Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

N Arulnathan
Department of Animal
Nutrition, Veterinary College
and Research Institute,
Tirunelveli, Tamil Nadu, India

R Karunakaran
Department of Animal
Nutrition, Madras Veterinary
College, Chennai, Tamil Nadu,
India

V Balakrishnan
Department of Animal
Nutrition, Madras Veterinary
College, Chennai, Tamil Nadu,
India

M Chellapandian
Department of Animal
Nutrition, Veterinary College
and Research Institute,
Tirunelveli, Tamil Nadu, India

ST Selvam
Department of Poultry Science,
Madras Veterinary College,
Chennai, Tamil Nadu, India

Effect of different dietary oil sources of omega- 3 poly unsaturated fatty acids on the meat quality characteristics in Japanese quail

N Arulnathan, R Karunakaran, V Balakrishnan, M Chellapandian and ST Selvam

DOI: https://doi.org/10.22271/j.ento.2020.v8.i5w.7732

Abstract
A feeding trial was conducted in Japanese quail broiler birds for a period of five weeks to study the effect of various inclusion levels of feed ingredients rich in omega-3 fatty acids to meatquality characteristics. 360 numbers of day old Japanese quail chicks were selected and distributed randomly into six treatment groups (T1-PO 4%; T2 LO 4%:T3 LO 3% + SO 1%; T4 LO 2% +SO 2%; T5 LO 1% + SO 3%; T6 SO 4%). Six replicates of ten birds (6 x 10 = 60) were maintained in each treatment. The Japanese quail broiler rations were iso-caloric and iso-nitrogenous. The source of omega-3 rich oils and their combinations are the key variable in these rations. The birds were slaughtered by Halal method at the end of the experiment on 35th day. There is no significant difference ($P>0.05$) in the dry matter, crude protein, ether extract and total ash content in the Japanese quail meat fed with different sources oil and its combination. No significant ($P>0.05$) difference was observed on pH, shear force value, water holding capacity and colour of breast meat of Japanese quail fed with different oil sources rich in omega-3 fatty acids. The sensory evaluation of the breast meat of Japanese quail fed with different oil sources rich in omega-3 fatty acids had significant ($P<0.05$) difference among the treatments. Hence, from this study T3 (LO-3% and SO-1%) was recommended based on the sensory evaluation studies to produce omega-3 enriched Japanese quail meat.

Keywords: Omega-3 fatty acids, Japanese quail, meat quality characteristics, sensory evaluation

Introduction

In the present scenario, consumers are much conscious about their health and as a result worldwide demand for functional foods is increasing day by day. In this context, functional foods can be produced from poultry meat when it is fortified with nutrients that are very much essential to health but are not usually present inadequate quantity in the regular food to meet the recommended daily requirement of human beings. However, the fortification of various nutrients in poultry meat and egg is solely dependent on the nutritional manipulation of the poultry ration. Thus enrichment of poultry meat through nutritional manipulations is capable of capturing the market by appealing to a segment of health conscious consumers who are willing to pay more for such modified meat.

Omega-3 polyunsaturated fatty acids (n-3 PUFA) play an important role in human nutrition since they help to reduce the incidence of life style diseases such as coronary artery diseases, hypertension and diabetes, as well as some autoimmune and inflammatory diseases such as arthritis and dermatitis (Simopoulos, 2001) [17]. It has been shown that the consumption of long chain omega-3 polyunsaturated fatty acids ensures vital components for the retina and for the membrane phospholipids of the brain (Rymer and Givens, 2006) [12]. The omega-3 polyunsaturated fatty acids content of poultry products can be enriched effectively through dietary manipulation, either directly by using fish oil, marine algae or indirectly by increasing the level of precursor of omega -3 polyunsaturated fatty acids.

Commercial Quail farming is becoming more popular and is being increasingly promoted in a number of Asian and European countries (Vali, 2008) [22]. The advantages of quail farming includes minimum floor space, low investment, comparatively sturdy birds, early market age and sexuality, high rate of egg production and less feed requirement. Besides, Quail meat and egg are tastier than chicken and less fat contents.

