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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 soybean 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). Results showed that 50% aging corn or addition of 3% soybean oil did not affect on duck growth performance. Although 100% aging corn significantly ($P < 0.05$) decreased feed intake (FI) from 15 to 35 d. However, the oil addition in 100% aging corn diet increased FI during 15 to 35 d, FCR at 15 to 35 d and 1 to 35 d. In contrast, the oil addition in non-aging corn diet increased feed conversion ratio (FCR) significantly ($P < 0.05$) during 1 to 14 d, while significantly ($P < 0.05$) decreased from 15 to 35 d and 1 to 35 d. Aging corn levels with 50% and 100% resulted in breast meat color change with decreased of b* value at 35 d. Addition of oil in 100% aging corn significantly reduced the breast meat pH, a*, and b* value and skin L* value at 35 d. The aging corn and oil addition resulted in change of antioxidative enzymes *e.g*., CAT, SOD, TAOC and the level of MDA, may relate to the aging corn%, duck age, and the interaction of aging corn and oil. In conclusion, the aging corn reduced FI with 100% aging corn from 15-35d ,while decrease the breast meat and skin color b* value with 50% and 100% aging corn, it could be associated to the oxidative stress by aging corn. The oil addition perhaps increases the effects of aging corn on meat and skin color.

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; Fu *et al*., 2018). 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, 2017/2018).

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

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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 of 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 fed aging corn diets were more likely to obtain oxidative damage, which resulted in reduced growth performance (Mcfarlane *et al.*, 1989).

Vegetable oils are easily prone to oxidation because of high amount of unsaturated fatty acids (UFA) (Farhoosh *et al.*, 2009). 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 UFA. 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 of body weight gain (BWG) (Barbour *et al.*, 2006). However, as far as ascertained, limited studies on effects of feeding aging corn with or without oil supplementation in duck diets are reported, the oil may increase the effects of aging corn on duck performance or meat quality. 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

Physical and chemical properties of aging corn and normal corn: Aging and normal corn were originated from National barns, China after the storage period of 4 years and 0.5 year, respectively. Some of physicochemical 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 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 by method GB/T 20570-2015 (MOH and SAC, 2015). The national standard methods GB 5009.168-2016 (MOH and SAC, 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 (MOH and SAC, 2014), GB/T 28716-2012 (MOH and SAC, 2012) and SN/T 1571-2005 (MOH and SAC, 2005). Fatty acids were quantified by the national standard methods GB 5009.168-2016 (MOH and SAC, 2016) (Table 1).

Experimental designs, 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 (2.2 × 1.2× 0.9 m/pen), and 16 ducks were kept in each pen for 35 days. 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.

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
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 kilogram of diet: Cu ($CuSO_4 \cdot 5H_2O$), 8 mg; Fe ($FeSO_4 \cdot 7H_2O$), 80 mg; Zn ($ZnSO_4 \cdot 7H_2O$), 90 mg; Mn ($MnSO_4 \cdot H_2O$), 70 mg; Se ($NaSeO_3$), 0.3 mg; I (KI), 0.4 mg. [3]Provided per kilogram of diet: vitamin A, 9,000 IU; vitamin D3, 1,500 IU; vitamin e, 7.5 IU; thiamine, 0.6 mg; riboflavin, 4.8 mg; pyridoxine, 1.5 mg; vitamin B12, 0.009 mg; calcium pantothenate, 7.5 mg; folate, 0.15 mg; niacin, 20 mg.

Measurements

Growth performance: At 14 d and 35 d of age, after 12 h, the feed was withdrawn, ducks were weighed and feed consumption stayed obtained by pen. Body weight (BW), body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR, FI/BWG) were calculated.

Meat Quality: The pH of breast muscle at 45 min was measured by submersing a digital pH meter (Hanna, Italy) into meat of breast samples. 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

The results showed that 50% aging corn or by 3% soybean oil addition did not affect the duck growth performance. Although 100% aging corn significantly ($P < 0.05$) decreased the feed intake (FI) during 15 to 35 d and FCR during 15 to 35d and 1 to 35 d of age. However, the oil addition in 100% aging corn diet increased the FI at 15 to 35 d, FCR at 15 to 35 d and 1 to 35 d of age. In contrast, the oil addition in non-aging corn diet increased the FCR at 1-14 d, while decreased the FCR at 15 to 35 and 1 to 35 d of age significantly ($P < 0.05$). While, throughout the experiment non-significant ($P < 0.05$) effects on BW and BWG was observed among the treatments (Table 3).

