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Effect of breeding mode, type of muscle and slaughter age on technological meat quality of local poultry population of *Gallus gallus* species of Benin

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Abstract

Indigenous chickens in Benin represent various populations including Holli, Sahoue, Fulani, North and South ecotypes. The current study aims to assess the technological quality of their meat according to genetic type, breeding system and age. Thus, 52 chickens of each ecotype were divided in two lots of 26 birds bred respectively under traditional system and improved system. For each breeding system, 26 cockerels of each ecotype were slaughtered at 20, 24 and 28 weeks old. It appears that the meat of South chickens had the highest shear force (47.76 N), redness (8.08) and chroma ($P<0.01$). The lowest pH_{24} was recorded in North (5.66) and Fulani (5.71) ecotypes ($P<0.05$). The highest luminance was found in meat of North chickens (59.74). Chickens Holli had the lowest yellowness and the highest hue value (3.72). The cooking loss of thigh of Sahoue was higher than in the other genotypes ($P<0.05$). The chickens bred under traditional system had the highest shear force and luminance ($P<0.001$), whereas birds of improved system had the highest pH24, yellowness and chroma ($P<0.05$). The shear force, redness, yellowness, hue, chroma and pH of thigh were higher than those of the breast ($P<0.001$). The breast was clearer than the thigh-drumstick (58.98 *vs* 49.09; $P<0.001$). The luminance, redness, yellowness, chroma and cooking loss decreased with age ($P<0.05$) while shear force and pH increased ($P<0.001$). Overall, South chickens provided the toughest and darkest meat, while traditional free range system was more favorable for firm and white chicken meat production.

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Introduction

The main challenge of developing countries is to ensure food self-sufficiency and food safety to the population more important but relatively poor (Mankor, 2009). These countries have therefore focused their development program of food safety and security on the livestock production in general and short-cycle species in particular. Among the breeding of short-cycle species, improved and traditional poultry breedings systems are an important source of animal protein supply for the population and income for producers and poultry sellers.

In Sub-Saharan Africa, the traditional poultry breeding based on the exploitation of local chickens under traditional farming system is the main source of chicken production (Mlozi *et al.*, 2003, Ahuja and Sen, 2007)and a livelihood for households (FAO, 2002, Ali *et al.,* 2011). These local chickens represent more than 80% of the total poultry population in West Africa (FAO, 2011). The aims of production of this breeding system are mainly the meat production and secondarily the egg production. The scavenging of birds in free range is the rule, as well as the diversity of species in the same farm. In Benin, the national poultry livestock on 2011 is estimated to 17087000 heads with 81% of local chickens for 6000000 inhabitants (CountrySTAT, 2012). Despite the numerical importance, local production of poultry meat remains below the needs expressed by consumers and this gap is filled by imports that increase from year to year. In 10 years, the volume of imports of poultry meat in Bénin increased from 19.361 metric tons in 2000 to 49.634 metric tons in 2010 (CountrySTAT, 2012). Despite the low domestic production of local chickens (2,020 tons in 2010), the local chicken meat is preferred by consumers in comparison with imported frozen chicken meat (Houéssionnon, 2011). The “cock” operation carried out in Benin in 1963 and that consists to introduce exotic roosters bred in the village poultry farms to improve performances of local chicken populations by crossing had not been accepted by Holli, Sahoue and Fulani sociocultural groups. Today, this operation creates genetic erosion within the local poultry population of the others sociocultural groups who agreed. However, the reluctance of populations of Holli, Sahoue and Fulani sociocultural groups had promoted conservation and perpetuation of varieties or breeds of chickens owned by these sociocultural groups, which bear now their name. Then, the socio-cultural groups Holli, Sahoue and Fulani are respectively the undisputed holders of Holli, Sahouè and Fulani chickens. The local population of poultry of the species *Gallus gallus* of Benin is then composed of various ecotypes among which are North, South, Holli, Fulani and Sahoue ecotypes (Bonou, 2006).

Several studies were carried out on the zootechnical and phenotypic characterization of local chickens in Benin in general. Most of these works on carcass traits were done on North, South, Holli, Fulani and Sahoue ecotypes. The previous works carried out by Tougan *et al.* (2013) on the variability of carcass traits of local poultry populations of *Gallus gallus* species of Benin showed that significant differences exist among ecotypes (North, South, Holli, Fulani and Sahoue), breeding mode and slaughter age. In spite of the fact that difference between the carcass traits of those ecotypes is well known (Tougan *et al.,* 2013), little knowledge exists on their meat characteristics, while farmers and consumers have a preference for their meat (Bonou, 2006). Thus, the aims of this study were to characterize the local chicken population in order to improve the quality of their meat for food security of Benin population and the promotion of local chicken. Specifically, it is to assess technological quality of the meat of local chickens of North, South, Holli, Fulani and Sahoue ecotypes of Benin in relation with their breeding system, the type of muscle and their slaughter age. To achieve this, it is necessary to evaluate the factors that influence the meat quality of these five genetic types of local chickens in order to characterize them and establish a genetic improvement program by selecting or crossing.

