Study on muscle histological structure and meat quality of Guinea foul (*Numida meleagris*) fattened to different ages

Desislava Vangelova[1], Matina Nikolova[2*], Desislav Balev[1] , Angel Angelov[2]
[1]*University of Food Technologies – Plovdiv, Bulgaria, 4002, 26, Maritsa Blvd.*
[2]*Agricultural University – Plovdiv, Bulgaria, 4000, 12, D. Mendeleev Str.*
[*]correspondence: dimitrova@hotmail.com

Citation: Vangelova, D., Nikolova, M., Balev, D., & Angelov, A. (2022). Study on muscle histological structure and meat quality of Guinea foul (*Numida meleagris*) fattened to different ages. *Zhivotnovadni Nauki*, 59(3), 48-57 (Bg).

Abstract

A study was carried out on the muscle microstructure in a local population of Guinea foul with a pearl-colored plumage. The experiment was performed with three groups of Guinea foul chicks, 30 birds in each group (equal number of both sexes) fattened to different ages (16, 20 and 24 weeks). The results of the histological analysis were consistent with the values of pH, WHC and meat tenderness in both sexes for the respective ages of the Guinea foul. The muscle fibers of male and female individuals at 16 weeks of age had the finest structure and the smallest diameter. Although the diameter of the muscle fibers increased with age in both sexes, no significant differences were found in tenderness of the breast muscle meat. At 25 min after slaughter pH in tights was higher than pH in breasts non depending of the age. To 24 h post mortem pH significantly decreased both in breast and tights, regardless of sex and age. The decrease in WHC was most affected by age (from 16 to 24 weeks) in *m. femorotibialis* both for males and females guinea towl (*Numida meleagris)* while *m. pectoralis superficialis* was slightly affected by age and sex.

Key words: Guinea foul, muscle histological structure, meat quality

Проучване върху хистоструктурата и технологичните характеристики на мускулатура от токачки *(Numida meleagris),* угоявани до различна възраст

Десислава Вангелова[1], Матина Николова[2*], Десислав Балев[1], Ангел Ангелов[1]
[1]*Университет по хранителни технологии – Пловдив, 4002, 26, бул. Марица*
[2]*Аграрен университет – Пловдив, 4000, 12, ул. Димитър Менделеев*
[*]Автор за кореспонденция: dimitrova@hotmail.com

Резюме

Проведено е проучване върху хистологията на мускулатура при токачки местна популация с бисерно-сив цвят на оперението. Експериментът е изведен с три групи от по 30 токачета (по равен брой от двата пола), угоявани до различна възраст (16, 20 и 24 седмици).

Резултатите от хистологичния анализ са в съответствие със стойностите на показателите pH, ВЗС и крехкост на месото при двата пола за съответните възрасти токачки.

Ключови думи: Токачки, хистология на мускулатурата, качество на месото

Introduction

In recent years the production and consumption of Guinea foul (*Numida meleagris*) products have increased throughout the world. That is due to the fact that Guinea foul is characterized by very high adaptability and thanks to that it shows high reproductive capacity and production performance in extremely hot – both dry and wet – and in extremely cold regions, equally well under the conditions of extensive, semi-intensive and intensive production systems (Kokoszyński et al., 2011; Crowe, 1978; Ayorinde and Okaeme, 1984; Ayorinde at al., 1984; Ayorinde, K. L., 1987 a; Ayorinde, 1987 b; Ayorinde and Ayeni, 1987 a; Ayorinde and Ayeni, 1987 b; Ayorinde at al., 1989; Ayorinde, 1990; Ayorinde, 1991 a; Ayorinde, 1995 a; Ayorinde, 1991 b; Adeyeye E. I., 2011). The species efficiently utilizes the feed and it is not susceptible to any disease (Tye and Gyawu, 2001; Moreki, 2009; Adeyeye E. I., 2011).

Over the past 30 years, a large part of Europe has estimated Guinea foul as a source of dietary meat with a wild game flavour, attractive to the luxury food markets. However, in Europe itself, there is an impressive niche for the production and marketing of that type of meat (Baeza et al., 2001; Sharma and Singh, 2006; Santiago et al., 2007).

Studies on muscle microstructure in domestic birds, and especially in Guinea foul, are quite scarce (Ward et al., 2009; Danmaigoro et al., 2016; Dransfield and Sosnicki, 1999; Baeza et al., 2000; Wattanachant et al., 2005; Karl-Heinz Kiessling, 1977).

