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Submission date: 15-Sep-2022 12:19PM (UTC+0700)
Submission ID: 1900252059
File name: Growth_Performance,_Carcass_Characteristics_and_Fatty_Acids.pdf (578.46K)
Word count: 9804
Character count: 47882

PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

OPEN ACCESS

Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2017.719.730

Research Article

Growth Performance, Carcass Characteristics and Fatty Acids Profile of Broilers Supplemented with Lauric Acid and Natural Antioxidant from *Areca vestiaria* Giseke

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Abstract

Background: Besides as an energy source, coconut oil with its lauric acid content can improve the growth performance, carcass characteristics and fatty acids profile of broiler chickens. Conventional processing of coconut oil is susceptible to hydrolytic oxidation that reduces its antioxidant content. *Areca vestiaria* Giseke (AV) with its phenol content acts as a natural antioxidant in the diet. **Materials and Methods:** Two hundred and forty day-old unsexed Lohmann broiler chicks (MB-202 P) were divided into 24 experimental units (ten chicks/unit) and arranged in a completely randomized design with a 2×4 factorial arrangement. Each experimental unit was repeated 3 times each with ten chicks. The first factor was the source of lauric acid in the ration consisted of 2 levels i.e., coconut oil and pure lauric acid. The second factor was dose of antioxidant consisted of 4 levels i.e., 0 [without antioxidant (AV and lauric acid) supplementation], AV at a dose of 625 mg kg^{-1} ration, AV at a dose of 1250 mg kg^{-1} ration and tocopherol at a dose of 200 ppm). Parameters measured were growth performance, carcass characteristics and fatty acid profiles of broiler breast meat. **Results:** On the first stage trial, AV can be used as a source of natural antioxidant in the diet of broiler. The feeding trial showed that the treatments highly significantly affected ($p<0.01$) weight gain, feed consumption, feed conversion ratio, breast weight/eviscerated weight percentage, abdominal fat weight/eviscerated weight percentage and significantly affected ($p<0.05$) dressing percentage. Low growth performance and carcass characteristics in broiler chickens supplemented with vitamin E were assumed to be caused by the inhibition of absorption. Fatty acids in feed after consumption will be relatively unchanged in body tissue. Lauric acid can be deposited in breast meat. **Conclusion:** AV as a source of natural antioxidant can be used as a supplement in broiler ration containing coconut oil as a source of lauric acid.

Key words: Breast meat, dressing percentage Lohmann broiler chick

Received: June 26, 2017 **Accepted:** August 02, 2017 **Published:** August 15, 2017

Citation: Jola J.M.R. Londok, Wasmen Manalu, Komang G. Wiryawan and Sumiati, 2017. Growth performance, carcass characteristics and fatty acids profile of broilers supplemented with lauric acid and natural antioxidant from *Areca vestiaria* giseke. Pak. J. Nutr., 16: 719-730.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Coconut oil is used in broiler rations as a source of energy that can play a unique role as an important functional component in the feed. This functional component is found as a part of lipids. Lauric acid as a major part of coconut oil is well known for its antiviral, antibacterial and antiprotozoal activities[1]. Coconut oil contains 92% saturated fatty acid (triglyceride form), 70% as a medium chain fatty acids (MCFA) and 45-65% as a lauric acid[2]. In the body, lauric acid is converted into monolaurin, dilaurin and trilaurin. The antivirus, antibacterial and antiprotozoal activities are shown by monolaurin. Monolaurin from lauric acid gives more potential than that from caprilic acid and myristic acid. Dilaurin and trilaurin have not shown that activity[3,4].

Fats and oils as feed are significantly affected by the oxidative rancidity that occurs during or after feed preparation. Rancidity can affect the organoleptic qualities of fat including color and texture that can cause damage to fat-soluble nutrients such as vitamins in both feed and fat reserves in the bird's body[5]. Conventional processed coconut oils generally have low quality because of their high water contents and hydrolytic rancidity. One way that can be done to maintain the quality of fat, both in the diet and in the body of broiler, is by providing antioxidants. Synthetic antioxidants (tetrabutylhydroxyquinone, TBHQ; butylated hydroxytoluen, BHT; and butylated hydroxyanisole, BHA) are prohibited for use because of their carcinogenic effects. Therefore authors are searching for natural ingredients as sources of antioxidant. Based on several studies that have been developed, the compounds that have potential as antioxidant are generally phenols substances such as flavonoids. Phenolic compounds are a group of aromatic secondary plant metabolites widely spread throughout the plant kingdom and they have been reported to possess multiple biological effects such as antioxidant capacity and antimicrobial activity[6]. *Areca vestiaria* Giseke contains flavonoids. According to phytochemical tests, *Areca vestiaria* seeds contain tannins, triterpenoids, flavonoids and saponins as potential bioactive compounds. Tannins and flavonoids compounds have antitumor, antiallergic, antihepatotoxic, cardiovascular and antioxidant activities. The triterpenoid group can be used as an antibacterial, anticancer and for wound care and antiinflammation[7].

Areca vestiaria Giseke with secondary metabolite compounds is potential to be used in phytopharmacology and as a source of antioxidant. However, until now there is no information about its use as a source of natural antioxidants in broiler rations. This study was conducted to determine the effect of coconut oil on rations as a source of lauric acid and supplementation of *Areca vestiaria* Giseke as a source of natural antioxidant on the growth performance, carcass characteristics and fatty acids profile of broiler chickens.

