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Improved Nutritional Value of Broiler Meat as Healthy Food by Feeding Chickens Blends of Vegetable Oils

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Abstract

The study was conducted to improve the nutritional value of poultry meat as a healthy food for humans. The responses of serum lipid profile, lipid oxidation and fatty acids profile in broiler chickens were assessed by feeding different levels of oil blend. The diet supplemented with palm oil (PO), soybean oil (SO) and linseed oil (LO) with a ratio of 4:1:1 PO, SO and LO, respectively. A total of 216 one-day-old broiler chicks (Cobb 500) were randomly assigned to six dietary treatments. Each treatment consisted with six replicates (pens) and six birds in each. The dietary treatments supplemented with oil blend at 0%, 2%, 4%, 6%, 8%, and 10%. Increasing the level of oil blend resulted in an increase in the total n-3 and n-6 fatty acids (FA) and a reduction in n-6: n-3 fatty acid ratio (FAR) in the breast muscle tissues. Serum cholesterol, triacylglycerol and breast muscle cholesterol significantly decreased with increasing the level of oil blend in broiler diets. The combination of PO, SO and LO can be incorporated in broiler diets to increase the levels of n-3 long chain polyunsaturated fatty acid (LCPUFA) and decrease n-6: n-3 FAR and decrease cholesterol content in breast meat.

Keywords: broiler, oil blend, serum lipid profile, fatty acid composition.

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Introduction

Supplementation of poultry feeds with dietary oils has significant advantages. Oil can be used as a cheap source of dietary energy (Sahito et al., 2012). Additionally, dietary oils may improve the utilization of fat-soluble vitamins (Baião and Lara, 2005) by reducing dustiness, enhancing palatability of diets and may as well improve the efficient utilization of energy (Monfaredi et al., 2011). Furthermore, dietary fat lowers the rate of feeds movement into the gastro intestinal tract, which offers an alternative for better utilization of all nutrients in diet (Firman et al., 2008). Despite benefits of dietary oil in poultry feeds, there are some shortcomings. Supplementation of high level of oils rich in saturated fatty acid (SFA) in broiler diets affects carcass composition and increase abdominal fat deposition (Fouad and El-Senousey, 2014; Abdulla et al., 2019). Dietary oils rich in unsaturated fatty acids (UFA) can increase lipid oxidation and negatively affect the color and flavor of poultry meat (Saleh et al., 2010).(Abdulla et al., 2015; Abdulla et al., 2016) observed that birds fed diet supplemented with 6% of palm oil (PO), which is rich in SFA, increased abdominal fat and however decreased lipid oxidation. In contrast, birds fed diets supplemented with 6% linseed oil, which is rich in UFA, decreased body weight and increased lipid oxidation in breast muscle. In most cases, studies have been conducted in rodents and ruminants where the breakdown of lipids is different from that of broiler chickens which has limited studies. Thus, this study is aimed at examining the effects of using different levels of blended palm, soybean and linseed oil in a ratio of 4:1:1 on serum lipid profile, fatty acid profile (FA), and meat cholesterol in broiler chicken.

Materials and methods

Birds and experimental diets

The current experiment was piloted following the recommendations made by the animal welfare ethics of the Research Policy of University Putra Malaysia. A total of 216 Cobb 500 one-day-old male broiler chicks were bought from a local hatchery. Each bird was weighed and tagged by the wing, and randomly allotted into 36 pens with 6 chicks per pen. Birds were raised in a deep litter system at the Poultry Unit of the Department of Animal Science, Faculty of Agriculture, University Putra Malaysia (UPM). Six different diets were formulated in the feed factory at the Poultry Unit, and supplemented with oil blend at 0%, 2%, 4%, 6%, 8%, and 10%. The oil blend was a combined of palm oil (PO), soybean oil (SO) and linseed oil (LO) in a ratio of 4:1:1, respectively. Each treatment consisted of 6 replicates (pens), and the feeding trial lasted for 42 days. Feeds and water were provided *ad libitum*. The birds were vaccinated against infectious bronchitis disease (IB), Newcastle disease and infectious bursal disease (IBD) as described by Alshelmani et al. (2017). All the experimental feeds were isocaloric and isonitrogenous and formulated based on nutrient requirements of poultry (NRC, 1994). The FA compositions of finisher (22 – 42 days) diet in this experiment is shown in Table 1.