The muscle architecture and the physiological properties of the muscle fibers are important in assessing muscle capacity and thus predicting the muscle function (Ward et al., 2009). According to Danmaigoro et al. (2016), the breast muscle of the domestic fowl contains thick muscle fibers with few and poorly developed capillaries. That type of fiber performs strong and prolonged contractions. They help muscle mobility, maintaining a great amount of strength for a short period of time. According to the authors, that was also the typical histological image of *m.m. pectorales* in the domestic Guinea foul. The diameter of the muscle fibers, and hence, the muscle mass and its derivatives, such as meat quality and muscle productivity, depend on various factors, such as bird species, sex, age, connective tissue content and connective tissue layer thickness, etc. (Wattanachant et al., 2005). Thus, when studying the relationship between the muscle fiber properties and broiler meat quality, a significant influence of the age factor on the muscle structure was observed, while the sex influence was poorly expressed (Dransfield and Sosnicki, 1999).

Similar results were obtained by Baeza et al. (2000) in a study on the effect of sex on the technological and morphological characteristics of mule duck meat. Statistically significant differences in the structure of the muscle tissue from male and female birds were also not established in their investigation.

Taking into consideration the lack of research in that scientific area in our country for that species of domestic fowl, we set the aim of studying the histological structure of the muscle in Guinea foul of a local population, fattened to different ages.

Material and methods

The experimental work of the present study was carried out on the poultry farm at the Experimental Fields of the Agricultural University of Plovdiv, with three groups of Guinea foul of a local population, 30 birds in each group, with a pearl-gray color of the plumage (in equal numbers of both sexes), kept in separate sections of the premises.

Upon reaching the appropriate age of slaughter (16, 20 and 24 weeks), four males and four females were selected from each group, with a live weight close to the average for the group, and prepared for slaughter analysis.

The physicochemical properties of the meat and the morphological structure of the muscles were determined in the meat laboratory of the University of Food Technologies, Plovdiv.

The pH values of the breast and thigh muscles were measured between 20th and 30th minute af-

ter slaughtering (pH1), at 4th (pH4) and 24th hour (pH24). Standard parts of the carcass without skin were used, according to AOAC (1990). The pH value of the studied muscles was determined using a portable pH meter Hanna HI99121 with a glass electrode and an electrode for measuring the temperature. The measurement was carried out at a depth of 1 cm in the middle of the studied muscle.

The water holding capacity (WHC) of the meat was determined at 24th hour *post mortem* and for that purpose, samples were collected from *m. pectoralis superficialis*, *m. pectoralis profundus* and *m. femorotibialis*. The analysis was carried out following the classical method of Grau and Hamm. The test was performed by compressing the meat on a filter paper placed between two slides, then pressed with a weight of 5 kg for 5 minutes. The WHC of the sample was calculated by the formula:

WHC, % = Sample weight before pressing – Sample weight after pressing / Sample weight before pressing × 100

Breast muscle tenderness was determined using RA-1 penetrometer fitted with a penetration nozzle. The method is based on the deep penetration of the needle into the meat sample under the pressure of the screw with the needle weight, which is 103,3 g for that device. The values of meat tenderness were reported in degrees of penetration (°P), where 1 °P = 0,1 mm.

Samples of 2 × 1 × 1 cm were used for the morphological analysis. Sample fixation and contrasting was carried out according to the method described by Barbut et al. (2005). Sample analysis was performed with a microscope (Olympus BX41TF, Japan), at a magnification of 1000 x.

The results for pH, WHC and muscle tenderness were processed with IBM SPSS Statistics 17.0 software.

Results and discussion

Microscopic images of longitudinal and transverse sections of the thigh muscle are presented in Fig. 1.

At the fourth hour *post mortem* (Fig. 1) the muscle fibers (*m. femorotibialis*) have a loose structure and retained integrity. The objective studies of the microscopic samples correspond to the data obtained for pH (Table 1) and WHC (Table 2) of the thigh muscle (*m. femorotibialis*) of Guinea foul (both male and female) at the age of 16, 20 and 24 weeks.

Histological observations showed that the muscle fibers have the smallest diameter and the most delicate structure in 16 weeks of age male and female individuals (Fig. 1).

Comparing the microscopic images of male and female individuals of the same age (16, 20 or 24 weeks), no significant differences in the fiber structure were found (Fig. 1). It could be concluded that the bird sex has a slight effect on the diameter of the muscle fibers (*m. femorotibialis*). Similar results were obtained by Baeza et al. (2000) in a study on the effect of sex on the technological and morphological characteristics of meat from avian species. In their study, there were no statistically significant differences in the structure of the muscle tissue from males and females.

The light microscopy of the longitudinal and transverse sections of the thigh muscle (*m. femorotibialis*) showed that in both sexes the diameter of the fibers increased with age (Fig. 1). Those results were confirmed in the studies of Dransfield and Sosnicki (1999). In examining the relationship between the muscle mass and meat quality in broilers, the authors found a significant effect of the age factor on the muscle structure, while the effect of sex was insignificant (Dransfield and Sosnicki, 1999).

At 4 h *post mortem m. pectoralis* superficialis had a preserved integrity with opened myofibrillar grid confirmed the early *post mortem* period (4 h *post mortem*), when the muscle tissue is characterized by still high pH and WHC values of meat (Table 1).