MATERIALS AND METHODS

Bird management: This study was conducted by using 240 Lohmann broiler chickens MB-202 P, which were obtained from broiler breeding company, PT Japfa Comfeed Indonesia Tbk. Poultry Breeding Division Unit 13 Kauditan, Jl. Raya Manado Bitung, Tumaluntung Village, North Minahasa District. Each bird was marked and the experimental birds were placed in 24 units of 100×100 and 60 cm high experimental pens equipped with a place to eat and drink. Each experimental unit housed 10 birds so that each treatment was repeated with 30 chickens. Rations and drinking water were provided *ad libitum*. The experimental broiler chickens were free from pullorum. Vaccination programs including for Newcastle Disease were given on day-old chickens.

Experimental diets: AV fruit was obtained from Tomohon area, North Sulawesi. Preparation of AV flour was begun by separating the flesh from the fruit in a fresh state, the seed part was dried and after drying the seed was separated from the skin of the seeds. The seeds were then dried again using a 40°C oven, resulting in a water content of less than 10%. The dried seed sample was milled with a JZ7114 1400 rpm type milling machine to obtain a size of 65 meshes[8]. Proximate analysis of yaki betel nut flour was conducted by following AOAC method[9]. The vitamin E used was d-α-tocopherol (caprimun-E). The composition of rations and the content of feed substances are presented in Table 1. Coconut oil (CO) as a source of medium chain fatty acid (MCFA) especially lauric acid was used in ration formula as much as 1.5% at starter period (0-21 days) and 3% at grower period (22-35 days) (Table 1).

Experimental design: The experiment was conducted in a completely randomized design with a 2×4 factorial arrangement with 3 replications. Each replication consisted of 10 experimental chickens. The first factor was sources of lauric acid in the basal diet consisted of 2 levels i.e., coconut oil (CO) and pure lauric acid (LA). The second factor was dose of AV and vitamin E supplementation as sources of antioxidants consisted of 4 levels i.e., 0 AV, AV at a dose of 625 mg kg^{-1} ration, AV at a dose of 1250 mg kg^{-1} ration and vitamin E or tocopherol (TF) at a dose of 200 ppm. Therefore, the experiment consisted of 8 experimental units:

Table 1: Ingredient composition and nutrient content of diets as fed basis

	Starter phase (1-21 days)		Grower phase (22-35 days)	
Items	CO	LA	CO	LA
Ingredients (%)				
Corn	53	54.4	53	56.2
Soybean meal	27	27	24	22
Fish meal	8	8	7.5	8
Rice bran	0	0	4	4
Meat bone meal	9	8.5	7	7
Coconut oil	1.5	0	3	0
Lauric acid	0	0.65	0	1.3
Limestone	1	1	1	1
Sodium chloride	0.35	0.35	0.35	0.35
Dl-methionine (99%)	0.05	0.05	0.05	0.05
Vitamin-mineral premix[1]	0.1	0.1	0.1	0.1
Total	100	100	100	100
Nutrient content (%)	53	54.4	53	56.2
ME (Kcal kg^{-1})	3127	3132	3180	3130
Crude protein	27.1	29.96	25.08	25.88
Ether extract	3.72	3.87	5.06	4.73
Crude fiber	1.56	1.54	2.73	2.83
Calcium	1.68	1.64	1.48	1.51
P available	0.49	0.49	0.49	0.50
Lysine	1.64	1.63	1.48	1.45
Methionine	0.56	0.56	0.53	0.53
Methionine+cysteine	0.97	0.97	0.90	0.90
Linoleic acid	1.73	1.73	1.67	1.73
Sodium	0.26	0.26	0.25	0.25
Chloride	0.17	0.16	0.15	0.15
Fatty acid profile (%)[2]				
Lauric acid (12:0)	0.74	0.89	3.59	1.40
MCFA	0.90	0.89	3.94	1.40
LCFA	112.09	111.09	108.44	111.15
SFA	29.85	28.54	40.77	24.69
UFA	83.14	83.44	71.66	87.86
MUFA	0.98	1.27	0.77	1.27
PUFA	82.16	82.02	70.79	86.43
ω-3	1.90	1.89	0.76	1.79
ω-6	39.11	42.49	33.00	46.69
ω-6/ω-3	20.57	22.51	43.50	26.03

ME: Metabolizable energy, MCFA: Medium chain fatty acid, LCFA: Long chain fatty acid, SFA: Saturated fatty acid, UFA: Unsaturated fatty acid, MUFA: Mono unsaturated fatty acid, PUFA: Poly unsaturated fatty acid, [1]Mixtrouwvit mineral and vitamin supplied the following/t of diet: Iron 40 mg, Copper 26.16 mg, Zinc 40 mg, Manganese 44 mg, Selenium 0.08 mg, Cobalt 0.08 mg, Iodine 0.52 mg, Vitamin A 12500 IU, Vitamin D3 35000 IU, Vitamin E 25 IU, Vitamin K3 4 mg, Vitamin B1 4 mg, Vitamin B2 8 mg, Vitamin B6 20 mg, Vitamin B12 50 mcg, Pantothenic acid 15 mg, Niacin 50 mg, Biotin 125 mcg, Calcium D-pantothenate 16.30 mg, Folic acid 1 mg, [2]All values are means as weight percentages of total fatty acid

- Experimental chickens fed with standard corn-soy based ration supplemented with 3% CO without antioxidant (AV or TF) supplementation
- Experimental chickens fed with standard corn-soy based ration supplemented with 3% CO and AV at a dose of 625 mg kg^{-1}
- Experimental chickens fed with standard corn-soy based ration supplemented with 3% CO and AV at a dose of 1250 mg kg^{-1}
- Experimental chickens fed with standard corn-soy based ration supplemented with 3% CO and TF at a dose of 200 ppm
- Experimental chickens fed with standard corn-soy based ration supplemented with 13 mg LA without antioxidant (AV or tocopherol) supplementation
- Experimental chickens fed with standard corn-soy based ration supplemented with 13 mg LA and AV at a dose of 625 mg kg^{-1}
- Experimental chickens fed with standard corn-soy based ration supplemented with 13 mg LA and AV at a dose of 1250 mg kg^{-1}
- Experimental chickens fed with standard corn-soy based ration supplemented with 13 mg LA and TF at a dose of 200 ppm