Table (1). Fatty acid composition (percentage of total fatty acids identified) in finisher diet[1]

Fatty acid (%)	Dietary treatments[9]						SEM[8]
	0%	2%	4%	6%	8%	10%	
C14:0	0.31	0.28	0.42	0.50	0.52	0.60	0.03
C16:0	13.35	19.06	22.31	24.45	25.01	26.69	1.09
C16:1n-7	0.24	0.24	0.25	0.23	0.21	0.20	0.00
C18:0	2.21	2.80	3.33	3.56	3.52	3.73	0.13
C18:1n-9	27.42	30.42	32.14	33.11	33.11	33.66	0.52
C18:2n-6	53.06	41.10	33.79	29.23	28.57	25.36	2.29
C18:3n-3	2.23	5.24	7.08	8.45	8.57	9.25	0.59
C20:4n-6	0.24	0.20	0.19	0.18	0.16	0.16	0.01
C20:5n-3	0.37	0.22	0.17	0.10	0.07	0.05	0.04
C22:5n-3	0.30	0.21	0.17	0.14	0.13	0.11	0.02
C22:6n-3	0.24	0.19	0.14	0.13	0.11	0.09	0.01
SFA[2]	15.88	22.15	26.07	28.51	29.05	31.04	1.24
USFA[3]	84.12	77.85	73.93	71.48	70.94	68.95	1.24
MUSFA[4]	27.66	30.66	32.38	33.25	33.32	33.87	0.52
PUFAn-3[5]	3.15	5.87	7.56	8.81	8.87	9.57	0.54
PUFAn-6[6]	53.31	41.30	33.98	29.41	28.74	25.52	2.29
n-6: n-3 ratio[7]	16.94	7.03	4.49	3.33	3.23	2.67	1.21
USFA: SFA	5.29	3.51	2.83	2.50	2.44	2.22	0.25
PUFA: SFA	3.55	2.13	1.59	1.34	1.29	1.13	0.20

[1]The data was expressed as the percentage of fatty acids identified.
[2]Total saturated fatty acids= sum of C14:0+ C16:0+C18:0.
[3]Total unsaturated fatty acids= sum of C16:1+ C18:1n-9+ C18:2n-6+C18:3n-3+C20:4n 6+C20:5n-3 +C22:5n-3+C22:6n-3. [4]Total monounsaturated fatty acids= sum of C16:1n-7+C18:1n-9.
[5]polyunsaturated fatty acids n-3 = sum of C18:3n-3+C20:5n-3+C22:5 n-3+C22:6n-3.
[6]polyunsaturated fatty acid n-6 = sum of C18:2n-6+C18:3n-6+C20:4n-6.
[7]polyunsaturated fatty acids n-6: polyunsaturated fatty acids n-3= (C18:2n-6+C18:3n-6+C20:4n-6) ÷ (C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3).
[8]SEM: Standard error of mean.
[9]Oil blend: 4:1:1 of PO, SO and LO.

Samples and data collection

At the end of feeding trial (42 day), 12 broiler chickens from each treatment were selected and slaughtered by neck cutting, and prepared for blood sampling and breast meat for further analysis. Samples from the *Pectoralis major* (breast) muscle were removed within 45 min after slaughter from all carcasses. Immediately after removal, muscle samples were instantly iced up in liquid nitrogen and kept at -80°C until consequent analyses. Samples from the breast muscle were collected for the

determination of total cholesterol and fatty acids composition. Blood samples were collected for serum lipid profile.