Material and methods

Area of study

The study was conducted conjointly at the experimental farm of “Ecole Polytechnique d'Abomey-Calavi (EPAC)" and at the traditional poultry breeders located in Abomey-Calavi in Atlantic Department. Situated at a latitude of 6 ° 27 'north and at a longitude of 2 ° 21' east, the Commune of Abomey-Calavi covers an area of 650 km² with a population of 307,745 inhabitants (INSAE, 2010). This area exhibits climatic conditions of sub-equatorial type, characterized by two rainy seasons with an uneven spatial and temporal distribution of rainfall: major (from April to July) and minor (from September to November). These two seasons are separated by a dry season. Average rainfall is close to 1200 mm per year. The monthly average temperatures vary between 27 and 31°C and the relative air humidity fluctuates between 65%, from January to March, and 97%, from June to July. The study on the technological quality was carried out in Laboratory of Animal Biotechnology and Meat Technology of the Department of Animal Production and Health of EPAC in Benin.

Birds sampling

The chickens used in this trial were produced from breeding nuclei of 10 hens and 3 cocks of each genetic type (North, South, Holli, Fulani and Sahoue), reared in confinement at the experimental farm of EPAC. The eggs of each genetic type collected from the breeding nuclei were incubated and the chicks were weighed after hatching and identified by genetic type. These chicks were reared in confinement according to the improved breeding system until the age of 12 weeks and then divided into two lots. Only the males were used in this study. Lot 1 composed of 26 cockerels of each genetic type was reared under improved breeding system and the Lot 2 also made of 26 cockerels of each genetic type was bred in free range according to the traditional breeding system at local chicken breeders targeted in each agro-ecological area. Each bird was identified by a sterile numbered ring fastened to the wing.

Characteristics of traditional breeding system

The scavenging of birds was the rule in this breeding system. The birds were in free range on during the day but housed at night in rudimentary shelters (traditional henhouse made of mud, straw or wicker), or kept outside on any support that could serve as a perch. There are nor quantitative nor qualitative standards in their feeding. The birds fed themselves around concessions, by gleaning here and there, and receiving occasionally from the traditional breeder some grain supplement. Their diet was composed of energetic elements (kitchen waste, bran ...), vitamins (green fodder, sprouted grains ...), minerals (salt, pounded shells) and protein (termites, legumes) (Tougan, 2008; Youssao *et al.*, 2012). Drinkable water was distributed in rudimentary watering tank. Various discarded containers were often used for drinking. In this type of farming, no health follow-up and no prophylactic standard were observed.

Characteristics of improved breeding system

In the improved breeding system used in this study, the birds were bred on a fresh wood shavings litter in buildings of california type. The livestock equipments used were composed of brooders, feeders, drinkers. The number of these devices depended on the number of birds in the henhouse. All the animals were fed with the same diet. Three diets were used: starting (2880 EM Kcal/kg and 18% of crude protein), growing (2969 EM Kcal/kg and 18% crude protein) and laying (2800 EM Kcal/kg of feed and 20% of crude protein). The starter feed was used from the hatching to the age of 2 months and the growth feed from 2 month old to the point of laying (22 weeks). From the point of laying to the end of the experimentation, the laying feed was used. The animals were fed *ad-libitum* throughout the study. The composition of the three diets used in these experiments is given by Youssao *et al.* (2009). Feed transitions were done during three days between the different growth periods by gradual incorporation to the previous diet with the respective proportions of 25, 50 and 75% of the new diet.

Habitat used at the Experimental Farm of EPAC to house chickens during this experiment was composed of six buildings of 15 m² each divided into compartments of 5m ² with screens in which the animals divided into groups were reared. The floor was cemented and the wall height was of 90 cm, and topped with wire-netting. The compartments were heated by using incandescent lamps of 100 watt and brooders consist of jars filled with charcoal lit each night until the chicks were three weeks old.

Health and medical prophylaxis consisted of the real respect of breeding hygiene rules, deworming and prevention against certain diseases such as avian chronic respiratory disease, coccidiosis, Newcastle disease, Gumboro, fowl pox, Marek's disease, avian infectious bronchitis, bursal infectious disease, small pox and avitaminosis (Youssao *et al.*, 2009). Monthly, a sample of feces were analyzed in order to follow the deworming efficiency and to make sure that the coccidium and gastro-intestinal parasites didn't affect the growth performances of the birds. The prophylaxis schedule used had been described by Youssao *et al.* (2009). Between two bands, the henhouses were disinfected and left unoccupied for one to two weeks (all in-all out policy). At the entrance of each building, a footbath solution based on cresyl was installed to disinfect feet to each entry.

Slaughtering process and analytical methods

The slaughtering process used in the current study is the one described by Tougan *et al.* (2013) when studying the variability of carcass traits of local poultry populations of *Gallus gallus* species of Benin according to genetic type, breeding mode and slaughter age. After slaughtering, the cuts of breast and thigh-drumstick were used to evaluate the technological properties (pH, color, hue, chroma, cooking loss and texture) of the meat quality.

pH

The pH was measured by genetic type, by breeding mode and by slaughter age at different times *post mortem* (1 h; 4 h; 8 h; 12 h and 24 h) in the breast muscle (*Pectoralis major*) and the thigh muscle (*Ilio tibialis*) at 2 cm depth (Fernandez *et al.*, 2002; Berri *et al.*, 2002; Raach-Moujahed *et al.*, 2011). The pH was measured using a pH-meter (Hanna Instruments Inc., model HI99161) provided with a specialized probe and temperature control system. This apparatus was calibrated with two buffers pH-meter: pH = 4.0 and pH = 7.0 following a procedure provided by manufacturer. Between the measurements the muscle was stored at 4°C in an individual plastic container.