Corresponding Author:
N Arulnathan
Department of Animal
Nutrition, Veterinary College
and Research Institute,
Tirunelveli, Tamil Nadu, India

It has been shown to promote body and brain development in children and nursing mothers. Rearing of Japanese quail for meat production is a genuine alternative to other animal protein. Quail meat has been known for centuries despite of the biblical quotations of their use as a meat source and quail is one of the leanest types of poultry (Boni *et al*., 2010) [5]. Lately, quail meat has gained much popularity among consumers (Ikhlas *et al*., 2011) [9]. The ratio between PUFAs and SFAs was 0.43 in female quail meat and 0.40 in male quail meat and the ratios are in accordance with the WHO recommendations (Umit Gecgel *et al.,*2015) [24].

Moreover, study of nutritional manipulation to produce omega-3 enriched quail meat is also a novel one. And while enriching the meat with different oil sources we have to ensure that the inclusion level for meat quality and sensory characteristics and mainly it should be accepted by the consumers. Hence, this study was proposed with the objective to assess the effect of dietary oil sources on quality parameters of Japanese quail meat enriched with omega-3 fatty acids.

Material and Methods
A feeding trial was conducted in Japanese quail broiler birds at Department of Animal Nutrition, Veterinary College and Research Institute, Tirunelveli, for a period of five weeks to study the effect of various inclusion levels of feed ingredients rich in omega-3 fatty acids to produce omega-3 fatty acid enriched meat. For the feeding experiment, 360 numbers of day old Japanese quail broiler chicks belonging to a single hatch were purchased. Upon arrival, Japanese quail chicks were wing banded, weighed individually and distributed randomly into six treatment groups (T1-PO 4%; T2 LO 4%:T3 LO 3% + SO 1%; T4 LO 2% +SO 2%; T5 LO 1% + SO 3%; T6 SO 4%). Six replicates of ten birds (6 x 10 = 60) were maintained in each treatment. The experimental birds were housed individually in two tier well ventilated battery cages provided with artificial lighting. The Japanese quail broiler rations were isocaloric and isonitrogenous. Both starter and finisher ration met the nutrient requirement as per BIS (2007) [03]. The metabolisable energy and crude protein content of starter and finisher ration were 3000, 2900 kcal/kg diet and 28, 24 per cent, respectively. The source of omega-3 rich oils and their combinations are the key variable in these rations (Table 1 and 2). Japanese quails were fed *ad libitum* of their respective experimental rations in separate feed troughs. Clean drinking water was provided *adlibitum* initially in water trough and later in nipple drinkers. The management practices adopted were as per the standards and were uniform for all the treatments. The birds were slaughtered by Halal method at the end of the experiment on 35th day. The carcasses were skinned and eviscerated. The carcasses for analysis of meat quality studies were kept in deep freezer (- 40° C) until analysed.

Chemical composition of the meat
For chemical composition analysis and meat quality studies six samples from each treatment were taken. Samples of Japanese quail meat from all treatments were analyzed for their proximate principle viz. crude protein (CP), ether extract (EE) and total ash (TA) as per the methods described in AOAC (2000) [01]. All the values estimated were expressed as percentage on dry matter basis (DMB).

Meat Quality Characteristics
pH
The pH of the meat sample was measured using a digital pH meter (Digisun Electronic System, Model: 2001) by following the procedure of Trout *et al*., (1992*)* [21]. About 5 g of meat sample was homogenised with 45 ml of distilled water in a laboratory blender for about one minute. The pH was recorded by immersing the combination glass electrode of the digital thermometer in the homogenised meat sample.

Shear Force Value
Shear force value of meat samples were estimated by employing Warner -Bratzler shear press (Salter model No. 235 6S) by following the procedure of Bratzler (1954) [02]. Force needed to shear one cm^3 of meat was expressed in kg cm^{-2}.

Water holding capacity
Water holding capacity of the Japanese quail breast muscle sample was assessed by adopting the filter paper press method as recommended by Grau and Hamm (1953) [07]. Approximately 300 mg of muscle tissue was kept in between a folded Whatman No. 41 filter paper. Two glass slides, one below and one above the folded filter paper were kept. The muscle tissue was subjected to a downward pressure force by keeping a 100 g weight on the top of the glass slide for 3 minutes. The entire process was carried out on a hard top table. The area of the two resultant impressions left on each half of the filter paper on account of the force was measured using a digital planimeter (Model KP – 90 N, PLACOM) and expressed in square centimeters.