By comparing Guinea foul images at the three different ages (16, 20 and 24 weeks, Fig. 2), a significantly smaller diameter of the muscle fibers (*m. pectoralis superficialis*) was found in the tissue of individuals at 16 weeks of age. Similar re-

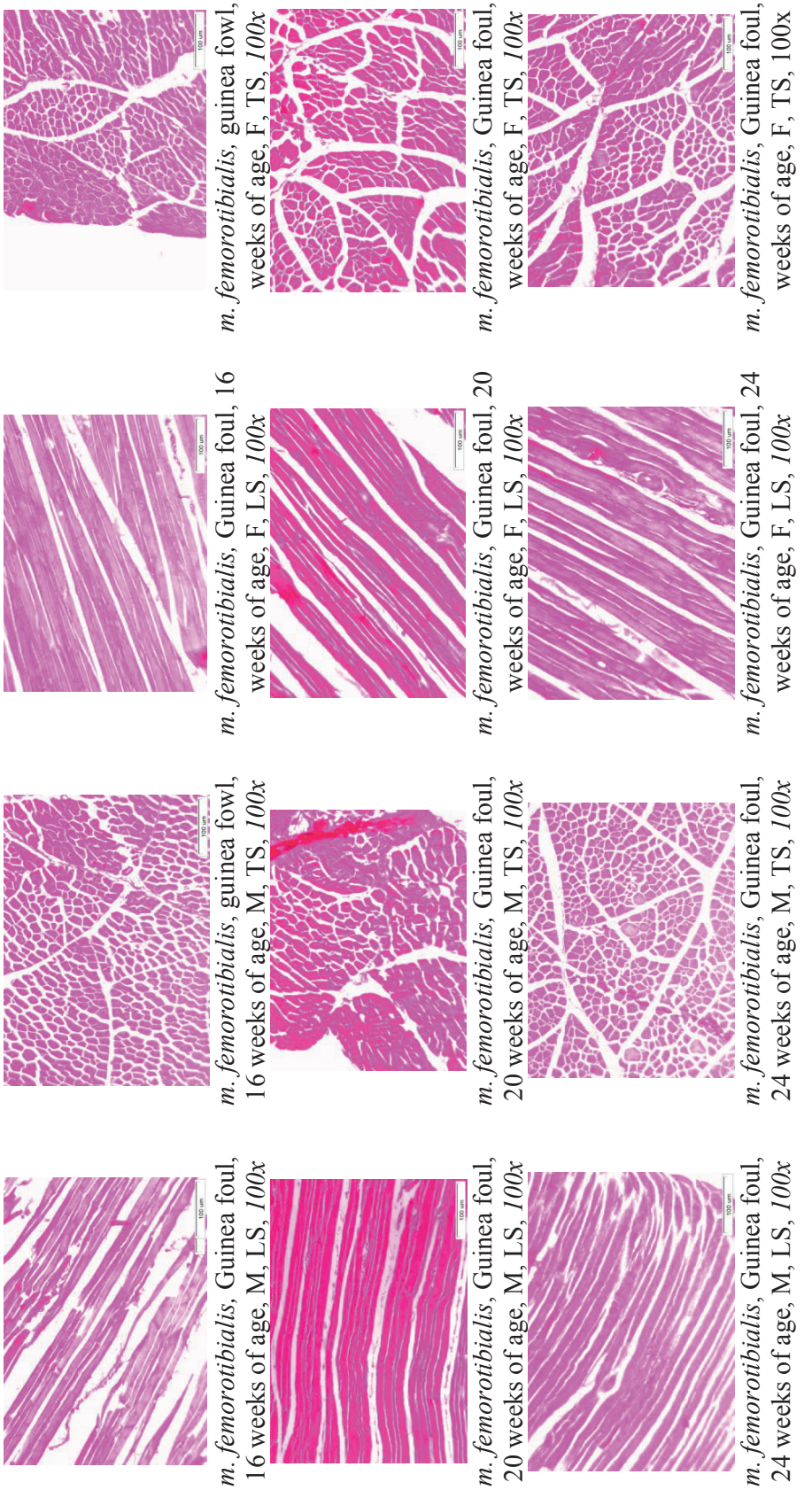
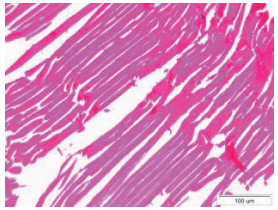
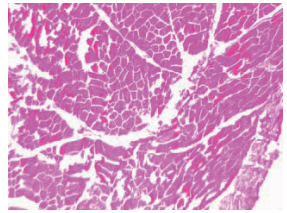