Serum lipid profile

Plain serum tubes were used for collecting blood samples for serum lipid profile. Blood samples were centrifuged for 10 min at a speed of 3000 *g*; the supernatants (serum) were transferred into 2 mL eppendorff tubes and kept at -80 °C until analysis. An automatic analyser (Automatic analyser 902, Hitachi, Germany) was used in determining the serum total cholesterol, triacylglycerol, and high density lipoprotein cholesterol (HDL). Friedewald Equation was used to determine the levels of low density lipoprotein cholesterol (LDL) and very low density lipoprotein cholesterol (VLDL) (Friedewald et al., 1972).

LDL cholesterol = Total cholesterol - HDL cholesterol- VLDL cholesterol.

Where VLDL cholesterol = Triacylglycerol/5

Analysis of cholesterol and fatty acid in breast muscle tissues

Extraction of fats from breast muscle tissues following the protocols of Folch et al. (1957), by adding chloroform: methanol (2: 1, v/v). extracted fats were converted to their fatty acid methyl esters (FAME) by trans methylation and adding 0.66 N of KOH in methanol and 14% methanolic boron trifluoride (BF_3) in line with the procedures outlined by AOAC (2007). The fatty acid methyl esters (FAME) were split by gas liquid chromatography (GC) on an Agilent 7890A GC system and quantified as defined by Abdulla et al. (2015). The muscle cholesterol content was quantified following the protocol of Rudel and Morris (1973), described by Abdulla et al. (2015).

Statistical analysis

The experiment was a completely randomized design. Statistical analysis was performed using the Generalized Linear Model (GLM) procedures of Statistical Analysis System (SAS) package Version 9.2 software (SAS, 2007). Duncan's Multiple Range Test was used to compare the means of treatments at probability ($P < 0.05$).Orthogonal contrasts (linear and quadratic effects) were tested with coefficients estimated based on the level of dietary oil blend.

Results and Discussions

Fatty acid profiles of breast muscle tissue

Table 2 shows the effect of feeding different levels of oil blend and the fatty acid composition in breast muscle tissues of broilers. Increasing the level of oil blended diets amplified the concentrations of C14:0, C20:5n-3 (linear, $P< 0.01$ and quadratic $P< 0.01$), C18:3n-3 ($P< 0.01$), C18:2n-6, C22:6n-3 (linear, $P< 0.01$) and C18:0 (Quadratic, $P< 0.01$).

On contrary, concentrations of the following FA decreased as the level of oil blend increased: C16:1, C18:1n-9 (linear, $P< 0.01$ and quadratic $P< 0.01$), C16:0 ($P< 0.05$) and C22:5n-3 (linear, $P< 0.01$). Dietary oil blend had no effect on total SFA and USFA. Though, the total n-3 and n-6 PUFA increased linearly with increasing dietary levels of oil blend. In contrast, the total MUFA decreased (linear, $P< 0.01$ and quadratic $P< 0.01$) with increasing level of oil blends. Furthermore, the ratio between n-6: n-3 FA

decreased (linear, P< 0.01 and quadratic P< 0.01), while the PUFA: SFA ratio increased (linear, P< 0.01) with increasing level of oil blend.

Table (2). The composition of fatty acids (percentage of total identified fatty acids) in breast muscle tissues of broiler chicken fed diets containing different levels of oil blend[1]