Meat Colour Quality (Instrumental colour)
The colour of meat sample were tested using Hunter lab Mini scan XE plus Spectro- colorimeter (Model No. 45/O-L, Reston Virgenia, USA) with geometry of diffuse/80 (sphere – 8mm view) and an illuminant of D65/10 deg (Bindu *et al*., 2007) [04]. Colorimetry measures colour with quantitative physical methods and can define them within well established numerical values. Here they are expressed using the standard Hunter L* a* b* system: a lightness axis (white – black, L*); and two axes representing both hue and chroma, one red - green (a*) and other blue – yellow (b*). This system provides unambiguous description of colour and has the advantage that colour differences between samples can be determined using simple computer programs.

Sensory Evaluation
Sensory evaluation was assessed by subjecting six meat samples from each treatment to a sensory scores of colour, odour and overall acceptability by trained and semi trained panel drawn from Department of Meat Science and Technology, Madras Veterinary College, on a 9-point Hedonic scale of a standard score card.

Statistical Analysis
Statistical analysis of experimental data was carried as per Snedecor and Cochran (1994) and by SPSS statistics for windows, version 17.0 (2008) [19].

Results and Discussion
Chemical composition of the meat
The data on chemical composition of meat of Japanese quail fed with different sources oil and its combination are

presented in Table 3. The per cent dry matter, crude protein, ether extract and total ash ranged between 28.89 ± 0.68 to $29.64 \pm 0.22, 75.63 \pm 0.89$ to $81.31 \pm 0.31, 11.23 \pm 1.49$ to 15.16 ± 0.29 and 4.30 ± 0.04 to 5.01 ± 0.25 respectively. There is no significant difference ($P>0.05$) in the dry matter, crude protein, ether extract and total ash content in the omega 3 enriched Japanese quail meat fed with different sources oil and its combination. This results was corroborated with the findings that lipid supplementation did not affect the chemical composition of the breast meat in Muscovey ducks (Schiavone et al., 2004) [15], in broiler chickens (Suksombat et al., 2007 and Ebeid et al., 2011) [20, 21] and in Japanese quails (Yamany et al., 2008) [23].

In this study, even though the source of oils and their combinations were different, but all the treatment groups had received isocaloric and isonitrogenous ration. The fatty acid profile of the rations did not significantly ($P>0.05$) affect the chemical composition (DM, CP, EE and TA) of Japanese quail meat. Since, the fatty acid profile of control and treatment groups varied by saturated and unsaturated fatty acids, on metabolism and enzymatic changes the fatty acid profile of the feed did not influence the chemical composition of the meat.

Meat Quality Characteristics

The results of the pH, shear force value and Water Holding capacity of breast meat of Japanese quail fed with different oil sources rich in omega-3 fatty acids are furnished in Table 4.

pH

The results of pH of the omega-3 enriched meat of Japanese quail fed with different oil sources rich in omega-3 fatty acids did not significantly differ ($P>0.05$). It varied from 5.67 ± 0.02 to 5.77 ± 0.02 among the treatments. Since, the different oil sources did not influence on the chemical composition of the meat, neither the cell integrity was affectednor glycolysis occurred. This result was similar to the findings reported by Ribeiro et al., (2013) [13] that lipid supplementation had no effect on breast meat pH in broilers.

Shear Force Value

No significant ($P>0.05$) difference was observed on shear force value of breast meat of Japanese quail fed with different oil sources rich in omega-3 fatty acids. Since the oil sources did not influence the fibre strength or softness, the shear force value of Japanese quail meat was not affected by the different oil sources fed to explore the possibilities to enrich the Japanese quail meat with omega-3 fatty acids. This results was corroborated with Ribeiro et al. (2013) [13] observed that lipid supplementation had no effect on breast meat shear force value in broilers.

Water holding capacity

Water holding capacity is an important attribute of meat quality. If water-holding capacity is poor, whole meat and further-processed products will lack juiciness. The water holding capacity did not significantly ($P>0.05$) differ among the treatments with different oil sources rich in omega-3 fatty acids inclusion in the Japanese quail broiler meat. The oil sources did not affect the cell membrane integrity. This might be reason for the insignificant difference ($P>0.05$) between the treatment groups fed with different oil sources rich in omega-3 fatty acids. The supplementation in vegetable extracts and oil mixture had no effects on water holding

capacity of the breast meat (Elmali et al., 2014) [06].

