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Full Length Article

Effect of Oil Supplementation on Growth Performance, Meat Quality and Antioxidative Ability in Meat Ducks Fed a Diet Containing Aging Corn

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Abstract

This study investigated the effect of dietary aging corn with or without supplementation of oil on performance, meat quality and antioxidative ability in meat ducks. A total of 768, one day old ducks were allotted randomly into 6 treatments with 8 replicates per treatment for 35 days as follow: T1 (0% aging corn and 0% oil), T2 (0% aging corn and 3% oil), T3 (50% aging corn and 0% oil), T4 (50% aging corn and 3% oil), T5 (100% aging corn and 0% oil), T6 (100% aging corn and 3% oil). The results showed that 100% aging corn significantly ($P < 0.05$) decreased the feed intake (FI) and feed conversion ratio (FCR) during 15 to 35 days. However, the addition of oil increased FI and FCR from 15 to 35 days. In contrast, throughout the experiment non-significant ($P < 0.05$) effects on body weight (BW) and body weight gain (BWG) was observed with or without oil addition in aging corn diet. The meat quality, breast pH, color parameters were decreased by the supplementation of oil at 35 d, while, the color of breast meat and skin in term of yellowness (b*), and the levels of CAT, MDA and SOD in breast were reduced on 35d ($P < 0.05$) with 100% aging corn. The levels of antioxidant markers e.g. CAT, GSH-PX, MDA and T-AOC significantly ($P<0.05$) decreased on 35d in liver with 100% aging corn diet. In conclusion, the results revealed that oil supplementation could lessen the negative effects of aging corn on meat ducks to some extent. © 2018 Friends Science Publishers

Keywords: Aging corn; Antioxidative ability; Duck; Oil; Liver; Meat quality

Introduction

In the recent decades, the demand of poultry production has increased and attained considerable attention due to its cost-effective and human health aspects. However, the prominent characteristics of poultry meat are highly dependent on the feed ingredients that define the quality and overall metabolic changes in the body (Ivanovich *et al.*, 2017). It has been estimated that 70% of the total cost for raising poultry is experienced on feed management. Diet plays a vital role in evaluating the quality of animal meat. According to the report of FAO 2005, 65% corn grown in the world is used for animal feed industry (FAO, 2005). In fact, corn also called as maize is the ideal grain for nourishing due to its improved nutritional value as compared to others cereals with very little change in composition during storage of several years (Salman and Copeland, 2007). United States (US) is the largest corn producer in the world with a volume amounting to about 370.96 million metric tons during 2107/2018. After US, China and Brazil are second and third largest corn producing countries, with the production of 215.89 and 94.5 million metric tons, respectively (USDA, 2017).

Presently, research based on stored (aging) corn has gained much importance because China's corn reserves exceeded 200 million tons in 2017. China has been spending a large amount of investment on the storage of surplus corn, and as a result corn is stored in many countries for two or more than two years and then used as an animal and poultry feed. However, a significant quantity of stored cereals grains lost due to interactions between biological, chemical and physical elements (Choct and Hughes, 2000).

Stored corn has highest risk of mold growth and more prone to lipid oxidation. Storage time increases the oxidation of lipid and content of free fatty acid (FFA) in meal flour and also increase the fat acidity value (FAV) of wheat flour (Galliard, 1986).Whereas reduced the values of iodine-binding (Salman and Copeland, 2007). FFA oxidized easily to produce H_2O_2, and these can affect the activities of enzymes like as peroxidase (POD) and catalase (CAT) in maize (Bailly *et al.*, 2002). The CAT and POD are also affected through cell-membrane lipid peroxidation and these two enzymes are used as indicators to measure the quality stored corn (Salman and Copeland, 2007). Long-term storage of corn feed has negative impact on animal health. It is reported that broilers fed with aging corn diets resulted in decreased antioxidant function. Ducks feed aging corn diets were more likely to obtain oxidative damage, which resulted in reduced growth performance (Mcfarlane *et al.*, 1989).

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Vegetable oils are easily prone to oxidation because of high amount of unsaturated fatty acids (Farhoosh *et al.*, 2009). Therefore, adverse effect of oxidized oil in aging corn could be compensating by oil supplementation in feed. Now a day the most important edible oil is Soy bean oil (SBO) which is produced worldwide. The main characteristic of SBO is that it contains high proportion of unsaturated fatty acids. About 85% of the fatty acids (FA) mostly contain oleic acid, linoleic acid, or linolenic acid. The SBO which shows an indication of whole biochemical unsaturation is usually higher in between 125-135 IV. The double bonds present in oleic, linoleic and linolenic acids are chemically reactive. However, these SBO properties make them easy for oxidative rancidity (Buck, 1981). The addition of fat and oil plays a key role in the poultry growth to improve the energy levels of diet. The inclusion of oil in the poultry feed; as well providing energy, enhanced fat-soluble vitamins absorption, reduces the pulverulence, enhanced the rations palatability and efficacy of the expended energy. Moreover, it decreases the digesta passage rate in the gastrointestinal tract (GIT), which permits an enhanced the all nutrients absorption present in the diet (Baião and Lara, 2005). High energy diets have been shown to increase growth and feed efficiency (FE) (Hosseini-Vashan *et al.*, 2010; Sahito *et al.*, 2012).

