EFFECT OF OMEGA-3 FATTY ACID ENRICHED FEED SUPPLEMENT ON BROILER PERFORMANCE AND CARCASS QUALITY

Deanna Joy M. Marco[1], Sonia P. Acda[2], Domingo B. Roxas[2] and Florinia E. Merca[3]

ABSTRACT

A study was conducted to determine the effect of omega-3 fatty acid enriched feed supplement on performance and carcass quality of broilers. A total of 250 seven day-old Cobb broiler chicks were randomly assigned to five treatments in a completely randomized design. The treatments were: diet with coconut oil (control) and diets with omega-3 fatty acid enriched feed supplement (n-3 FAS) replacing coconut oil at 25, 50, 75 and 100% (full replacement). Performance parameters (body weight gain, feed intake, feed efficiency, livability rate and dressing percentage) and organoleptic characteristics and fatty acid composition of meat were determined. The performance and organoleptic characteristics of broiler meat did not differ (P>0.05) among treatments. The concentration of omega-3 fatty acid (alpha linolenic acid) in thigh meat increased (P<0.05) upon complete replacement of coconut with n-3FAS. The n-3 FAS can, therefore, be used to replace coconut oil in the diet at any level without affecting the performance and carcass quality of birds. It can also be used to enrich the broiler meat with omega-3 fatty acid.

Keywords: alpha-linolenic acid, broiler, omega-3 fatty acid, organoleptic characteristics, performance parameters

INTRODUCTION

Consumers are now becoming more aware of the effect of diet on health and are associating dietary choices with long-term health objectives (Zuidhof *et al*. 2009). The potential health benefits of omega-3 fatty acids have been widely reported for several conditions including cardiovascular disease, hypertension, atherosclerosis, brain development, diabetes, cancer, arthritis, inflammatory, autoimmune and neurological disorders. Omega-3 fatty acids have been used therapeutically for these diseases (Guilliams, 2000). As a result, consumer awareness of the health benefits of omega-3 fatty acids is growing and this drives the demand for enriched food products. Also, it opens opportunities for the animal

[1]Congressional Ave., cor. San Beda St., Quezon City, Philippines (e-mail: deannajoym@yahoo.com); [2]Animal and Dairy Sciences Cluster, College of Agriculture, University of the Philippines Los Baños (UPLB), Laguna, Philippines; [3]Institute of Chemistry, College of Arts and Sciences, UPLB, Laguna, Philippines.

production sector to add value to their products.

Attempts have been made to enrich broiler muscle tissues or products with linolenic acid and its elongated omega-3 fatty acids (Mirghelenj *et al*., 2009; Lopez-Ferrer *et al*., 1999; Lopez-Ferrer *et al*., 2001). One of the approaches to enrich chicken meat with omega-3 fatty acid is by incorporating omega-3 containing ingredients such as marine sources and vegetable sources into the animal diet.

Marine products, like fish oil, are very good sources of omega-3 fatty acids such as eicosapentaenoic acid and docosahexaenoic acid. However, in various studies the use of fish oil to enrich broiler meat with omega-3 resulted in deterioration of the sensory quality of meat (Lopez-Ferrer *et al*., 1999; Alsparlan and Ozdogan, 2006). Omega-3 fatty acid can also be obtained from polyunsaturated fatty acid rich oil seeds, like flax seed and canola seed. These seeds contain high amounts of alpha-linolenic acid. In addition, flax seed and canola seed could serve as alternative sources of dietary energy for the bird. In the Philippines, coconut oil is widely used as dietary energy supplement in animal feeds. However, the price of coconut oil is said to be unstable due to increasing demand as it is an important raw material in biodiesel production. Also, coconut oil has low omega-3 fatty acid.

This study was conducted to determine the effect of omega-3 fatty acid enriched feed supplement on broiler performance, sensory quality and fatty acid composition of broiler meat.

