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Influence of pre-slaughter rest duration on carcass and meat quality of indigenous chicken stressed by transport

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Abstract

Mastering the influence of pre-slaughter stress on animal products is crucial. The study aimed to improve carcass and meat qualities of local chicken slaughtered after transport stress. Forty-eight (48) local chickens of 6-7 months divided into four homogenous groups were used. Group A wasn't transported before slaughter while groups B, C and D underwent 2 hours of transportation and were respectively slaughtered after 4, 2 and 0 hours of rest. Carcass quality and meat organoleptic and technological quality were evaluated. Carcass quality didn't vary. Control chickens' pH was lower than that of 4-hour of rest chickens also lower than that of 2-hour of rest chickens at 1, 4, 8, 12, 20 and 24 hours. Meanwhile, pH was similar in 4-hour-rest chickens and those slaughtered without rest. Thigh pH trend was almost similar at several times. But at 12 hours, control and 4-hour-rest chickens showed similar thigh pH lower than those of the other groups that were equal. 2-hour-rest chickens had the lowest drip loss while it was similar in the other 3 groups. On the first day and at 24 hours, lightness in breast and thigh were similar for control and 4-hour-rest chickens. Thigh red index was lower and similar in control and 2-hour-rest chickens the first day and in addition, in 4-hour-rest birds at 24 hours. However, it was similar in the three transported groups. Thus, after 2 hours of transportation of local chicken, a 4-hour-rest starts to improve meat organoleptic and technological qualities while a 2-hour-rest is detrimental.

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Introduction

Stress is a behavioral, physiological and emotional state of an animal facing a situation it perceives as threatening to the functioning of its bodily or mental state (Terlouw, 2005; Bonou *et al.*, 2017e). It is the body reaction to a stimulus that disrupts its normal physiological balance or homeostasis (Lara *et al.*, 2013) and is characterized by the activation of autonomic and neuroendocrine nervous systems. In an animal to be slaughtered, it can be caused by several factors including capture and loading in a cage, loading in a vehicle, transport, internal and external climatic conditions, destination period, feed withdrawal and waiting time (Petracci *et al.*, 2010; Radu *et al.*, 2012; Tamzil *et al.*, 2019). These stress factors can negatively affect production (Lara *et al.*, 2013), animal welfare (Voslarova *et al.*, 2007) as well as carcass and meat quality (Radu *et al.*, 2012; Tamzil *et al.*, 2019) with consequences on food and health security. Therefore, in a bid to prevent these consequences, studies related to the influence of pre-slaughter stress conditions and to the control of meat and carcass quality variations caused by these conditions are being initiated in several countries throughout America, Europe, Asia and Africa (González *et al.*, 2007; Minka and Ayo., 2007; Minka *et al.*, 2009; Frimpong *et al.*, 2014; Perai *et al.*, 2014; Zhang *et al.*, 2014; Tougan *et al.*, 2016; Bonou *et al.*, 2017a, b, c and d; Tamzil *et al.*, 2019). Diverse paths have been explored to improve the quality of exotic animal's products. Meanwhile in many Sub-Saharan African countries, such research works on local animal species are limited.

In Benin, the attention is first focused on local chicken whose pre-slaughter conditions are particularly stressful due to its breeding and marketing system. A study characterizing transport, capture chase and pre-slaughter waiting carried out in the Atlantic Department, one of the smallest Departments of the country, revealed durations of significant stress conditions.

According to Bonou *et al.* (2017d), chickens are chased and captured for 8 to 19.1 minutes then, some are transported over 7.10 to 59.72 km for 33 to 169 minutes in cages, baskets or simply tied in clusters and hung up upside down with occurrence of accidents, illness or death. At the end of this study, a series of research on the influence of pre-slaughter stress conditions on the quality of carcass and meat from these chickens was carried out. The works successively evaluated the influence of transport and capture chase stress (Bonou *et al.*, 2017a), the influence of capture chase duration (Bonou *et al.*, 2017b) and that of pre-slaughter transport duration (Bonou *et al.*, 2017c). A study also investigated the effect of feed withdrawal duration on carcass and meat quality of local chicken (Tougan *et al.*, 2016). This various works have revealed huge consequences on the organoleptic and technological quality of meat with risks for the products' preservability and for the health safety of the consumer.