Most of the countries in the world use fat and oil as major sources of energy in poultry rations. It was reported that addition of 30-40 g of oil per kg in diet resulted in increase ($P < 0.05$) the body weight gain (BWG) (Barbour *et al.*, 2006). However, to our best of our knowledge, limited studies on effects of feeding aging corn with or without oil supplementation in broiler diets are reported, but no study has been reported on meat duck. Thus, the purpose of the current research was to explore the effects of aging corn along with or without addition of oil on growth performance, meat quality and antioxidative ability in meat ducks.

Materials and Methods

Experimental Material

Aging and normal corn were originated from national barns, Jining, China and Ningxia, China after the storage period of 4 years and 0.5 year, respectively. Some of phycochemical properties of stored samples of corn were analyzed and presented in (Table 1). The ether extract, crude protein and dry matters were analyzed by Soxhlet fat analysis (method No. 920.39), Kjeldahl (method No. 984.13) and by oven drying (method No. 930.15), respectively as per AOAC International guidelines (Anastassiades *et al.*, 2003). An adiabatic bomb calorimetry (Parr Instrument Company, IL, and USA) was used to analyze the gross energy. Titratable acidity was revealed as potassium hydroxide to neutralize the acids in a 100 gram of sample (GB/T 20570-2015). The national standard methods GB 5009.168-2016) were used to quantify the fatty acids. The content of peroxidase (POD), catalase (CAT) and malondialdehyde (MDA) were measured through a Multiskan Spectrum Reader (Model 1500; Thermo Scientific, Nyon, Switzerland) according to recognition kits from Nanjing Jiancheng Bioengineering Institute (Nanjing, Jiangsu Province, P. R. China) with a Multiskan Spectrum Reader (Model 1500; Thermo Scientific, Nyon, Switzerland). Aflatoxin, zealeranol and deoxynivalenol were measured using the national standard methods (GB/T 30955-2014, GB/T 28716-2012 and SN/T 1571-2005) Fatty acids were quantified by the national standard methods (GB 5009.168-2016), (Table 1).

Bird's Management and Diets

The design and protocol of current research was supported by the Animal Care and Use Committee of Sichuan Agricultural University, Chengdu, China. A completely randomized design (CRD) containing 2 × 3 (3 aging Corn percentage × 2 oil levels) with T1 (0% aging corn and 0% oil), T2 (0% aging corn and 3% oil), T3 (50% aging corn and 0% oil), T4 (50% aging corn and 3% oil), T5 (100% aging corn and 0% oil), T6 (100% aging corn and 3% oil) was used. There were 6 dietary treatments and each treatment have 8 replicates. A 1-day-old 768 ducks were distributed to 48 pens (3 × 4 cf), and 16 ducks were kept in each pen. Before the start of the experiment, pens were disinfected with Bromogeramine (1%) solution. The basal diet composition and nutrient level was prepared according to the NRC as corn - soybean meal type. All these diets formulated were iso-caloric and iso-protein and provide to the birds *ad libtum* (Table 2).

Sample Collections

Sampling collection was completed at 14 and 35 days of age. At 14 d and 35 d of the experiment, one replicate was randomly taken for meat quality determination and antioxidative status analysis of serum. Blood was taken from the juggler vein by expending the sterilized needles besides randomly certain syringes and placed in non-anticoagulant tubes having heparin sodium to allow the collection of serum. Liver and breast sample were collected after the blood collection from the same birds.

Growth Performance

At the start of experimental trail, initial live body weight was recorded, and then body weight was recorded at 14^{th} and 35^{th} day of experiment. Offered feed as well as refusal feed were weighed at 14^{th} and 35^{th} day to determine FI, while FCR was calculated from the body weight gain and feed consumption at 14^{th} and 35^{th} day.

Meat Quality

The breast muscle pH values were measured by submersing a digital pH meter (Hanna, Italy) into meat of breast samples.

Table 1: Physicochemical properties of aging corn and normal corn (air-dried basis)

Items	Aging corn	Normal corn
Moisture (%)	13.06	14.31
Crude protein (%)	7.73	7.56
Gross energy (cal/g)	3846	3799
Crude fat (%)	3.31	3.42
Acidity of fatty acids (KOH mg/100 g)	126	64
MDA (nmol/mL)	96.03	40.30
CAT (U/mg)	17.00	28.49
POD (U/mg)	34.26	64.93
Aflatoxin (μg/kg)	-	1.9
Zealerenol (μg/kg)	87.4	63.4
Deoxynivalenol (μg/kg)	240.9	-
Fatty acid methyl esters (mg/g)		
Palmitic acid (C16:0)	2.448	3.156
Stearic acid (C18:0)	0.256	0.314
Oleic acid (C18:1)	3.872	5.727
Linoleic acid (C18:2)	9.232	11.391
Linolenic acid (C18:3)	0.012	0.318