Colour

The colour of skin and meat (breast and thigh) were determined at 24 h *post mortem* using a Minolta chromameter CR-400 (Japan) in the trichromatic system (CIE L * a * b*). The surface was exposed to air for 20 min at room temperature before determining the color of the muscle. The readings were taken on equivalent positions. The tip of the chromameter measuring head was placed flat against the surface of the skin or of the meat for breast and thigh. For each reading, 6 measurements were performed and the average of these readings was considered as the final value. Skin and meat color were expressed in the CIE L*a*b* dimensions of lightness (L*), redness (a*) and yellowness (b*). The colorimeter was calibrated using the specific white board (Minolta CR 400), before measurement began. From the a* and b* values, the hue (H_{ab}) and the chroma (C_{ab}) values were calculated.

Hue, namely the observable colour (e.g. red, blue, yellow), is an angular measurement calculated by the following equation: $H_{ab} = \tan^{-1} b^*/a^*$(Hunt, 1991).

chroma is an expression of saturation or intensity of the color attained and is expressed by the equation: $C_{ab} = (a^{*2} + b^{*2})^{1/2}$ (Hunt, 1977).

Cooking loss

The Water Holding Capacity was measured by cooking loss. The breast and thigh-drumstick cuts were separately weighed and wrapped by placing inside vacuum bags (COPVAC 17025, Vigoclima S.L., Vigo, Spain), sealed without vacuum, and cooked placing vacuum-package bags in bain-marie (Memmert GmbH + Co, GK, Germany) until the core temperature reached 70°C (Franco *et al.*, 2012). The core temperature was controlled by inserting the electrode of a digital thermometer (TestoAG, Lenzkirch, Germany) into the center of the meat sample for the duration of the boiling process. After boiling the samples were removed, cooled to room temperature, and reweighed (Jaturasitha *et al*., 2008; Chueachuaychoo, 2011). The cooking loss was calculated as the loss of weight during the boiling process and was expressed as a percentage (Raach-Moujahed *et al*., 2011) as follows:

$$\textbf{Cooking loss}\ (\%) = \frac{\textbf{Weight loss}}{\textbf{Initial fresh meat weight}} \times 100$$

Texture

The samples prepared for the determination of the cooking loss were subsequently used for the Warner-Bratzler shear force analysis according to Bratcher *et al.* (2005). Cores with a diameter of 1.27cm were removed from the sample at different positions parallel to fiber orientation (longitudinal axis of the myofibres) and sheared as described by Honikel (1998). Shear force determinations were conducted on a texture analyzer LF plus (LLOYD Instruments) equipped with a Warner-Bratzler shear force head vertical to the fiber direction. The Warner-Bratzler single blade was used. The shear velocity was 200 mm/min. Each value was an average of at least 5 measurements.

Statistical analysis

The data collected on technological quality of meat of the five genetic types of chicken were analyzed with the software SAS (Statistical Analysis System, 2006). For the analysis of variance, a fixed effects linear model was adjusted to the data and includes the fixed effects of genetic type, breeding system and slaughter age. The interaction between genetic type and age and between breeding system and age were significant and taken into account in the model of variance analysis. The mathematical expression of this model is as follows:

$$Y_{ijklm} = \mu + E_i + BM_j + M_k + Age_l + E{*}M_{ik} + M{*}Age_{kl} + e_{ijklm}$$

With:

- Y_{ijkl}= performance mean of individual l, of ecotype i, of the breeding system j, of the muscle k and of slaughter age l.
- μ= average performance;
- E_i : fixed effect of ecotype i (Holli, Fulani, Sahoue, North et South) ;
- BM_j: fixed effect of breeding mode j (traditional and improved);
- M_k: fixed effect of muscle k (thigh-drumstick and breast).
- Age_l: fixed effect of age at slaughter l (20, 24 and 28 weeks);
- $E{*}M_{iij}$: Interaction between ecotype i and muscle j;
- $M{*}Age_{jk}$: Interaction between muscle k and slaughter age l;
- e_{ijklm}: Effect of random residual average performance of the individual m, of ecotype i, of the breeding mode j, of the muscle k and slaughter age l.

The F test was used to determine the significance of each effect in the model. Means were compared two by two by the Student's t test.

Comparisons between parameters of meat quality were also made between ecotypes by type of muscle (thigh-drumstick and breast).