Coconut oil (CO) was supplemented in the diet as a source of lauric acid. As a comparison, pure lauric acid (LA) was used to replace coconut oil. *Areca vestiaria* Giseke (AV) as a source of natural antioxidant was used in the form of seed powder at doses of 0, 625 and 1250 mg kg^{-1}. The dose of AV (625 mg kg^{-1}) used was equivalent to the dose of vitamin E (TF) which is calculated based on its antioxidant activity. Two hundred part/million of vitamin E as a synthetic antioxidant was used to compare the effect of AV as an antioxidant. The experimental rations were analyzed for crude protein, fat, crude fiber, Ca and P contents[9]. Lysine and methionine were calculated by using Leeson and Summers Table 5. Fatty acid profiles were determined by gas chromatography[10]. The treatments were conducted for 35 days.

Parameters measured: Mortality rate of the experimental chickens during the study was less than 1%. Growth performance (feed intake, weight gain and feed conversion) were the major responses criteria. The weights of feed offered and unconsumed ration were recorded to determine the feed intake (FI). Initial live body weights (BW) of the experimental chickens were recorded and the body weights were then measured weekly. Weight gain (WG) was calculated by difference between two consecutive weighing. Before weighing, the experimental chickens were fasted first for 8 h. Feed conversion ratio (FCR) was calculated as the ratio of FI to WG. Data of growth performances were determined for starter phase (1-21 days), grower phase (22-35 days) and during the experiment.

At the end of experiment (35 days of age), two male broilers/treatment were randomly selected from each pen for carcass measurement. The birds were fasted about 8 h (overnight) and weighed early in the morning (6.00 am), then slaughtered by exsanguination and bled horizontally by decapitation using a sharp knife. Slaughtered birds were scalded in hot water (60-65°C) in a bath for 3 min, hanged and eviscerated manually.

The carcass, after evisceration, was weighed and expressed as a percentage of the live BW after fasting as a dressing percentage. The breast and leg (including thighs and drumsticks) were then cut with bone and skin using a scalpel blade and abdominal fats (fat around gizzard, vent and hearth) were weighed and expressed as percentages of the eviscerated weight. Samples of muscle were then rapidly excised and stored at -20 until further analysis. The right breast meat was used to determine the fatty acids profile.

Statistical analysis: Completely randomized design (CRD) with a 2×4 factorial arrangement was used to study the effects of sources of lauric acid (coconut oil and pure lauric acid) and doses of antioxidants (AV at doses of 0, 625 and 1250 mg kg^{-1} and 200 ppm TF) and their interactions on the growth performances, productions and carcass qualities of broiler chickens. The whole data analysis was done by general linear model on MINITAB (version 16). Differences between treatments means were tested by Tukey simultaneous test (HSD). Significance was evaluated at the level of $p \leq 0.01$ and $p \leq 0.05$. Data of fatty acids profile were analyzed descriptively.

RESULTS

Growth performance: The growth performances of experimental broiler chickens during starter phase, grower phase and during the starter to grower phase are presented in Table 2. During starter phase, the source of lauric acid affected the growth rate and feed intake of experimental chickens ($p<0.01$) without affecting feed conversion ratio ($p>0.05$). At this starter phase, concentration of antioxidant significantly affected growth rate, feed intake and feed conversion ratio. However, in this starter phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on weight gain, feed intake and feed conversion ratio of the experimental chickens.

During starter phase, the source of lauric acid and concentration of antioxidant affected the growth rate of experimental chickens ($p<0.01$). However, in this starter phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on weight gain. During starter period, experimental chickens supplemented with pure lauric acid had higher body weight gains (4.84% or 32.99 g/day) compared to those supplemented with coconut oil as a source of lauric acid ($p<0.01$). Supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect body weight gain of the experimental chickens compared to control without AV supplementation ($p>0.05$). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect body weight gains of the experimental chickens ($p>0.05$). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased body weight gain by 22.94, 25.03 and 23.56% ($p<0.01$) compared to experimental chickens without AV supplementation, supplemented with 625 and 1250 mg kg^{-1}, respectively.

During starter phase, the source of lauric acid affected the feed intake of experimental chickens ($p<0.01$). At this starter phase, concentration of antioxidant significantly affected feed intake. However, in this starter phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on feed intake of the experimental chickens. During starter period, experimental chickens supplemented

Table 2: Effect of dietary lauric acid and natural antioxidant from *Areca vestiaria* Giseke on performance of broiler[1]