"-" represented not detected

Table 2: Composition and nutrient level of basal diet (air-dried basis)

	1-14d		15-35d	
Ingredients %	Low fat diet	High fat diet	Low fat diet	High fat diet
Corn[1]	62.80	50.52	70.00	57.50
Soy bean meal	32.40	31.92	22.50	21.50
Wheat bran	1.50	10.00	4.00	14.00
Soy bean oil	0.00	3.00	0.00	3.00
$CaCO_3$	1.08	1.08	1.27	1.28
$CaHPO_4$	1.40	1.38	1.00	0.96
DL-Methionine	0.18	0.20	0.10	0.11
L-Lys-HCL	0	0	0	0
Mineral Premix[2]	0.05	0.05	0.05	0.05
Choline chloride, 50%	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Unite bran	0.15	1.42	0.64	1.16
Vitamin Premix[3]	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00
Duck ME MJ/kg	11.91	11.91	12.04	12.05
CP %	19.43	19.48	15.98	15.99
EE %	2.87	5.72	3.04	5.92
Ca %	0.85	0.85	0.80	0.80
NPP %	0.40	0.40	0.32	0.32
Lys %	1.02	1.02	0.78	0.78
Met %	0.47	0.47	0.35	0.35
Cys %	0.31	0.31	0.26	0.26
Met+Cys %	0.78	0.78	0.61	0.61
Thr %	0.74	0.74	0.60	0.60
Trp %	0.23	0.23	0.18	0.18

[1]All normal corn was replace by aging corn. [2]Provided per Kg of diet: 60 mg Mn (as MnO_2); 80 mg Zn (as $ZnSO_4$); 8 mg Cu (as $CuSO_4$•$5H_2O$); 60 mg Fe (as $FeSO_4$•$7H_2O$); 0.35 mg I (as KI), and 0.30 mg Se (as Na2SeO_3•$5H_2O$). [3]Provided per kilogram of diet: vitamin A, 8,000 IU; vitamin D3, 1,600 IU; vitamin K3, 0.5 mg; vitamin B1, 0.8 mg; vitamin B2, 2.5 mg; vitamin B6, 3.0 mg; vitamin B12, 0.004 mg; folic acid, 0.25 mg; niacin, 20 mg; Ca-pantothenate acid, 2.2 mg and biotin, 0.10mg; vitamin E, according to the amount of each treatment (0,20 or 100 mg)

The analysis of Meat colors were determined as: Lightness (L*), yellowness (b*), and redness (a*) values with an apparatus recognized as Konica Minolta colorimeter CR-400 (Chiyoda-ku, Japan) as demonstrated by Pi *et al.* (2005).

Antioxidative Status Analysis

Subsequently the blood was collected, the tubes comprising blood were centrifuged for 10 min (3000 ×g) at 4°C, after that, the serum was collected in other new tubes and kept at −20°C until antioxidative status analysis. The biochemical analysis in liver, breast muscle and serum including Catalase (CAT), Glutathione peroxidase (GSH-Px), Malondialdehyde (MDA), Superoxide dismutase (SOD), and Total antioxidant capacity (T-AOC) by using a detection kits from Nanjing Jiancheng Bioengineering Institute (Nanjing, Jiangsu Province, P. R. China) with a Multiskan Spectrum Reader (Model 1500; Thermo Scientific, Nyon, Switzerland).

Statistical Analysis

Data were analyzed as 2 × 3 (3 Aging Corn percentage × 2 oil levels) factorial arrangement of treatments by Two-way ANOVA with a model that comprised the main effects of aging corn percentage and oil levels, as well as their interaction. Once the result was significant, the means value was compared by Duncan's multiple comparison tests. Statistical significance was established at ($P < 0.05$) level.

Results

Growth Performance

During starter phase, from 1st - 14th day, the supplementation of oil did not significant effect on BW, BWG and FI irrespective of aging corn levels in diet, though only effect on FCR by the interaction of corn*oil showed significant ($P<0.05$) (Table 3). In contrast, during grower phase, from 15th-35th days, the FI and FCR in the treatments that were fed with 100% aging corn diets were significantly ($P < 0.05$) reduced, and their interaction of corn*oil also showed significant($P < 0.05$) effect. However, during the whole experimental period 1st - 35th days, only FCR were decreased with 100% aging corn, while the interaction of corn*oil showed significant ($P < 0.05$) differences in FI and FCR (Table 3).

Meat Quality

pH measurement of breast meat: The pH of breast meat values was significantly ($P < 0.05$) affected by aging corn at 14 d of feeding, without aging corn or 100% aging corn the pH values were higher as compared to 50% aging corn, while decreased significantly by the inclusion of oil in 100% aging corn diet at 35 d. However, by the interaction of corn*oil showed significant effect at 35 d on pH of breast meat (Table 4).