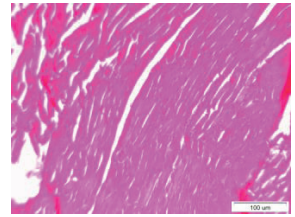
Fig. 1. Microscopic images of Guinea foul thigh muscle (*m. femorotibialis*), 24 weeks of age, 4 hours *post mortem*, 100x, *transverse section (TS), longitudinal section (LS), female (F), male (M)*



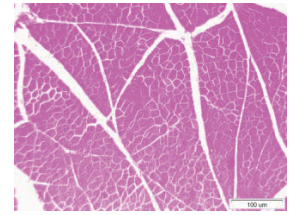
m. pectoralis superficialis, Guinea foul, 16 weeks of age, *M, LS, 100x*



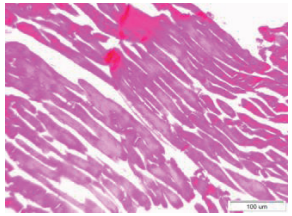
m. pectoralis superficialis, Guinea foul, 16 weeks of age, *M, TS, 100x*



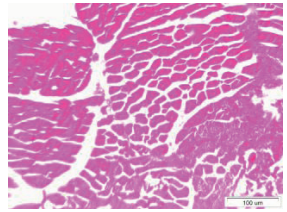
m. pectoralis superficialis, Guinea foul, 16 weeks of age, *F, LS, 100x*



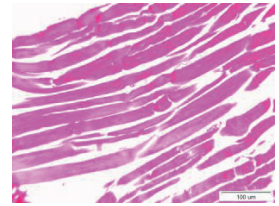
m. pectoralis superficialis, Guinea foul, 16 weeks of age, *F, TS, 100x*



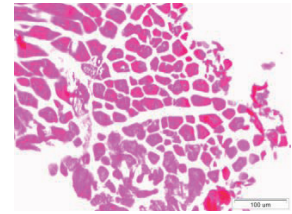
m. pectoralis superficialis, Guinea foul, 20 weeks of age, *M, LS, 100x*



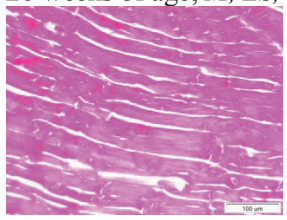
m. pectoralis superficialis, Guinea foul, 20 weeks of age, *M, TS, 100x*



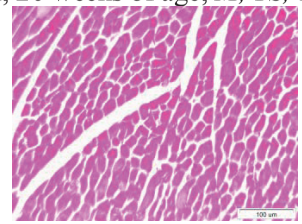
m. pectoralis superficialis, Guinea foul, 20 weeks of age, *F, LS, 100x*



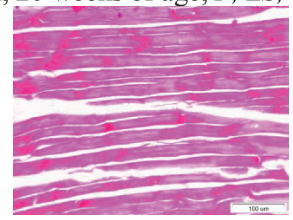
m. pectoralis superficialis, Guinea foul, 20 weeks of age, *F, TS, 100x*



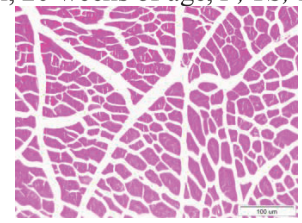
m. pectoralis superficialis, Guinea foul, 24 weeks of age, *M, LS, 100x*



m. pectoralis superficialis, Guinea foul, 24 weeks of age, *M, TS, 100x*



m. pectoralis superficialis, Guinea foul, 24 weeks of age, *F, LS, 100x*



m. pectoralis superficialis, Guinea foul, 24 weeks of age, *F, TS, 100x*

Fig. 2. Microscopic images of breast muscle (*m. pectoralis superficialis*) of Guinea foul, 24 weeks of age, 4 hours *post mortem*, 100x, *transverse section (TS), longitudinal section (LS), female (F), male (M)*

Table 1. pH values in breast and thigh muscles, depending on sex and duration of the fattening period (age of slaughter)