Variables	Source of lauric acid	Antioxidant 0	625 mg AV	1250 mg AV	200 ppm TF	Average
Starter phase (1-21 days)						
Weight gain (g-h)	CO	715.53±12.44	747.87±1.55	717.00±15.90	548.13±18.53	682.13±45.29^{B}
	LA	752.67±13.12	761.30±11.02	763.20±19.07	583.33±9.24	715.12±43.99^{A}
	Average	734.1±18.57^{A}	754.585±6.71^{A}	740.10±23.10^{A}	565.73±17.64^{B}	
Feed intake (g-h)	CO	1150.43±15.47	1156.00±9.84	1120.50±19.97	958.57±17.64	1096.38±46.59^{b}
	LA	1178.15±9.88	1159.57±14.99	1163.77±19.23	1009.17±21.04	1127.67±39.70^{a}
	Average	1164.29±13.86^{A}	1157.79±1.79^{A}	1142.14±21.64^{A}	983.87±25.3^{B}	
Feed conversion ratio	CO	1.61±0.01	1.55±0.02	1.56±0.01	1.75±0.03	1.62±0.05
	LA	1.57±0.02	1.52±0.01	1.53±0.03	1.73±0.02	1.59±0.05
	Average	1.59±0.02^{B}	1.54±0.02^{B}	1.55±0.02^{B}	1.74±0.01^{A}	
Grower phase (22- 35 days)						
Weight gain (g-h)	CO	1050.01±11.27	1054.43±24.54	980.53±6.90	541.32±38.51	906.57±122.92
	LA	1094.13±33.74	1066.18±34.32	1074.43±70.13	531.04±16.44	941.45±136.93
	Average	1072.07±22.06^{A}	1060.31±5.88^{A}	1027.48±46.95^{A}	536.18±5.14^{B}	
Feed intake (g-h)	CO	2022.16±24.31	2003.15±46.38	1894.06±41.77	1375.04±56.50	1823.60±152.16
	LA	2009.51±41.76	1982.67±43.50	2065.00±63.56	1374.80±19.48	1857.00±161.97
	Average	2015.84±6.33^{A}	1992.91±10.24^{A}	1979.53±85.47^{A}	1374.92±0.12^{B}	
Feed conversion ratio	CO	1.93±0.02	1.90±0.02	1.93±0.03	2.55±0.08	2.08±0.16
	LA	1.84±0.03	1.86±0.04	1.93±0.07	2.59±0.04	2.06±0.18
	Average	1.89±0.04^{B}	1.88±0.02^{B}	1.93±0.00^{B}	2.57±0.02^{A}	
Overall phase (1-35 days)						
Weight gain (g-h)	CO	1765.55±22.74	1802.30±23.91	1697.53±21.86	1089.45±56.22	1588.71±167.83^{b}
	LA	1846.79±46.33	1827.48±39.79	1837.63±65.65	1114.38±11.82	1656.57±180.77^{a}
	Average	1806.17±40.62^{A}	1814.89±12.59^{A}	1767.58±70.05^{A}	1101.92±12.47^{B}	
Feed intake (g-h)	CO	3172.59±33.63	3159.15±54.38	3014.56±59.74	2334.01±72.26	2920.08±198.60
	LA	3187.67±51.16	3142.24±51.55	3228.77±45.05	2383.96±28.52	2985.66±201.34
	Average	3180.13±7.54^{A}	3150.70±8.46^{A}	3121.67±107.11^{A}	2358.99±24.97^{B}	
Feed conversion ratio	CO	1.80±0.01	1.75±0.01	1.78±0.02	2.15±0.05	1.87±0.09
	LA	1.73±0.02	1.72±0.03	1.76±0.04	2.14±0.01	1.84±0.10
	Average	1.77±0.04^{B}	1.74±0.02^{B}	1.77±0.01^{B}	2.15±0.01^{A}	

[1]Values are the means of 3 replications of 10 birds, values are expressed as Mean± SEM, $^{A-B}$Different superscripts within row shows highly significantly different (p<0.01), $^{A-B}$Different superscripts within column shows highly significantly different (p<0.01), $^{a-b}$Different superscripts within column shows significantly different (p<0.05), $^{A-B}$Different superscripts within row and column shows highly significantly different (p<0.01), CO: Coconut oil, LA: Lauric acid, TF: Tocopherol

with pure lauric acid had higher feed intake (28.54% or 31.29 g/day) compared to those supplemented with coconut oil as a source of lauric acid (p<0.01). Supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect feed intake of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect feed intake of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased feed intake by 15.50, 15.02 and 13.86% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with 625 and 1250 mg kg^{-1}, respectively.

During starter phase, the source of lauric acid did not affect feed conversion ratio (p>0.05). At this starter phase, concentration of antioxidant significantly affected feed conversion ratio. However, in this starter phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on feed conversion ratio of the experimental chickens. Supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect feed conversion ratio of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect feed conversion ratio of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly increased feed conversion ratio by 9.43, 12.99 and 12.26% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with AV at doses of 625 and 1250 mg kg^{-1}, respectively.

During starter phase, the source of lauric acid affected the growth rate and feed intake of experimental chickens (p<0.01) without affecting feed conversion ratio (p>0.05). At this starter phase, concentration of antioxidant significantly affected growth rate, feed intake and feed conversion ratio. However, in this starter phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on weight gain, feed intake and feed conversion ratio of the experimental chickens.

During grower phase, the source of lauric acid did not affect (p>0.05) the weight gain, feed intake and feed conversion ratio of experimental chickens. However, in this grower phase, the concentration of antioxidant significantly affected weight gain, feed intake and feed conversion ratio (p<0.01). In this grower phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on weight gain (p>0.05).

During the grower phase, supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect body weight gain of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625 to 1250 mg kg^{-1} did not affect body weight gains of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased body weight gain by 49.99, 49.43 and 47.82% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with 625 and 1250 mg kg^{-1}, respectively.

During grower period, supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect feed intake of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect feed intake of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased feed intake by 31.79, 31.01 and 30.54% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with 625 and 1250 mg kg^{-1}, respectively.

During grower phase, supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect feed conversion ratio of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect feed conversion ratio of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly increased feed conversion ratio by 35.98, 36.70 and 33.16% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with AV at doses of 625 and 1250 mg kg^{-1}, respectively.