Meat Quality - pH of breast meat and color measurement: Ducks fed with 50% aging corn reduced the breast meat pH at 14 d, a* and b* value at 35 d, while 100% aging corn decreased ($P < 0.05$) significantly the b* value at 14 and 35 d. At 35d of age 100% aging corn increased significantly ($P < 0.05$) the skin a* value but decreased b* value. The oil addition decreased the breast meat L* value at

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		
			1 d	14 d	35 d	1-14 d	15-35 d	1-35 d	1-14 d	15-35 d	1-35 d	1-14 d	15-35 d	1-35 d
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 ($P < 0.05$), SEM: stander error of Mean. During the experiment from 1-14 d each treatment has 8 replicates, while for 15-35 d and 1-35 d each treatment contains seven replicates respectively.

Table 4: Effect of oil supplementation on pH of breast meat at 45 min and skin color at 14 and 35 days in meat ducks fed a diet containing aging corn

			Breast Meat pH		14 d Breast Meat color			35 d Breast Meat color			35 d 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: standard error of mean

14 days, L*, a*, and b* value or skin L* value at 35 d, while the oil addition in non-aging corn diet decreased significantly ($P < 0.05$) the breast meat L*, a*, and b* value at 35 d, and the oil addition in 100% aging corn significantly ($P < 0.05$) decreased breast meat pH, a*, b* value and skin L* value at 35 d of age (Table 4).

Antioxidant Status of Breast, Serum and Liver

Our results showed that the activity of CAT was increased by 50% aging corn in serum at 14 and 35 d of age, similarly 100% aging corn in breast meat at 14 d, although decreased in liver by 50% aging corn at 14 d, 100% aging corn at 35 d of age. Oil addition intend to increase the 50% aging corn effect on CAT in serum and breast meat at 14 d, while decrease the 100% aging corn effect on CAT in liver at 35 d. Ducks fed with 50% aging corn increased the activity of CAT in serum and breast meat at 14 d particularly with oil addition, but decreased in liver at 14 d. At 35 d 100% aging corn also reduced the activity of CAT in liver, but resulted as increase with the addition of oil. Aging corn increased the activity of CAT at 35 d, TAOC at 14 d in breast meat, CAT in serum at 35 d, the level of MDA in serum at 14 d, however decreased the activity of SOD and the level of MDA in breast meat at 35 d. With 100% aging corn increased the activity of CAT, TAOC at 14 d in breast meat, CAT in serum at 35 d, the level of MDA in serum at 35 d, but decreased the activity of SOD and the level of MDA in breast meat at 35 d. Addition of oil increased the activity of CAT at 14 d in breast meat and in serum at 35 d, the level of MDA in serum at 35 d, but decreased the activity of TAOC in serum at 35 d. The oil addition in 50% aging corn diet increased significantly ($P < 0.05$) the activity of CAT in breast meat and serum at 14 days that was the

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 (U/mgprot)		GSH-Px (U/mgprot)		MDA (nmol/mgprot)		SOD (U/mgprot)		TAOC (nmol/mgprot)	
Treatment	aging corn %	Oil %	14d	35d	14d	35d	14d	35d	14d	35d	14d	35d
T1	0	0	0.93^{b}	0.79^{bc}	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}	0.93^{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												
Aging 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

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 (U/ml)		GSH-PX (U/ml)		MDA (nmol/ml)		SOD (U/ml)		T-AOC (nmol/L)	
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												
Aging 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 ($P < 0.05$), SEM: standard error of mean

same in the 100% aging diet with oil addition for CAT in breast meat at 35 d. At 14 and 35 d MDA level in serum was increased significantly ($P < 0.05$), by the oil addition in non- aging diet or 50% and 100% aging corn; on the contrary, the oil addition in 50% aging corn decreased the level of MDA in serum at 14 d. The addition of oil in 100% aging corn decreased the activity of SOD in serum at 35 d in 50% aging corn. However GSH-PX did not showed any significant effect in serum and breast while in liver it's significantly altered between 50% aging corn diet with or without oil addition (Table 5, 6 and 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 to 6.5%, but the UFA are more than 80%. 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 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

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 (U/mgprot)		GSH-PX (U/mgprot)		MDA (nmol/mgprot)		SOD (U/mgprot)		T-AOC (nmol/mgprot)	
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												
Aging 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 ($P < 0.05$), SEM: standard error of mean

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 affected (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*., 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 ability in meat ducks but this study may helpful to sought out this problem.

Conclusion and Application

It can be said that 100% aging corn affected the performance of ducks by reducing the FI, as well as decreased the breast pH, breast and skin color at 14 and 35 days of the experiment, which partly decreased the antioxidative ability. However, by addition of oil, MDA contents was increased, serum T-AOC, color of skin and breast meat were decreased. In addition, 100% aging corn with oil supplementation increased FI, and serum MDA content, while decreased breast meat pH at 45 min, a* ,b* and L* of breast meat and skin, and serum SOD activity when compared with 100% aging corn without oil supplementation.

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