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Evaluation of Technological and Organoleptic Quality of Meat of Muscovy Duck from South-Benin

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ABSTRACT

Muscovy duck is the most reared palmiped species in Benin. However, no scientific data exist on its meat quality. The objective of this study was to evaluate the technological and organoleptic qualities of meat from this species reared in South-Benin. Data on technological and organoleptic qualities were collected on 40 ducks. Females' breast muscle pH was lower than that of males during the 48-h post-mortem ($p<0.001$). The breast and the thigh muscles pH and temperature and the water holding capacity varied significantly with animal age at slaughter ($p<0.001$). The breast muscle red index of females was higher ($p<0.05$) than that of males. On the contrary, it was lower in females ($p<0.01$) than in males for the thigh-drumstick. The lightness decreased ($p<0.05$) with ducks age in both muscles. The red index of the breast and of the thigh-drumstick increased gradually with ducks age. The red index decreased progressively from 24 to 48 h post-mortem ($p<0.05$). The yellow index was correlated with the lightness and the red index. The pH was positively correlated with lightness, yellow index, and temperature ($p<0.05$). Flavor, tenderness and juiciness of females were higher than those of males, regardless of the cooking method. The tenderness and the juiciness of 4 to 6 months old ducks were higher than those of birds older than 10 months ($p<0.01$). Breast meat was more appreciated by the jury than thigh meat ($p<0.001$). The technological and organoleptic qualities of Muscovy duck meat depend significantly on sex and birds' age at slaughter.

Keywords: Muscovy duck, Meat, pH, Temperature, Colour, Tasting, Benin.
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INTRODUCTION

In Benin, poultry farming is the second-largest livestock sub-sector after cattle and provides 10 to 22% of national meat production (FAO, 2015). This product is mainly supplied by local chickens, guinea fowl, ducks and turkeys. Among these poultry species, Muscovy duck also called *Cairina moschata*, is the most reared after chickens and guinea fowl. It is characterized by a good rusticity, a good prolificacy, a good growth, and a high weight at slaughter compared to chickens and guinea fowl (FAO, 2017; Houessionon and Youssao, 2018). It could contribute sufficiently to the satisfaction of the population's animal protein need. Thus, in order to better

Table 1. Nutritional values of feeds.

Items	First Period	Growing Period	Laying Period
Crude protein (%)	21	19	18.5
Lysine (%)	1.1	1	0.9
Methionine (%)	0.5	0.44	0.44
Calcium (%)	1	1.01	5
Total phosphorus (%)	0.55	0.5	0.5
Crude ash (%)	7.37	7.12	13
Crude cellulose (%)	2.5	3.32	-
Sodium (%)	0.2	-	-
Crude fat (%)	5.54	5	4.5
Flavomycin (%)	0.007	0.007	0.005
Chloride (%)	0.23	-	-
Metabolizable energy (kcal/kg)	2900	2800	2500

valorize this species, its breeding was first characterized in South-Benin and three breeding types were described (Houessionon and Youssao, 2018). Suggestions have been made to address the bottlenecks that limit its productivity in each type of breeding (Houessionon and Youssao, 2018). The zootechnical performances and carcass characteristics were then evaluated (Houessionon and Youssao, 2018). Although carcass weight and carcass cut weight of duck are quantitatively better than those of local chickens and of guinea fowl, consumers often declare that its meat is less appreciated at the technological, organoleptic and sensory levels (Houessionon and Youssao, 2018). But no scientific data exists on this declaration. Thus, investigating the exact quality components values of this duck meat will allow its better use. The aim of this study was to evaluate the technological and organoleptic qualities of meat from Muscovy duck reared at a station in South-Benin.

MATERIALS AND METHODS

Study Area

The Muscovy ducks used in the present study were reared at Duck Experimental Farm of the Laboratory of Animal Biotechnology and Meat Technology of the University of Abomey-Calavi. This farm is in South-Benin, precisely in the Township of Abomey-Calavi, district of Togba, area of Agori, at 6° 42' 6'' North longitude and 2° 32' 4'' East latitude. The Township of Abomey-Calavi is bounded to the North by the Township of Zè, to the South by the Atlantic Ocean, to the East by the Townships of So-Ava and Cotonou and to the West by the Townships of Tori-Bossito and Ouidah. It has an area of 539 km^2 and a population of more than 656,358 inhabitants in 2013 (INSAE, 2016). The climate is of subequatorial type with 2 rainy seasons and 2 dry seasons. The major rainy season is from April to July and the minor from September to November. These seasons are separated by two dry seasons.

METHODOLOGY

Animal Management

This study was carried out on 40 Muscovy ducks produced from two males and four females. At the hatching, they were first reared in chicken coops up to 8 weeks old, then in henhouses up to 4 months and finally on a courtyard of 300 m^2. These chickens coops and henhouses were all made of local materials and well ventilated for animals. Three feeds were distributed during the animal breeding: a starter feed, a growing feed and a laying feed. For all the ducks, the starter feed was used for eight weeks and was followed by the growing feed, from the 8^{th} week up to the laying onset at 6 months. The laying feed was served to the birds from 6 months old. Feeds given to animals were bought from feed companies and their nutritional values are presented in Table 1.

Health Monitoring

Animals were regularly given health and medical care. In order to limit mortalities and maintain their vitality in the farm, sanitary prophylaxis was instituted by installing footbaths at the farm entrance and the breeding facilities were also cleaned and disinfected. Concerning the medical prophylaxis, birds were vaccinated against Newcastle disease CEVA® NEW L : lentogenic strain of the Sota, regularly treated against gastrointestinal parasites with Alfamisole® (Levamisole 200 mg) and monthly treated against coccidiosis using Amprolium® (hydrochloride of amprolium).