For example, studies on the influence of transport and its duration have shown meat with abnormal coloring and very low acidity during the 48 hours after slaughter which can favor proliferation of pathogenic microorganisms. It is therefore imperative to explore local possibilities for the improvement of the meat quality from indigenous chicken in view of its pre-slaughter stress conditions, especially those of transport. One apparently easy possibility is the rest given to chickens after transportation and prior to slaughter. It is also generally recommended in slaughter procedures. But which rest duration would be sufficient to ensure good quality of local chicken products after its transport conditions? The present study is initiated to provide answer to this concern and specifically, it aims to evaluate the effect of the rest duration before slaughter on i) the carcass quality of local chicken under transport stress and ii) the technological and organoleptic meat quality of local chicken under transport stress.

Materials and methods

Area of study

The study was carried out at the Laboratory of Animal Biotechnology and Meat Technology and at the Laboratory of Food Sciences which are respectively components of the Polytechnic School of Abomey-Calavi and of the Faculty of Agronomic Sciences, both units of the University of Abomey-Calavi (UAC). The chickens used were produced on a farm that is also in Abomey-Calavi, a township of southern Benin precisely of the Department of Atlantic. The township is limited to the North by the township of Zè, to the South by Atlantic Ocean, to the East by the township of Sô-Ava and Cotonou, and to the West by the township of Tori-Bossito and Ouidah. The climate is of subequatorial type characterized by two rainy seasons with an unequal spatial and temporal repartition of rainfall. The major season is from April to July and the minor from September to November. These seasons are separated by two dry seasons. Annual average rainfall is close to 1200 mm. The monthly average temperatures are between 27°C and 31°C and the relative air humidity varies between 65% from January to March and 97% from June to July.

Animal breeding and sampling

A total of forty-eight (48) local chickens of six to seven months produced from two (2) roosters and ten (10) hens all of South ecotype of Benin were used. They were raised under traditional breeding system where they have a henhouse for night housing or protection against bad weather and a front yard of 400 m^2. They fed themselves around and also received grains, agricultural by-products and kitchen rests. The chickens were vaccinated against fowl pox with Diftosec® vaccine and against Newcastle disease with Itanew® vaccine. On the eve of the slaughter day, the birds were divided into four homogeneous groups of 6 males and 6 females each and registered.

Pre-slaughter conditions, slaughter process and carcass cutting

On the slaughter day's eve, the chickens were weighed using a 2500 g scale with precision of 20 g and then divided into four homogeneous groups (A to D) of six males and six females each. The birds in batch A were not transported before slaughter while those in B, C and D batches were attached on legs and kept until the morning for 2 hours of transport over 34 km by motorcycle. During the transportation, they were all hung upside down. The birds of batch B were transported from 6 a.m. to 8 a.m., those of batch C from 8 a.m. to 10 a.m. and those of batch D from 10 a.m. to 12 p.m. On arrival, they were slaughtered by jugular vein section respectively after a rest of 4 hours (Lot B), 2 hours (Lot C) and 0 hour (Lot D).

Then, chickens were scalded in a hot water (75°C) and plucked manually. The legs were sectioned at the tarsometatarsal joint level and the head were separated from the neck at the skull-atlas junction. The abdominal and thoracic cavities organs were taken off. Hot carcasses have been weighed and immediately cut. Birds from all batches underwent a feed withdrawal length of 6 hours.

Data collecting

Live weight before slaughter, hot carcass weight and carcass cuts weight (breast, wings, thigh-drumstick) were registered. Carcass yield was determined from the live weight and the percentage of each carcass cut from the hot carcass weight.

The pH was measured in the right slice of the breast muscle (*Pectoralis major*) and in the right thigh muscle (*Iliotibialis superficialis*) at 2 cm depth with a portable pH-meter (HANNA Instrument R, Italy) provided with a specialized probe and a temperature control system. Measures were taken at 1 h, 4 h, 8 h, 12 h, 16 h, 20 h, 24 h and 48 h after slaughter. For every measure, 5 repetitions were performed. On each measure day, the pH-meter has been calibrated previously with two buffers pH-meter: pH 4 and pH 7 following a procedure described by the manufacturer.

The drip loss was determined with the left slice of the breast muscle according to the procedure described by Honikel (1987). Each sample was hung to a hook, put into a refrigeration bag without touching its bottom. After 24 hours at 4°C in hung position, the samples were taken out of the bag without touching the bottom that contains the draining juice. They were mopped, weighted and drip loss was calculated as the percentage of weight loss during the storage.