MATERIALS AND METHODS

Omega-3 fatty acid enriched feed supplement

The omega-3 fatty acid enriched feed supplement was used in the study as a source of metabolizable energy (5380 kcal/kg), omega-3 fatty acid (linolenic-17.09%) and protein (20.7%). It is a scientific blend of cooked and hydrolyzed whole flax seed, whole canola seed, canola meal and field peas and manufactured under Hazard Analysis Critical Control Point (HACCP). Table 1 shows the nutrient composition of the omega-3 fatty acid enriched feed supplement.

Experimental design, birds and diets

A total of 300 day-old straight-run Cobb broiler chicks were group-brooded. After 7 days of brooding, 250 birds with about the same size and weight were selected and randomly distributed to 50 cages with five birds per cage. Five treatments were assigned to the 50 cages following a completely randomized design. The dietary treatments consisted of: 1) diet with coconut oil; 2) 25% of coconut oil being replaced with n-3 FAS; 3) 50% of coconut oil being replaced with n -3 FAS; 4) 75% of coconut oil being replaced with n-3 FAS; and 5) diet with n-3 FAS completely replacing coconut oil.

The composition and calculated nutrient analysis of the diets are presented in Tables 2 and 3. Diets were formulated isocaloric at 2990 kcal/kg for broiler starter (BS) and 3084 kcal/kg for broiler finisher (BF) diet, and isonitrogenous with 21% CP for BS and 19% CP for BF (Unpublished report).

Coconut oil as dietary energy supplement in treatment 1 was replaced with

Table 1. Nutrient composition of the omega-3 fatty acid enriched feed supplement.*

Nutrient	Amount
Proximate components, % as fed	
Crude protein	20.70
Crude fiber	5.00
Crude fat	41.40
Metabolizable energy, kcal/kg	5380
Minerals, %	
Calcium	0.42
Available phosphorus	0.20
Total phosphorus	0.72
Potassium	1.20
Magnesium	0.35
Sodiuim	001
Sulfur	0.40
Amino acids, %	
Lysine	1.20
Methionine + cystine	0.93
Methionine	0.40
Tryptophan	0.23
Threonine	0.86
Fatty acids, % of total fat	
Oleic	58.46
Linoleic	20.84
Linolenic	17.09

*Data provided by the manufacturer of the test material.

omega-3 fatty acid enriched feed supplement partially at 25%, 50% and 75% for dietary treatments 2, 3 and 4, respectively, and completely for dietary treatment 5 based on the caloric value. The omega-3 fatty acid enriched feed supplement had a caloric value (ME) of 5380 kcal/kg. To keep the diets isocaloric and isonitrogenous, other ingredients were modified. Diets were supplemented with required amount of vitamins, amino acids and minerals.

Feeding trial

Day-old broiler chicks were group-brooded and fed a commercial booster ration from day 1 to day 7. Starter feeds were given from day 8 to day 28. From day 29, the finisher feeds were provided until the birds reached 42 days of age. All birds in all treatments were given similar care and management practices throughout the feeding trial. Feeds and water were made available at all times.

Live weights and feed intake were determined on the 29^{th} and 42^{nd} day of the trial. Feed efficiency was computed by dividing the feed consumed by the total weight gain of the broilers. Mortality was monitored on a daily basis.

Table 2. Ingredient composition and calculated nutrient content of broiler starter diets (as fed).