Results

Effect of the ecotype on technological quality of meat

The technological properties of meat quality varied according to the genetic type (Table 1). The pH, the lightness (L*), the redness (a*), the yellowness (b*), the cooking loss, the hue value, the chroma value and the shear force were affected by genetic type ($P<0.05$). The meat of the chickens of South ecotype was the most though with the highest Warner-Bratzler shear force (47.76 N). However, the Warner-Bratzler shear force of the meat of Holli (41.95 N) and North (41.97 N) ecotype of chickens were similar ($P>0.05$), but lower than the one of Fulani chicken meat (45.08N; $P<0.001$) whose texture was comparable to the one of South ecotype. No significant difference was observed between the extensions (12.94 mm to 13.58 mm) of the meat among the 5 genotypes of chickens ($P>0.05$).The pH of the meat of Holli chicken recorded at 1 hour (pH1 = 5.91) and 4 hours (pH4 = 5.74) *post-mortem* were higher ($P<0.001$; table 1) than those obtained in the four others genotypes, whereas pH1 and pH4 of meat of North, Fulani, Sahoue and South chickens were similar and fluctuate respectively between 5.69 and 5.83, and between 5.55 and 5.63 ($P>0.05$). The weakest pH at 8 hours *post mortem* (pH8) was recorded in South ecotype chickens ($P<0.01$), whereas the pH8 values measured in the other genotypes of chicken were similar ($P>0.05$; table 1). The pH of the meat of Holli chicken at 12 hours *postmortem* were similar the one of the meat of South and Fulani ecotype ($P>0.05$; table II) but significantly higher than those obtained in North and Sahoue ecotypes ($P<0.05$). The pH at 24 hours *post mortem* of Holli, South and Sahoue chicken meat were identical and the highest whereas the lowest value was recorded in North and Fulani ecotypes ($p<0.01$). There was significant difference in luminance (L*), redness (a*) and yellowness values among genotype. The luminance (L*) of the meat of Holli chicken (58.12%), Fulani (57.43%) and South (57.4%) were similar but lower than the one of North (59.74%) ecotype ($P<0.05$). The Sahoue ecotype presented an intermediate value (58.2%) of luminance among genotypes. In return, the highest redness value was recorded in south ecotype (8.08), then come the Sahoue ecotype (7.73), Fulani (7.26), Holli (7.12) and North (6.73) ($p<0.001$). The yellowness value of North, Fulani, Sahoue and South ecotypes were identical ($P>0.05$; table II), whereas the Holli one had the lowest yellowness value ($p<0.01$). The hue value of meat of North, Fulani, Sahoue and South chickens were similar and fluctuate respectively between 1.55 and 1.75, whereas the meat of Holli ecotype had the highest Hue value (Hue = 3.72; $p<0.01$). The highest chroma value was recorded in Sahoue (9.31) and South (9.71) ecotypes whereas the lowest value was observed in Holli (7.96) chicken ($P>0.05$; table 1).The cooking loss of thigh-drumstick cuts of Sahoue (36.48%) chicken meat was more important than the one of the other genotypes ($P<0.001$). The lowest cooking loss of thigh-drumstick cuts was recorded in South ecotype chicken (28.07%). The cooking loss of breast cuts of Sahoue (31.48%) and South (29.74%) chicken meat was identical ($P>0.05$; table 2), but more important than the one of Holli (27.61%), North (26.64%) and Fulani (27.68%) ecotypes ($p<0.001$). However, no significant difference was observed between the cooking loss of breast cuts of Holli, North, and Fulani chickens ($P>0.05$; table 1).

Effect of the breeding mode on technological quality of meat

The breeding mode influenced only the shear force, the extension, the pH recorded at 24 hours *post-mortem*, the lightness, the yellowness and the chroma ($P<0.05$; table 2). Indeed, the chickens bred under traditional breedings system had shear force, extension and a luminance value higher than the chickens bred in improved breeding system ($P<0.01$), whereas birds of improved breeding had the higherpH24, yellowness (b*) and chroma ($P<0.05$). No significant difference was observed between the pH1, the pH4, the pH8, the pH12, the redness (a *), the hue value and the cooking loss of breast and thigh among the breeding modes (improved system and traditional system) ($P>0.05$; Table 2).

Effect of type of muscle on technological quality of meat

The type of muscle had affected all the technological meat quality parameters studied in the current study ($P<0.001$; table 2). The luminance of breast meat was significantly higher than those of the thigh ($P<0.001$). In return, the shear force, pH1, pH 4, pH 8, and pH 12 pH24 of thigh-drumstick were significantly higher than those of the breast ($P <0.001$;table 2). Likewise, the redness (a*), the yellowness (b*), the hue value (H*) and chroma (C*) of thigh meat were stronger ($P <0.001$; table 2) than those recorded in breast meat, whereas the luminance (L*) of breast was significantly greater than the one measured in thigh-drumstick meat ($P <0.001$; Table 2).

Table 1. Effect of genetic type on meat quality parameters of indigenous chickens of Benin.

Variables	Holli	North	Fulani	Sahoue	South	RSD	ANOVA
Shear Force (N)	41.95a	41.97a	45.08bc	44.69ab	47.76c	7.12	***
Extension (mm)	12.94a	13.08a	13.05a	13.58a	13.22a	1.31	NS
pH1	5.91a	5.69c	5.73c	5.71c	5.83b	0.22	***
pH4	5.74a	5.55b	5.62bc	5.57bc	5.63c	0.21	***
pH8	5.77a	5.59b	5.69a	5.71a	5.72a	0.23	**
pH12	5.81a	5.7c	5.78ab	5.71bc	5.80a	0.21	*
pH24	5.80a	5.66b	5.71±b	5.74ab	5.82a	0.22	**
L*	58.13b	59.74a	57.43b	58.2ab	57.4b	5.31	*
a*	7.12c	6.73c	7.26b	7.73ab	8.08a	1.74	***
b*	2.81a	3.93b	4.11b	4.23b	4.63b	2.04	**
Hue	3.72a	1.59b	1.75b	1.74b	1.55b	2.76	**
Chroma	7.96d	8.15cd	8.67bc	9.31a	9.71a	2.12	***
Thigh cooking loss (%)	33.46b	28.94c	31.3b	36.48a	28.07c	4.1	***
Breast cooking loss (%)	27.61b	26.64b	27.68b	31.48a	29.74a	4.24	***

NS:** Non Significant; ***:** P<0.05; *:** P<0.01 ; ***** :** P<0.001. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%; pHi= pH at i hours. ANOVA: Analysis of Variance (test of significance);* RSD: Residual Standard Deviation.