After that, each sample was put in a cooking bag and carefully sealed manually without trapping air. The samples were placed in a water bath and cooked at a core temperature of 75°C. Finally, they were taken out of the bags and cooled to room temperature in trays. The juice loss during cooking was determined by the difference between the weight before and after cooking.

The meat color was determined using a Minolta Chromameter CR-400 (Japan) in the trichromatic system (CIE L*a*b *) based on three dimensional space with one dimension for luminance (L* is the lightness) and two for color a* (a* is the redness) and b * (b* is the yellowness) (Zhang and Barbut, 2005). The chroma (C) and the hue angle (h) were determined as followed: $C= (a^{*2}+ b^{*2})^{1/2}$ and $h = \tan^{-1} b^*/a^*$. For each measure, 5 repetitions were performed. The measures were taken on the ventral face, at the third superior on the thickest part of the left slice of breast muscle and on the middle of the ventral face of the left thigh muscle. The Minolta was calibrated using standard color tiles. The color was measured on the slaughter day and at 24 hours *post mortem*.

The right slice of the *Pectoralis major* of each chicken was used for the sensory analysis. The samples were put in cooking bags separately without seasoning and boiled in a water bath until the meat core temperature reached 75°C. A trained jury of ten (10) members was used for the test. After cooling to room temperature, each cooked meat sample was cut into ten (10) identical pieces at least. Every judge received in a plate divided in four parts a piece of meat of the same sex of each chicken group and filled in a recapitulative results form. Thus, four samples of which one by group were put by turn in the plate under numbers 1 to 4. The judges appreciated the meat tenderness, juiciness, flavor and global acceptance under marks going from 1 to 5.

Statistical analysis

The data were analyzed using SAS (Statistical Analysis System, 2013) software. General Linear Model procedure was used for variance analysis and the Fisher test was used to test the significance of rest duration, sex effects on carcass and meat quality traits and their interaction. For each group, averages were calculated using Proc means procedure and they were compared by pair using the Student test.

Results

Carcass traits according to rest duration in local chickens stressed by transport

Live weight, hot carcass weight, breast weight, thigh-drumstick weight and wing weight were similar for not transported chickens, transported and slaughtered without rest and those transported and slaughtered after 2 hours and 4 hours of rest (Table 1). Hot carcass, breast, thigh-drumstick and wings yields were also similar. No significant variation was also obtained between males and females of the four groups for the studied carcass quality parameters (Table 2).

Variation in pH and water holding capacity of meat according to rest duration in local chickens stressed by transport

The variation in pH of *Pectoralis major* (breast) and *Iliotibialis superficalis* (thigh-drumstick) muscles according to rest duration in local chickens stressed by transport is presented in Table 3. In the breast, pH was lower in control chickens than in those from 4 hours of rest after transport which also had a lower pH than chickens from 2 hours of rest at 1 hour, 4 hours, 8 hours, 12 hours, 20 hours and 24 hours. During these times, pH was similar in local chickens transported and slaughtered after 4 hours of rest and those transported and slaughtered without rest. At 16 hours and 48 hours postmortem, pH did not vary between control chickens, chickens transported and slaughtered immediately and those slaughtered after 4 hours of rest. Meanwhile, chickens from 2 hours of rest had the highest pH but similar to that of birds from 4 hours of rest at 16 hours after slaughter. In the thigh, at 1 hour after slaughter, the lowest pH value was observed in control chickens followed respectively by chickens transported and slaughtered after 4 hours of rest, chickens slaughtered without rest after transport and those slaughtered after 2 hours of rest following transport. This same trend was noticed for these first three chickens' batches at 4 hours, 8 hours, 16 hours and 20 hours while local chickens transported and slaughtered without rest and those transported and slaughtered after a 2-hours-rest had similar pH values. At 24 hours, pH in control group was lower than that of chickens from 4 hours of rest which was similar to that of chickens slaughtered without post-transport rest but lower than the pH of birds from 2 hours of rest.