Birds Choice and Slaughter

Animals were chosen according to their age and weight. Males and females with weights close to the average weight were selected and each age class was composed of ten (10) birds including five (5) males and five (5) females. In total, 4 age classes were formed:

- 1^{st} class: (4 months; 6 months)
- 2^{nd} class: (6months; 8 months)
- 3^{rd} class: (8 months; 10 months)
- 4^{th} class: > 10 months.

They were fed until the eve of the slaughter day before a feed withdrawal of 12 h. They were bled by section of the

jugular vein and then scalded in boiling water and manually plucked. Birds were labeled with a specific number for easy identification.

Evaluation of Technological and Organoleptic Qualities of Muscovy Duck Meat
Technological Quality of Meat

After slaughter and plucking, ducks' legs were sectioned at the tibio-tarsal joint and the head separated from the neck at the skull-atlas junction. The abdominal and thoracic cavities organs were removed as well as the abdominal fat. Slaughtered animals' carcasses were kept in coolers and sent to the Laboratory of Animal Biotechnology and Meat Technology. After batches composition and identification, carcasses were divided into two parts and the breast bone was removed in order to get the pectoral muscle.

Measure of pH and Temperature

The pH and temperature were measured using a portable HANNA pH-meter at 1, 4, 8, 12, 16, 20, 24 and 48 h on the right side of the *Pectoralis major* and *Iliotibialis superficialis* muscles in a cold room. For every measure, 5 repetitions were performed. On each measurement day, the pH-meter was previously calibrated with two pH-meter buffers, pH 4 and pH 7 following a procedure described by the manufacturer.

Water Holding Capacity

On average, a sample of 50 g of the right *P. major* muscle from each bird was taken to determine the water holding capacity. Each sample was hanged to a hook and placed in a refrigeration bag without touching its bottom. After 24 h in a fridge in a hanging position, the sample was removed from the bag without touching the bottom that contains the dripping juice and was sponged. Then, each sample was put into a bag and manually sealed carefully without storing air. Samples were placed in a bain-marie and cooked up to a core temperature of 75°C for 15 min. They were then cooled to room temperature. Each slice was taken out of the bag and weighed after being lightly wiped. The drip loss at 24 h was calculated per sample and expressed as a percentage of the taken sample weight. The cooking loss was determined by the difference between the weight before and after cooking.

Color

Meat color was measured on the breast and thigh muscles fillet of the right half-carcass with the CIELAB trichromatic system (Debut et al., 2004) composed of the lightness (L*), of the red index (a*) and of the yellow index (b*). It was taken at 24 and at 48 h after slaughter.

Sensory Analysis

The sensory analysis was performed on the breast and thigh muscles fillet of the left half-carcass. These two muscles were equally divided into two parts of which, one was tasted after cooking with water and the other after braising. The muscle pieces (thigh, breast) intended for water cooking were prepared without seasoning and salt for a time proportional to their weight "ready to cook", on a basis of 1 h per kg in a bain-marie up to a core temperature of 75°C. After water cooking, these muscle cuts were tasted hot. The cuts intended for braising were prepared without seasoning, oil and salt for a time proportional to their weight. A jury panel of 10 trained members was used for the tasting. For each cooking method, each judge had received on a plate separated in four different parts, a piece of each homologous cut belonging to each category of duck and had filled out a form summarizing the tasting results. The important traits for the meat quality were: tenderness, juiciness and flavor, marked from 1 to 5. For the tenderness, 1 corresponds to very hard, 2 to hard, 3 to acceptable, 4 to tender and 5 to very tender. As for juiciness, 1 corresponds to very dry, 2 to dry, 3 to acceptable, 4 to soft and the 5 to very soft. Finally, the flavor is very low (1), low (2), acceptable (3), high (4), and very high (5). All the collected data were recorded on a sheet on which each sample has a number and all its information.

Statistical Analysis

The collected data were analysed with the Statistical Analysis System (SAS, 2013) software. Means, standard deviations and variation coefficients were calculated using the Proc means procedure and frequencies using the Proc freq procedure. A linear fixed effects model has been adjusted to data and includes sex and slaughter age as fixed effects. The F test was used to determine the significance of each fixed effect. Means were compared paired by the t test. The correlations between variables were determined using the Proc corr procedure.

RESULTS

Technological Quality of Meat from Muscovy Ducks

Variation of pH, Temperature and Water Holding Capacity

Effect of Sex

Table 2 presents the evolution of pH and temperature as well as the water holding capacity of Muscovy duck meat by sex and age. Females' breast pH (5.9) was significantly lower than that of males (6.02) during the 48-h *post-mortem* ($p<0.0001$). On the other hand, no difference was observed between the pH of the thigh-drumstick of females and that of males ($p>0.05$). The same trend was observed between breast and thigh-drumstick temperatures. In addition, there was no

Table 2. Evaluation of pH, temperature and water holding capacity of Muscovy duck meat by sex and animal slaughter age.