Effect of slaughter age on technological quality of meat

The slaughter age affected several properties of meat quality (table 2). The Warner-Bratzler shear force and the pH1, pH4, pH8, pH12 and pH24 of meat increased significantly with the age; the highest values were obtained at 28 weeks (P<0.01). Furthermore, the luminance, the redness, the yellowness, the chroma value and the breast cooking loss of meat decreased significantly with the slaughter age (P <0.05), while the hue value and the thigh cooking loss didn't vary significantly with the slaughter age (P>0.05; table 2).

Interaction between ecotype and type of muscle on technological quality of meat

The interaction between ecotype and type of muscle were significant on several parameters of the meat quality (P<0.05; Table 3).

In Holli ecotype, the shear force, pH1, pH 4, pH12 and pH24 of thigh-drumstick were significantly higher than those of the breast (P<0.001). By the same way, the redness, the yellowness and the chroma of thigh meat were stronger (P <0.001) than those recorded in breast meat, whereas the luminance of breast was significantly greater than the one measured in thigh-drumstick meat (P <0.001). Nevertheless, pH8 and the hue value of Holli chicken meat didn't vary significantly depending on the type of muscle (P>0.05; table 3).

In North ecotype, the shear force, pH1, pH4, pH8, pH12 and pH24 of thigh-drumstick were significantly higher than those of the breast (P<0.001). By the same way, the redness, the yellowness and the chroma of thigh meat were stronger (P<0.001) than those recorded in breast meat, whereas the luminance of breast was significantly greater than the one measured in thigh-drumstick meat (P<0.001). Nevertheless, the ash percentage and the hue value of North chicken meat didn't vary significantly depending on the type of muscle (P>0.05; Table 3).

Table 2. Variation of technological quality of meat by type of muscle, breeding mode and slaughter age.

Variables	Muscle		Breeding mode		Ages			RSD	Muscle effect	Breeding mode effect	Age effect
	Breast	Thigh-drumstick	Traditional	Improved	20 Weeks	24 Weeks	28 Weeks				
Shear force (N)	36.55a	52.03b	46.99a	41.59a	39.47a	44.05b	49.35c	7.12	***	***	***
Extension (mm)	12.48a	13.87b	13.42a	12.93a	12.76a	12.77a	14b	1.31	***	**	***
pH1	5.67a	5.87b	5.77a	5.77a	5.68a	5.90b	5.74a	0.22	***	NS	***
pH4	5.52a	5.72b	5.64a	5.61a	5.57a	5.66b	5.63b	0.21	***	NS	**
pH8	5.6a	5.79b	5.69a	5.7a	5.64a	5.73b	5.72b	0.23	***	NS	*
pH12	5.69a	5.83b	5.74a	5.78a	5.71a	5.80b	5.78b	0.21	***	NS	**
pH24	5.64a	5.85b	5.72a	5.78a	5.69a	5.79b	5.77b	0.22	***	*	**
L*	58.98a	49.09b	58.98a	57.40b	59.43a	52.66b	57.48b	5.31	***	**	**
a*	3.88a	13.40b	7.31a	7.46a	7.65a	7.4ab	7.1b	1.74	***	NS	*
b*	3.34a	4.71b	3.56a	4.31b	4.37a	4.02ab	3.43b	2.04	***	**	*
Hue	1.56a	3.24b	2.15a	2a	1.69a	2.26a	2.27a	2.76	***	NS	NS
Chroma	5.43a	14.30b	8.43a	9.09b	9.21a	8.83a	8.24b	2.12	***	**	**
Thigh CL (%)	-	-	31.61a	31.68a	31.2a	31.79a	31.96a	4.1	-	NS	NS
Breast CL (%)	-	-	28.47a	28.78a	28.9a	29.69a	27.33a	4.24	-	NS	NS

NS: Non Significant; *: P<0.05; **: P<0.01 ; *** : P<0.001. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%; pHi= pH at i hours. ANOVA: Analysis of Variance (test of significance); RSD: Residual Standard Deviation; CL: cooking loss.

As for Fulani ecotype, the shear force, pH1, pH4, pH8, pH12 and pH24 of thigh-drumstick were significantly higher than those of the breast (P<0.001). By the same way, the redness, the yellowness and the chroma of thigh meat were stronger (P<0.001) than those recorded in breast meat, whereas the luminance of breast was significantly greater than the one measured in thigh-drumstick meat (P<0.001). Nevertheless, the pH1 and pH4 of Fulani chicken meat didn't vary significantly depending on the type of muscle (P>0.05; table 3).

About Sahoue ecotype of chicken, the shear force, pH1, pH4, pH8 and pH24 of thigh-drumstick were significantly higher than those of the breast (P<0.001). By the same way, the redness and the chroma of thigh meat were stronger (P<0.001) than those recorded in breast meat, whereas the luminance of breast was significantly greater than the one measured in thigh-drumstick meat (P<0.001). Nevertheless, the pH12 and the yellowness value of Sahoue chicken meat didn't vary significantly depending on the type of muscle (P>0.05; table 3).

In South ecotype chicken, the shear force, pH1, pH4, pH8, pH12 and pH24 of thigh-drumstick were significantly higher than those of the breast (P<0.001). By the same way, the redness and the chroma of thigh meat were stronger (P<0.001) than those recorded in breast meat, whereas the luminance of breast was significantly greater than the one measured in thigh-drumstick meat (P<0.001). Nevertheless, the yellowness value of South chicken meat didn't vary significantly depending on the type of muscle (P>0.05; table 3).