Table 1. Carcass characteristics and water holding capacity of *Pectoralis major* according to rest duration in local chickens stressed by transport

Variable	NT	TR0	TR2	TR4	Standard Error	ANOVA
Live weight, g	846.66a	778.75a	770.83a	755.83a	39.73	NS
Hot carcass weight, g	517.50a	469.83a	466.66a	458.75a	26.36	NS
Breast weight, g	135.37a	122.57a	119.48a	119.02a	8.17	NS
Thigh-drumustick weight, g	164.00a	152.39a	144.24a	150.33a	9.06	NS
Wings weight, g	64.87a	59.87a	58.14a	59.80a	2.78	NS
Hot carcass yield, %	60.93a	60.47a	60.78a	60.29a	1.14	NS
Breast yield, %	15.98a	15.82a	15.40a	15.64a	0.47	NS
Thigh-drumustick yield, %	19.19a	19.52a	18.62a	19.78a	0.37	NS
Wings yield, %	7.67a	7.72a	7.64a	7.91a	0.16	NS
Drip loss, %	0.69a	0.47ab	0.35b	0.62ab	0.09	*
Cooking loss, %	10.35a	7.89a	8.17a	8.16a	1.20	NS

NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: $p>0.05$; *: $p<0.05$; Averages of the same row followed by different letters differ significantly at the threshold of 5%

Table 2. Carcass characteristics and water holding capacity of *Pectoralis major* according to rest duration in males and females local chickens stressed by transport

Variable	NT		TR0		TR2		TR4		Standard Error	ANOVA
	Female	Male	Female	Male	Female	Male	Female	Male		
Live weight, g	756.66	936.66	733.33	824.16	725.00	816.66	718.33	793.33	56.19	NS
Hot carcass weight, g	461.66	573.33	451.33	488.33	427.50	505.83	440.00	477.50	37.28	NS
Breast weight, g	126.65	144.09	122.06	123.08	114.80	124.16	118.74	119.31	11.55	NS
Thigh-drumustick weight, g	139.60	188.39	140.26	164.53	125.05	163.43	133.66	166.99	12.81	NS
Wings weight, g	57.62	72.13	56.53	63.21	55.37	60.91	55.50	64.09	3.93	NS
Hot carcass yield, %	60.92	60.94	61.41	59.53	59.12	62.45	60.99	59.59	1.61	NS
Breast yield, %	16.69	15.27	16.62	15.03	15.81	14.98	16.31	14.96	0.66	NS
Thigh-drumustick yield, %	18.37	20.01	19.11	19.93	17.39	19.85	18.62	20.95	0.53	NS
Wings yield, %	7.62	7.72	7.73	7.71	7.76	7.52	7.77	8.04	0.23	NS
Drip loss, %	0.66	0.72	0.47	0.47	0.38	0.32	0.45	0.79	0.13	NS
Cooking loss, %	10.85	9.85	7.59	8.19	8.72	7.63	7.89	8.42	1.69	NS

NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: $p>0.05$

Besides, at 12 hours, not transported and 4 hours of rest chickens had similar thigh pH lower than those the other two batches which were equal. At 48 hours, pH values were identical in the controls, those of slaughtered without rest and those slaughtered after 4 hours of rest. At this time, chickens of 2 hours of rest had the highest thigh pH that was however statistically similar to that of chickens slaughtered without rest.

The variation in pH of breast and thigh-drumstick depending on sex in the control chickens and those slaughtered following the different post-transport rest periods was presented in Table 4. In the breast, pH of males was higher than that of females in control chickens at 1 hour ($p<0.001$) and in chickens from two hours of post-transport rest at 1 hour ($p<0.001$), 20 hours ($p<0.05$) and 48 hours ($p<0.001$). On the other hand, the pH of males was lower than that of females in chickens slaughtered immediately after transport at 1 hour (p<0.001), 4 hours (p<0.05), 12 hours (p<0.05), 16 hours (p<0.05) and 48 hours (p<0.001); then in the 4 hours post-transport rest chickens at 4 hours (p<0.05), 12 hours (p<0.05) and at 16 hours (p<0.05). At the other times, pH was similar between males and females of the different batches. In the thigh muscle, no difference in pH was observed between sexes at all measurement times for all batches.

The results of water holding capacity according to rest duration are presented in Table 1. Drip loss of chickens transported and slaughtered immediately and that of those slaughtered after a 4-hours-rest were similar to the drip loss of control chickens. But chickens transported and slaughtered after 2 hours of rest had a lower value than control chickens. Concerning the cooking loss, it did not vary according to transport and resting time (Table 1), nor according to sex (Table 2).

