composition and quality of broiler meat .*Poultry Sciences*,68(8),1109-1113.

Sadallah, M. W., and Alhaji, T. (2021). Effects of pectin and tomato paste as a natural antioxidant on inhibition of lipid oxidation and production of functional chick breast sausage. *Mesopotamia Journal of Agriculture*, 49(1), 76-88.

SAS, Intstitue. (2010). SAS User's Guide: Statistics Version 6. 12th Ed, SAS Institute, Inc., Cary, NC. USA.

Sharbati, A., Daneshyar, M., Aghazadeh, A., Aliakbarlu, J., and Hamian, F. (2015). Effects of *Rhus coriaria* on nutrient composition, thiobarbituric acid reactive substances and colour of thigh meat in heat-stressed broilers. *South African Journal of Animal Science*, 45(1), 49-55.

Shata, R. F., Elkloub, K., and El Moustafa, M. (2017). Effect of dietary sumac seed powder as an antioxidant and growth promoter on growth performance of Japanese quill. *Egyptian Journal of Nutrition and Feeds*, 20(1), 105-113.

Singh, T. S., Kshetri, P., Devi, A. K., Langamba, P., Tamreihao, K., Singh, H. N.& Roy, S. S. (2023). Bioactivity and nutritional quality of nutgall (Rhus semialata Murray), an underutilized fruit of Manipur. Frontiers in Nutrition, 10, 1133576.

St. Angelo, A. J., Vercellotti, J., Jacks, T and Legendre, M. (1996). Lipid oxidation in foods. Critical Reviews: *Food Science and Nutrition*, 36(3), 175-224.

Sturkie,P.D. (2000). Avian Physiology.5th Ed. New York. Heiderberg. Barlin,Springer Verlag.

Suliman, G. M., Al-Owaimer, A. N., Swelum, A. A., Alhotan, R., Qaid, M. M., Azzam, M. M., & Hussein, E. O. (2023). Does slaughter age affect amino acids and fatty acids profiles and health and nutritional values of male and female ROSS 308 broiler chicken breast muscle?. *Poultry science*, *102*(11), 103085.

West, D.B., Delany, J.P., Camet, P.M., Blohm, F., Truett, A.A. and Scimeca, J. 1998. Effects of conjugated linoleic acid on body fat and energy metabolism in the mouse. American Journal of Physiology-Regulatory, *Integrative and Comparative Physiology*, 44: 667–672.

Yusop, S. M., O'sullivan, M. G., Kerry, J. F., and Kerry, J. P. (2009). Sensory evaluation of Chinese-style marinated chick by Chinese and European naïve assessors. *Journal of Sensory Studies*, *24*(4), 512-533.

Zhang, H., Wang, Z. and Liu, O. 2015. Development and validation of a GC–FID method for quantitative analysis of oleic acid and related fatty acids. *Journal of Pharmaceutical Analysis*, 5(4), 223-230.