Ingredient	Dietary treatment*				
	1	2	3	4	5
	100:0	75:25	50:50	25:75	0:100
Yellow corn	53.31	54.70	55.28	56.28	57.71
US Soybean meal	31.62	31.27	30.87	30.55	30.50
Rice bran D1	7.95	6.94	5.93	4.87	2.08
Lysine	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.34	0.34	0.34	0.33	0.33
Limestone	1.60	1.60	1.60	1.60	1.60
Monodicalcium phosphate	1.90	1.90	1.90	1.90	1.90
Molasses	0	0	0	0	1.00
Coconut oil	2.50	1.88	1.25	0.62	0
Omega-3 feed supplement	0	1.02	2.05	3.07	4.10
Coccidiostat	0.05	0.05	0.05	0.05	0.05
Choline chloride	0.10	0.10	0.10	0.10	0.10
Salt	0.20	0.20	0.20	0.20	0.20
Vitamin concentrate[1]	0.08	0.08	0.08	0.08	0.08
Mineral premix	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100
Calculated analysis					
ME, kcal/kg	2990	2990	2990	2990	2990
Crude protein, %	21.14	21.14	21.12	21.12	21.12
Crude fiber, %	3.06	3.07	3.07	3.07	2.99
Ether extract, %	5.57	5.28	4.98	4.68	4.23
Calcium, %	1.04	1.05	1.05	1.05	1.06
Available phosphorus, %	0.51	0.51	0.51	0.51	0.50
Total phosphorus, %	0.86	0.85	0.84	0.84	0.81
Lysine, %	1.28	1.28	1.28	1.28	1.27
Methionine + Cystine, %	0.89	0.89	0.89	0.89	0.89
Threonine, %	0.65	0.66	0.66	0.66	0.66
Tryptophan, %	0.22	0.22	0.22	0.22	0.22
Omega-3 f.a (Linolenic)	0.07	0.14	0.21	0.28	0.35

*Level of replacement (% coconut oil: % omega-3 feed supplement).

[1]Per kg vitamin premix contains: Vit A 16,000,000 IU; Vit D_3 36,000,000 IU; Vit E 300 g; Vit K_3 4g; Vit B_1 4g; Vit B_2 14g; Vit B_6 6g; Vit B_{12} 0.03g; Niacin 100g; Pantothenic acid 20g; Folic acid 2g; Biotin 0.30g .

Carcass and sensory evaluation

At the end of the feeding trial, one bird from each replicate of each treatment was randomly sampled to determine the dressing percentage. Three carcasses per treatment were randomly selected and stored in the freezer (-18ºC) for 2 weeks and used for sensory evaluation and fatty acid analysis.

Table 3. Ingredient composition and calculated nutrient content of broiler finisher diets (as fed).

Ingredient	Dietary treatment*				
	1	2	3	4	5
	100:0	75:25	50:50	25:75	0:100
Yellow corn	54.30	55.78	57.18	58.70	60.97
US Soybean meal	27.45	26.50	25.79	25.24	24.80
Rice bran D1	10.05	8.92	7.62	6.06	2.51
Lysine	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.34	0.34	0.34	0.34	0.34
Limestone	1.60	1.60	1.60	1.60	1.60
Monodicalcium phosphate	1.78	1.78	1.78	1.78	1.90
Molasses	0	0	0	0	1.00
Coconut oil	3.75	2.81	1.88	0.94	0
Omega-3 feed supplement	0	1.54	3.08	4.61	6.15
Coccidiostat	0	0	0	0	0
Choline chloride	0.10	0.10	0.10	0.10	0.10
Salt	0.20	0.20	0.20	0.20	0.20
Vitamin concentrate[1]	0.08	0.08	0.08	0.08	0.08
Mineral premix	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100
Calculated analysis					
ME, kcal/kg	3084	3084	3084	3084	3084
Crude protein, %	19.49	19.34	19.27	19.26	19.14
Crude fiber, %	3.11	3.13	3.14	3.14	3.04
Ether extract, %	7.04	6.64	6.23	5.78	5.16
Calcium, %	1.01	1.02	1.02	1.03	1.06
Available phosphorus, %	0.49	0.49	0.49	0.49	0.50
Total phosphorus, %	0.84	0.83	0.83	0.82	0.81
Lysine, %	1.16	1.15	1.14	1.13	1.12
Methionine + Cystine, %	0.84	0.84	0.84	0.84	0.84
Threonine, %	0.60	0.60	0.60	0.60	0.60
Tryptophan, %	0.20	0.20	0.20	0.20	0.20
Omega-3 f.a (Linolenic)	0.06	0.17	0.28	0.38	0.49

*Level of replacement (% coconut oil: % omega-3 feed supplement).

[1] Per kg vitamin premix contains: Vit A 16,000,000 IU; Vit D_3 36,000,000 IU; Vit E 300 g; Vit K_3 4g; Vit B_1 4g; Vit B_2 14g; Vit B_6 6g; Vit B_{12} 0.03g; Niacin 100g; Pantothenic acid 20g; Folic acid 2g; Biotin 0.30g.