Characteristics			16 weeks of age			20 weeks of age			24 weeks of age		
			pH 25th min	pH 4th h	pH 24th h	pH 25th min	pH 4th h	pH 24th h	pH 25th min	pH 4th h	pH 24th h
BREAST	Males	$\bar{x}$ ± SEM	$6.70^{c,x} \pm 0.10$	$6.23^{b,x} \pm 0.08$	$6.09^{a,x} \pm 0.06$	$6.66^{c,x} \pm 0.11$	$6.35^{b,x} \pm 0.05$	$6.14^{a,x} \pm 0.07$	$6.63^{c,x} \pm 0.17$	$6.21^{b,x} \pm 0.03$	$6.02^{a,x} \pm 0.05$
	Females	$\bar{x}$ ± SEM	$6.80^{c,x,y} \pm 0.11$	$6.33^{b,x} \pm 0.07$	$6.15^{a,x} \pm 0.02$	$6.68^{c,x} \pm 0.13$	$6.33^{b,x} \pm 0.07$	$6.16^{a,x} \pm 0.06$	$6.61^{c,x} \pm 0.18$	$6.24^{b,x} \pm 0.08$	$6.15^{b,a,x} \pm 0.09$
THIGH	Males	$\bar{x}$ ± SEM	$7.01^{d,y} \pm 0.14$	$6.72^{c,y} \pm 0.1$	$6.48^{b,y} \pm 0.12$	$7.01^{d,y} \pm 0.04$	$6.85^{d,y} \pm 0.06$	$6.54^{c,y} \pm 0.09$	$7.05^{d,y} \pm 0.26$	$6.71^{c,y} \pm 0.15$	$6.27^{b,c,x,y} \pm 0.26$
	Females	$\bar{x}$ ± SEM	$7.01^{d,y} \pm 0.11$	$6.70^{c,y} \pm 0.09$	$6.27^{a,x,y} \pm 0.17$	$7.08^{d,y} \pm 0.07$	$6.77^{c,y} \pm 0.04$	$6.59^{c,y} \pm 0.04$	$7.00^{c,d,y} \pm 0.16$	$6.80^{c,y} \pm 0.12$	$6.45^{b,y} \pm 0.08$

$^{a, b, c}$ – Means in the same row with different superscript letters differ significantly ($p < 0.05$)
^{x,y} – Means in the same colunm with different superscript letters differ significantly ($p < 0.05$)

Table 2. Water holding capacity of breast and thigh muscles in Guinea foul depending on bird sex and the duration of the fattening period (age of slaughter) LSD Test

WHC, %		16 weeks of age			20 weeks of age			24 weeks of age		
		m. pectoralis superficialis	*m. pectoralis profundus*	*m. femorotibialis*	*m. pectoralis superficialis*	*m. pectoralis profundus*	*m. femorotibialis*	*m. pectoralis superficialis*	*m. pectoralis profundus*	*m. femorotibialis*
Males	$\bar{x}$ ± SEM	$17.39^{d,x} \pm 1.30$	$16.75^{c,d,x} \pm 1.57$	$13.31^{c,x} \pm 1.33$	$15.18^{c,x} \pm 1.43$	$16.29^{c,d,x} \pm 1.06$	$14.82^{c,x} \pm 1.40$	$13.02^{b,c,x} \pm 0.74$	$11.29^{b,x}$ 0.68	$7.84^{a,x} \pm 0.62$
Females	$\bar{x}$ ± SEM	$19.15^{d,x} \pm 1.09$	$21.58^{d,y} \pm 1.32$	$15.92^{c,y} \pm 0.68$	$15.96^{b,c,x} \pm 1.17$	$14.04^{b,y} \pm 0.53$	$14.89^{b,x} \pm 1.3$	$14.14^{b,x} \pm 0.90$	$13.08^{b,y} \pm 0.84$	$9.02^{a,y} \pm 0.85$

***a, b, c, d** – Means in the same row with different superscript letters differ significantly ($p < 0.05$)*
***x,y** – Means in the same colunm with different superscript letters differ significantly ($p < 0.05$)*
SEM – standard error of the mean

sults were obtained by light microscopy of the thigh muscle (Fig. 1).

The longitudinal and transverse sections of the breast muscle (*m. pectoralis superficialis*) showed an increase in the diameter of the muscle fibers with age (Fig. 2).

Again, insignificant differences in *m. pectoralis superficialis* structure were found between male and female individuals of the same age (Fig. 2).

Although the diameter of the muscle fibers increased with age, no significant differences were found in tenderness of the breast muscle meat (Table 3).

As meat tenderness depends not only on the size of the muscle fibers, but also on other factors such as the connective tissue content and the connective tissue thickness (Wattanachant et al., 2005), it could be concluded that Guinea foul species is characterized by high positive values of the indicators that characterize meat tenderness. Thickening of endo- and perimysium was not observed in the studied samples of breast muscle (*m. pectoralis superficialis*), therefore, no statistically significant decrease in meat tenderness was established with the age increase of the Guinea fowl.

Histological observations in *m. pectoralis profundus* (Fig. 3) are similar to changes found in *m. pectoralis superficialis* (Fig. 2) and *m. femorotibialis* (Fig. 1).

The muscle fibres were intact and with proper arrangement, confirming the *post mortem* period (4 h *post mortem*) and corresponded with the values obtained for pH and WHC (Fig. 3, Table 1 and Table 2).

Although the increase in diameter of *m. pectoralis profundus* in 20- and 24-week old Guinea foul was poorly expressed, again the age factor had a more significant effect than the Guinea foul sex.

Table 1 presents the pH-values of Guinea foul breast and thigh muscles, measured between 20^{th}–30^{th} min (pH1), 4^{th} h (pH4) and 24^{th} h (pH24), depending on sex, on the duration of the fattening period and the averaged data. To 24 h post mortem pH significantly decreased ($p > 0.05$) both in breast and tights, regardless of sex and age. The results obtained are in accordance to postmortal pH changes in poultury described by Von Lengerken et al., 2002.