During starter to grower phase, the source of lauric acid significantly affected (p<0.05) the weight gain of experimental chickens. However, during starter to grower phase, the source of lauric acid did not significantly affect (p>0.05) the feed intake and feed conversion ratio of experimental chickens. During this starter to grower phase, the concentration of antioxidant significantly affected weight gain, feed intake and feed conversion ratio (p<0.01). In this starter to grower phase, there was no interaction effect between the source of lauric acid and concentration of antioxidant on weight gain (p>0.05).

During starter to grower phase, experimental chickens supplemented with pure lauric acid had higher body weight gain (4.27% or 67.84 g) (p<0.05) compared to those supplemented with coconut oils a source of lauric acid. During starter to grower phase, supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect body weight gain of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect body weight gains of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased body weight gain by 38.99, 39.28 and 37.66% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with AV at 625 and 1250 mg kg^{-1}, respectively.

During starter to grower period, supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect feed intake of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect feed intake of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased feed intake by 25.82, 25.13 and 24.43% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with 625 and 1250 mg kg^{-1}, respectively.

At the starter to grower phase, supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect feed conversion ratio of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect feed conversion ratio of the experimental chickens (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly increased feed conversion ratio by 21.47, 23.56 and 21.47% (p<0.01) compared to experimental chickens without AV supplementation, those supplemented with AV at doses of 625 and 1250 mg kg^{-1}, respectively.

Carcass characteristics: The carcass characteristics of experimental broiler chickens supplemented with different sources of lauric acid and different doses of antioxidant are presented in Table 3.

Dressing percentages [the percentage of carcass weight (defeathered and eviscerated) to body weight] of the experimental chickens were not affected by the source of lauric acid (p>0.05). Concentrations of AV and vitamin E as an

Table 3: Effect of dietary lauric acid and natural antioxidant from *Areca vestiaria* Giseke on carcass characteristics of broiler[1]

Variables	Source of Lauric acid	Antioxidant 0	625 mg AV	1250 mg AV	200 ppm TF	Average
Dressing (%)[2]	CO	70.76±0.81	70.68±0.89	73.82±1.32	66.50±0.78	70.44±1.50
	LA	70.22±1.62	72.057±0.23	72.61±1.07	67.87±2.42	70.69±1.07
	Average	70.49±0.27^{AB}	71.37±0.69^{A}	73.22±0.60^{A}	67.19±0.69^{B}	
Breast weight (g)	CO	369.67±19.92	406.33±23.51	408.33±13.59	223.67±17.48	352.00±43.69^{B}
	LA	470.33±15.81	438.67±3.53	514.00±36.83	280.00±24.98	425.75±50.98^{A}
	Average	420.00±50.33^{A}	422.50±16.17^{A}	461.17±52.83^{A}	251.83±28.17^{B}	
Breast weight/eviscerated weight (%)	CO	30.61±1.31	29.23±1.21	31.03±0.71	26.06±0.67	29.23±1.13^{B}
	LA	34.73±1.09	31.57±0.73	37.17±1.36	27.88±1.58	32.84±2.01^{A}
	Average	32.67±2.06^{AB}	30.40±1.17^{B}	34.10±3.07^{A}	26.97±0.91^{C}	
Leg weight (g)[3]	CO	346.67±26.96	453.00±36.12	356.67±6.74	217.67±12.99	343.50±48.31
	LA	395.00±11.27	398.3±15.01	411.67±16.84	275.33±33.58	370.08±31.79
	Average	370.83±24.17^{A}	425.67±27.33^{A}	384.17±27.50^{A}	246.50±28.83^{B}	
Leg weight/eviscerated weight (%)	CO	28.56±0.40	29.09±1.33	27.13±0.61	28.30±0.62	28.27±0.41
	LA	29.18±0.99	28.65±0.89	28.62±1.13	30.39±0.96	29.21±0.42
	Average	28.87±0.31	28.87±0.22	27.87±0.74	29.34±1.05	
Abdominal fat weight (g)	CO	7.33±2.40^{C}	24.00±1.53^{AB}	20.33±2.91^{AB}	2.67±0.33^{C}	13.58±5.10^{B}
	LA	24.00±3.79^{AB}	31.33±2.03^{A}	14.33±4.10^{BC}	6.33±1.45^{C}	19.00±5.47^{A}
	Average	15.67±8.33^{B}	27.67±3.67^{A}	17.33±3.00^{B}	4.50±1.83^{C}	
Abdominal fat weight/eviscerated weight (%)	CO	0.59±0.18^{D}	1.73±0.08^{AB}	1.55±0.22^{ABC}	0.35±0.04^{BCD}	1.05±0.34^{b}
	LA	1.77±0.27^{D}	2.25±0.11^{AB}	1.00±0.30^{A}	0.68±0.09^{CD}	1.43±034^{a}
	Average	1.18±0.59^{A}	1.99±0.26^{B}	1.27±0.27^{B}	0.52±0.17^{C}	

[1]Values are the means of 3 birds/experimental units, values are expressed as Mean±SEM, [2]Dressing percentage is carcass weight (defeathered and eviscerated) as a percentage of body weight, $^{A-C}$Different superscripts within row shows highly significantly different (p<0.01), $^{A-B}$Different superscripts within column shows highly significantly different (p<0.01), $^{a-b}$Different superscripts within column shows significantly different (p<0.05), $^{A-D}$Different superscripts within row and column shows highly significantly different (p<0.01), CO: Coconut oil, LA: Lauric acid, TF: Tocopherol

antioxidant in the diet significantly affected the dressing percentages of the experimental chickens (p<0.01). There was no significant interaction effects of source of lauric acid and concentration of antioxidant in the diet on the dressing percentages of the experimental chickens (p>0.05).

Supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect the dressing percentages of the experimental chickens compared to control without AV supplementation (p>0.05). Increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect the dressing percentages of the experimental chickens (p>0.05). The use of tocopherol at a dose of 200 ppm as a source of antioxidant did not affect the dressing percentages of the experimental chickens compared to control without AV supplementation (p>0.05). However, the use of tocopherol at a dose of 200 ppm as a source of antioxidant decreased the dressing percentages of the experimental chickens by 5.86 and 8.24%, compared to those supplemented with AV at doses of 625 and 1250 mg kg^{-1}, respectively.

Source of lauric acid and concentrations of AV and vitamin E as an antioxidant in the diet significantly affected breast weight (p<0.01). However, there was no interaction effect of source of lauric acid and concentration of AV and tocopherol as antioxidants (p>0.05). Regardless of the concentration of antioxidant supplementation, the experimental broiler chickens supplemented with pure lauric acid had higher breast weight (20.95%) (p<0.01) compared to those supplemented with coconut oil as a source of lauric acid. Regardless of source of lauric acid, the experimental broiler chickens supplemented with 200 ppm tocopherol had lower breast weights (40.04, 40.40 and 45.39%) compared to control experimental broiler chickens without antioxidant supplementation (not supplemented with AV and tocopherol), the experimental broiler chickens supplemented with AV at doses of 625 and 1250 mg kg^{-1} and those supplemented with 200 ppm tocopherol, respectively (p<0.01).

The source of lauric acid and the concentration of AV and vitamin E as an antioxidant in the diet significantly affected the breast percentages (the percentage of breast weight to carcass weight) of the experimental chickens (p<0.01). However, there was no interaction effects of source of lauric acid and the concentration of AV and vitamin E as an antioxidant in the diet on the breast percentages of the experimental chickens (p>0.05).

Regardless of doses of antioxidant supplementation, experimental broiler chickens supplemented with pure lauric acid had higher breast percentages (12.35%) compared to those supplemented with coconut oil as a source of lauric acid (p<0.01).

Supplementation of AV at doses of 625 and 1250 mg kg^{-1} did not affect the breast percentages of the experimental chickens compared to control without AV supplementation

(p>0.05). However, the increased dose of AV supplementation from 625-1250 mg kg^{-1} increased the breast percentages of the experimental chickens by 12.17% (p<0.01). The use of tocopherol at a dose of 200 ppm as a source of antioxidant significantly decreased the breast percentages of the experimental chickens by 17.45, 11.28 and 20.91% compared to control without AV supplementation, those supplemented with 625 and 1250 mg kg^{-1}, respectively (p<0.01).

Regardless of the concentrations of antioxidant supplementation, source of lauric acid did not affect leg weight (p>0.05). However, regardless of source of lauric acid in the diet, concentrations of antioxidant supplementation significantly affected the leg weight (p<0.01). There was no interaction effect of source of lauric acid and concentration of antioxidant supplementation on the leg weight of the experimental broiler chickens. The experimental broiler chickens supplemented with 200 ppm tocopherol had lower leg weights (33.53, 42.09 and 35.84%) compared to the experimental broiler chickens without antioxidant supplementation and those supplemented AV at doses of 625 and 1250 mg kg^{-1} as sources of antioxidant, respectively (p<0.01).

Even though there was a significant effect of concentration of antioxidant supplementation on the leg weight of the experimental broiler chicken, there was no significant effects of antioxidant concentration on leg weight percentage (p>0.05). Source of lauric acid and its interaction with concentration of antioxidant supplementation in the diet did not affect leg weight percentage of the experimental chickens (p>0.05).

The source of lauric acid and the concentration of AV and vitamin E as an antioxidant in the diet and their interactions significantly affected the abdominal fat percentage (the percentage of abdominal fat to carcass weight) of the experimental chickens (p<0.01).

Experimental broiler chickens supplemented with pure lauric acid had higher abdominal fat percentage (36.19%) compared to those supplemented with coconut oil as a source of lauric acid (p<0.01).

Experimental broiler chickens supplemented with AV at doses of 625 and 1250 mg kg^{-1} had higher abdominal fat percentages (68.64 and 7.63%), respectively, compared to control experimental broiler chickens (p<0.01). However, experimental broiler chickens supplemented with 200 ppm tocopherol had lower abdominal fat percentages by 55.93, 73.87 and 59.06% compare to control experimental broiler chickens without AV and TF supplementations and those supplemented with AV at doses of 625 and 1250 mg kg^{-1}, respectively (p<0.01). However, the increased dose of AV supplementation from 625-1250 mg kg^{-1} did not affect abdominal fat percentage (p>0.05).

Since the source of lauric acid and concentrations of antioxidant had significant interaction effects, the effects of the source of lauric acid are dependent upon the concentrations of antioxidant used or vice versa.

The order of the experimental broiler chickens from the highest to the lowest abdominal fat percentage was found in the experimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 625 mg kg^{-1}, the experimental broiler chickens supplemented with pure lauric acid without AV supplementation, the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 625 mg kg^{-1}, the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1}, the experimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1}, the experimental broiler chickens supplemented with pure lauric acid and supplemented with tocopherol at a dose of 200 ppm, the experimental broiler chickens supplemented with CO as a source of lauric acid without supplementation of antioxidant either AV or TF and the lowest was the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with tocopherol at a dose of 200 ppm.

The experimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 625 mg kg^{-1}, the experimental broiler chickens supplemented with pure lauric acid without AV supplementation, the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 625 mg kg^{-1} and the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1} all had similar abdominal fat percentages (p>0.05).

The experimental broiler chickens supplemented with pure lauric acid without AV supplementation, the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 625 mg kg^{-1}, the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1} and the experimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1} had similar abdominal fat percentages (p>0.05).

The experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1}, the experimental broiler chickens

supplemented with pure lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1} and the experimental broiler chickens supplemented with pure lauric acid and supplemented with tocopherol at a dose of 200 ppm had similar abdominal fat percentages ($p>0.05$).

The experimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1}, the experimental broiler chickens supplemented with pure lauric acid and supplemented with tocopherol at a dose of 200 ppm, the experimental broiler chickens supplemented with CO as a source of lauric acid without supplementation of antioxidant either AV or TF and the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with tocopherol at a dose of 200 ppm had similar abdominal fat percentages ($p>0.05$).

The experimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 625 mg kg^{-1} had higher abdominal fat percentages ($p<0.05$) compared to those supplemented with pure lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1}, those supplemented with pure lauric acid and supplemented with tocopherol at a dose of 200 ppm, those supplemented with CO as a source of lauric acid without supplementation of antioxidant either AV or TF and those supplemented with CO as a source of lauric acid and supplemented with tocopherol at a dose of 200 ppm.

The expeimental broiler chickens supplemented with pure lauric acid and supplemented with AV at a dose of 625 mg kg^{-1}, the experimental broiler chickens supplemented with pure lauric acid without AV supplementation, the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 625 mg kg^{-1} and the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with AV at a dose of 1250 mg kg^{-1} had higher abdominal fat percentage compares to the experimental broiler chickens supplemented with CO as a source of lauric acid without supplementation of antioxidant either AV or TF and the experimental broiler chickens supplemented with CO as a source of lauric acid and supplemented with tocopherol at a dose of 200 ppm.

Profiles of fatty acid contents of the broiler meats: The profiles of fatty acids (the percentage from total fatty acids) and chemical composition of meats of experimental broiler chickens are presented in Table 4 and 5, respectively. The meat samples of 3 experimental broiler chickens for each experimental unit were mixed and the compositions of fatty acids in the mixed meat samples were analyzed. Even though the data obtained were the averages of three samples, since there was no individual variation in each experimental unit, the statistical analyses could not be conducted.

In general, the content of fatty acids in the experimental diets did not far different from the contents of fatty acids deposited in the meats of the experimental broiler chickens. It was found that long-chain fatty acid (LCFA) and PUFA dominated the fatty acids in the meats of experimental broiler chickens. The oleic acid in the ration contained lauric acid originated from the coconut oils and pure lauric acid supplementations. It could be concluded that the composition of fatty acids in the meats of experimental broiler chickens is affected by the composition of fatty acids in the experimental rations. In addition, the averages of water, protein and fat contents of the meats of male experimental broiler chickens at the age of 5 weeks in this experiment are 84.47, 22.14 and 1.5%, respectively.

DISCUSSION

In general, the supplementation of lauric acid and AV improved growth performances of broiler chickens and improved carcass characteristics and fatty acid profiles of the breast meat. However, there was a general tendency that tocopherol supplementation decreased growth performances of broiler chickens and decreased carcass characteristics and fatty acid profiles of the breast meat.

In general, body weight is determined by the degree of feed intake so that the feed intake is the main variable to measure feed efficiency[5]. Feed conversion in the experimental broiler chickens in this experiment is affected by the presence and the use of antioxidants. Supplementation of AV in the ration increased the quality of the experimental rations due to the increased lauric acid contents of the experimental rations. In the year of 1960s, FCR was around 2.2. The improved genetic quality with the advances of time, the current level of FCR for broiler chickens is around 1.75.[5] The decrease in FCR is caused by the greater used of feed for body growth and less is used for maintenance until finishing.

Some researchers report that the use of coconut oil and herbal as natural antioxidants have a potency to improve growth rate[11] and do not show the incidence of toxicities in rats[12]. Leeson and Summers[5] recommend the needs for tocopherol for broiler as much as 50 IU kg^{-1}. The toxicity of tocopherol has never been reported[13] but the dose of 150 mg kg^{-1} does not affect consumption and body weight gain[14]. The dose of 250 mg kg^{-1} in heat stress condition (32°C) produce the optimum feed consumption and body weight

Table 4: Effect of dietary lauric acid and natural antioxidant from *Areca vestiaria* Giseke on fatty acids profile and chemical composition of broiler breast meat[1]

		Antioxidant				
Variables	Source of lauric acid	0	625 mg AV	1250 mg AV	200 ppm TF	Average
Lauric acid	CO	4.59	3.67	5.66	3.60	4.38
	LA	6.99	5.98	6.70	4.03	5.93
	Average	5.79	4.83	6.18	3.82	
MCFA	CO	4.86	3.87	5.71	3.80	4.56
	LA	7.03	6.02	6.75	4.21	6.00
	Average	5.95	4.95	6.23	4.01	
LCFA	CO	95.12	96.13	94.30	96.19	95.44
	LA	92.97	93.97	93.23	95.79	93.99
	Average	94.05	95.05	93.77	95.99	
SFA	CO	38.73	41.09	42.28	39.96	40.52
	LA	40.63	40.20	39.95	38.98	39.94
	Average	39.68	40.65	41.12	39.47	
UFA	CO	61.25	58.91	57.74	60.04	59.49
	LA	59.37	59.79	60.02	61.02	60.05
	Average	60.31	59.35	58.88	60.53	
MUFA	CO	6.32	5.97	7.20	4.93	6.11
	LA	6.69	6.14	6.23	3.72	5.70
	Average	6.51	6.06	6.72	4.33	
PUFA	CO	54.93	52.94	50.53	55.11	53.38
	LA	52.68	53.65	53.79	57.31	54.36
	Average	53.81	53.30	52.16	56.21	
ω-3	CO	13.78	13.25	11.64	13.62	13.07
	LA	12.70	14.26	14.01	16.79	14.44
	Average	13.24	13.76	12.83	15.21	
ω-6	CO	40.81	39.28	38.34	40.62	39.76
	LA	39.55	38.64	39.30	39.84	39.33
	Average	40.18	38.96	38.82	40.23	
ω-6/ ω-3	CO	67.31	53.78	32.76	19.78	43.41
	LA	44.36	23.17	39.75	37.13	36.10
	Average	55.84	38.48	36.26	28.46	