Breast meat samples were evaluated based on the organoleptic characteristics: flavor, off-flavor, tenderness, juiciness and general acceptability. Eleven experienced sensory panelists evaluated the meat samples for three consecutive days. Carcasses were thawed for 10 hours at room temperature prior to

the evaluation date. The samples were cooked by steaming until the internal temperature reached 71.11ºC. Small servings of cooked samples were evaluated using a modified nine-point hedonic scale (Peryam and Pilgrim, 1957).

Analyses

Fatty acid content of thigh meats (with skin) was determined by slicing (paper-thin) and freeze-drying meat samples and submitting them to the National Institute of Molecular Biology and Biotechnology for fatty acid analysis using gas chromatography.

Production parameters data and fatty acid composition of meat were subjected to analysis of variance in completely randomized design and randomized complete block design for sensory evaluation with sensory panelist as the block to lessen the variability due to panelist response.

RESULTS AND DISCUSSION

Performance parameters

The effect of replacing coconut oil with omega-3 fatty acid enriched feed supplement on performance of birds is shown in Table 4. The birds' performance (live weight gain, feed intake, feed efficiency, livability rate and dressing percentage) was not affected (P>0.05) when coconut oil was replaced with omega-3 fatty acid enriched feed supplement in the diet throughout the trial. Birds received similar nutrients since diets were formulated isocaloric and isonitrogenous.

In contrast, studies conducted by Zuidhof *et al*. (2009) and Rahimi *et al.* (2011) showed a poorer performance after the birds were fed flax seed and canola seed. Results were attributed to the drawbacks in feeding flax seed to birds such as presence of anti-nutritional factors and digestibility problems. However, flax processing technologies such as mild heat treatment may eliminate some of these drawbacks (Gonzalez-Esquerra and Leeson, 2001). In this study, flax seed and canola seed were cooked, hydrolyzed and manufactured under HACCP.

Sensory evaluation

Table 5 shows the effect of replacing coconut oil with omega-3 fatty acid enriched feed supplement on meat sensory quality. Results showed that replacing coconut oil with n-3FAS did not affect (P>0.05) the organoleptic characteristics (flavor, off-flavor, tenderness, juiciness and general acceptability) of broiler meat.

In previous studies (Chekani-Azar *et al*., 2008; Mirghelenj *et al*., 2009), unacceptable odors were detected in carcass of chickens when diet was enriched with omega-3 fatty acid, due to the kind of ingredient used in these studies. The use of canola seed and flax seed as source of omega-3 resulted to a lesser degree of off -flavors compared to fish oil (Lopez- Ferrer *et al*., 2001).

Fatty acid composition

Table 6 shows the effect of replacing coconut oil with omega-3 fatty enriched feed supplement on fatty acid composition of thigh meat with skin. The capric, lauric and myristic acid contents of the thigh meat decreased (P<0.05) with corresponding

Table 4. Effect of replacing coconut oil with omega-3 fatty acid enriched feed supplement on performance of birds.

Parameter	Dietary treatment*					%CV	Prob.
	1	2	3	4	5		
	100:0	75:25	50:50	25:75	0:100		
Feed intake, g							
8d-28d	1809	1798	1797	1816	1813	1.75	0.5689
29d-42d	1988	2122	2028	2224	2075		
8d-42d	3797	3920	3825	4040	3888	5.62	0.1276
Live weight gain, g							
8d-28d	1146	1133	1158	1147	1157	6.78	0.5122
29d-42d	976	1022	1048	1006	948		
8d-42d	2123	2155	2206	2153	2105	6.15	0.5014
Feed efficiency							
8d-28d	1.58	1.59	1.57	1.59	1.57	7.01	0.9858
29d-42d	2.05	2.11	1.94	2.27	2.23		
8d-42d	1.79	1.82	1.74	1.90	1.85	9.48	0.3330
Livability rate	99	99	100	100	98	2.77	0.4571
Dressing percentage	72.13	70.95	72.33	71.61	70.08	4.07	0.4188

No significant differences on performance of birds were observed among treatments (P>0.05).