Table 3. Interaction between ecotype and type of muscle on technological quality of meat.

Variables	HOLLI		NORTH		FULANI		SAHOUE		SOUTH		RSD	Interaction ecotype X muscle
	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh		
Shear Force (N)	35.56±1.35a	50.35b	35.97a	47.98b	34.56a	55.62b	37.75a	51.63b	40.98a	54.55b	7.12	*
Extension (mm)	12.00±0.25a	13.90b	12.57a	13.59b	12.07a	14.06b	13.14a	14.02b	12.70a	13.76b	1.31	NS
pH1	5.79a	6.05b	5.6a	5.78b	5.7a	5.76a	5.59a	5.83b	5.70a	5.97b	0.22	NS
pH4	5.58a	5.91b	5.46a	5.64b	5.59a	5.67a	5.46a	5.68b	5.55a	5.73b	0.21	*
pH8	5.72a	5.83a	5.47a	5.72b	5.63a	5.76b	5.59a	5.84b	5.61a	5.84b	0.23	NS
pH12	5.72a	5.91b	5.62a	5.79b	5.72a	5.85b	5.67a	5.76a	5.74a	5.87b	0.21	NS
pH24	5.71a	5.90b	5.56a	5.77b	5.63a	5.80b	5.66a	5.83b	5.67a	5.97b	0.22	NS
L*	56.23a	50.51b	61.45a	50.68b	59.3a	46.48b	59a	49.96b	59.15a	47.62b	5.31	**
a*	3.66a	13.06b	3.47a	12.16b	4.08a	13.17b	3.87a	14.12b	4.32a	14.51b	1.74	NS
b*	2.01a	4.30b	3.56a	4.82b	3.39a	4.55b	3.49a	4.58a	4.30a	4.28a	2.04	NS
Hue	3.65a	3.64a	0.91a	2.60a	1.49a	3.22b	0.99a	3.80b	0.70a	3.06b	2.76	NS
Chroma	4.65a	13.85b	5.24a	13.14b	5.48a	14b	5.5a	14.98b	6.32a	15.54b	2.12	NS

NS:** Non Significant; ***:** P<0.05; *:** P<0.01 The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%; pHi= pH at i hours. ANOVA: Analysis of Variance (test of significance);* RSD: Residual Standard Deviation.

Interaction between muscle and age on technological quality of meat

The technological quality of meat of indigenous chickens varied depending on the interaction between age and type of muscle (P<0.01).

In thigh meat, the yellowness decreased with the slaughter age; the lowest value was obtained at 28 weeks (P <0.05). Nevertheless, the shear force of thigh meat increased significantly depending on the age; the highest values of shear force was recorded at 28 weeks (P<0.05; table 4).

In breast meat, the luminance and the yellowness decreased with the slaughter age (P<0.05); while the shear force, the extension, the pH and the hue value of thigh meat increased with age (P<0.05; Table 4).

As for the skin, the luminance, the redness and the chroma value decreased with the slaughter age (P<0.05). However, no significant difference was observed for the yellowness and the chroma value among the different slaughter age (P>0.05; Table 4).

The pH an indicator of meat quality differed between genetic types in the current study. Breast and thigh pH were similar to those reported for Thai native chicken (5.77) at the same age (Jaturasitha *et al.*, 2008), and to the findings of El Rammouz *et al.* (2004) on Label chicken (5.73) kept under conventional breeding conditions at the Poultry Research Center (INRA-Nouzilly) until the usual marketing age (12 weeks) and the results of Jehl *et al.* (2003) and Wattanachant *et al.* (2004) on slow growing broiler (5.66), while lower than values reported in the literature on thigh and breast meat of Label Rouge chickens bred under improved breeding system until 24 weeks old (Youssao *et al.*, 2012) and than the ultime pH value of 6.1 found at 24 hours *post-mortem* reported by Raach-Moujahed *et al.* (2008) on tunisian local poultry raised in outdoor access.

Table 4. Interaction between type of muscle and age on technological quality of meat.

Variables	Thigh			Breast			Skin			RSD	Interaction Muscle x Age
	20 weeks	24 weeks	28 weeks	20 weeks	24 weeks	28 weeks	20 weeks	24 weeks	28 weeks		
Shear Force (N)	47.19a	51.60b	57.33c	31.7a	36.51b	41.39c	-	-	-	7.12	NS
Extension (mm)	13.3a	13.40a	14.92b	12.2a	12.15a	13.09b	-	-	-	1.31	NS
pH1	5.81a	6.01b	5.81a	5.5a	5.79b	5.684c	-	-	-	0.22	NS
pH4	5.69a	5.78b	5.71a	5.4a	5.56b	5.56c	-	-	-	0.21	NS
pH8	5.75a	5.83b	5.82ab	5.5a	5.63b	5.63b	-	-	-	0.23	NS
pH12	5 .8a	5.87a	5.84a	5.6a	8.73a	5.73a	-	-	-	0.21	NS
pH24	5.83a	5.87a	5.86a	5.5a	5.71b	5.69b	-	-	-	0.22	NS
L*	0.48a	48.47a	48.21a	60.2a	57.37b	59.46ab	67.56a	67.15a	64.76b	5.31	NS
a*	13.39a	13.67a	13.46a	3.8a	4.02a	3.79a	5.72a	4.83b	4.05c	1.74	**
b*	5.61a	4.59a	3.92a	3.9a	3.35ab	2.80b	3.6a	4.13a	3.56a	2.04	NS
Hue	2.62a	3.37a	3.80a	0.8a	1.75a	2.08b	1.65a	1.67a	0.92a	2.76	NS
Chroma	14.62a	14.22a	14.01a	5.7a	5.53a	5.03a	7.26a	6.74a	5.63b	2.12	NS

NS:** Non Significant; ***:** P<0.05; *:** P<0.01 ; ***** :** P<0.001. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%; pHi= pH at i hours. ANOVA: Analysis of Variance (test of significance);* RSD: Residual Standard Deviation.