Variables	Female	Male	Age 1	Age 2	Age 3	Age 4	RSD	ANOVA Sex	ANOVA Age
Breast pH	5.9a	6.02b	5.91b	5.90b	5.91b	6.15a	0.16	***	***
Breast temperature (°C)	22.9a	23.02a	27.32a	21.37b	21.21b	21.19b	1.88	NS	***
Thigh-drumstick pH	6.1a	6.12a	5.93c	5.94c	6.09b	6.47a	0.21	NS	***
Thigh-drumstick temperature (°C)	22.8a	22.69a	27.18a	21.51b	20.82b	20.49b	1.99	NS	***
Drip loss (%)	1.62a	2.33a	1.59a	1.56a	1.27a	1.16a	2.29	NS	NS
Cooking loss (%)	39.16a	36.84a	39.87a	38.38ab	37.38ab	35.84b	3.68	NS	NS
Water holding capacity (%)	40.78a	39.17a	41.46ab	42.1a	39.34b	36.99b	2.93	NS	**

p<0.01; ***: p<0.001; NS: p> 0.05; RSD: residual standard deviation; Averages of the same row followed by different letters differ significantly at the threshold of 5%; Age 1: 4 months - 6 months; Age 2: 6 months - 8 months; Age 3: 8 months - 10 months; Age 4: 10 months and over.

Table 3. Interaction of sex and age on pH, temperature and water holding capacity of Muscovy duck meat.

Variables	Female				Male					
	Age 1	Age 2	Age 3	Age 4	Age 1	Age 2	Age 3	Age 4	RSD	ANOVA
Breast pH	5.83b	5.86b	5.91b	6.15a	5.99a	6b	6.02a	6.15b	0.16	***
Breast temperature (°C)	27.52a	21.71b	21.7b	21.65b	27.12a	21.02b	21.2b	21.2b	1.88	*
Thigh-drumstick pH	5.9a	5.93a	6.06a	6.51b	5.97a	6.12a	6.26a	6.44b	0.21	NS
Thigh-drumstick temperature (°C)	27.47a	22.12b	21.37b	21.25b	26.89a	20.89b	21.26b	21.72b	1.99	**
Drip loss (%)	1.31a	0.68a	0.78a	0.7a	1.86a	1.24a	1.62a	1.61a	2.29	NS
Cooking loss (%)	40.75a	40.3a	38.89ab	36.71b	38.99ab	35.87b	35.51ab	34.96ab	3.68	NS
Water holding capacity (%)	42.06a	39.57a	39.08a	37.41b	40.86a	39.12a	38.12a	36.58b	2.93	NS

*: p<0.05; **: p<0.01; ***: p<0.001; NS: p>0.05; RSD: residual standard deviation; Averages of the same row followed by different letters differ significantly at the threshold of 5%; Age 1: 4 months - 6 months; Age 2: 6 months - 8 months; Age 3: 8 months - 10 months; Age 4: 10 months and over.

difference between the drip loss, the cooking loss and the water holding capacity of meat from females and males (p>0.05).

Effect of Age

The breast and the thigh-drumstick muscle pH were significantly (p<0.001) affected by the duck age at slaughter (Table 2). Thus, in the breast muscle, the pH values recorded in ducks of age 1, 2 and 3 were lower than those recorded in age 4. Similarly, in the thigh-drumstick muscle, pH increased gradually with birds' age. It varied from 5.93 at age 1 (4 to 6 months) to 6.47 at age 4 (more than 10 months). This same trend was observed in the breast and thigh-drumstick temperatures (p<0.001). The water holding capacity of meat decreased gradually with birds' age evolution. In fact, it dropped from 41.46% at age 1 (4 to 6 months) to 36.99% at age 4 (more than 10 months). But no difference (p> 0.05) was observed between drip loss and cooking loss of Muscovy duck's meat in this study.

Interaction of Sex and Age on pH, Temperature and Water Holding Capacity

Table 3 presents the technological parameters of Muscovy duck meat by age at slaughter according to the sex. A significant difference (p<0.001) was observed on the breast pH at different ages in females and males. Thus, the pH at age 4 in more than ten months females was higher than those in 4 to 6 months, 6 to 8 months and 8 to 10 months ducks. The same trend was also observed in males.

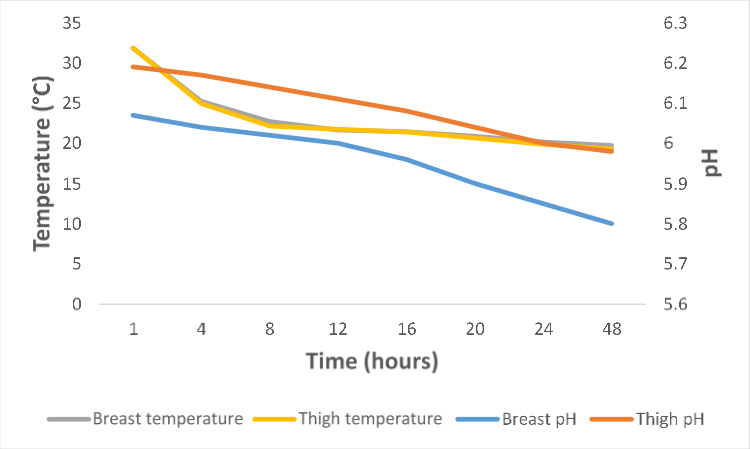

Figure 1. Evolution of pH and temperature of *P. major* and *I. superficalis* muscles of Muscovy ducks according to the time.

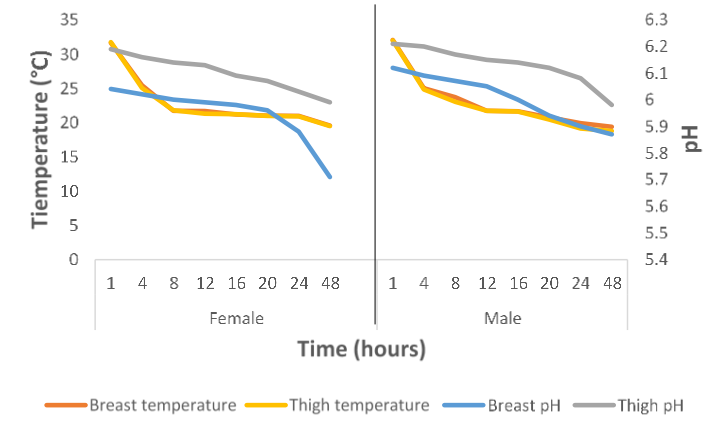

Figure 2. Evolution of pH and temperature of *P. major* and *I. superficalis* muscles of Muscovy ducks by sex according to the time.