At 25 min after slaughter pH in thights was higher ($p > 0.05$) than pH in breasts non depending of the age. This data confirmed previous results of Kokoszyński et al. (2011) found lower pH in 13 and 16 weeks old guinea breast muscles at 15 min post mortem compared to leg muscles.

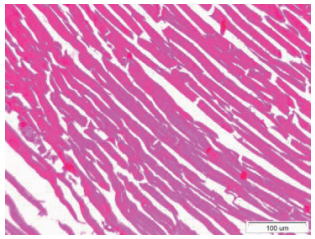
Table 2 shows the mean values of WHC for the different muscle types of 16, 20 and 24 weeks old male and female Guinea foul, respectively.

The results of WHC showed that the mean values in the studied muscles, expressed as a percentage, decreased significantly (p □ 0.05) with the increase of the slaughter age from 16 to 20 and 24 weeks. The most pronounced by 70% and 76% was this decrease in males and females *m. femorotibialis* resp. In opposite *m. pectoralis superficialis* WHC was slightly affected by age, as well as the sex. One possible reason is the different type of the muscles. The *m. femorotibialis* is classified as oxidative while the *m. pectoralis superficialis* is glicolitical, leading to different

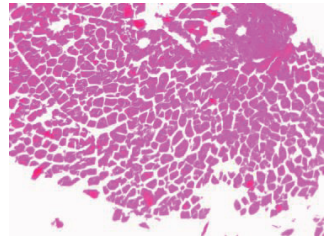
Table 3. Breast muscle tenderness of Guinea foul according to sex and duration of fattening period (age of slaughter) LSD test

Tenderness, °P		16 weeks of age *m. pectoralis superficialis*	20 weeks of age *m. pectoralis superficialis*	24 weeks of age *m. pectoralis superficialis*
Males	$\bar{x}$ ± SEM	$298.65^{a,x}$ ± 11.88	$301.3^{a,x}$ ± 20.46	$309.40^{a,x}$ ± 7.91
Females	$\bar{x}$ ± SEM	$309.75^{a,x}$ ± 17.04	$291.6^{a,x}$ ± 15.63	$305.75^{a,x}$ ± 8.57

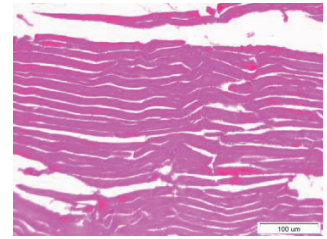
$^{a, b}$ *– Means in the same row with different superscript letters differ significantly ($p < 0.05$)*
^{x,y} *– Means in the same colunm with different superscript letters differ significantly ($p < 0.05$)*
SEM – standard error of the mean



m. pectoralis profundus, Guinea foul , 16 weeks of age, *M, LS, 100x*

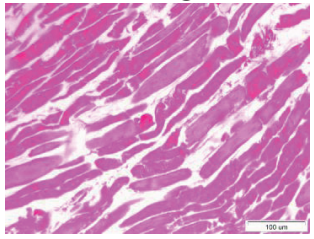


m. pectoralis profundus, Guinea foul , 16 weeks of age, *M, TS, 100x*



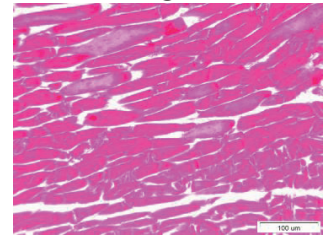
m. pectoralis profundus, Guinea foul, 16 weeks of age, *F, LS, 100x*

m. pectoralis profundus, Guinea foul , 16 weeks of age, *F, TS, 100x*

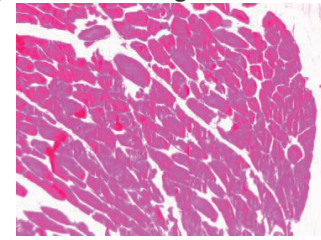


m. pectoralis profundus, Guinea foul, 20 weeks of age, M, LS, 100x

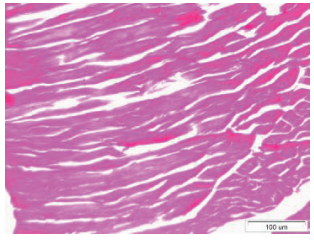
m. pectoralis profundus, Guinea foul, 20 weeks of age, M, TS, 100x



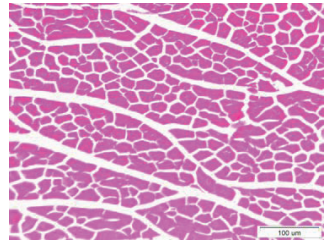
m. pectoralis profundus of Guinea foul, 20 weeks of age, F, LS, 100x