Table 3. Variation in breast and thigh meat pH according to rest duration in local chickens stressed by transport

Moment (hour)	Muscle	NT	TR0	TR2	TR4	Standard Error	ANOVA
1	Breast	5.96a	6.16b	6.36c	6.15b	0.05	***
	Thigh	5.93a	6.31c	6.46d	6.12b	0.03	***
4	Breast	5.78a	6.03b	6.28c	6.01b	0.05	***
	Thigh	5.96a	6.32c	6.39c	6.10b	0.04	***
8	Breast	5.61a	5.87b	6.12c	5.84b	0.06	***
	Thigh	5.70a	6.14c	6.16c	5.91b	0.05	***
12	Breast	5.53a	5.81b	6.05c	5.80b	0.06	***
	Thigh	5.71a	6.12b	6.16b	5.85a	0.05	***
16	Breast	5.67a	5.79a	6.00b	5.80ab	0.07	*
	Thigh	5.62a	6.10c	6.16c	5.82b	0.06	***
20	Breast	5.69a	5.87b	6.16c	5.89b	0.05	***
	Thigh	5.77a	6.11c	6.21c	5.97b	0.05	***
24	Breast	5.38a	5.75b	6.02c	5.64b	0.06	***
	Thigh	5.65a	5.93bc	6.01c	5.81b	0.05	***
48	Breast	5.34a	5.46a	5.80b	5.38a	0.07	***
	Thigh	5.75a	5.85ab	5.94b	5.75a	0.05	*

NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: p>0.05; *: p<0.05; ***: p<0.001; Averages of the same row followed by different letters differ significantly at the threshold of 5%

Table 4. Variation in breast and thigh meat pH according to rest duration in males and females local chickens stressed by transport

Moment (hour)	Muscle	NT		TR0		TR2		TR4		Standard Error	ANOVA
		Female	Male	Female	Male	Female	Male	Female	Male		
1	Breast	5.81a	6.10b	6.29b	6.02a	6.21a	6.50b	6.16a	6.15a	0.07	***
	Thigh	5.88a	5.98a	6.31a	6.32a	6.51a	6.40a	6.06a	6.17a	0.05	NS
4	Breast	5.83a	5.72a	6.20b	5.86a	6.22a	6.34a	6.14b	5.88a	0.07	*
	Thigh	5.99a	5.92a	6.35a	6.29a	6.42a	6.37a	6.09a	6.10a	0.06	NS
8	Breast	5.52a	5.70a	5.96a	5.78a	6.01a	6.23a	5.90a	5.79a	0.08	NS
	Thigh	5.64a	5.76a	6.20a	6.08a	6.16a	6.17a	5.84a	5.98a	0.08	NS
12	Breast	5.51a	5.55a	5.96b	5.66a	5.99a	6.11a	5.95b	5.64a	0.09	*
	Thigh	5.68a	5.75a	6.10a	6.15a	6.21a	6.11a	5.81a	5.88a	0.08	NS
16	Breast	5.76a	5.58a	6.04b	5.54a	5.98a	6.01a	6.00b	5.60a	0.10	*
	Thigh	5.61a	5.64a	6.11a	6.08a	6.24a	6.09a	5.80a	5.84a	0.08	NS
20	Breast	5.60a	5.79a	5.95a	5.80a	6.01a	6.30b	5.90a	5.89a	0.07	*
	Thigh	5.61a	5.93a	6.05a	6.16a	6.15a	6.26a	5.84a	6.10a	0.07	NS
24	Breast	5.41a	5.34a	5.88a	5.63a	5.97a	6.08a	5.74a	5.54a	0.08	NS
	Thigh	5.58a	5.71a	5.93a	5.93a	6.01a	6.00a	5.76a	5.86a	0.07	NS
48	Breast	5.27a	5.42a	5.62b	5.31a	5.51a	6.09b	5.39a	5.36a	0.10	***
	Thigh	5.78a	5.73a	5.95a	5.76a	5.86a	6.03a	5.78a	5.73a	0.07	NS

NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: p>0.05; *: p<0.05; ***: p<0.001; Intraclass averages of the same row followed by different letters differ significantly at the threshold of 5%