However, the age effect on the thigh-drumstick muscle pH was not observed either in females or in males ($p>0.05$). Concerning the temperature in both studied muscles, the highest values were obtained in females and males of 4 to 6 months old. In addition, the drip loss, the cooking loss and the water holding capacity did not vary ($p>0.05$) with the male or female birds age.

Evolution of pH and Temperature of *P. major* and *I. superficalis* Muscles of Muscovy Ducks During 48 h *Post-mortem*

Figure 1 shows Muscovy duck pH and temperature evolution in the *P. major* and *I. superficalis* muscles during 48 h *post-mortem*. The *I. superficalis* pH was higher than the *P. major* pH during the 48-h *post-mortem*. By contrast, no difference was observed between breast and thigh-drumstick temperatures. Moreover, these two muscles pH and temperatures had dropped gradually from 1 to 48 h *post-mortem*.

Evolution of ph and Temperature of *P. major* and *I. superficalis* Muscles of Muscovy Ducks by Age According to The Time

Figure 2 shows the pH and temperature of *P. major* and *I. superficalis* muscles of Muscovy ducks by age according to the time. In females, the breast and the thigh-drumstick pH and temperatures dropped gradually from 1 to 48 h *post-mortem*. Similar results were also observed with males.

Characteristics of *P. major* and *I. superficalis* Muscles Color in Muscovy Ducks

Effect of Sex

The sex effect on Muscovy ducks color parameters is presented in Table 4. The lightness, the yellow index, the hue angle and the chroma of the *P. major* muscle did not vary according to the sex. Besides, this muscle red index

Table 4. Variation of *P. major* and *I. superficalis* color traits of Muscovy ducks in South-Benin by sex according to the animal slaughter age.

Variables		Female	Male	Age 1	Age 2	Age 3	Age 4	RSD	ANOVA Sex	ANOVA Age
Breast	L*	37.52a	36.95a	38.01a	37.12a	35.41b	34.51b	2.59	NS	***
	a*	19.41a	18.93b	19.01a	18.94a	18.59a	20.15b	1.63	*	***
	b*	6.21a	5.48a	5.43a	5.3a	5.3a	6.85b	1.11	NS	***
	Hue angle	3.17a	3.55a	3.35a	3.66a	3.5a	4.5b	0.63	NS	***
	Chroma	20.42a	19.75a	19.97a	19.69a	19.35a	18.25b	1.71	NS	***
Thigh-drumstick	L*	41.5	40.52	43.4a	42.5a	35.57b	34.57b	2.96	NS	***
	a*	17.93	19.44	17.8a	17.98a	18.62a	20.33b	1.32	***	***
	b*	6.39	6.62	6.95a	6.64a	5.27b	5.20b	1.33	NS	***
	Hue angle	2.85	2.94	2.55a	2.68a	3.52b	3.80b	0.59	NS	***
	Chroma	19.1	20.57	19.33a	19.05a	19.37a	21.59b	1.40	*	***

NS: p>0.05; *: p<0.05; ***: p<0.001; L*: lightness; a*: red index; b*: yellow index; RSD: residual standard deviation; Intra-class averages of the same row followed by different letters differ significantly at the threshold of 5%; Age 1: 4 months - 6 months; Age 2: 6 months - 8 months; Age 3: 8 months - 10 months; Age 4: 10 months and over.

in females was higher (p<0.05) than that in males. Concerning *I. superficalis*, the red index of females was lower (p<0.001) than that of males. This same trend was observed for this muscle chroma (p<0.05). Moreover, its lightness, yellow index and hue angle did not vary according to the sex.

Effect of Age

Color traits varied with the duck's slaughter age (Table 4). The breast muscle lightness decreased significantly (p<0.001) from 38.01 in 4 to 6-month-old birds to 34.51 in those older than 10 months. On the contrary, the red index values at 1, 2 and 3 ages were identical but lower than the one of age 4 (p<0.001). Similar results were even obtained for the breast yellow index, hue angle, and chroma. As for *I. superficalis* muscle, the lightness varied with birds' age. The highest value (43.4) was obtained in birds between 4 and 6 months of age and the lowest (34.57) in those of over 10 months (p<0.001). By contrast, the red index higher value (20.33) was recorded in ducks older than 10 months. On the other hand, the yellow index decreased significantly (p<0.001) as ducks grew older. Contrary results were observed about hue angle and chroma where values increased with animals' age evolution.

Interaction of Sex and Age on *P. major* and *I. superficalis* Muscles Color Traits

Table 5 presents the interactions between sex and age at slaughter on the meat color parameters of Muscovy ducks. In the *P. major* and *I. superficalis* muscles, the lightness decreased (p<0.05) with ducks age evolution. The red index of the breast and of thigh-drumstick didn't vary with females' age. In males, however, the red index in both muscles increased progressively (p<0.05) as birds grew. The breast yellow index decreased (p<0.001) in females but increased in males according to the age. On the contrary, the breast muscle hue angle increased with age evolution in females but decreased in males. Besides, the chroma in both *P. major* and *I. superficalis* increased with males and females age. Concerning the yellow index and the hue angle of thigh-drumstick, no difference (p>0.05) was observed in females and males.

