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Original Article

Physico-Chemical Parameters, Oxidative Stress, and Fatty Acid Profile of American Pekin Ducks (Anas Platyrhynchos Domesticus) Raised under Different Production Systems

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Rearing system, Pekin ducks, fatty acid, meat coloration, oxidative stress.

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ABSTRACT

Rearing of American Pekin ducks in different production systems plays a vital role in the determination of the internal climatic conditions of the house for optimum health and meat quality parameters. The experiment was designed to evaluate the influence of different rearing systems fed on kitchen waste on meat quality parameters of American Pekin ducks. A total of 180 ducklings (10 days old) were distributed randomly into three experimental groups; intensive production system (IPS), free-range production system (FRPS), and pool with yard production system (PYPS). We investigate the physicochemical parameters, meat coloration, oxidative stress, and fatty acid (FA) profile of Pekin ducks. Ducks reared in PYPS showed better physico-chemical parameters and meat coloration than those of ducks reared in IPS and FRPS. Drip loss % and cooking loss % are significantly low in FPRS while (L*) l-lightness, (a*) redness, and (b*) yellowness are significantly higher in IPS ($p \leq 0.05$). The oxidative stress was reduced in PYPS due to the natural behavior of ducks. Moreover, the fatty acid profile was improved in PYPS fed with 100% kitchen waste. In conclusion, this experiment confirmed that ducks reared in PYPS improve their meat quality parameters, fatty acid, and oxidative stress.

INTRODUCTION

The growth of the duck industry has increased substantially over the last 20 years, with about 1.15 billion ducks being raised worldwide in 2017. The American Pekin duck (*Anas platyrhynchos domestica*) is known to the world for its rapid growth and excellent quality of meat. Pekin ducks are commonly raised for fattening purposes (El-Edel *et al.,* 2015). Red muscles are higher in ducks as compared to chickens, so it is considered red meat (Graczyk *et al.,* 2016). Furthermore, duck meat demands are increasing due to its great nutritional value. Duck meat is enriched in protein, ash, a lesser quantity of water and fat, and a greater quantity of red muscles in breast meat as compared to broiler breast chicken (Ali *et al.,* 2007). Additionally, duck meat is an efficient source of amino acids and polyunsaturated fatty acids (Wołoszyn *et al.,* 2006).

In 2018, worldwide duck meat production was (4464925 tons), 83 % (3705427 tons) of the production accounted for Asia, 11.7% (520456 tons) for Europe, and the rest of the world for only 5.3% of total meat production. In 2018, the largest duck meat producing country is China (3015003t). Pekin ducks are mainly used for red meat production in Asia, Central and North Europe have lower production obtained after mallard & Muscovy ducks. Large meat-producing countries in Europe are France, Hungary, and Germany with the production of 246209 tons, 93622 tons, and 37058 tons respectively (Starčević *et al.,* 2021). Breeds of meat-producing ducks are growing rapidly due to efficient housing systems, genetic selection, and superior nutrition (Adeola, 2003). Pekin ducks have high growth rates due to their efficient digestive system, acquired body weight, and whole-body formation. In this context, many studies investigated growth rate and meat quality in commercial Pekin ducks (Kwon *et al.,* 2014; Kokoszyński *et al.,* 2015; Kokoszyński *et al.,* 2019b; Kokoszyński *et al.,* 2019a). Pekin ducks showed highest growth rate and reached almost 3.5 kg weight during 6 to 8 weeks and were subjected to slaughter (Kokoszyński *et al.,* 2020). However, there will be adverse effects on meat quality due to the selection of fast growth and high yields (Kwon *et al.,* 2014).