Meat color: The breast meat color L* was decreased by the addition of oil and b* was decreased by the addition of 100% aging corn at 14 d. At 35 d, the breast meat color L* also was decreased by the addition of oil particularly fed without aging

Table 3: Effect of oil supplementation on growth performance at 1-35 days in meat ducks fed a diet containing aging corn

Treatment	Aging Corn %	Oil%	BW(g)			BWG(g)			FI(g)			FCR		
			1d	14d	35d	1-14d	15-35d	1-35d	1-14d	15-35d	1-35d	1-14d	15-35d	1-35d
T_1	0	0	54.88	595.9	2435.1	541.1	1840.3	2380.2	771.6	4071.7^{a}	4842.7	1.43^{b}	2.21^{a}	2.033^{a}
T_2	0	3	54.87	595.4	2461.6	540.5	1865.9	2406.7	805.4	3983.4^{a}	4794.0	1.49^{a}	2.14^{b}	1.99^{bc}
T_3	50	0	54.93	600.6	2452.2	545.7	1850.51	2397.3	789.6	3995.8^{a}	4786.9	1.45^{ab}	2.16^{b}	2.00^{bc}
T_4	50	3	54.89	588.2	2449.1	533.3	1866.91	2394.2	790.3	4038.1^{a}	4818.4	1.48^{ab}	2.16^{b}	2.01^{ab}
T_5	100	0	54.88	582.8	2425.5	527.9	1841.3	2370.6	791	3790.4^{b}	4584.7	1.50^{a}	2.06^{c}	1.94^{d}
T_6	100	3	54.92	603.2	2479.9	548.3	1876.7	2425.0	789.2	3995.9^{a}	4785.4	1.44^{ab}	2.13^{b}	1.98^{c}
SEM			0.036	7.418	26.738	7.421	22.057	26.741	14.72	47.65	57.35	0.02	0.013	0.01
Main Effect														
Aging Corn	0		54.88	595.7	2448.4	540.8	1853.1	2393.5	788.5	4027.5^{a}	4818.3	1.46	2.17^{a}	2.01^{a}
	50		54.91	594.4	2450.6	539.5	1858.7	2395.7	789.9	4017.0^{a}	4802.6	1.46	2.16^{a}	2.00^{a}
	100		54.90	593.0	2452.7	538.1	1859.0	2397.8	790.1	3893.1^{b}	4685.1	1.47	2.10^{b}	1.96^{b}
Oil	0		54.90	593.1	2437.6	538.2	1844.0	2382.7	784.0	3952.6	4738.1	1.46	2.15	1.99
	3		54.89	595.6	2463.5	540.7	1869.8	2408.6	795.0	4005.8	4799.2	1.47	2.14	1.99
P-Value	Corn		0.569	0.938	0.987	0.937	0.955	0.987	0.993	0.013	0.052	0.836	<.0001	<.0001
	Oil		0.875	0.685	0.242	0.685	0.161	0.243	0.367	0.18	0.201	0.416	0.928	0.65
	Corn * Oil		0.55	0.094	0.565	0.095	0.912	0.566	0.410	0.015	0.10	0.009	<.0001	0.001

[a,b,c] Means with different superscripts within a column differ significantly ($P < 0.05$).BW: body weight (g) BWG: body weight gain, FI: feed intake (g), FCR: feed conversion ratio, SEM: stander error of Mean. During the experiment from 1-14d each treatment has 8 replicates, while for 15-35d and 1-35d each treatment contains 7 replicates respectively

Table 4: Effect of oil supplementation on breast meat and skin color at 14 and 35 days in meat ducks fed a diet containing aging corn