Meat Colour Quality (Instrumental colour)

The results of the Japanese quail breast meat colour are given in the Table 5. In this study no significant ($P>0.05$) difference was noticed in the meat colour of Japanese quail fed with different oil sources rich in omega-3 fatty acids to explore the possibilities of enrichment of omega-3 fatty acids in Japanese quail meat.This result was similar to the findings reported by several authors. The colour of meat is an organoleptic trait which could be directly evaluated and indicates the topographic area, species, freshness and tenderness of produced meat. Meat colour depends on the amount of heme pigments, and mostly on the chromoprotein myoglobin (Mb) and the post mortem chemical alterations it suffers. The colour traits are also dependent on the amount, the colour and distribution of intramuscular fat, as well as on structural and ultrastructural changes in myofibrillar proteins by the time of rigor mortis. In this study there was no significant ($P>0.05$) difference noticed in breast meat colour among the treatment groups. Since the different oil sources used in this study to explore the possibilities of enrichment of Japanese quail with omega-3 fatty acids did not negatively influence the meat colour since it did not affect the chemical composition and other physic-chemical parameters of meat quality. This results was corroborated with Malgorzata et al., (2012) [10] who reported that dietary flax oil supplementation did not differ significantly ($P>0.05$) in meat colour in quail meat. The supplementation of vegetable extracts and oil mixture had no effects on color (lightness, redness and yellowness coordinate) of the breast meat (Elmali et al., 2014) [06].

Sensory evaluation

The results of the sensory evaluation of Japanese quail breast meat are given in Table 6. The sensory properties of a food are features that the consumer can discern directly thanks to its senses. These sensations can be qualitative, quantitative, or hedonic.

This study revealed that the sensory evaluation of the breast meat of Japanese quail fed with different oil sources rich in omega-3 fatty acids had significant ($P<0.05$) difference among the treatments. The T3 group was significantly ($P<0.05$) higher in all sensory parameters among the treatments. Musty taint in T2 and fishy taint inT4, T5 and T6 are observed by the sensory panel. This might be due to 4 per cent inclusion of linseed oil in T2 and more than 1% inclusion level of fish oil in T4, T5 and T6. Lopez-Ferrer et al., (1999) [08] reported that the inclusion of linseed oil as alternative source to fish oil for n-3FA enrichment involves lesser degree of off flavor and odour and higher quantities of linseed lead to negative sensory attributes and Lopez-Ferrer et al., (2001) [09] recorded that the use of fish oil greater than 1 to 2% in poultry diets leads to several organoleptic problems in the final product and compromises the oxidative stability of the meat. Use of 2% fish oil for enrichment of chicken with n-3 PUFA gave fishy taint in broiler chicken (Mirghelenj et al., 2009) [11]. It has been reported that pelleting increases fatty acid retention and makes it more bioavailable (Shen et al., 2005) [16]. Hence, from this study T3 (LO-3% and SO-1%) was selected based on the sensory evaluation studies. Since, ultimately the consumer satisfaction and acceptance should be taken as very important factor while producing the functional foods.

Table 1: Percent ingredient composition of Japanese quail broiler (Starter 1-3 weeks) to explore the scope for producing omega- 3 enriched meat

Ingredients Ingredient composition	T1 PO – 4%	T2 LO-4%+ SO-0%	T3 LO-3%+ SO-1%	T4 LO-2% + SO-2%	T5 LO-1% + SO-3%	T6 LO-0% + SO-4%
Maize	39.1	39.1	39.1	39.1	39.1	39.1
DORB	3.2	3.2	3.2	3.2	3.2	3.2
Soya bean meal	39.6	39.6	39.6	39.6	39.6	39.6
Maize gluten meal	10.0	10.0	10.0	10.0	10.0	10.0
Vegetable oil	4	0	0	0	0	0
Linseed oil	0	4	3	2	1	0
Fish oil (Sardine Oil)	0	0	1	2	3	4
Limestone powder	1.6	1.6	1.6	1.6	1.6	1.6
DCP	1.4	1.4	1.4	1.4	1.4	1.4
Lysine	0	0	0	0	0	0
Methionine	0.03	0.03	0.03	0.03	0.03	0.03
Salt + Additives	1.07	1.07	1.07	1.07	1.07	1.07
Total	100	100	100	100	100	100

DORB-Deoiled rice bran
DCP=Dicalcium phosphate
PO-Palm oil; LO – Linseed oil ; SO- Sardine fish oil