Color of Pectoralis major and Iliotibialis superficalis muscles according to rest duration in local chickens stressed by transport

The effect of pre-slaughter rest duration on color of *Pectoralis major* and *Iliotibialis superficalis* muscles of local chickens stressed by transport on slaughter day and 24 hours after slaughter is presented in Table 5. The lightness was higher in control chickens than in chickens transported and slaughtered immediately or after the rest periods (p<0.001), in the thigh, on the slaughter day and in the breast, 24 hours later. It was followed by that of chickens slaughtered without rest and with 4 hours of post-transport rest which had a similar value. The lowest value was observed in chickens transported and slaughtered after 2 hours of rest. Furthermore, in the breast on the slaughter day and in the thigh at 24 hours post-mortem, the lightness was similar for control and 4 hours of rest chickens. In these muscles and during these times, chickens slaughtered without rest and those after 2 hours of post-transport rest had the lowest lightness values (p<0.001).

Table 5. Color of *Pectoralis major* and *Iliotibialis superficalis* muscles according to rest duration in local chickens stressed by transport

Moment	Muscle	Variable	NT	TR0	TR2	TR4	Standard Error	ANOVA
Slaughter day	Thigh	L*	82.14a	80.28bc	79.27c	80.59b	0.47	***
		a*	7.11a	7.78b	7.65ab	8.14b	0.21	**
		b*	5.51a	4.04b	4.05b	4.35ab	0.42	*
		Hue angle	-0.60a	2.90a	3.61a	3.32a	1.41	NS
		Chromacity	9.42a	9.20a	8.96a	9.45a	0.36	NS
	Breast	L*	83.05a	80.94b	78.49c	81.45ab	0.60	***
		a*	6.10a	6.44a	6.92a	6.12a	0.30	NS
		b*	7.47a	5.09b	5.51b	6.01b	0.36	***
		Hue angle	0.43a	1.42b	1.17b	0.96b	0.13	***
		Chromacity	9.88a	8.65a	9.01a	8.96a	0.37	NS
24 hours after slaughter	Thigh	L*	79.74a	77.24b	77.42b	79.20a	0.50	***
		a*	7.45a	8.46b	8.19ab	8.14ab	0.26	*
		b*	5.56a	3.59b	3.56b	4.86a	0.37	***
		Hue angle	1.95a	-7.09a	3.19a	2.61a	3.83	NS
		Chromacity	9.67a	9.43a	9.08a	10.02a	0.32	NS
	Breast	L*	81.92a	79.18b	77.30c	80.21b	0.54	***
		a*	6.78a	7.47a	7.47a	7.04a	0.26	NS
		b*	8.34a	4.86b	4.92b	5.24b	0.35	***
		Hue angle	1.41a	1.61a	1.87a	1.63a	0.79	NS
		Chromacity	11.18a	9.20b	9.14b	8.99b	0.33	***

L* : lightness ; a* : red index ; b* : yellow index ; NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: p>0.05; *: p<0.05; **: p<0.01; ***: p<0.001; Averages of the same row followed by different letters differ significantly at the threshold of 5%

As for the red index, it significantly varied only in the *Iliotibialis superficalis* muscle at both times. Indeed, the red index was lower and similar in control chickens and those transported and slaughtered after 2 hours of rest on the slaughter day and moreover, in 4 hours of rest chickens at 24 hours after slaughter. However, the values recorded in the three batches of transported chickens were similar.

Besides, at both measurement times, the breast yellow index was higher in control chickens than in those transported and slaughtered immediately or after a rest period which had similar values. In the thigh, the yellow index was similar in control chickens and those of 4 hours of rest after transport with higher values than chickens from the two other groups whose values were identical. The hue was lower on the slaughter day and the chromacity higher 24 hours after slaughter in the *Pectoralis major* of control chickens (p<0.001).

The color variation by sex in control chickens and chickens from different post-transport conditions is presented in Table 6. The lightness of males was higher than that of females on the slaughter day in the thigh in two hours of rest chickens and in the breast for those of 4 hours of rest after transport. This same trend was observed for the red index on the slaughter day in the thigh of chickens slaughtered without rest and after 2 hours of rest then, at 24 hours post-mortem in the breast of the control chickens. On the other hand, for this color index, the opposite trend was recorded 24 hours after slaughter in chickens with two hours of post-transport rest. Furthermore, the hue of males was higher than that of females in the breast on the slaughter day in control birds. The trend was the same for the chromacity in the thigh at 24 hours after slaughter in transported and slaughtered without rest chickens.