In recent decades, duck meat production takes to become more intensive, to provide appropriate condition for welfare of animals and enhance the quality of meat, therefore, there is a need to develop a suitable production system (Chen *et al.,* 2015). They need higher quality ducks for the production of duck meat to be maintained under conditions of environmental protection and management that ensure the provision of adequate welfare level, because duck meat quality, fattening performance and welfare are largely influenced by rearing or housing and environmental system. Different types of duck meat production systems have been used which differ in rearing or housing system (intensive, free-range, and semi-intensive), different types of flooring, different types of feeding and drinking systems, light systems that affect the welfare of animals, meat quality, growth rate, and carcass yield (Onbaşilar & Yalcin, 2018). Peking ducks are very susceptible to environmental stress, which is influenced by housing conditions (Faure *et al.,* 2003). The improved quality of duck meat production is responsible for the reduction of malnutrition. So, there is a need to provide more information on the meat quality parameters of ducks in different housing systems. Currently, there are no data regarding the effect of different rearing systems on meat quality traits of American Pekin ducks such as fatty acid profile, meat colorations, and oxidative stress. Therefore, this experiment was designed to compare the effects of three different rearing production systems (intensive, free-range, and pool with yard) on physico-chemical characteristics, oxidative stress & fatty acid profile of American Pekin ducks.

MATERIALS AND METHODS

Location and Period

The experiment was conducted at the Integrated Aquaculture Research Unit (IARU), Department of Fisheries and Aquaculture, University of Veterinary and Animal Sciences, Lahore, Pakistan. The duration of the proposed study was 3 months.

Statement of animal rights

In this study, all the trials were performed in agreement with the ethical standards of the University of Veterinary and Animal Science, Lahore, Pakistan and with the approval.

Experimental design

The experimental bird was reared in three different production system (Intensive, free-range and pool with yard). 180 straight-run American Pekin duckling (10-day old) with an average weight of (147.2 ± 4.5) g purchased from local market, in Lahore and divided into 3 experimental units with 3 replicates each replicate comprising 20 birds. A completely randomized design under factorial arrangements was used in this study (Table 1). In the intensive system the stocking density was 0.060 m^2 per duck and the nipple drinking system was used in the intensive system @10 ducks per nipple up to the age of six weeks. With the growing age, the stocking density was tuned to a maximum of 0.139 m^2 per bird. In free range production system, guidelines from United State Department of Agriculture were followed with a stationary indoor house as a shelter and an outdoor area which could be a concrete floor for movement. For this, measuring of pen 11.14 m^2 for outdoor and 11.14 m^2 indoor area and access was provided to 20 ducks @ 0.92 m^2/bird. While additional drinkers and feeders were placed @15 ducks per drinker and 10 ducks per feeder. The experiment was performed from August to October with temperatures ranging from 22 to 32 which is good rearing environment with minimum air draft. Experimental birds were fed (IPS) 100 % commercial feed, (FRPS) 50 % each commercial feed +kitchen waste (KW) and (PYPS) 100 % kitchen waste (KW) correspondingly. The proximate composition of kitchen waste and feed ingredients is shown in (Table 2).

Table 1 – Experimental layout.

Rearing System	Feed Offered	No. of Birds
IPS	100% Commercial Feed	
FRPS	50 % Commercial feed + 50 % kitchen Waste	3x3x20=180
PYPS	Kitchen Waste 100%	

IPS= Intensive production system (IPS), FRPS = Free-range production system (FRPS), PYPS= Pool with yard production system (PYPS)

Physico-chemical parameters

To determine the physico-chemical parameters of duck, both breast and leg muscles tissues were taken.

A total of 27 birds was selected for slaughtering, before slaughter, the birds were off food for 8 hours and then weighed. All the birds were manually slaughtered (halal system), degutted, and de-feathered. After bleeding, carcasses were dipped in hot water (60°C for 2 minutes) and then plucked, gutted to take the breast meat. All skin, visible connective tissues and subcutaneous fat were completely removed from the breast meat before the assessment of fatty acid parameters. There were samples immediately stored for 24 h at 4 °C for further analysis. A digital pH meter (Hanna HI 99163N) was used to measure the pH after 24 hours of slaughter. After measuring the pH, thigh and breast meat were selected for the evaluation of physical meat quality parameter. A colorimeter (CR-310, Minolta Co., Ltd., Osaka, Japan) was used to measure meat color, (L*) lightness, (a*) redness and (b*) yellowness after 24 hours post mortem. Drip loss% was measure as follows: within one hour of slaughter, a muscle sample (20g) of 1 cm thickness cut from fat (W1) was weighed, suspended with metal wire in cup and placed in a fresh bag and wrapped, preserved at -4 °C in a refrigerator, filter paper was used to clean surface water 24 hours after storage and then reweigh (W2).