Fatty acid (%)	Dietary treatments[9]						SEM[8]	P- Value	
	0%	2%	4%	6%	8%	10%		Line.	Quad
C14:0	0.18 ^{c}	0.80 ^{b}	1.52 ^{a}	1.75 ^{a}	1.38 ^{a}	1.41^{a}	0.09	0.001	0.001
C16:0	26.97 ^{a}	26.20^{ab}	25.63 ^{b}	26.26^{ab}	25.66 ^{b}	25.79^{ab}	0.17	0.042	0.237
C16:1n-7	6.55 ^{a}	4.93 ^{b}	3.87 ^{c}	2.57^{de}	2.76 ^{d}	1.73 ^{e}	0.26	0.001	0.005
C18:0	7.57 ^{b}	8.10^{ab}	8.21^{ab}	8.75 ^{a}	8.12^{ab}	7.76 ^{b}	0.11	0.455	0.002
C18:1n-9	36.07 ^{a}	33.97^{ab}	33.09 ^{b}	28.92 ^{c}	30.00 ^{c}	29.37 ^{c}	0.49	0.001	0.045
C18:2n-6	14.27 ^{d}	16.45 ^{c}	17.28 ^{c}	19.63 ^{b}	20.05 ^{b}	21.97 ^{a}	0.41	0.001	0.470
C18:3n-3	0.91 ^{d}	1.76 ^{c}	2.62 ^{b}	2.83 ^{b}	4.24 ^{a}	4.41 ^{a}	0.20	0.286	0.532
C20:4n-6	3.72 ^{ab}	4.16 ^{ab}	3.51 ^{ab}	4.23 ^{a}	3.19 ^{b}	3.58 ^{ab}	0.13	0.286	0.532
C20:5n-3	0.63 ^{c}	0.77^{bc}	0.95^{abc}	1.25 ^{a}	1.13 ^{ab}	1.05 ^{ab}	0.06	0.001	0.041
C22:5n-3	1.20 ^{a}	1.09 ^{a}	1.05 ^{a}	1.06 ^{a}	0.68 ^{b}	0.74 ^{b}	0.04	0.001	0.462
C22:6n-3	1.24 ^{c}	1.58 ^{c}	1.88 ^{abc}	2.67 ^{a}	2.23 ^{ab}	2.57 ^{a}	0.13	0.002	0.230
SFA[2]	34.73 ^{b}	35.12^{ab}	35.25^{ab}	36.78 ^{a}	34.75 ^{b}	34.97^{ab}	0.25	0.752	0.098
USFA[3]	65.26 ^{a}	64.88^{ab}	64.28^{ab}	63.21 ^{b}	65.24 ^{a}	65.02^{ab}	0.26	0.820	0.054
MUSFA[4]	43.26 ^{a}	38.90 ^{b}	36.96 ^{b}	31.50 ^{c}	33.18 ^{c}	31.10 ^{c}	0.76	0.001	0.012
PUFAn-3[5]	3.99 ^{d}	5.20 ^{c}	6.30 ^{b}	7.84 ^{a}	8.20 ^{a}	8.78 ^{a}	0.29	0.001	0.083
PUFAn-6[6]	18.00 ^{c}	20.62 ^{b}	20.80 ^{b}	23.87 ^{a}	23.86 ^{a}	25.14 ^{a}	0.44	0.001	0.219
n-6: n-3 R[7]	4.84 ^{a}	3.87 ^{b}	3.21 ^{bc}	2.98 ^{c}	2.92 ^{c}	2.81 ^{c}	0.14	0.001	0.003
USFA: SFA	1.88	1.84	1.80	1.72	1.89	1.87	0.02	0.373	0.023
PUFA: SFA	0.63 ^{d}	0.74 ^{c}	0.75 ^{c}	0.86 ^{b}	0.88 ^{b}	0.97 ^{a}	0.02	0.001	0.880

^{a,b,c} Means within a row sharing different superscript letters are significantly different (P < 0.05).
[1]Data was expressed as the percentage of fatty acids identified.
[2]Total saturated fatty acids= sum of C14:0+ C16:0+C18:0.
[3]Total unsaturated fatty acids= sum of C16:1+ C18:1n-9+ C18:2n-6+C18:3n-3+C20:4n 6+C20:5n-3 +C22:5n-3+C22:6n-3.
[4]Total monounsaturated fatty acids= sum of C16:1n-7+C18:1n-9.
[5]polyunsaturated fatty acids n-3 = sum of C18:3n-3+C20:5n-3+C22:5 n-3+C22:6n-3.
[6] polyunsaturated fatty acid n-6 = sum of C18:2n-6+C18:3n-6+C20:4n-6.
[7]polyunsaturated fatty acids n-6: polyunsaturated fatty acids n-3= (C18:2n-6+C18:3n-6+C20:4n-6) ÷ (C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3).
[8]SEM: Standard error of mean.
[9]Oil blend: 4:1:1 of PO, SO and LO.