Color Traits of *P. major* and *I. superficalis* Muscles of Muscovy Ducks According to the *Post-mortem* Measure Time

Table 6 presents ducks meat color traits according to the measure time. No difference (p>0.05) was observed between the lightness, the yellow index and the chroma of the breast muscle obtained at 24 h and those at 48 h *post-mortem*. By contrast, the red index value (19.63) at 24 h was higher (p<0.01) than that obtained at 48 h (18.71). Similarly, in the thigh-drumstick muscle, only the red index varied (p<0.05) significantly according to the measured time (p<0.05) with values of 19.01 and 18.35, respectively at 24 and 48 h *post-mortem*.

Color Traits of *P. major* and *I. superficalis* Muscles of Muscovy Ducks by Age According to the *Post-mortem* Measure Time

Table 6 presents the interaction between age and *post-mortem* measure time on color traits of breast and thigh-drumstick muscles. There was no difference (p>0.05) between the breas t lightness

Table 5. Interaction between sex and age on color traits of *P. major* and *I. superficalis* muscles of Muscovy ducks in South-Benin.

Variables		Age 1	Age 2	Age 3	Age 4	Age 1	Age 2	Age 3	Age 4	RSD	ANOVA
Breast	L*	37.52a	37.36a	35.04b	34.55c	38.51a	36.87a	35.79b	35.62b	2.59	*
	a*	19.88ac	19.66a	19.46a	19.63a	18.14a	18.21a	18.73a	20.66b	1.63	*
	b*	7.3a	5.89b	5.28b	5.25b	4.56b	4.7b	5.32b	5.3b	1.11	***
	Hue angle	2.75c	3.38b	3.5b	3.6b	3.95a	3.95a	3.5b	3.48a	0.63	**
	Chroma	21.24a	21.55a	21.50a	21.66a	18.71b	18.83b	19.48b	21.97a	1.71	**
Thigh-drumstick	L*	42.75a	42.8a	34.64b	33.81b	44.04a	42.19a	36.51b	35.35c	2.96	***
	a*	17.19c	17.26c	18.52b	18.75b	18.77b	18.74b	18.73b	21.91a	1.32	**
	b*	6.43ab	6.9a	6.92b	6.99a	7.47a	6.39a	5.32a	5.21a	1.33	NS
	Hue angle	2.68a	2.5a	3.53b	2.7a	2.41a	2.86a	3.51b	2.96a	0.59	NS
	Chroma	18.43a	18.65a	19.25a	20.06b	20.23b	19.45a	19.48a	23.12c	1.40	*

NS: p>0.05; *: p<0.05; **: p<0.01; ***: p<0.001; L*: lightness; a*: red index; b*: yellow index; RSD: residual standard deviation; Averages of the same row followed by different letters differ significantly at the threshold of 5%; Age 1: 4 months – 6 months; Age 2: 6 months – 8 months; Age 3: 8 months – 10 months; Age 4: 10 months and over.

Table 6. Variation in color traits of *P. major* and *I. superficalis* muscles of Muscovy ducks in south-Benin by *post-mortem* measure time and interaction between age and measures time.

Variables		24 h	48 h	Age 1		Age 2		Age 3		Age 4		RSD	ANOVA Day	ANOVA Day Age
				24 h	48 h	24 h	48 h	24 h	48 h	24 h	48 h			
Breast	L*	37.36a	37.11a	38.07a	37.96a	37.03a	37.2a	38.07a	38.71a	36.26ab	34.57b	2.59	NS	NS
	a*	19.63a	18.71b	18.39a	19.63ab	19.78b	18.09a	21.02c	19.28b	19.34a	17.85a	1.63	**	*
	b*	5.65a	6.04a	5.32a	6.54b	5.49a	5.11a	6.06a	7.63c	5.74ab	4.86a	1.11	NS	**
	Hue angle	3.46a	3.26b	3.44a	3.26a	3.61a	3.72a	3.42a	2.42b	3.35a	3.66a	0.63	*	**
	Chroma	20.44a	19.72a	19.16ab	20.79a	20.54a	18.84b	21.89c	20.74ab	20.19ab	18.51ab	1.71	NS	*
Thigh-drumstick	L*	41.27a	40.75a	42.71a	44.08a	43.22a	41.77a	43.29a	41.86a	35.86b	35.29b	2.96	NS	NS
	a*	19.01a	18.35b	18.19a	17.78a	18.26a	17.34a	20.21b	20.45a	19.4b	17.85a	1.32	*	NS
	b*	6.41a	6.6a	6.39a	7.5a	6.92a	6.367a	6.64a	7.66a	5.68b	4.86b	1.33	NS	*
	Hue angle	2.95a	2.84a	2.78a	2.31a	2.62a	2.75a	3.03a	2.63a	3.38b	3.66b	0.59	NS	NS
	Chroma	20.1a	19.57a	19.3a	19.36a	19.59a	18.52a	21.3b	21.88b	20.23a	18.51a	1.40	NS	*

NS: p>0.05; *: p<0.05; **: p<0.0; L*: lightness; a*: red index; b*: yellow index; RSD: residual standard deviation; Averages of the same row followed by different letters differ significantly at the threshold of 5%; Age 1: 4 months – 6 months; Age 2: 6 months – 8 months; Age 3: 8 months – 10 months; Age 4: 10 months and over.

recorded at 24 h and at 48 h *post-mortem* for different ages. The red index recorded at 24 h *post-mortem* was higher (p<0.05) than those registered at 48 h *post-mortem* in ducks of 6 to 8 months and of 8 to 10 months old. By contrast, the yellow index values recorded at 24 h were lower (p<0.01) than those recorded at 48 h after the slaughter in 4 to 6 months old birds and in those of 8 to 10 months. The red index did not vary for 4 to 6 months old ducks and for those older than 10 months, as well as the yellow index for ducks of 6 to 8 months and of more than 10 months at 24 and 48 h *post-mortem*. Similar results were obtained for the *P. major* hue angle and chroma. No significant difference (p>0.05) was observed between the lightness, the red index and the hue angle values of the thigh-drumstick. Concerning the yellow index, only the age class 2 (6 to 8 months) birds had higher values but similar at 24 and 48 h after slaughter.