Drip loss %=(W1-W2)/W1*100

48 hours' post-mortem, these muscle samples were placed in plastic bags and cooked in hot water till the core temperature reached 70 °C. The cooking loss % was calculated.

Table 2 – Proximate composition of kitchen waste and composition of experimental feed and its nutrients profile.

Proximate Kitchen Waste	
Dry Matter %	36.7
Crude Protein %	15.9
Moisture %	43.88
Ether Extract %	19.01
Ash %	7.01
Feed Ingredient (%) Grower	
Methionine	0.12
NaCl	0.30
Soybean Meal (30 CP%)	32.01
Soybean Oil	3.02
Corn (8.5 %)	62.01
DCP	1.70
Total	100
Nutrient composition	
Dry Matter	89.5
Calcium	0.92
Crude Protein	20.09
Methionine	0.45
Metabolizable Energy (Kcal/Kg)	3020
Phosphorus	0.39
Lysine	1.10

Oxidative stress

The parameters of oxidative stress, consisting of superoxide dismutase (SOD), malondialdehyde (MDA), and glutathione peroxidase (GPx) were evaluated by using spectrophotometry followed by the method of (Perveen *et al.,* 2022; Jo & Ahn 1998; Paglia & Valentine 1967).

Fatty acid profile

FA profile of American Pekin ducks was evaluated using AOAC protocol (2000). According to this method, 1.5 ml of 0.5 M sodium hydroxide in methanol was added for 25 mg of lipids to prepare fatty methyl esters of methyl esters (FAME). Contents were heated at boiling water bath for 2 min at 100°C and then cooled. 2ml of 14% boron trifluoride is added in methanol and heating again at water bath for half hour then 1 ml of isooctane was added. For the separation of isooctane and methanol, 5 ml of saturated NaCl was added. Isooctane was collected in a separate tube and the process is repeated one more time. Nitrogen gas (2ml was dried at room temperature. A flame ionization detector coupled with gas chromatography (GC) (7890, B Agilent Technology) was utilized for the analysis of methyl esters and fatty acids. A 140-220 °C quartz capillary column was used for the GC, while the temperature for the detector and injector was automated at 200 °C. During the experiment, as carrier gas helium was used, which run at a rate of 1.2 ml/min. Methyl esters of fatty acid were measure due to time of retention compared to a normal value provided by the GC-MS control computing system. The peaks of each fatty acid were analyzed to calculate the absolute response (Qian, 2003).

Statistical analysis

Current research was planned in completely randomized design and experiments were run in triplicates. Data was analyzed through one ANOVA for different rearing system impact on different treatments and their interaction and expressed as mean ± SD. Significant differences between different treatments were considered at $p \leq 0.05$. Duncan's Multiple Range test (DMR) was applied for the determination of difference among the studied treatments using integrated system of software of Statistical Analysis System (SAS) of 9.1 version.

RESULTS

Physico-chemical parameters

The physico-chemical traits of breast and leg muscles of ducks was evaluated and presented in Table

3. Regarding pH, there is significant difference among treatments, pH level was higher in ducks reared under pool with yard production system than those raised under intensive and free-range production system in both breast and leg muscles (5.77 vs 5.29, 5.54), (6.20 vs 5.21, 5.83) respectively. Pool with yard production system showed significant effect on improved drip loss % than those of raised in intensive and free-range production system in breast muscles (2.45 vs. 3.35, 3.10) and leg muscles (1.25 vs 2.80, 2.35). There is significant difference between the treatment regarding cooking loss %, the lowest value of both breast and leg muscles is shown in PYPS (15.05; 17.99) and highest value shown in IPS (20.01; 20.30).