*Level of replacement (% coconut oil: % omega-3 feed supplement).

decrease in the amount of coconut oil and increase in the amount of omega-3 fatty acid enriched feed supplement in the diet. On the other hand, the amount of oleic and linolenic acid in the thigh meat increased (P<0.05). This was attributed to the fact that coconut oil is composed mainly of saturated fatty acids especially lauric acid while the omega-3 fatty acid enriched feed supplement is rich in unsaturated fatty acids. The fatty acid composition of the broiler meat was altered by changing the fatty acid content of the broiler diets.

Replacing coconut oil with omega-3 fatty acid enriched feed supplement in the diet increased the proportion of omega-3 fatty acid in the form of ALA. More importantly, replacing coconut oil with omega-3 fatty acid enriched feed supplement at any level met the minimum level of 300 mg/100 g of meat to label the product omega-3 PUFA enriched as recommended by the Canadian Food Inspection Agency (Zuidhof *et al*., 2009). Also, meat from birds fed diet with omega-3 fatty acid enriched feed supplement fully replacing coconut oil had approximately 2.52 % ALA, and it was calculated that a serving size of 220 g meat would be required to meet the recommended daily intake of ALA (2200 mg) set by the International Society for the Study of Fatty Acids and Lipids (Zuidhof *et al*., 2009).

Table 5. Effect of replacing coconut oil with omega-3 fatty acid enriched feed supplement on meat sensory quality.

Quality attribute	Dietary treatment*					%CV	Prob.
	1	2	3	4	5		
	100:0	75:25	50:50	25:75	0:100		
Flavor	4.91	5.33	5.06	5.27	5.03	19.22	0.3769
Off-flavor	1.12	1.12	1.36	1.21	1.18	36.41	0.2613
Tenderness	5.33	5.39	5.36	5.61	5.33	18.92	0.7982
Juiciness	4.48	4.82	4.91	4.67	4.48	22.85	0.3741
General acceptability	4.73	5.21	4.85	5.0	4.61	20.26	0.1149

*Level of replacement (%coconut oil: %omega-3fatty acid enriched feed supplement).

No significant differences on meat sensory quality were observed among treatments (P>0.05).

Flavor: 1= very weak flavor, 2= moderately weak flavor, 3= slightly weak flavor, 4= neither full nor weak flavor, 5= slightly full flavor, 6= full flavor, 7= very rich flavor characteristics.

Off- flavor: 1= slightly perceptible, 2= moderately perceptible, 3= highly perceptible, 4= neither strong nor perceptible, 5= slightly strong off-flavor, 6= strong off-flavor, 7= very strong off-flavor.

Juiciness: 1= very dry, 2= moderately dry, 3= slightly dry, 4= neither juicy nor dry, 5= slightly juicy, 6= juicy, 7= very juicy.

Tenderness: 1= very tough, 2= moderately tough, 3= slightly tough, 4= neither tender nor tough, 5= slightly tender, 6= tender, 7= very tender.

General Acceptability: 1= very undesirable, 2= moderately undesirable, 3= slightly undesirable, 4= neither desirable nor undesirable, 5= slightly desirable, 6= desirable, 7= very desirable.

CONCLUSION

Based on the result of the study, replacing coconut oil with omega-3 fatty acid enriched feed supplement is acceptable without compromising the growth performance and meat quality of broilers. In addition, the omega-3 fatty acid enriched feed supplement can be used to produce omega-3 enriched chicken meat and a premium price can be levied on omega-3 enriched chicken meat which can subsequently benefit both the consumer and the producer.

Table 6. Effect of replacing coconut oil with omega-3 fatty acid enriched feed supplement on fatty acid composition of thigh meat with skin (%, as analyzed).