The same trend was observed in the age class 3 (8 to 10 months) ducks.

Table 7. Correlations between color traits, pH and temperature of Muscovy duck meat in female and male (above the diagonal, are female coefficients and below are those of male).

Variables	L*	a*	b*	pH	Temperature	Hue angle	Chroma
L*	1	-0.13^{NS}	0.46***	-0.35**	-0.06^{NS}	0.16^{NS}	0.01^{NS}
a*	-0.07^{NS}	1	0.14^{NS}	-0.21^{NS}	-0.18^{NS}	0.13^{NS}	0.95***
b*	0.34**	0.53***	1	-0.3**	0.06^{NS}	-0.01^{NS}	0.44***
Ph	-0.02^{NS}	-0.07^{NS}	-0.21^{NS}	1	-0.18^{NS}	-0.21^{NS}	-0.28*
Temperature	0.25*	-0.01^{NS}	0.10^{NS}	-0.25*	1	0.02^{NS}	-0.15^{NS}
Hue angle	-0.07^{NS}	-0.09^{NS}	-0.24*	0.04^{NS}	-0.01^{NS}	1	0.12^{NS}
Chroma	0.01^{NS}	0.98***	0.68***	-0.11^{NS}	0.02^{NS}	-0.13^{NS}	1

NS: p> 0.05; *: p<0.05; **: p<0.01; ***: p<0.001; L*: lightness; a*: red index; b*: yellow index.

Table 8. Correlations between colour traits, pH and temperature of Muscovy duck meat at 24 and 48 h *post-mortem* (above the diagonal, are 24 hours coefficients and below are those of 48 h).

Variables	L*	a*	b*	pH	Température	Hue Angle	Chroma
L*	1	-0.15^{NS}	0.37***	-0.26*	0.08^{NS}	0.05^{NS}	-0.06^{NS}
a*	-0.11^{NS}	1	0.31**	-0.17^{NS}	-0.23*	0.09^{NS}	0.98***
b*	0.46***	0.41***	1	-0.12^{NS}	-0.01^{NS}	-0.09^{NS}	0.50***
pH	-0.26*	-0.20^{NS}	-0.38***	1	-0.23*	-0.17^{NS}	-0.17^{NS}
Temperature	0.11^{NS}	0.05^{NS}	0.16^{NS}	-0.19^{NS}	1	-0.03^{NS}	-0.22^{NS}
Hue angle	0.14^{NS}	0.02^{NS}	-0.06^{NS}	-0.12^{NS}	0.05^{NS}	1	0.07^{NS}
Chroma	0.04^{NS}	0.96***	0.64***	-0.28*	0.10^{NS}	0.01^{NS}	1

NS: p>0.05; *: p<0.05; **: p<0.01; ***: p<0.001; L*: lightness; a*: red index; b*: yellow index.

Correlations Between Color Traits, pH and Temperature of Muscovy Duck Meat

Correlations between Color Traits, pH and Temperature of Muscovy Duck Meat in Female and Male

Table 7 presents the correlation coefficients between color traits, pH and temperature of duck meat. In females, the lightness was highly associated with the yellow index (p<0.001). On the contrary, it was negatively correlated with meat pH (p<0.01). The same trend was observed between yellow index and pH (p<0.01). Besides, red index and yellow index were positively correlated with chroma (p<0.001).

In males, meat yellow index was correlated with lightness and red index (p<0.05). The same similarity was observed between red index, yellow index and chroma (p<0.001). The meat temperature was correlated with the lightness and inversely with the pH (p<0.05).

Correlations Between Color Traits, pH and Temperature of Muscovy Duck Meat after 24 and 48 h *Post-mortem*

The coefficients of correlations between color traits, pH and temperature of Muscovy duck meat at 24 and 48 h *post-mortem* are presented in Table 8. At 24 h *post-mortem*, the lightness was significantly and positively correlated (p<0.001) with the yellow index and negatively with the pH (p<0.05). In the same way, the temperature was inversely correlated with yellow index and Ph

Concerning the 48 h *post-mortem* measures, the yellow index was positively correlated with the lightness and the red index (p<0.001). The pH was negatively associated with the lightness and the yellow index (p<0.05). On the other hand, the red index and the yellow index were positively correlated with the chroma at 24 and 48 h *post-mortem* (p<0.001).

Correlations Between Color Traits, pH and Temperature of Muscovy Duck Meat by Organ

Table 9 presents the coefficients of correlations between color traits, pH and temperature of Muscovy ducks' meat by organ. In the breast, the meat red index was positively correlated with the yellow index and both were positively correlated with chroma (p<0.001). On the contrary, yellow index and chroma were negatively correlated with meat pH (p<0.05). As for the thigh-drumstick, the yellow index was positively correlated with the lightness and the red index. Also, pH was negatively associated with lightness, yellow index and temperature (p<0.05).