Table 3 – Physico-chemical parameters of Pekin duck among different housing systems.

Parameters		IPS	FRPS	PYPS	*p*-Value
pH	BM	5.29±0.05^{b}	5.54±0.11^{ba}	5.77±0.01^{a}	0.0344
	LM	5.21±0.02^{b}	5.83±0.04^{a}	6.20±0.20^{a}	0.0219
Drip loss %	BM	3.35±0.05^{a}	3.10±0.10^{a}	2.45±0.05^{b}	0.0062
	LM	2.80±0.10^{a}	2.35±0.05^{b}	1.25±0.05^{c}	0.0013
Cooking loss %	BM	20.01±0.10^{a}	15.66±0.01^{b}	15.05±0.55^{b}	0.0031
	LM	20.30±0.60^{a}	18.40±0.20^{b}	17.99±0.01^{b}	0.0397

Values are means ± SE, means followed by different superscripts indicate significant differences ($p \leq 0.05$) between three treatments by Duncan's test; IPS= Intensive production system (IPS), FRPS = Free-range production system (FRPS), PYPS= Pool with yard production system (PYPS). BW: Breast muscles. LM: Leg Muscles.

Meat coloration

The meat coloration traits are presented in Table 4. Different housing system impacted on meat coloration. There is significant difference between the treatment. The highest value of L-lightness and b-yellowish in both breast and leg muscles was observed in IPS (45.65; 50.85) and the lowest value in PYPS (42.75; 48.80) respectively. The highest value of a-redness and yellowness was higher in ducks raised in IPS of both breast and leg muscles (6.35; 6.75) then those reared under FRPS and PYPS.

Oxidative stress

The oxidative stress is generally caused by the decrease of the mechanism of antioxidant and/ or enhance of the free-radical's production. The data presented in (Figure 1) revealed that SOD was significantly decreased in PYPS then in IPS and FRPS (54.85 vs 88.75 and 67.85 U/gHb, respectively). The MDA results showed that PYPS ducks were significantly lowers than IPS and FRPS (1.68 vs 2.42 and 1.06 nmol/ Ml, respectively). Birds reared in PYPS have a lowest value of GPx as compared to other production systems (17.39 vs 21.8, 19.80 U/gHb).

Table 4 – Meat coloration of Pekin duck among different housing systems.

Parameters		IPS	FRPS	PYPS	*p*-Value
L-lightness	BM	45.65±0.05^{a}	45.20±0.70^{a}	42.75±0.25^{b}	0.0322
	LM	50.85±0.05^{a}	50.15±0.35^{a}	48.80±0.10^{b}	0.0142
a-redness	BM	17.60±0.20^{b}	18.99±0.01^{a}	19.35±0.45^{a}	0.0439
	LM	14.63±0.07^{b}	15.62±0.2^{a}	14.59±0.08^{b}	0.0024
b-yellowness	BM	6.35±0.05^{a}	5.52±0.28^{b}	5.20±0.10^{b}	0.0401
	LM	6.75±0.05^{a}	5.35±0.05^{b}	5.50±0.20^{b}	0.0070

Values are means ± SE, means followed by different superscripts indicate significant differences ($p \leq 0.05$) between three treatments by Duncan's test; IPS= Intensive production system (IPS), FRPS = Free-range production system (FRPS), PYPS= Pool with yard production system (PYPS). BW: Breast muscles. LM: Leg Muscles.

Fatty acid profile

Fatty acid profile of Pekin duck meat among different housing systems is presented in Table 5. The results showed that Pekin duck meat is composed of essential fatty acids and it was noticed that concentration of fatty acids affected significantly by housing systems. The results showed that the concentration of C18:1, C18:2, C18:3, C20:3n-6, C22: 6n-3 in PYPS is greater than IPS and FRPS. The concentration of C14:1, C16:0, C18:0, C18:1, C18:2 and C18:3 in FRPS is 10.3%, 26%, 10.9%, 16.46%, 46% and 17.1% more than IPS respectively. The concentration of C14:1, C16:0, C18:0, in FRPS is 4%, 5%, and 5%, more than PYPS respectively. The concentration of saturated fatty acid in IPS and FRPS is 5% and 4% more than PYPS respectively.