Fatty acid	Dietary treatment					%CV	Prob.
	1	2	3	4	5		
	100:0	75:25	50:50	25:75	0:100		
Caprylic acid^{ns}	0.15	0.04	0.04	0	0	196.54	0.2861
Capric acid	0.37^{a}	0.33^{a}	0.33^{a}	0^{b}	0.08^{b}	47.08	0.0004
Lauric acid	7.94^{a}	7.01^{a}	7.01^{a}	3.51^{b}	0.78^{c}	18.59	0.0001
Myristic acid	4.64^{a}	4.29^{a}	4.29^{a}	2.48^{b}	0.71^{c}	18.01	0.0001
Penta-decanoic acid	0.66^{a}	0.60^{ab}	0.60^{ab}	0.43^{b}	0.12^{c}	22.7	0.0006
Palmitic acid	24.43^{ab}	22.03^{b}	22.03^{b}	26.5^{a}	22.76^{b}	5.76	0.0219
Palmi-toleic acid^{ns}	7.29	6.29	6.29	7.45	7.61	12.91	0.3027
Stearic acid	4.74a^{b}	4.42	4.42^{b}	5.33^{a}	4.14^{b}	8.72	0.0381
Oleic acid	35.69^{b}	36.1^{b}	40.58^{a}	40.88^{a}	42.5^{a}	5.01	0.0051
Linoleic acid^{ns}	6.87	13.73	9.26	6.17	15.3	52.58	0.1485
Linolenic acid	0.08^{b}	0.64^{ab}	0.68^{ab}	1.04^{ab}	2.52^{a}	72.02	0.0175

^{abc}: Row means with different superscripts are different (P<0.05).

*Level of replacement (% coconut oil: % omega-3 fatty acid enriched feed supplement).

ACKNOWLEDGEMENT

Partial financial support and test material for this study were provided by XFE products and DOST-ASTHRDP. The authors would also like to thank St. Louis Golden Harvest Agro-Industrial Corp. for mixing the feeds and INAVET Nutrition Technologies Inc. and Triple F for the assistance and support.

REFERENCES

AOAC**.** 1995. *Association of Official Analytical Chemists Official Method of Analysis*. Cunnif P (ed.). Virginia: AOAC International.

Alsparlan G and Ozdogan M. 2006. The effects of diet containing fish oil on some blood parameter and the performance values of broilers and cost efficiency. *Int J Poult Sci* 5 (5): 415-419.

Chekani-Azar S, Shahriar HA, Maheri-Sis N, Ahmazadeh AR and Vahdatpoor T. 2008. Omega-3 fatty acids enrichment and organoleptic characteristics of broiler meat. *Asian J Anim Vet Adv* 3 (2): 62-69.

Gonzalez-Esquerra R and Leeson S. 2001. Alternatives for enrichment of eggs and chicken meat with omega-3 fatty acids. *Can J Anim Sci* 81: 295-305.

Guilliams TG. 2000. Fatty Acids: Essential…Therapeutic. *The Standards* 3 (2): 1-7.

Lopez-Ferrer S, Baucells MD, Barroeta AC and Grashorn MA. 1999**.** N-3 enrichment of chicken meat using fish oil: alternative substitution with rapeseed and linseed oils. *Poult Sci* 78: 356-365.

Lopez-Ferrer S, Baucells MD, Barroeta AC, Galobart J and Grashorn MA. 2001. N-3 enrichment of chicken meat. 2. Use of precursors of long-chain polyunsaturated fatty acids: Linseed oil. *Poult Sci* 80: 753-761.

Mirghelenj S, Golian A and Taghizadeh. 2009. Enrichment of chicken meat with long chain omega 3 fatty acids through dietary fish oil. *Res J Biol Sci* 4: 604-08.

Peryam DR and Pilgrim FJ**.** 1957. Hedonic scale method of measuring food preferences. *Food Tech* 11: 9-14.

Rahimi S, Kamran-Azad S and Karimi Torshizi MA. 2011. Omega-3 enrichment of broiler meat using two oil seeds. *J Agr SciTech* 13: 353-365.

Zuidhof MJ, Betti M, Korver DR, Hernandez FIL, Schneider BL, Carney VL and Renema RA. 2009. Omega-3-enriched broiler meat: 1. Optimization of a production system. *Poult Sci* 88: 1108-1120.