Table 2: Percent ingredient composition of Japanese quail broiler (Finisher 4-5 weeks) to explore the scope for producing omega-3 enriched meat

Ingredients	T1 PO – 4%	T2 LO-4%+ SO-0%	T3 LO-3%+ SO-1%	T4 LO-2% + SO-2%	T5 LO-1% + SO-3%	T6 LO-0% + SO-4%
Maize	36.7	36.7	36.7	36.7	36.7	36.7
DORB	19.5	19.5	19.5	19.5	19.5	19.5
Soya bean meal	26.4	26.4	26.4	26.4	26.4	26.4
Maize gluten meal	10.0	10.0	10.0	10.0	10.0	10.0
Vegetable oil	4	0	0	0	0	0
Linseed oil	0	4	3	2	1	0
Fish oil (Sardine oil)	0	0	1	2	3	4
Limestone powder	1.6	1.6	1.6	1.6	1.6	1.6
DCP	0.5	0.5	0.5	0.5	0.5	0.5
Lysine	0.17	0.17	0.17	0.17	0.17	0.17
Methionine	0.03	0.03	0.03	0.03	0.03	0.03
Salt + Additives	1.10	1.10	1.10	1.10	1.10	1.10
Total	100	100	100	100	100	100

DORB-Deoiled rice bran
DCP=Dicalcium phosphate
PO-Palm oil; LO – Linseed oil ; SO- Sardine fish oil

Table 3: Effect of different sources of omega -3 PUFA on percent chemical composition of meat (in percent) in Japanese quail (Mean* ± SE)

Characteristics	T1 PO – 4%	T2 LO-4%+ SO-0%	T3 LO-3%+ SO-1%	T4 LO-2% + SO-2%	T5 LO-1% + SO-3%	T6 LO-0% + SO-4%
Dry matter [NS]	28.89 ± 0.68	29.24 ±0.27	29.32 ± 0.58	29.64 ± 0.22	29.53 ±0.44	29.28 ± 0.10
Crude Protein [NS]	75.63± 0.89	76.43 ± 1.98	76.85 ±1.78	81.31 ± 0.31	76.30 ± 2.19	76.12 ± 0.87
Ether Extract [NS]	15.16 ± 0.29	13.84 ± 2.28	11.23 ± 1.49	9.38 ±0.95	12.90 ± 1.40	12.43 ± 0.75
Total Ash [NS]	4.81 ± 0.16	4.30 ± 0.04	4.82 ± 0.05	4.68 ± 0.27	5.01 ± 0.25	5.13 ± 0.07

*Mean of six observations
NS- Not significant among values in a row
PO-Palm oil; LO – Linseed oil ; SO- Sardine fish oil
PUFA-Poly unsaturated fatty acids

Table 4: Effect of different sources of omega -3 PUFA on the meat quality Characteristics in Japanese quail (Mean* ± SE)

Characteristics	T1 Control PO – 4%	T2 LO-4%+ SO-0%	T3 LO-3%+ SO-1%	T4 LO-2% + SO-2%	T5 LO-1% + SO-3%	T6 LO-0% + SO-4%
pH [NS]	5.67 ± 0.03	5.67 ± 0.02	5.66 ± 0.04	5.77 ± 0.01	5.68 ± 0.02	5.75 ± 0.03
Water holding capacity (cm^2) [NS]	2.18 ± 0.19	2.00 ± 0.19	2.00 ± 0.12	2.12 ± 0.15	2.41 ± 0.27	2.55 ± 0.12
Shear Force value (kg/cm^2)[NS]	0.94 ± .018	0.70 ±0.05	0.67 ±0.05	0.95 ±0.08	0.71 ±0.09	0.69 ±0.08

*Mean of six observations
NS- Not significant among values in a row
PO-Palm oil; LO – Linseed oil ; SO- Sardine fish oil ; PUFA-Poly unsaturated fatty acids

Table 5: Effect of different sources of omega -3 PUFA on the colour (in points) in Japanese quail meat (Mean* ± SE)