DISCUSSION

Globally, there is increased demand for meat production and consumption due to increased

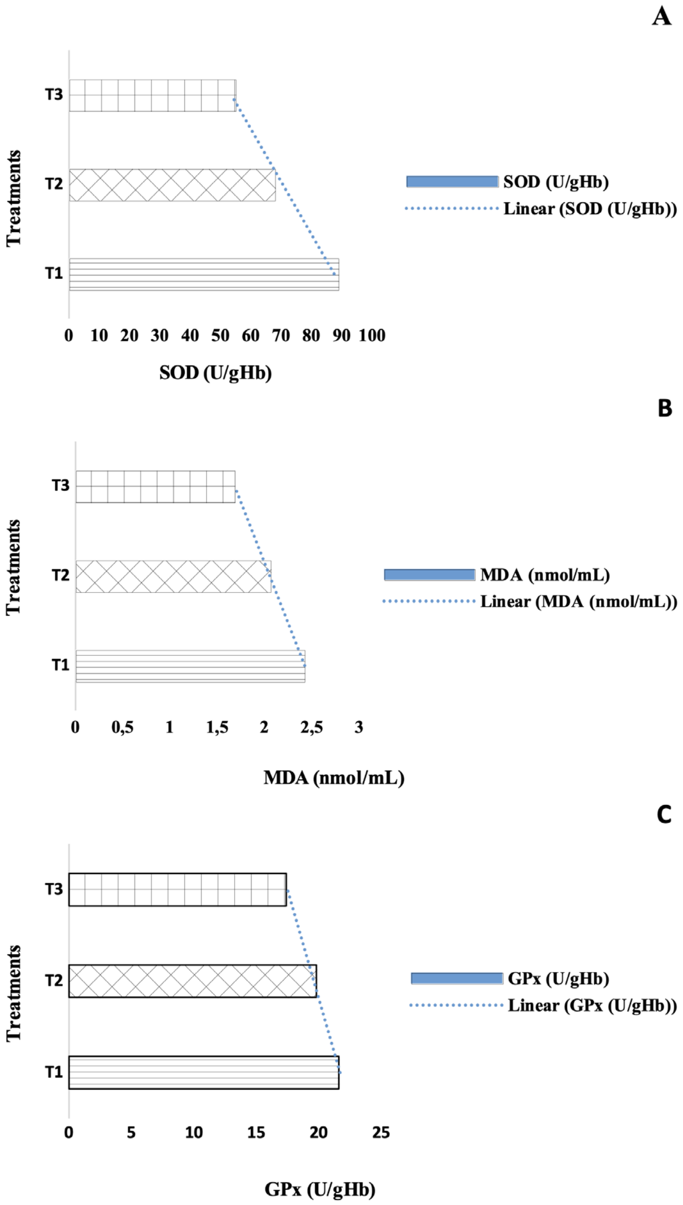

Figure 1 – Oxidative stress parameters in different rearing systems, a) superoxide dismutase SOD (U/gHb), b) Malondialdehyde MDA (nmol/mL), and c) glutathione peroxidase GPx (U/gHb),