			Breast Meat pH		14d Breast Meat color			35d Breast Meat color			35d Skin color		
Treatments			14d	35d	L*	a*	b*	L*	a*	b*	L*	a*	b*
T_1	0	0	7.03	6.30^{ab}	56.0	7.9	12.7^{a}	45.6^{a}	12.8^{a}	7.1^{a}	71.5^{b}	1.39	13.6
T_2	0	3	7.15	6.26^{abc}	52.9	8.9	12.6^{a}	40.7^{c}	8.3^{b}	5.3^{b}	69.5^{bc}	1.75	14.3
T_3	50	0	6.77	6.10^{bc}	54.1	8.6	12.5^{a}	41.5^{bc}	8.9^{b}	4.1^{cd}	70.4^{bc}	1.94	13.3
T_4	50	3	6.85	6.23^{abc}	52.1	9.2	11.50^{ab}	41.8^{bc}	9.1^{b}	4.8^{bc}	71.1^{b}	1.80	13.8
T_5	100	0	7.05	6.37^{a}	54.1	8.9	10.5^{b}	43.6^{ab}	13.2^{a}	5.6^{b}	74.6^{b}	2.66	11.6
T_6	100	3	7.01	6.08^{c}	53.8	8.7	10.9^{b}	42.5^{bc}	8.5^{b}	3.2^{d}	68.1^{c}	3.10	11.4
SEM			0.063	0.064	1.077	0.743	0.462	0.903	0.531	0.389	0.792	0.44	0.521
Main Effect													
Corn	0		7.10^{a}	6.27	54.5	8.43	12.6^{a}	43.1	10.5^{a}	6.2^{a}	70.5	1.56^{b}	14.0^{a}
	50		6.81^{b}	6.16	53.1	8.88	12.0^{a}	41.6	9.0^{b}	4.4^{b}	70.7	1.87^{b}	13.5^{a}
	100		7.03^{a}	6.23	54.2	8.76	10.7^{b}	43.0	10.9^{a}	4.4^{b}	71.4	2.88^{a}	11.5^{b}
Oil	0		6.95	6.25	54.9^{a}	8.46	11.9	43.5^{a}	11.6^{a}	5.6^{a}	71.1^{a}	2.00	12.8
	3		7.00	6.19	52.9^{b}	8.92	11.7	41.7^{b}	8.70^{b}	4.4^{b}	69.6^{b}	2.21	13.2
P-Value	Corn		<.0001	0.221	0.419	0.823	0.0003	0.181	0.0013	<.0001	0.505	0.0097	<.0001
	Oil		0.365	0.251	0.027	0.456	0.537	0.013	<.0001	0.0003	0.0001	0.556	0.440
	Corn * Oil		0.399	0.006	0.579	0.705	0.323	0.015	<.0001	0.0004	<0.0001	0.774	0.619

[a,b,c] Means in columns with different superscripts differ significantly (P<0.05), color: L*, a*, b* lightness redness and yellowness at different days 14 and 35, SEM: stander error of Mean

corn diet, while a* and b* was decreased significantly by the aging corn, a* only in 50% aging corn, b* mainly in 100% aging corn. The supplementation of oil significantly decreased the L* of the breast meat especially in 100% aging corn diet. While the interaction of corn*oil in meat color L*, a* and b* at 35 d were also showed significant ($P <$ 0.05). The skin color a* was increased, but the b* was decreased significantly ($P < 0.05$) by the aging corn. However the interaction of corn*oil showed significant in L* of skin color (Table 4).

Breast meat: At 14 d, the 50% aging corn diet decreased significantly the breast CAT, while the MDA was decreased significantly by the 100% aging corn (Table 5). While the SOD value was significant higher in the 100% aging corn without the oil addition compared to the aging corn diet without oil, or the 50% aging corn without the oil. In addition, the T-AOC decreased in without aging corn diet while increase in 50% and 100% aging corn diet without oil addition. At 35 d, the aging corn decreased significantly the CAT, SOD and MDA in breast with significant difference between non-aging corn and 100% aging corn (Table 5).

Antioxidant Status

Serum: At 14 day, the aging corn addition in duck diet had significant ($P < 0.05$) effect on the values of CAT and MDA in serum with the decrease of CAT in 50% aging corn but numerically increased with the addition of oil, while MDA was increase in 50% aging corn but decrease with the addition of oil (Table 6). At 35 day, the CAT was increased significant ($P < 0.05$) by the addition of aging corn.

Table 5: Effect of oil supplementation on Breast meat antioxidative ability at 14 and 35 days in meat ducks fed a diet containing aging corn

			CAT		GSH-Px		MDA		SOD		TAOC	
Treatment	aging corn %	Oil %	14d	35d	14d	35d	14d	35d	14d	35d	14d	35d
T1	0	0	0.93^{b}	0.79^{cb}	14.21	13.20	1.31	2.05	95.49^{a}	83.06	0.076	0.112^{ab}
T2	0	3	0.81^{b}	0.52^{c}	13.77	11.80	1.35	1.63	79.41^{b}	69.53	0.089	0.114^{ab}
T3	50	0	0.70^{b}	1.81^{a}	16.52	11.22	1.60	1.48	75.04^{b}	67.69	0.095	0.107^{ab}
T4	50	3	1.44^{a}	1.81^{b}	21.12	9.05	1.46	1.61	92.65^{a}	68.68	0.100	0.128^{a}
T5	100	0	1.38^{a}	0.41^{c}	13.38	14.01	1.33	1.46	100.36^{a}	69.94	0.108	0.119^{ab}
T6	100	3	1.49^{a}	0.97^{b}	16.48	8.92	1.56	1.43	91.53^{a}	67.67	0.097	0.094^{b}
SEM			0.122	0.137	16.481	1.535	0.118	0.117	4.163	3.276	0.008	0.008
Main effect												
corn	0		0.87^{b}	0.65^{b}	13.99	12.5	1.33	1.84^{a}	87.45^{ab}	76.30^{a}	0.082^{b}	0.113
	50		1.07^{b}	1.37^{a}	18.82	10.13	1.53	1.54^{b}	83.85^{b}	68.19^{b}	0.099^{a}	0.117
	100		1.44^{a}	0.69^{b}	14.93	11.46	1.44	1.44^{b}	95.95^{a}	68.80^{b}	0.102^{a}	0.107
Oil		0	1.01^{b}	1.00	14.7	12.81	1.41	1.66	90.3	73.57	0.093	0.113
		3	1.25^{a}	0.81	17.13	9.92	1.46	1.56	87.87	68.63	0.097	0.112
P-value	CORN		0.0003	<.0001	0.054	0.316	0.276	0.005	0.02	0.034	0.041	0.484
	OIL		0.022	0.095	0.152	0.028	0.643	0.278	0.48	0.075	0.601	0.891
	CORN*OIL		0.004	<.0001	0.448	0.457	0.306	0.066	0.001	0.083	0.288	0.035