Serum lipid profile and breast muscle cholesterol

The effect of different levels of oil blend fed to birds in total serum cholesterol, triacylglycerol, HDL, VLDL and LDL are shown in Table 3. Total serum cholesterol, triacylglycerol, HDL and VLDL decreased (linear, P< 0.01 and quadratic P< 0.01) with increase in the level of oil blend. Moreover, the concentration of serum LDL decreased (P< 0.01) with increasing level of oil blend. The cholesterol content in breast muscle decreased linearly (P< 0.01) with an increasing level of oil blend.

Table (3). Serum lipid profile (mmol/L) and breast meat cholesterol (mg/100g of meat) in broiler chicken fed diets containing different levels of oil blend

Parameters	Dietary treatments[1]						SEM[2]	P- Value	
	0%	2%	4%	6%	8%	10%		Lin.	Quad.
Cholesterol	4.62^{a}	2.86^{b}	2.60^{b}	2.56^{b}	2.47^{b}	2.07^{b}	0.19	0.001	0.019
Triglycerides	1.09^{a}	0.60^{b}	0.46^{bc}	0.39^{c}	0.49^{bc}	0.30^{c}	0.05	0.001	0.003
HDL	3.03^{a}	1.92^{b}	1.84^{b}	1.81^{b}	1.53^{b}	1.47^{b}	0.12	0.001	0.027
VLDL	0.21^{a}	0.12^{b}	0.09^{bc}	0.08^{bc}	0.09^{bc}	0.06^{c}	0.01	0.001	0.004
LDL	1.34^{a}	0.81^{b}	0.66^{b}	0.67^{b}	0.83^{b}	0.53^{b}	0.08	0.006	0.12
Meat cholest.	23.20^{a}	22.92^{a}	19.44^{b}	17.20^{bc}	16.97^{bc}	15.71^{c}	0.58	0.001	0.393

$^{a-c}$Means in the same column with different superscripts are significantly differ (P< 0.05).
[1]Oil blend: 4:1:1 of PO, SO and LO.
[2]SEM: Standard error of mean.

Fatty acid profiles of breast muscle tissues

To intensify the production of poultry meat, parameters such as the carcass composition and meat FA profile need to be considered. The composition of lipids in broiler meat can be manipulated by adding C18:3n-3 and C18:2n-6 (Newman et al., 2002).The ratios of n-6: n-3 PUFA in broiler meat decrease as dietary oil blend increase in diet. The findings are consistent with Salamatdoustnobar et al. (2008), who observed similar outcomes in their findings. As observed results in the current study shows that increasing the levels of dietary oil blend from 0 to 10 % increased the C18:3n-3, C20:5n-3 and C22:5n-3 and reduced the n-6: n-3 PUFA ratio in breast muscle of broiler chickens. The conversion of C18:3n-3 into long chain n-3 poly unsaturated fatty acid is swayed by the presence of the substrates and levels of desaturation and elongating enzymes located in the liver. Nonetheless, these same enzymes are also involved in the conversion of the 18:2n6, to 20:4n6.Thus, there is a potential for competitive inhibition between n-3 and n-6 PUFA in the diet (Portolesi et al., 2007). Hence, consuming diets high in n-6 have the ability to decrease the assemblage of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and favor a higher transformation to arachidonic acid simply by competitively inhibiting C18:3n-3 access to key enzymes such as delta 6 desaturase (Sprecher et al., 1995). Thus, a major determinant for the optimal conversion of α-linolenic acid is the ratio of n-6: n-3 FA in the diet.