population. The housing system or rearing system is the most important factor that affects the quality of meat parameters (Chen *et al.*, 2015). Basically, American Pekin is reared for meat production and the main goal for the cross of this breed is to improve the quality of meatiness. The American Pekin is bred primarily for meat production, and the main goal of crossing ducks with this breed is to improve fleshiness (Xie *et al.*, 2014). The meat quality is determined by Physical and chemical parameters of meat (Color, pH, digestibility, water holding capacity and nutritive value of meat protein). The following parameters are affected by rearing housing technology, animal species individual features, age, sex, as well as other meat production methods (transporting, slaughtering, feeding and processing (Liu *et al.*, 2018). pH is a very important factor in meat quality (Kokoszyński *et al.*, 2019b). In our study, the highest pH of both breast and leg muscles showed in bird reared in PYPS and lowest pH is observed in IPS. The optimum pH value of duck meat is usually between 5.7 and 5.9 (Larzul *et al.*, 2006; Witak, 2008). Our results are consistent with (Baltić *et al.*, 2015, Kokoszyński *et al.*, 2019a). Drip loss % evaluated in our study ranging 3.5 to 1.5, these are higher than that concluded by (Kokoszyński *et al.*, 2019a; Kokoszyński *et al.*, 2019b). Moreover, regarding cooking loss was significantly higher in IPS (intensive production system) and lowest in PYPS (pool with yard production system). Cooking loss ranged from 15 to 20. Numerous studies showed a different result (Kwon *et al.*, 2014; Kokoszyński *et al.*, 2019b; Kokoszyński *et al.*, 2019a), which might be due to different measuring methods adopted by researchers. Lowest drip loss and cooking loss% are shown in PYPS, it indicated that PYPS are suitable for the rearing of ducks. These results can be associated to the natural behavior of ducks as waterfowl and pool is responsible for improving the meat quality parameters. In addition, an eco-friendly environment provided by permitting ducks to take a suitable backyard, without allowing ducks in a free-range production system by the loss of energy, might be the main reason for efficient improvements in different traits in PYPS group. Muhlisin *et al.*, (2013) concluded that imported commercial ducks have greater cooking loss% of breast meat as compared to Korean native ducks. Similar authors reported that the genotype of ducks has a major effect on the cooking loss % of breast muscle. From the point of view of consumers, the most important meat quality parameter is color. It is also a significant indicator of the technological usability of meat as a raw material, which can then be directly sold or sent for further processing (Wołoszyn *et al.*, 2009; Mikulski *et al.*, 2011). The imbalance between the production of reactive oxygen and antioxidant defenses there are, cause an oxidative stress, so that the defenses are overcome by the generation of radicals causing oxidative damage to biomolecules (Halliwell & Gutteridge 2015). In our study, oxidative stress reduced in birds reared in pool with yard production system. Athira *et al.*, (2018) concluded after 6 days of force feeding (from 37 to 42 day), that due to oxidative injury in duck body that significantly increased the serum CORT content. The content of MDA significantly increased after the force

Table 5 – Fatty acid profile of Pekin duck among different housing systems.

Parameter	IPS	FRPS	PYPS	*p*-Value
Myristoleic acid (C14:1)	19.61±0.29^{b}	21.88±0.43^{a}	22.93±0.05^{ba}	0.0287
Stearic acid (C18:0)	16.38±0.18^{c}	18.35±0.35^{b}	20.35±0.05^{a}	0.0027
Oleic acid (C18:1)	19.84±0.04^{a}	23.75±1.45^{a}	24.31±1.01^{a}	0.1276
Myristic acid (C14:0)	0.78±0.02^{b}	0.81±0.01^{b}	0.88±0.01^{a}	0.0182
Linoleic acid (C18:2)	17.08±0.52^{a}	17.65±0.25^{a}	19.35±0.05^{a}	0.1586
Palmitic acid (C16:0)	0.25±0.01^{a}	0.34±0.03^{a}	0.29±0.06^{a}	0.3540
α-linolenic acid (C18:3n-3)	0.33±0.02^{a}	0.31±0.01^{a}	0.39±0.02^{a}	0.4847
Palmitoleic acid (C16:1)	0.11±0.01^{b}	0.14±0.01^{b}	0.83±0.04^{a}	0.0005
Eicosatrienoic acid (C20:3n-6)	1.50±0.05^{a}	1.66±0.01^{a}	1.80±0.07^{a}	0.1320
Eicosenoic acid (C20:1)	0.41±0.01^{c}	0.48±0.01^{b}	0.58±0.02^{a}	0.0164
Adrenic acid (C22:4)	1.45±0.02^{a}	1.33±0.01^{a}	1.44±0.02^{a}	0.0219
Arachidonic acid (C20:4)	0.21±0.00^{a}	0.16±0.01^{ba}	0.19±0.02^{b}	0.0808
Docosapentaenoic acid (C22:5n-3, DPA)	0.02±0.01^{a}	0.03±0.01^{a}	0.08±0.00^{a}	0.2895
Docosadienoic acid (C22:2)	0.14±0.02^{a}	0.16±0.03^{a}	0.18±0.00^{a}	0.7343
Getoleic acid (C22:1)	13.31±0.11^{a}	13.96±0.56^{a}	13.66±0.54^{a}	0.6426
Docosahexaenoic(C22:6n-3, DHA)	0.08±0.01^{a}	0.08±0.01^{a}	0.11±0.01^{a}	0.8394
Behenic acid (C22:0)	1.34±0.02^{a}	1.35±0.04^{a}	1.28±0.05^{a}	0.4059
Eicosapentaenoic (C20:5n-3, EPA)	0.04±0.01^{a}	0.03±0.01^{a}	0.08±0.00^{a}	0.4072
Lignoceric (C24:0)	2.89±0.01^{a}	1.88±0.01^{c}	2.44±0.01^{b}	<.0001
Saturated fatty acid (SFA)	22.61±0.84^{a}	22.40±0.05^{a}	20.61±0.29^{a}	0.4525
Mono unsaturated fatty acid (MUFA)	54.75±0.45^{a}	53.45±1.05^{a}	54.52±0.09^{a}	0.2304
Poly unsaturated fatty acid (PUFA)	22.55±0.24^{a}	12.65±9.78^{a}	23.75±0.35^{a}	0.4524