Our Luminance and redness values are higher than those found by Lonergan *et al.* (2003) for Fayoumi breed for breast at the age of 8 weeks (L* = 40.31, a* = 6.08, b* = 12.52), but lower than values reported for Tunisian local poultry raised in outdoor access (L* = 62.57, a* = 12.54, b* = 7.53 for thigh and L* = 66.42, a* = 12.64, b* = 15.44 for Breast meat). On the other hand the values of the yellowness observed in our study were lower than to those found by Jaturasitha *et al.* (2008) in local chicken Thai native for breast and the thigh (13.6 and 7.8 respectively). However, our L*, a*, b* values are similar to the finding of Leusink (2010). Furthermore, Quentin *et al.* (2003) and Kisiel and Ksiazkiewicz (2004) reported in chicken that breast and thigh meat color in terms of Luminance, redness and yellowness values revealed significant differences among genotypes. As Roy *et al.* (2007) reported, Slow growing genotypic chickens show a lower ratio of white to dark meat than conventional broilers, and are selected to produce dark meat rather than white (Fanatico *et al.*, 2005).This effect of genetic type on the color of meat is also reported by Janisch *et al.* (2011) who recorded great differences in CIE lab values among intensive breeding broilers Ross 308, Ross 708, and Cobb 700 at the same age with the highest Luminance values recorded in Cobb 700 broilers muscles. As found by Berri *et al.* (2001) and Debut *et al.* (2003), genetics are a relevant factor for determining color characteristics of the meat. Nethertheless, Bianchi *et al.* (2006) found no differences on color coordinates (L*, a*, or b*) between intensive breeding broilers Ross 508 and Cobb 500.

The hue value of meat of North, Fulani, Sahoue and South chickens were similar and fluctuate respectively between 1.55 and 1.75, whereas the meat of Holli ecotype had recorded the highest hue value (hue = 3.72). This difference is due to the lower a* values reached by these birds. Our result confirm these of Diàz *et al.* (2010) who showed that the hue angle was higher in the Mos slow-growing breed than in Sasso T-44 slow growing strain and Sasso X-44 medium growing strain. Nevrtheless, our result differs from the one of Bianchi *et al.* (2006) who found that Ross 508 broilers exhibited a lower H* compared with Cobb 500 (45.12 *vs* 48.52; P<0.01).

The highest Chroma value was recorded in Sahoue and South ecotypes whereas the lowest value was observed in Holli chicken. By the same way, Venturini *et al.* (2011) observed a significant difference in Chroma value among genotypes of chickens.

The cooking loss of thigh-drumstick cuts of Sahoue chicken meat was more important than the one of the other genotypes. The lowest cooking loss of thigh-drumstick cuts was recorded in chicken of South ecotype. The cooking loss of breast cuts of Sahoue and South chicken meat was more important than the one of Holli, North and Fulani ecotypes. This variation of cooking loss among genotypes is consistent with the finding of Janisch *et al.* (2011). In contrast, Diàz *et al.* (2010) reported that no significant effect of breed was observed in the cooking loss of the breast meat.

Effect of breeding mode on technological quality of meat

Shear force and colour of poultry meat is the most important attributes in consumers' final satisfaction (Fletcher, 1999; Fletcher, 2002). In our study, the chickens bred under traditional breeding system had the highest shear force and extension than the chickens bred in improved breeding system. This result is consistent with other research showing that outdoor access results in either the breast or drumstick meat of fast growing chickens that is more firm than meat produced indoors (Castellini *et al.*, 2002b; Santos *et al.*, 2005; Fanatico *et al.*, 2007). An earlier study carried out by Fanatico *et al.* (2005) indicates that the meat of 56-day old Cobb chickens given outdoor access was characterized by higher tenderness compared to the meat of birds reared indoors (P≤0.05). Motory activity of the birds may cause a strengthening of connective tissue fiber structure (Aberle *et al.*, 2001) and can also affect fiber type proportions. The diameter of the muscle fiber is positively related to the tenderness of the meat (Fanatico *et al.*, 2007); however, according to Dingboom and Weijs (2004), the impact of exercise on meat quality is minor and ambiguous. Moreover, Wang *et al.* (2009) and Ponte *et al.* (2008) found no effect of the rearing system on shear force value of the muscles from slow-growing chickens.

Furthermore, the chickens bred only under traditional breeding system in the current study had the highest luminance value whereas birds of improved breeding had the higher chroma value. Castellini *et al.* (2002) reported that the organic production system with free-range access increased the lightness of meat, which was paler than the meat of birds kept indoors. In a study of Husak *et al.* (2009), thigh muscles of free-range chickens were characterized by higher redness compared to conventional birds, but they were slaughtered at different age. Meanwhile, Fanatico *et al.* (2007) demonstrated that the meat of chickens kept indoors only was characterized by lighter colour than that of free-range reared birds. The greater yellowness of carcasses from improved breeding system could thus result from their intake of diet supplemented with palm oil, which is a great source of carotenoids. The difference in chroma value observed in the current study by breeding mode is due to the lower redness values reached by the birds bred under traditional chicken in our study.