Characteristics	T1 Control PO – 4%	T2 LO-4%+ SO-0%	T3 LO-3%+ SO-1%	T4 LO-2% + SO-2%	T5 LO-1% + SO-3%	T6 LO-0% + SO-4%
Lightness (L) [NS]	51.88 ± 2.31	46.72± 1.71	47.79 ±2.66	47.33 ±1.29	48.24± 1.92	49.60 ± 1.66
Redness(a)[NS]	12.78 ± 0.56	11.69 ±1.41	14.17 ±1.17	10.26 ±1.07	11.69 ± 0.25	10.30 ± 2.04
Yellowness(b) [NS]	18.56 ± 1.62	17.52 ±2.39	17.97 ±1.74	16.87±0.73	16.51 ± 1.18	16.72 ± 0.97

*Mean of six observations
NS- Not significant among values in a row
PO-Palm oil; LO – Linseed oil ; SO- Sardine fish oil
PUFA-Poly unsaturated fatty acids

Table 6: Effect of different sources of omega -3 PUFA on the sensory evaluation (in points) in Japanese quail (Mean* ± SE)

Characteristics	T1 Control PO – 4%	T2 LO-4% +SO-0%	T3 LO-3% +SO-1%	T4 LO-2% +SO-2%	T5 LO-1% +SO-3%	T6 LO-0% + SO-4%
Appearance	8.00[a] ± 0.00	7.00[c] ± 0.00	8.00[a] ± 0.00	7.50[b] ± 0.28	7.50[b] ± 0.28	7.50[b] ± 0.28
Flavour	8.00[a] ± 0.00	6.00[c] ± 0.00	8.00[a] ± 0.00	7.00[b] ± 0.00	4.75[d] ± 0.25	4.00[e] ± 0.00
Tenderness	8.00[a] ± 0.00	7.25[b] ± 0.25	8.00[a] ± 0.00	8.00[a] ± 0.00	7.00[b] ± 0.00	7.00[b] ± 0.00
Juiciness	8.00[a] ± 0.00	7.00[b] ± 0.00	8.00[a] ± 0.00	7.25[b]± 0.00	6.50[b] ± 0.28	6.50[b] ± 0.28
Overall acceptability	8.00[a] ± 0.00	6.25[c] ± 0.25	8.00[a] ± 0.00	7.00[b] ± 0.00	6.00[c] ± 0.00	5.00[d] ± 0.00

*Mean of six observations
Mean values having different alphabets in a row differ significantly ($P<0.05$)
PO-Palm oil; LO – Linseed oil ; SO- Sardine fish oil
PUFA-Poly unsaturated fatty acid

Conclusion
The result of the study conducted to assess the effect of various inclusion levels of feed dietary oil sources on meat quality characteristics of Japanese quail in which the source of omega-3 rich oils and their combinations were the key variable in the experimental rations revealed that there is no significant difference ($P>0.05$) in the chemical composition of meat viz. dry matter, crude protein, ether extract and total ash and the quality characteristics like pH, shear force value, water holding capacity and colour of breast meat content in the Japanese quail meat fed with different sources oil and its combination. The sensory evaluation of the breast meat had significant ($P<0.05$) difference among the treatments. This study revealed that a combination of 3% linseed oil and 1% sardine fish (LO-3% and SO-1%) was recommended based to produce omega-3 enriched Japanese quail meat.