Means ± standard error; different superscripts within the same rows signify significant difference ($p \leq 0.05$); IPS= Intensive production system (IPS), FRPS = Free-range production system (FRPS), PYPS= Pool with yard production system (PYPS)

feeding related to antioxidant levels in duck body whereas the content of CAT, GSH-PX and SOD in jejunum and duodenum mucosa reduced. Our results are consistent with (Abo Ghanima *et al.*, 2020), as oxidative stress is reduced in birds reared in house with pool.

Meat quality and nutritional profile was affected significantly by the FA profile (Fan *et al.,* 2020). Many studies showed that the housing system had a distinct effect on duck meat quality and FA profile (Onbaşilar & Yalcin 2018). The results showed that Pekin duck meat is a source of essential FAs and it was observed that the concentration of FAs is significantly affected by housing systems. Many studies indicated that housing system had a distinct effect on FA profile and duck meat quality (Onbaşilar & Yalcin 2018). Aronal *et al.,* (2012) study showed that oleic acid, linoleic acid, alpha-linolenic acid was lower in duck meat in intensive housing as compared to in semi-intensive housing. However, in the current study, n-6 and n-3 PUFA were greater in PYPS as compared to IPS and FRPS. Hocquette *et al.,* (1998) study proves that the different FA proles of intensively and semi-intensively ducks in free housing system with open access to land, led to greater metabolism. Abo Ghanima *et al.,* (2020) investigation showed that different housing systems has effects on growth rates, carcass traits, immunity, different meat quality parameter, and oxidative stress of ducks. Free range housing system positively has effect on growth rate, antioxidant and lipid profile. However, oleic acid (C18:1), linoleic acid (C18:2), and polyunsaturated fatty acid (PUFA) differed significantly ($p<0.05$) between treatments. (Kamboh & Zhu 2013) results showed that pool with yard housing gave the highest polyunsaturated (C18:3n-3; C22:6n-3) and batter oxidative stress was observed.

CONCLUSION

It is concluded that physico-chemical parameters, meat coloration, oxidative stress and FA profile was improved in ducks reared with feeding 100% kitchen waste in pool with yard production system. The results suggested that PYPS is an efficient way to improve meat coloration, reduce the drip loss, cooking loss % and oxidative stress and enhance the fatty acid profile of American Pekin Ducks. Moreover, the utilization of kitchen waste may reduce the feeding cost of farmers and plays an important role for the improvement of the environment.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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