Ponte *et al.* (2008c) found that in Red Bro poultry, pasture improved breast skin pigmentation (p<0.001), so influenced breast skin yellowness but not skin Luminance and redness. In addition, Grashorn and Serini (2006) found that skin and breast meat showed lower redness but higher yellowness in organic poultry carcasses.

No significant difference was observed between the cooking loss of breast and thigh among the breeding modes in our study. Our result confirm the finding of Fanatico *et al.* (2007) who reported that the rearing system had no effect on thermal loss from breast muscles of broiler chickens (20.94%). Lack of effect of housing system on thermal loss from the chicken breast muscle was also found by Dunn *et al.* (1993). Nevertheless, significant differences within this trait were observed by Połtowicz and Doktor (2011) who reported higher thermal loss in chickens reared indoors.

Brown *et al.* (2008) reported that there were significant differences between rearing systems, with fillet muscles from birds grown under the standard system having a higher ultimate pH. This result is consistent with our finding that showed that birds of improved breeding system had the higher pH24.

Effect of type of muscle on technological quality of meat

The shear force, pH1, pH4, pH8, pH12 and pH24 of thigh-drumstick were significantly higher than those of the breast. This result confirm the one reported by Wattanachant *et al.* (2004a) and Chuaynukool *et al.* (2007) who stipulated that the muscle pH of Thai indigenous chickens was 5.80 - 5.93 for *pectoralis muscle* (breast) and 5.85 - 6.06 for *biceps femoris* muscle (thigh).

In this study, breasts of local poultry are characterized by a clearer appearance than the thigh (58.98% *vs* 49.09 %) and the intensity of the yellow color was much higher in thigh than in breast (3.34 *vs* 4.71).This variation of local chicken meat luminance according to the type of muscle is also reported by Raach-Moujahed *et al.* (2011) in Tunisian indigenous chicken raised in outdoor access. The breast in our study presents a higher L* value (58.98%) than that found by Ponte *et al.* (2008a) in Label rouge chicken meat (55.36%) at 56 days old. The redness, the hue value and chroma of thigh meat in our study is stronger than those recorded in breast meat. This finding confirms that colour in general, and redness in particular could vary significantly between different type of muscles (Ponte *et al*., 2008a; Raach-Moujahed *et al.*, 2011)).The redness of the breast meat in our study is highly more intense (3.88) than which reported in the label rouge chickens (-1.059) by Ponte *et al.* (2008a), and slightly more important than the value (6.08) found by Raach-Moujahed *et al.* (2011) in Tunisian indigenous chicken raised in outdoor access. Meanwhile, the yellowness in the breast of the five local populations studied in this experiment (3.34) was lower than that (9.42) in the Label rouge chicken (Ponte *et al.*, 2008a) and in Tunisian indigenous chicken raised in outdoor access (Raach-Moujahed *et al.,* 2011). On the other hand the values of the yellowness (b*) for breast and the thigh were lower than those found by Jaturasitha *et al.* (2008) in local chicken Thai native at the same age (13.6 and 7.8 respectively).

Effect of slaughter age on technological quality of meat

The slaughter age affected several properties of meat quality. The shear force and pH1, pH4, pH8, pH12 and pH24 of meat measured at 28 weeks were significantly higher than the values obtained at 20 and 24 weeks. The values of shear force of 39.47 N, 44.05 N, and 49.35 N recorded respectively at 20, 24 and 28 weeks old are comparable to those recorded Wattanachant (2008) in local chickens of Thailand. In addition, our pH values could be related to the late age of slaughtered birds (20, 24, 28 weeks), since meat from old age birds had consistently high pH values (Ponte *et al.,* 2008a). Diàz *et al.* (2010) reported that no significant effect of age was observed in the cooking loss of the chicken meat. This finding is consistent with our results in cooking loss of breast and thigh-drumstick.

In our study, the luminance, the redness, the yellowness, the chroma value and the breast cooking loss of meat decreased significantly with the slaughter age ($P<0.05$), while the hue value didn't vary significantly with the slaughter age. In contrast to our results, Smith *et al.* (2002) compared breast fillets from birds processed at various ages (from 42 to 52 d) and reported that breast meat color is not affected by age.

Conclusion

The results of the present study on the technological quality of white meat (breast muscle) and dark meat (thigh muscle) of 5 indigenous chicken populations of Benin bred under improved or traditional system reveals that the pH, the lightness, the redness, the yellowness, the cooking loss, the hue value, the chroma value, and the shear force were affected by the genetic type.

The chickens bred under traditional breedings system were more though and clearer than the chickens bred in improved breeding system, whereas birds of improved breeding had the higher pH24, yellowness and chroma. The meat of thigh-drumstick was more firm with high pH1, pH4, pH8, pH12 and pH24 comparatively to those of the breast. The breast meat was characterized by a clearer appearance than the thigh. The lower shear force of thigh and breast meat was recorded at 20 and 24 weeks.

Overall, the traditional free range rearing system was more favorable to improve technological quality of chicken meat. Moreover, the less though thigh and breast meat was obtained between 20 and 24 weeks. The ideal slaughter age of chickens of Holli, North, Fulani, Sahoue and South chickens ecotypes is then24 weeks.

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