[a,b,c] Means in columns with different superscripts differ significantly (*P*<0.05), Breast 14d: Breast CAT U/mgprot, GSH-Px U/mgpro, MDA nmol/mgprot, SOD U/mgprot and T-AOC nmol/mgprot at 14 days of age, Breast 35d: Breast CAT U/mgprot, GSH-Px U/mgpro, MDA nmol/mgprot, SOD U/mgprot and T-AOC nmol/mgprot at 35 day of age SEM: stander error of Mean

Table 6: Effect of oil supplementation on serum antioxidative ability at 14 and 35 days in meat ducks fed a diet containing aging corn

			CAT		GSH-PX		MDA		SOD		T-AOC	
Treatment	Aging corn %	Oil %	14d	35d	14d	35d	14d	35d	14d	35d	14d	35d
T1	0	0	0.86^{a}	0.61	251.90	226.72	7.63^{c}	7.11^{bc}	71.76	70.31^{b}	1.39	1.35
T2	0	3	0.84^{a}	0.78	252.83	231.53	8.87^{b}	7.22^{bc}	75.72	74.75^{ab}	1.37	1.20
T3	50	0	0.41^{b}	0.72	267.12	214.56	9.95^{a}	6.60^{c}	80.5	77.19^{ab}	1.32	1.38
T4	50	3	0.76^{a}	1.45	290.89	200.52	8.62^{bc}	8.43^{a}	75.02	72.95^{ab}	1.4	1.29
T5	100	0	0.81^{a}	0.74	252.24	222.93	8.69^{b}	6.12^{c}	76.83	78.99^{a}	1.37	1.44
T6	100	3	0.76^{a}	1.29	292.52	169.44	9.15^{ab}	8.03^{ab}	81.32	71.23^{b}	1.36	1.35
SEM			0.071	0.162	14.002	14.391	0.341	0.364	2.348	2.235	0.05	0.049
Main effect												
Corn	0		0.85^{a}	0.69^{b}	252.36	229.12	8.25^{b}	7.16	73.74	72.53	1.38	1.28
	50		0.59^{b}	1.08^{a}	279.01	207.54	9.28^{a}	7.52	77.76	75.07	1.36	1.33
	100		0.78^{a}	1.01^{ab}	272.38	196.19	8.92^{ab}	7.08	79.08	75.12	1.36	1.39
Oil		0	0.69	0.69^{b}	257.09	221.4	8.76	6.61^{b}	76.36	75.5	1.36	1.39^{a}
		3	0.78	1.17^{a}	278.74	200.5	8.88	7.89^{a}	77.36	72.98	1.38	1.28^{b}
P-value	CORN		0.003	0.05	0.158	0.083	0.016	0.445	0.076	0.428	0.932	0.082
	OIL		0.123	0.001	0.068	0.085	0.675	0.0001	0.608	0.177	0.666	0.010
	CORN*OIL		0.016	0.229	0.381	0.136	0.002	0.031	0.073	0.03	0.497	0.803

[a,b,c] Means in columns with different superscripts differ significantly (*P*<0.05), serum 14d: serum CAT/U/mL, GSH-Px U/mL, MDA nmol/mL, SOD U/mL and T-AOC nmol/L at 14 days of age, serum 35d: serum CAT U/mL, GSH-Px U/mL, MDA nmol/mL, SOD U/mL and T-AOC nmol/L at 35 days of age, SEM: stander error of Mean

The MDA was increased by oil addition particularly in 50% and 100% aging corn diets. In addition, the interaction showed significant effect on SOD with the significant higher in 100% aging corn without oil diet compared to the aging corn diet without oil (Table 6).

Liver: At 14 day, the 50% aging corn diet decreased significantly the level of CAT in liver, while the MDA was decreased significantly by the addition of 100% aging corn (Table 7). On the other hand, the GSH-Px value was significant higher in the 50% aging corn with the addition of oil as compared to the 50% aging corn without oil (*P* <0.05), while the SOD value was significant higher in the 100% aging corn without the oil addition compared to the non-aging corn without oil, or the 50% aging corn without the oil. At 35 day, the aging corn decreased significantly the level of CAT and T-AOC in liver with significant difference between non-aging corn and 100% aging corn. While increased significantly the GSH-PX and MDA level by the 50% aging corn (Table 7).