The n-3 PUFA accumulation in meat followed a similar pattern to those observed in previous studies (Kartikasari et al., 2012). These results suggest that incorporating long-chain n-3 PUFA (20:5n-3 and 22:6n-3) in breast meat is reliant on the level of dietary

oil blend. The current finding shows that increasing the level of oil blend in broiler chickens is capable of providing appreciable levels of n-3 PUFA to consumers.

Serum lipid profile and breast muscle cholesterol

The serum triacylglycerol, HDL cholesterol, VLDL cholesterol, LDL cholesterol and total cholesterol in breast muscle of broiler chickens decrease with increasing level of oil blend in the broiler diet. This observation could be due to a rise in the levels of n-3 FA in liver and breast muscle samples with increasing dietary levels in blended oil. The n-3 FA suppresses the synthesis of triacylglycerol, increases the removal of VLDL cholesterol via peripheral tissues or the liver, and increases the excretion of bile in feces (Leaf and Weber, 1988), which can also reduce the serum concentration of cholesterol and triacylglycerol. The significant negative correlation between tissue n-3 FA and serum triacylglycerol, VLDL cholesterol, LDL cholesterol and total cholesterol levels also supported the cholesterol lowering the effects of n-3 FA. These findings are in agreement with those of Celebi and Utlu (2006), who reported that inclusion of 4% flaxseed oil as a source of n-3 FA in the diets of layers which leads to a significant decrease in serum triglyceride, total cholesterol, VLDL cholesterol and LDL cholesterol levels. The findings are also in agreement with those of Crespo and Esteve-Garcia (2003), Newman et al. (2002) and Shearer et al. (2012), who described the effectiveness of n-3 fatty acids in decreasing plasma triglyceride concentration.

Conclusion

It can be concluded that oil blend (PO, SO and LO in a ratio of 4:1:1) included in broiler diets improve breast meat quality and reduces the cholesterol in the breast muscle and serum. Thus, the oil blend used in the present study could improve meat quality, in terms of n-3 LCPUFA levels with a positive effect on the oxidative stability of lipids. These changes would likely improve the suitability of broiler meat as healthful food source.

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تحسين القيمة الغذائية للحوم الدواجن كغذاء صحي بتغذيتها على خليط من الزيوت النباتية

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المستخلص

أجريت الدراسة لتحسين القيمة الغذائية للحوم الدواجن كغذاء صحي للإنسان. تم اختبار استجابة دهون الدم، أكسدة الدهون، والأحماض الدهنية في دجاج اللحم بواسطة تغذيتها على مستويات مختلفة من مخلوط الزيوت. تمت إضافة خليط من زيت النخيل، الذرة وزيت بذرة الكتان بنسب 1:1:4، على التوالي. تم توزيع 216 كتكوت نوع (Cobb 500) بعمر يوم واحد بصورة عشوائية إلى ست معاملات غذائية. كل معاملة تألفت من ست مكررات (أقفاص) محتويةً على ست طيور في كل منها. تم إضافة خليط الزيت إلى العليقة بنسب 2%، 4%، 6%، 8%، و10%. أدت زيادة مستويات خليط الزيت إلى زيادة الأحماض الدهنية ن−3 ون−6 وانخفاض نسبة ن−6: ن−3 في أنسجة لحم الصدر. انخفضت مستويات كولستيرول الدم، الجليسريدات الثلاثية والكوليستيرول في لحم الصدر معنوياً بزيادة مستوى خليط الزيت في علائق الطيور. إن التوليفة بين الزيوت المذكورة آنفاً قد تكون ذات فائدة عند إضافتها في علائق دجاج اللحم لزيادة مستوى الحامض الدهني طويل السلسلة ذو الروابط غير المشبعة المتعددة ن−3 وخفض نسبة ن−6 ن−3 ومحتوى الكوليستيرول في لحم الصدر.

الكلمات المفتاحية: دجاج اللحم، مزيج زيت، الدهون في الدم، تكوين الأحماض الدهنية

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