Acknowledgement

References
1. AOAC, Official methods of analysis.16th ed. Association of Official Analytical Chemists, Washington, DC. 2000.
2. Bratzler LJ. On using the warner-bratzler shear. Proc. 7th Annual Receip. Meat Conf., Chicago, IL. 1954, 154.
3. Bureau of Indian Standards. New Delhi, India. 2007.
4. Bindu J, Ravisankar CN, Srinivasa Gopal TK. Shelf life evaluation of a Ready to eat black cam (*Villoritacy prinoides*) product in indigenous retort pouches. J Food Engineer. 2007; 78:995-1000.
5. Boni H Nurul, Noryati I. "Comparison of meat quality characteristics between young and spent quails," International Food Research Journal. 2010; 17(3):661-667,
6. Ebeid T, Fayoud A, Abou El-Soud S, Eid Y, El-Habbak M. The effect of omega-3 enriched meat production on lipid peroxidation, antioxidative status, immune response and tibia bone characteristics in Japanese quail. Czech J. Anim. Sci. 2011; 56:314-324.
7. Elmali AD, Yakan A, Kaya O, Elmali M, Onk K, Sahin T, Durna O. Effects of plant extracts and (essential) oil mixture on breast meat quality of Japanese quails (*Coturnixcoturnix japonica*). Revue Méd. Vet. 2014; 165:104-110.
8. Grau R, Hamm R. Eineeinfache Methodezur Bestimmung der asser bindungim Muskel. Erstes. 1953; 40:29-30
9. Ikhlas B, Huda N, Noryati I. "Chemical composition and physicochemical properties of meatballs prepared from mechanically deboned quail meat using various types of flour," International Journal of Poultry Science. 2011; 10(1):30-37.
10. Lopez-Ferrer S, Baucells MD, Barroeta AC, Grashorn MA. N-3 Enrichment of Chicken Meat Using Fish Oil: Alternative Substitution with Rapeseed and Linseed Oils. Poult. Sci. 1999; 78:356-365.
11. Lopez-Ferrer S, Baucells MD, Barroeta AC, Grashorn MA. N-3 enrichment of chicken meat. 1. Use of very long-chain fatty acids in chicken diets and their influence on meat quality: Fish oil, Poult. Sci. 2001; 80:741-752.
12. Małgorzata Jakubowska, Józefa Gardzielewska, Danuta Szczerbi´nska, Tadeusz Karamucki, Zofia Tarasewicz, Marek Ligocki, Effect of flax seed in feed on the quality of quail meat. Acta Sci. Pol., Zootechnica, 2012; 11:41-52.
13. Mirghelenj S, Golian A, Taghizadeh. Enrichment of chicken meat with long chain omega 3 fatty acids through dietary fish oil. Res., J Biol. Sci. 2009; 4:604-608.
14. Rymer C, Givens DI. Effect of species and genotype on the efficiency of enrichment of poultry meat with n-3 polyunsaturated fatty acids. Lipids. 2006; 41:445-451.
15. Ribeiro I, Vieira Lopes, Jorge Fernando, Fuentes Zapata, Ednardo Rodrigues Freitas, Daniela Vieira de Souza, *et al*. Meat quality and color of abdominal fat of broilers fed diets containing cashew nut meal treated with

antioxidant. Maringá. 2013; 35:169-174.

16. Sahin K, Sahin N, Kucuk O. Effects of chromium and ascorbic acid supplementation on growth, carcass traits, serum metabolites and antioxidant status of broiler chickens reared at a high ambient temperature (32 °C). Nutr. Res. 2003; 23:225-238.

17. Schiavone A, Romboli I, Chiarini R, Marzoni M. Influence of dietary lipid source and strain on fatty acid composition of Muscovy duck meat. J Anim. Physiol. and Anim. Nutr. 2004; 88:88-93.

18. Shen Y, Feng D, Oresanya TF, Chavez ER. Fatty acid and nitrogen utilization of processed flax seed by adult chickens. J Sci. Food Agric. 2005; 85:1137-1142.

19. Simopoulos AP. Evolutionary aspects of diet, essential fatty acids and cardiovascular disease. European Heart Journal Supplements, 2001; 3:D8-D21

20. Snedecor GW, Cochran WG. Statistical Methods. 8th ed. Iowa State University press, Iowa. USA, 1994.

21. SPSS, Statistical Package for Social Science (SPSS) for windows, Version 17.00. Chicago, IL, USA: SPSS Inc, 2008.

22. Suksombat W, Boonmee T, Lounglawan P. Effects of various levels of conjugated linoleic acid supplementation on fatty acid content and carcass composition of broilers. Poult Sci. 2007; 86:318-324.

23. Troutt ES, Hunt MC, Johnson DE, Claus JR, Kastner CL, Krof DH. Characteristics of low fat ground beef containing texture - modifying ingredients. Journal of food science. 1992; 57:19-24

24. Umit Gecgel, Ismail Yilmaz, Eser Kemal Gurcan, Salih Karasu, Gizem Cagla Dulger. Comparison of Fatty Acid Composition between Female and Male Japanese quail Meats. Journal of Chemistry, 2015, 1-8. Article ID 569746, http://dx.doi.org/10.1155/2015/569746

25. Vali N. The Japanese quail: A review. Inter J Poult Sci., 2008; 7:925-931.

26. Yamany AT, El MH, Hewida El, Allawy D Laila, Abd El-Samee, EL Ghamry AA. Evaluation of using different levels and sources of oil in growing Japanese quail diets. American-Eurasian J Agric. & Environ. Sci. 2008; 3:577-582.