Discussion

According to the previous studies, deviations in chemical composition and nutrition in various cereal grains values occur might be due to storage (Chrastil, 1990; Dhaliwal *et al.*, 1991; Rehman, 2006). Although the oil content in corn kernel is only 3.5%-6.5%, but the unsaturated fatty acids are more than 80%.

Table 7: Effect of oil supplementation on liver anti-oxidative ability at 14 and 35 days in meat ducks fed a diet containing aging corn

			CAT		GSH-PX		MDA		SOD		T-AOC	
Treatment	Aging corn %	Oil %	14d	35d	14d	35d	14d	35d	14d	35d	14d	35d
T1	0	0	3.17	3.29	84.68^{ab}	89.89	0.71^{ab}	0.60	333.29^{ab}	323.09	0.10	0.10
T2	0	3	2.93	2.56	80.89^{ab}	76.79	0.85^{a}	0.62	311.03^{b}	336.07	0.09	0.10
T3	50	0	2.15	2.74	75.94^{b}	103.76	0.63^{bc}	0.62	302.27^{b}	334.25	0.08	0.09
T4	50	3	2.64	2.41	92.44^{a}	92.34	0.71^{ab}	1.03	327.69^{ab}	355.31	0.09	0.10
T5	100	0	2.65	2.17	84.79^{ab}	76.79	0.76^{ab}	0.68	345.59^{a}	306.88	0.10	0.09
T6	100	3	2.83	2.33	84.52^{ab}	81.22	0.51^{c}	0.62	315.58^{ab}	326.79	0.09	0.08
SEM			0.213	0.239	3.928	6.06	0.056	0.093	10.707	15.684	0.005	0.004
Main effect												
corn	0		3.05^{a}	2.92^{a}	82.79	83.34^{b}	0.78^{a}	0.61^{b}	322.16	329.58	0.09	0.10^{a}
	50		2.40^{b}	2.58^{ab}	84.19	98.05^{a}	0.67^{ab}	0.95^{a}	314.98	344.78	0.09	0.10^{a}
	100		2.74^{ab}	2.25^{b}	84.66	79.01^{b}	0.63^{b}	0.65^{b}	314.98	316.84	0.09	0.09^{b}
Oil		0	2.66	2.73	81.8	90.15	0.70	0.72	327.05	321.41	0.09	0.09
		3	2.80	2.43	85.95	83.45	0.69	0.75	318.1	339.39	0.09	0.09
P-value	CORN		0.017	0.03	0.885	0.01	0.032	0.002	0.358	0.220	0.224	0.013
	OIL		0.413	0.133	0.206	0.186	0.859	0.604	0.314	0.171	0.158	0.709
	CORN*OIL		0.241	0.19	0.034	0.294	0.003	0.604	0.031	0.962	0.194	0.533

[a,b,c] Means in columns with different superscripts differ significantly ($P<0.05$), , Liver 14d: Liver CAT U/mgprot ,GSH-Px U/mgprot MDA nmol/mgprot, SOD U/mgprot and T-AOC nmol/mgprot at 14 days of age, Liver 35d:. Liver CAT U/mgprot, GSH-Px U/mgprot MDA nmol/mgprot, SOD U/mgprot and T-AOC nmol/mgprot at 35 days of age, SEM: stander error of mean

These fatty acids and lipids are prone toward oxidation and peroxidation during storage, leading to a deterioration of stored corn quality (Zhou *et al.*, 2007). Zhang *et al.* (2008) reported that CAT and POD of maize gradually reduced through increased storage time. The dry matter (DM), fatty acid value and peroxidase activity are the important parameters for the quality evaluation of corn storage (Mcdonough *et al.*, 2004; Yin *et al.*, 2017).

The fatty acid value of aging corn was higher than normal corn in this study, but moisture contents and peroxidase activity was lower (Table 1). The aging corn originated from grain depot, the storage condition was suitable, and the content of mycotoxins was not exceeded from considerable value. We found that the aging corn in this study decreased the FI and FCR at 15-35d or 1-35d particularly in 100% aging corn diet (Table 3) that were consistent with previous studies (Zhang *et al.*, 2015a; Yin *et al.*, 2017). Yin *et al.* (2017) found broiler chickens fed with different storage time of corn and storage time tended to linearly decrease the body weight gain. The decreased in FCR by aging corn might be due to the dry matter content in aging corn that was higher than normal corn, and then the nutrient intake was almost the same as that for control corn. The decreased in FI of aging corn might be due to oxidation of diet result in impairing nutritional value. The ducks fed aging corn were more susceptible to obtain oxidative damages and decreased performance (Salman and Copeland, 2007). Studies conducted on the broiler also showed the same trend of decrease in growth was due to addition of high levels of rice bran (Atapattu and Madushanka, 2015). In another study, the diet with 5.5% oxidized sunflower oil fed for 4 weeks to chickens resulted in significantly reduction of carcass weight (Lin *et al.*, 1989).