Table 6. Color of *Pectoralis major* and *Iliotibialis superficalis* muscles according to rest duration in males and females local chickens stressed by transport

Moment	Muscle	Variable	NT		TR0		TR2		TR4		Standard Error	ANOVA
			Female	Male	Female	Male	Female	Male	Female	Male		
Slaughter day	Thigh	L*	82.27a	82.02a	80.86a	79.69a	78.31a	80.23b	79.77a	81.42a	0.66	*
		a*	7.37a	6.84a	7.21a	8.35b	7.00a	8.30b	7.80a	8.49a	0.30	*
		b*	6.38a	4.64a	4.72a	3.36a	4.60a	3.50a	4.52a	4.18a	0.60	NS
		Hue angle	1.71a	-2.92a	1.71a	4.10a	2.92a	4.31a	2.10a	4.54a	2.00	NS
		Chromacity	10.13a	8.72a	9.10a	9.30a	8.72a	9.19a	9.25a	9.65a	0.50	NS
	Breast	L*	83.46a	82.63a	79.98b	81.90b	77.46b	79.53b	79.29a	83.60b	0.85	*
		a*	5.88a	6.32a	7.07a	5.82a	7.37a	6.48a	6.69a	5.55a	0.43	NS
		b*	8.74a	6.20a	5.12a	5.06a	5.86a	5.16a	6.43a	5.59a	0.51	NS
		Hue angle	0.13a	0.72b	1.68a	1.17a	1.12a	1.23a	1.17a	0.76a	0.19	*
		Chromacity	10.79a	8.97a	9.03a	8.27a	9.55a	8.47a	9.59a	8.33a	0.52	NS
24 hours after slaughter	Thigh	L*	79.90a	79.58a	76.57a	77.91a	76.54a	78.29a	77.62a	80.77a	0.71	NS
		a*	7.58a	7.32a	7.81a	9.10a	8.00a	8.38a	8.00a	8.29a	0.37	NS
		b*	6.31a	4.81a	3.18a	4.00a	3.94a	3.17a	5.08a	4.65a	0.52	NS
		Hue angle	1.38a	2.51a	2.90a	-17.09a	2.67a	3.71a	2.40a	2.82a	5.41	NS
		Chromacity	10.20a	9.15a	8.64a	10.21b	9.08a	9.08a	9.98a	10.05a	0.46	*
	Breast	L*	82.42a	81.42a	78.68a	79.68a	76.37a	78.24a	79.26a	81.16a	0.77	NS
		a*	5.89a	7.68b	7.79a	7.16a	7.99b	6.94a	6.87a	7.20a	0.37	***
		b*	9.53a	7.15a	5.38a	4.33a	5.62a	4.23a	5.55a	4.93a	0.50	NS
		Hue angle	1.66a	1.16a	1.70a	1.52a	1.51a	2.24a	1.23a	2.03a	1.12	NS
		Chromacity	11.51a	10.85a	9.72a	8.67a	9.94a	8.34a	9.05a	8.93a	0.48	NS

L* : lightness ; a* : red index ; b* : yellow index ; NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: $p>0.05$; *: $p<0.05$; ***: $p<0.001$; Intraclass averages of the same row followed by different letters differ significantly at the threshold of 5%

Table 7. Sensory quality of *Pectoralis major* according to rest duration in local chickens stressed by transport

Sex	Variable	NT	TR0	TR2	TR4	Standard Error	ANOVA
Male	Flavor	3.05a	3.26a	3.08a	2.95a	0.11	NS
	Juiciness	3.20a	3.25a	3.25a	3.11a	0.11	NS
	Tenderness	3.35a	3.33a	3.38a	3.25a	0.12	NS
	Global Acceptance	3.24a	3.35a	3.34a	3.13a	0.10	NS
Female	Flavor	3.08a	3.00a	2.85a	2.88a	0.10	NS
	Juiciness	3.13a	3.10a	3.05a	3.20a	0.10	NS
	Tenderness	3.08a	3.53b	3.26ab	3.35ab	0.12	*
	Global Acceptance	3.11a	3.29a	3.11a	3.27a	0.10	NS