[1]Since there was no individual variations, statistical analysis of variance was not conducted, [2]Total fatty acid (%), MCFA: Medium chain fatty acid, LCFA: Long chain fatty acid, SFA: Saturated fatty acid, UFA: Unsaturated fatty acid, MUFA: Mono unsaturated fatty acid, PUFA: Poly unsaturated fatty acid, CO: Coconut oil, LA: Lauric acid, TF: Tocopherol

Table 5: Effect of dietary lauric acid and natural antioxidant from *Areca vestiaria* Giseke on chemical composition of broiler breast meat[1]

		Antioxidant				
Variables (%)	Source of lauric acid	0	625 mg AV	1250 mg AV	200 ppm TF	Average
Fat	CO	1.34	2.50	1.31	0.67	1.46
	LA	1.87	0.80	2.31	1.90	1.72
	Average	1.61	1.65	1.81	1.29	
Protein	CO	21.27	23.95	23.50	22.90	22.91
	LA	19.53	21.69	21.18	23.09	21.37
	Average	20.40	22.82	22.34	23.00	
Water content	CO	84.59	84.97	80.98	84.03	83.64
	LA	83.16	87.70	83.70	86.51	85.27
	Average	83.88	86.34	82.34	85.27	

[1]Since there was no individual variations, statistical analysis of variance was not conducted, CO: Coconut oil, LA: Lauric acid, AV: *Areca vestiaria* Giseke, TF: Tocopherol

gains[15]. The present experiment showed the decreased feed consumption and body weight gains in the experimental broiler chickens fed ration contained tocopherol at a dose of 200 mg kg^{-1} feed. The low growth performances of experimental broiler chickens fed with ration supplemented with tocopherol are assumed to be caused by the inhibition of nutrient absorptions. In general, the relationship between the fat content of the diet and tocopherol metabolism is still controvercial[16]. The efficiency of tocopherol absorption is relatively low, about 20-40%. The absorption of tocopherol can be increased by the medium chain triglycerides and decreased by the high levels of linoleic acid[17]. The other report stated that medium chain fatty acids have a specifically decreasing effect on tocopherol in the chicks[18].

Dilauryl succinate supplemented with unsaturated fatty acids shows an indication of vitamin E deficiency that was more serious compared to chickens receiving feed only Dilauryl succinate or unsaturated fatty acids[19]. The increase in tocopherol absorptions is affected by both the digestibility and absorptions of the fat in the ration. The absorption of tocopherol is occurred by passive diffusion[16]. This process is determined by gradient concentrations in the membrane of intestine, luminal concentrations (vitamin intake) and concentrations in the enterocytes (the rate of incorporation of portomicron synthesis).

The percentage of carcass of experimental broiler chickens fed with ration supplemented with coconut oil and lauric acid with or without AV supplementation according to the recommendation for Lohmann strain i.e., 70% and for body weights at the age of 5 weeks is ±1.8 kg. Supplementation of MCFA in addition to energy sources can decrease the concentration of fat in the abdomen of the broiler[20-22]. MCFA, with 8-12 carbons can decrease body fat content of the animal and human[23-25]. The meats of chickens contain lower total saturated fatty acids and instead with higher content of total unsaturated fatty acids compared to the meats of pig, cattle and sheep[26]. In monogastric animals, fatty acids in the consumed ration will be absorbed and deposited into the body, relatively without a significant change[26,27]. Composition of fatty acid in the breast meat of broiler is affected by the consumption of fatty acids in the ration[28]. The experiment using palm oil produces the contents of SFA in the meat as much as 30.09% (the ration content is 29.62%), MUFA 49.30% (the ration content is 49.36%) and PUFA as much as 18.72% (the ration content is 20.59%)[29]. The lauric acids deposited in the breast meat of experimental broiler chickens in this present experiment is come from lauric acid in the coconut oil and pure lauric acid supplemented in the ration. Lauric acid from pure lauric acids supplemented in the ration is higher than that from coconut oil.

Factors affecting chemical compositions of the meat are genetic factor (species, breed, sex, muscle and individual animal), environmental factors (nutrition and ration, including additive materials), the handling factors prior to and after slaughtering (physiological factors), age and slaughtering weight[26]. Water, protein and fat contents of breast meat of male broiler chickens at the age of 6 weeks are: 73.27%, 22.08 and 2.98%, respectively[26]. Chemical composition of breast meat of broiler chicken in this present experiment is better based on the water and fat contents, with the protein content that is relatively similar.

CONCLUSION

Supplementation of *Areca vestiaria* Giseke as a source of natural antioxidant into broiler feed containing lauric acid from coconut oil can improve growth performance, carcass characteristic and fatty acid profile of meat of the experimental broiler chickens.

ACKNOWLEDGMENT

This study is part of PhD dissertation of the first author sponsored by BPP-DN scholarship provided by the Directorate for Higher Education, Ministry of Research, Technology and Higher Education of The Republic of Indonesia. The author would like to thank to the Head of Animal Husbandry of Sam Ratulangi University of North Sulawesi who has facilitated the research.

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Growth Performance, Carcass Characteristics and Fatty Acids Profile of Broilers Supplemented with Lauric Acid and Natural Antioxidant from Areca vestiaria Giseke

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