Variation in Sensory Meat Quality of Muscovy Duck by Cooking Method, Sex, Age at Slaughter and By Organ

Concerning sex, females' boiled meat was softer and juicier with a stronger smell (p<0.001) than that of males (Table 10). The same trends were observed when meat is braised (p<0.01). Females' meat acceptance was higher than the one of males, whatever the cooking method (p<0.01). On the other hand, tenderness and

Table 9. Correlations between colour traits, pH and temperature of Muscovy duck meat by organ (breast coefficients are above the diagonal and those of thigh-drumstick are below).

Variables	L*	a*	b*	pH	Temperature	Hue Angle	Chroma
L*	1	-0.02^{NS}	0.19^{NS}	-0.21^{NS}	0.03^{NS}	0.13^{NS}	0.02^{NS}
a*	-0.09^{NS}	1	0.50***	-0.18^{NS}	-0.03^{NS}	0.07^{NS}	0.98***
b*	0.48***	0.26*	1	-0.35**	0.08^{NS}	-0.09^{NS}	0.66***
pH	-0.55***	-0.02^{NS}	-0.41***	1	-0.18^{NS}	-0.08^{NS}	-0.24*
Temperature	0.18^{NS}	-0.20^{NS}	0.12^{NS}	-0.24*	1	-0.01^{NS}	-0.01^{NS}
Hue angle	0.10^{NS}	0.05^{NS}	-0.04^{NS}	-0.19^{NS}	-0.01^{NS}	1	0.04^{NS}
Chroma	0.04^{NS}	0.96***	0.51***	-0.12^{NS}	-0.15^{NS}	0.03^{NS}	1

NS: p>0.05; *: p<0.05; **: p<0.01; ***: p<0.001; L*: lightness; a*: red index; b*: yellow index.

juiciness varied according to the animal age at slaughter when meat was boiled. In fact, the meat of Muscovy ducks of age class 1 (4 to 6 months) was more tender and juicier than that of ducks of age class 4 (more than 10 months) (p<0.01). By contrast, for braised meat, flavor and juiciness did not differ from one age to another (p>0.05). Nevertheless, age 1 duck meat was more tender than that of birds older than 10 months (p<0.001). Similarly, age 1 duck meat was more accepted than birds older than 10 months meat (p<0.01). The boiled breast meat of Muscovy duck was softer and juicier with a strong smell than the boiled thigh-drumstick meat (p<0.001). The same trends were observed when meat was braised (p<0.001).

DISCUSSION

Technological Quality of Muscovy Ducks Meat in South-Benin According to The Sex

Effect of Sex On pH, Temperature and Water Holding Capacity

Meat characteristics of palmiped vary according to species (goose or duck), genetic type, breeding mode, feeding type, sex and age (Marie-Etancelin et al., 2010). In this study, pH, temperature, and water holding capacity depended on Muscovy ducks' sex. In fact, males' breast pH (6.02) was higher than that of females (5.90). This difference in male and female breast pH could be explained by the metabolic activity that occurs in the male breast muscle or by the physiological status of females at slaughter (reproductive hormone activities). The same trend was observed by Baeza et al. (2000) in France studying the sex effect on the technological meat traits of Mullet duck which is a crossbreed from Muscovy duck and Pekin duck. On the other hand, no effect of sex on pH has been reported by Onk et al. (2018) in Pekin ducks in Turkey. Similarly, in China, Zhang et al. (2018) obtained in a study on Chaohu duck meat traits that males and females' pH were similar. According to Adamski et al. (2011), there is no difference between the breast pH of males and females of Beijing duck in Poland. Also, Uhlířová et al. (2018) found no difference in the breast muscle pH of males and females in geese. This difference of trend about sex effect on breast pH values of these authors may be due to the slaughtered bird breeds. Moreover, apart from breast muscle pH, thigh-drumstick pH, temperature, drip loss and water holding capacity of ducks' meat were not affected by sex. The same trend was obtained in France by Baeza et al. (2010) in Muscovy ducks. In fact, the thigh-drumstick muscle pH did not vary according to the sex but it was higher than the breast pH. This higher thigh-drumstick muscle pH in males and females is due to the low glycogen reserve levels in this muscle. The same observations were reported by Chartrin et al. (2006) and Baeza et al. (2013) in Muscovy ducks in France and by Tougan et al. (2013) in local chickens in Benin.

Effect of Age on pH, Temperature and Water Holding Capacity

The technological quality of the breast and thigh-drumstick meat varied significantly with Muscovy ducks age. Thus, the pH of the breast and that of thigh-drumstick increased gradually with birds' age. Similar results were found by Baeza et al. (2010) in France in a study on the Muscovy duck meat characteristics. This age effect on pH was also observed by Baeza et al. (2000) in France in Mullet ducks and by Onk et al. (2018) in the Pekin ducks in Turkey. Usually, duck meat ultimate pH value is between 5.6 and 5.9 (Baeza et al., 2013). The lowest breast pH value (5.91) is obtained with 4 to 6 months old ducks. Similarly, in the thigh, birds of 4 to 6 months of age had a lower pH value (5.93). So, these values were recorded among the youngest Muscovy ducks. The pH increases in both muscles according to ducks age in the current study is due to the older one's growth level. On the other hand, the temperature of the breast and of thigh-drumstick muscles decreased with birds' age. This decrease in temperature may be due to the difference in these animals' weight (Larzul et al., 2006). Youssao et al. (2012) and Bonou et al. (2017) reported in *Gallus-gallus* chicken in Benin breast muscle ultimate pH values around 5.9 and these values depended on age. The *P. major* pH values at different

Table 10. Sensory traits of duck meat by cooking method, sex, age and by organ.