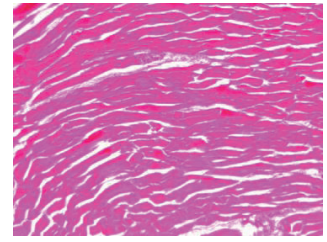
m. pectoralis profundus, Guinea foul, 20 weeks of age, F, TS, 100x



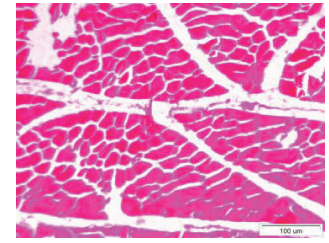
m. pectoralis profundus, Guinea foul, 24 weeks of age, M, LS, 100x



m. pectoralis profundus, Guinea foul, 24 weeks of age, M, TS, 100x



m. pectoralis profundus, Guinea foul, 24 weeks of age, F, LS, 100x



m. pectoralis profundus, Guinea foul, 24 weeks of age, F, TS, 100x

Fig. 3. Microscopic images of breast muscle (*m. pectoralis profundus*) from Guinea foul, 4 h *post mortem*, *100x*,transverse section (TS), longitudinal section (LS), female (F), male (M)

biochemical and functional postmortal changes (Von Lengerken et al., 2002).

Table 3 presents the mean values of breast muscle tenderness of Guinea foul at 16, 20 and 24 weeks of age. Kokoszyński et al. (2011) found decrease in breast tenderness in 16 weeks old guinea in comparison to younger birds (13 weeks old).

In our study no significant differences were found depending on sex and the duration of the fattening period, regardless of the increase in fiber diameter in both sexes found in the histological analysis.

Conclusions

There were no significant histological changes in the muscle tissue at the 4th h *post mortem*.

Histological observations showed that in the samples of male and female individuals at 16 weeks of age, the muscle fibers had the finest structure and the smallest diameter.

Comparing the microscopic images of male and female individuals of the same age (16, 20 or 24 weeks) no significant difference in the fiber structure was found. It could be concluded that the bird sex had a slight effect on the diameter of the muscle fibers (*m. femorotibialis*).

At 25 min after slaughter pH in tights was higher ($p > 0.05$) than pH in breasts non depending of the age. To 24 h post mortem pH significantly decreased ($p > 0.05$) both in breast and tights, regardless of sex and age.

The decrease in WHC was most affected by age (from 16 to 24 weeks) in *m. femorotibialis* both for males and females guinea towl (*Numida meleagris)* while *m. pectoralis superficialis* was slightly affected by age and sex.

Although the diameter of the muscle fibers increased with age in both sexes, no significant differences were found in tenderness of the breast muscle meat.

References

Adeyeye, E. I. (2011). Comparative evaluation of the amino acid profile of the muscle and skin of guinea fowl (Numida meleagris) hen. *Elixir Applied Chemistry*, *39*, 4848-4854. Available online at www.elixirpublishers.com (Elixir International Journal), DOI: 10.2174/1876396001003010220

Ayorinde, K. L. (1991). Guinea fowl (Numida meleagris) as a protein supplement in Nigeria. *World's Poultry Science Journal*, *47*(1), 21-26.

Ayorinde, K. I. (1987). Effect of holding room, storage position and duration on hatchability of guineafowl eggs. *Tropical Agriculture*, *64*(3), 188-190.

Ayorinde, K. L. (1987). Physical and chemical characteristics of the eggs of four indigenous guinea fowls (Numida meleagris galeata, pallas) in Nigeria. *Nigerian Journal of Animal Production*, *14*, 125-128.

Ayorinde, K. L. (1995). Genetic and phenotypic correlations of body weight, age at sexual maturity and some egg production traits in two local guinea fowl varieties. *Archiv für Geflügelkunde*, *59*(4), 215-219.

Ayorinde, K. L. (1995). Egg production and reproductive performance of local and exotic pearl and their crosses. *Nig. J. Genet*, 47-53.

Ayorinde, K. I., & Ayeni, J. S. O. (1987). Effect of management systems on the fattening of indigenous pearl guineafowl (Numida meleagris-galeata Pallas) in Nigeria. *Tropical Agriculture*, *64*(3). 185-187

Ayorinde, K. L., & Ayeni, J. S. O. (1987). Performance of guinea fowl breeders fed varying levels of Cyperus bulb. *Nigerian Journal of Animal Production*, *14*, 139-145.

Ayorinde, K. L., & Okaeme, A. N. (1984). All year guinea fowl-how feasible. *African Farming and Food Processing*, 21-22.

Ayorinde, K. L. (1987). Physical and chemical characteristics of the eggs of four indigenous guinea fowls (Numida meleagris galeata, pallas) in Nigeria. *Nigerian Journal of Animal Production*, *14*, 125-128.