The measurement of pH value is an important parameter while evaluating the meat quality (Table 4). The increase in pH of breast meat in 100% aging corn diet might be due to the physiological and nutritional changes which effect the pH, however the decreased pH in aging corn with oil addition may be because of increase in fatty acids and amino acids contents in oil with aging corn diets during storage process as reported by previous studies (Zhang *et al.*, 2008; Yin *et al.*, 2017). The significant difference in skin color parameter L* reflects the effect of feeding diet on color parameter (Table 4). The decreased in lightness of breast due to aging corn implies that aging corn could reduce the quality characteristics of meat. But values of a* and b* for skin color have not been affected. The Lightness L* and yellowness b* of breast muscle was decreased with oil supplementation and with levels of aging corn diet and increased in a* in aging corn diets that deteriorate fat contents which cause the deposition of oil in breast muscle result in increased brightness (Table 4). The oil reduced the red color and the yellow color that was also reported (Swatland, 2008; Saeed *et al.*, 2018). Moreover, the pH also affect the color as low pH scatter the light that results in pale color of the meat while high pH permit light to be transmitted into the deep section of meat, prominent too dark color (Swatland, 2008). Moreover, color values in our studies were in agreement with the prescribed standard of poultry meat (Awada *et al.*, 2012).

The breast meat is important in evaluating the meat quality and antioxidative status because it's easily affected by different dietary treatments. The levels of CAT significantly effected (Table 5) in breast meat increased oxidative stress at 14 d and 35 d with aging corn diets according to the chicken fed oxidative oil base diet (Zhang *et al.*, 2011). In addition, numerically high level of GSH-Px in breast muscle at 35d in aging corn diet suggested that the oxidative stress was increased (Table 5). The levels of MDA have no effect at 14 d and 35 d of age, however MDA levels was numerically high with oil contain aging corn diet as compared to the control.

The SOD levels in breast significantly altered and decreased at 35 d of age fed with 100% aging corn diet as contrast with this study, when oxidative oil diet were fed to the chicken (Zhang *et al.*, 2011) (Table 5).

Serum plays a vital role in growth, and helps as a transporter for enzymes, fats and micronutrients. It can reflect the different nutritional status in growing animals. The storage of corn and oxidative oil resulted in many free radicals, and birds fed aging corn had a lower serum antioxidant function status (Koch *et al.*, 2007; Salman and Copeland, 2007). The intake of exogenous free radicals can cause the decrease antioxidation of antioxidants. The numerical increased in GSH-PX levels in serum, (Table 6) showed that the capacity of eliminating free radical increased while the increased level of CAT in serum at 14d. The antioxidant activity and MDA level of serum was significantly affected at 14 and 35 days (Table 6). MDA is the terminal product of lipid peroxidation that is important factor indicates the amount of oxidative stress. The increase in MDA level was an index of lipid peroxidation in tissue possibly due to addition of oil. It results in insufficient elimination of reactive oxygen species (ROS) conquered in tissues (Lü *et al*., 2010). The T-AOC is an index of evaluating redox status specified the difference between production and elimination of free radical. With the supplementation of oil, the MDA levels increased while the SOD level increased on 35 day with 100% aging corn in serum while the level of T-AOC was decreased in serum, with supplementation of oil aggregated with previous studies conducted on chicken (Liu *et al.,* 2010; Liu *et al.,* 2013; Zhang *et al.*, 2015a).

The liver has numerous functions. It produces lot of enzymes and helps to regulate the body function, it can easily effected by the aging corn and oil same as our results showed the GSH-PX levels in liver were increased by diets with different aging corn levels at 14 d (Table 7), same trend were also observed in chicken reported by Zhang *et al.* (2015a). The GSH-Px level in liver at 14 day was significantly altered and suggested that levels of aging corn caused oxidative liver damage that were more dominant in those birds that were fed with oxidized oil (Ammouche *et al.,* 2002; Koch *et al*., 2007; Zhang *et al.*, 2015a). Some studies showed the increased MDA and SOD levels in liver were due to supplementation of essential oil but it was observed during transportation of pig (Zhang *et al*., 2015b). In contrast, our results (Table 7) showed the decreased level of SOD and MDA, when oil based aging corn levels diet was added. There is limited data available about the effects of aging corn levels with or without oil based diet on performance, meaty quality and antioxidative ablity in meat ducks but this study may helpful to sought out this problem.

Conclusion and Application

Aging corn affected the performance of ducks by reducing the FI and FCR, as well as decreased the breast pH, breast and skin color at 14 and 35d of the experiment. However, by addition of oil, FI and FCR were increased, reduced meat quality while did not cause oxidative stress in meat ducks. Although the aging corn and oil interaction also showed reduction of meat quality and antioxidative ability. The different levels of aging corn also changed the antioxidant status of serum liver and breast. In general, oil supplementation could alleviate the negative effects of aging corn on meat ducks to some extent.

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