Variables		Female	Male	Age 1	Age 4	Breast	Thigh-drumstick	RSD	ANOVA Sex	ANOVA Age	ANOVA Organ
Boiled	Flavor	3.16a	2.91b	3.07a	3.00a	3.24a	2.83b	0.78	***	NS	***
	Tenderness	3.39a	3.01b	3.36a	3.04b	3.61a	2.79b	0.91	***	***	***
	Juiciness	3.27a	2.94b	3.20a	3.01b	3.36a	2.85b	0.74	***	**	***
	Global acceptance	5.84a	5.42b	5.82a	5.44b	6.25a	5.01b	1.44	**	**	***
Braised	Flavor	3.31a	2.90b	3.15a	3.06a	3.23a	2.98b	0.77	***	NS	***
	Tenderness	3.17a	2.95b	3.30a	2.82b	3.35a	2.77b	0.85	**	***	***
	Juiciness	3.39a	2.91b	3.21a	3.09a	3.28a	3.03b	0.81	***	NS	***
	Global acceptance	5.99a	5.40b	5.93a	5.46b	6.09a	5.30b	1.49	***	***	***

NS: p>0.05; **: p<0.01; ***: p<0.001; RSD: residual standard deviation; Averages of the same row followed by different letters differ significantly at the threshold of 5%; Age 1: 4 months – 6 months; Age 4: 10 months and over.

post-mortem times were lower than those of the *I. superficialis*. The pH of these muscles varied from about 6.3 to about 5.7 for the breast and from 6.3 to 5.9 for the thigh during the 48-h *post-mortem*. The difference between breast and thigh ultimate pH values is related to the amount of glycogen in these muscles. In China, Zhang et al. (2018), reported lower pH values at 24 h *post-mortem* for *P. major* muscle in Pekin ducks. According to Lacin et al. (2008) in France and Marzoni et al. (2014) in Poland, breeding systems and diet have a significant effect on meat technological quality, especially on pH. Thus, meat pH varies according to the muscle.

Color Traits of *P. major* And *I. superficalis* Muscles of Muscovy Ducks

Consumers value meat organoleptic qualities and these include color, flavor, tenderness and juiciness. In poultry, these characteristics vary according to the genetic type, the sex and the animals' age at slaughter (Youssao et al., 2012; Tougan et al., 2013) and according to the antemortem stress level (Bonou et al., 2017). Color is the first meat organoleptic parameter that consumer appreciates. Thus, some of the color traits in the present study depended significantly on sex, age and studied organ. The breast red index of females was higher than that of males. By contrast, it was the opposite in the thigh. The same trend was observed by Uhlířová et al. (2018) in a study on geese in Turkey. Chatin et al. (2006) reported lightness values (39.03) almost similar to those obtained in our study for the male's breast. Also, chroma of males was higher than that of females. The lightness and the yellow index as the hue angle and the chroma did not vary according to sex and to organ. Zhang et al. (2018) reported lower values of color traits that did not depend on the Chaohu ducks' sex. On the other hand, lightness, red index, and yellow index, as well as hue angle and chroma of breast and thigh-drumstick muscles were different from one age class to another. Older is the duck, darker is the meat. Birds of more than 10 months had less light and the darker muscles. This explains the correlation obtained between both muscle color characteristics. Similar results have been observed in several previous studies on poultry (Chartin et al., 2006; Larzu et al., 2006; Tougan et al., 2013). Also, the measured time was highly associated with color traits values, especially to that of the red index, which progressively decreases from 24 to 48 h *post-mortem*.

Sensory Quality of Muscovy Duck Meat

Females meat was more appreciated than that of males whatever the cooking mode (boiling or braising). In fact, females got the highest meat tenderness (3.39) and juiciness (3.27) and this difference in meat quality between sexes can be explained by the muscular mass of females (Chartin et al., 2006) and by their lower pH (Bonou et al., 2017). Similar results are obtained in Nigeria by Omojola (2007) in a study on the organoleptic qualities of meat from Muscovy ducks. In general, poultry meat tenderness depends on the quality of connective tissue (collagen), on the myofibrillar structure and on the structural interactions between fibers and extracellular matrix. For that, Muscovy ducks would have a better muscular fibers structure and this is justified by values of color characteristics obtained in the current study. According to Youssao et al. (2012), the taste quality of poultry meat is

mainly determined by the slaughter age and the best quality for the older one is more evident for thighs than for breasts.Thus, the meat of the youngest ducks is more appreciated than that of ducks older than 10 months. It was also found that the breast meat was juicier and softer than the thigh meat. All these results are in accordance with those of pH and of color traits. The older is the bird, the higher is the pH in breast and thigh muscles and the lighter is the meat. Cooking methods also play a role in meat quality (Tanganyika and Webb, 2019). They participate greatly in the finality of the product ready to be eaten by acting on the sensory characteristics.

CONCLUSION

The study on the technological and organoleptic quality of Muscovy duck meat reveals that pH of breast muscle of females is lower than that of males during the 48-h *post-mortem*. The pH of breast and thigh-drumstick muscles increases with birds' age while the water holding capacity decreases with age. Sex does not influence the water holding capacity of duck meat. The pH and temperature of *P. major* and *I. superficalis* muscles of Muscovy duck drop gradually from 1 to 48 h *post-mortem*. The red index of *P. major* muscle of females is higher than that of males and the opposite is observed for the *I. superficalis* muscle. The lightness decreases with the bird's slaughter age while the red index increases with time in both muscles (*P. major* and *I. superficalis*). Females have softer and juicier meat than males, and the younger ducks also have softer and juicier meat than the older ones. Muscovy duck meat quality varies according to sex and slaughter age.

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