Ayorinde, K. L. (1990). Problems and prospects of guinea fowl production in the rural areas of Nigeria. *Rural Poultry in Africa, ed. Sonaiya, E.B.,* 106-115.

Ayorinde, K. L., Ayeni, J. S. O., & Oluyemi, J. A. (1989). Laying characteristics and reproductive performance of four indigenous helmeted guinea fowl varieties (Numida meleagris galeata Pallas) in Nigeria. *Tropical Agriculture*, *66*(3), 277-280.

Ayorinde, K. L., Ayeni, J. S. O., & Okaeme, A. N. (1984). The production potential of different varieties of the indigenous helmeted guinea fowl (N. m. galeata pallas) and the exotic golden sovereign (N. m. meleagris) in Nigeria. In *Proceedings of 9 th Annual Conference of Nigerian Society of Animal Production* (pp. 65-72).

Baéza, E., Lessire, M., Berri, C., & Juin, H. (2001, September). Compared carcass and meat characteristics of label and standard guinea fowl. In *15. European sym-*

posium on the quality of poultry meat. WPSA Turkish Branch.

Baéza, E., Juin, H., Rebours, G., Constantin, P., Marche, G., & Leterrier, C. (2001). Effect of genotype, sex and rearing temperature on carcase and meat quality of guinea fowl. *British Poultry Science*, *42*(4), 470-476. DOI: 10.1080/00071660120070640

Barbut, S., Zhang, L., & Marcone, M. (2005). Effects of pale, normal, and dark chicken breast meat on microstructure, extractable proteins, and cooking of marinated fillets. *Poultry science*, *84*(5), 797-802. DOI: 10.1093/ps/84.5.797

Crowe, T. M. (1978). Evolution and ecology of guineafowl. Ph.D. Thesis, University of Cape Town.Baeza, E., Salichon, M. R., Marche, G., Wacrenier, N., Dominguez, B., & Culioli, J. (2000). Effects of age and sex on the structural, chemical and technological characteristics of mule duck meat. British poultry science, 41(3), 300-307

Danmaigoro, A., Shehu, S. A., Habibu, H., Hena, S. A., Mahmud, M. A., & Bello, A. (2016). Comparative morphological and histochemical studies on major flight muscles of domestic fowl (Gallus gallus domesticus), guinea fowl (Numida maleagris) and pigeon (Culumba livia domesticus). Int. J. Curr. Res. Biol. Med. (2016). 1(3): 29-38 ISSN: 2455-944X, DOI: http://s-o-i.org/1.15/ijcrbm-2016-1-3-4

Dransfield, E., & Sosnicki, A. A. (1999). Relationship between muscle growth and poultry meat quality. *Poultry science*, *78*(5), 743-746. available at: available at: available at: https://doi.org/10.1093/ps/78.5.743

Kiessling, K. H. (1977). Muscle structure and function in the goose, quail, pheasant, guinea hen, and chicken. *Comparative Biochemistry and Physiology Part B: Comparative Biochemistry*, *57*(4), 287-292. DOI: 10.1016/0305-0491(77)90055-4

Kokoszyński, D., Bernacki, Z., Korytkowska, H., Wilkanowska, A., & Piotrowska, K. (2011). Effect of age and sex on slaughter value of guinea fowl (Numida meleagris). *Journal of Central European Agriculture. 12*(2). DOI: 10.5513/JCEA01/12.2.907.

Santiago, H. L., Díaz, V., & Rodríguez, A. A. (2007). Processing yields, meat quality attributes and nutrient composition of diverging genotypes of guinea-fowl (Numida meleagris) broilers reared on various planes of nutrition in a tropical environment. *Animal Science*, *13*, 236-238. DOI: 10.23880/FSNT-16000148

Sharma, D., & Singh, H. (2006), Future research priorities in Guinea foul breeding and Genetics, *Poultry Research Priorities* to 2020. pp. 22-30, available at: http://dx.doi.org/10.22161/ijeab/2.6.24

Teye, G. A., & Gyawu, P. (2001). The benefits of intensive indigenous guinea fowl production in Ghana. *World Poultry*, *17*(9), 53-54.

Ward, S. R., Eng, C. M., Smallwood, L. H., & Lieber, R. L. (2009). Are current measurements of lower extremity muscle architecture accurate?. *Clinical orthopaedics and related research*, *467*(4), 1074-1082.

Von Lengerken, G., Maak, S., & Wicke, M. (2002). Muscle metabolism and meat quality of pigs and poultry. *Veterinarija ir zootechnika*, *20*(42), 82-86.

Wattanachant, S., Benjakul, S., & Ledward, D. A. (2005). Effect of heat treatment on changes in texture, structure and properties of Thai indigenous chicken muscle. *Food chemistry*, *93*(2), 337-348. DOI: 10.1016/j.foodchem.2004.09.032