NT: not transported; TR0: transported and slaughtered without rest; TR2: transported and slaughtered after 2 hours of rest; TR4: transported and slaughtered after 4 hours of rest; NS: $p>0.05$; *: $p<0.05$; Averages of the same row followed by different letters differ significantly at the threshold of 5%

Sensory analysis of Pectoralis major according to rest duration in local chickens stressed by transport

The results of sensory analysis of *Pectoralis major* according to the rest duration in chickens stressed by transport are presented in Table 7. The flavor, juiciness, tenderness and global acceptance of meat did not vary according stress and rest in males. On the other hand, among females, tenderness was lower in control chickens than in chickens transported and immediately slaughtered. Meanwhile, birds from 2 hours and 4 hours of rest after slaughter had intermediate values similar to those of chickens from these first two groups.

Discussion

Carcass traits according to rest duration in local chickens stressed by transport

Carcass quality parameters were similar for control chickens, chickens transported and slaughtered immediately, and those slaughtered after 2 hours and 4 hours of rest following transport. Transport stress and rest duration therefore did not influence the evaluated carcass quality variables. The non-significant difference between weight and yield parameters according to transport stress and rest duration in the present study must be explained by the not too long transport and rest durations observed. Long rest before slaughter also negatively affects weight parameters due to food deprivation which is often observed during this period following the practice of food withdrawal. In addition, even when animal must continue life on farm after a stressful event, the immune reaction could result in a reduction in food consumption, growth disturbance and weight loss. Thus, Sohail *et al.* (2012) recorded in poultry exposed to chronic heat stress, a reduction of 16.4% in food consumption, of 32.6% in body weight and an increase of 25.6% in food conversion ratio. Besides, the non-existence of a stress effect on the carcass characteristics in the present study was also reported by Bonou *et al.* (2017a) with one hour of transportation stress. The study on the influence of pre-slaughter transport duration stress also confirmed this observation (Bonou *et al.*, 2017c). Apart from the study factors, the similarities between the carcass parameters confirm the age homogeneity of chickens from the different groups. In addition, the weight and yield results obtained in this study are close to those previously reported in local chickens of southern Benin ecotypes by Youssao *et al.* (2009), Tougan (2010) and Bonou (2018).

Variation in pH and water holding capacity of meat according to rest duration in local chickens stressed by transport

In the breast, pH was lower in control chickens than in those from 4 hours of rest after transport which also had a lower pH than chickens from 2 hours of rest at 1 hour, 4 hours, 8 hours, 12 hours, 20 hours and 24 hours. During these times, pH was similar in local chickens transported and slaughtered after 4 hours of rest and those transported and slaughtered without rest. In other words, in terms of acidity, the breast meat of chickens of 4 hours of rest is closer to that of the controls than the meat of chickens of 2 hours of rest and the 4 hours of rest effect is not different from that of the stress of 2 hours of transport not followed by rest at these measurement times. This also means that at these times, the 4-hour rest did not improve breast meat acidity compromised by the 2-hour transport stress. In addition, the higher pH of chickens of 2 hours of rest compared to those slaughtered immediately after transport in particular, indicates that during the first two hours of rest, the observed stress effect was worsened.

Stress in animals being a multifactorial phenomenon which can include psychological factors encompassing for example human's presence, absence of familiar congeneric or confrontation with new environments (Terlouw *et al.*, 2015), the worsening of the observed stress effect must be the consequence of an additional psychological stress. Indeed, after a 2-hour transport where chickens had both legs attached and hanged to motorcycle in upside down position as reported by Bonou *et al.* (2017d), these birds must be immersed in psychological stress during the first hours of rest.

This additional stress must be maintained by the new environmental conditions coupled with the fear to undergo this particularly stressful type of transport again.

Furthermore, at 16 hours and 48 hours after slaughter, pH did not vary between control chickens, chickens transported and slaughtered immediately, and those slaughtered after 4 hours of rest. Thus, at these times, the effect of transport stress on the pH and that of the 4-hour rest were not noticed but it was with the 2-hour rest that the reduction in the breast acidification reported in a situation of transport stress was observed at 48 hours after slaughter where the pH was higher. This observation then strengthens the additional psychological stress statement.

In the thigh, beyond the pH differences as observed in the breast, chickens transported and slaughtered without rest and those transported and slaughtered after a 2-hour rest had similar pH all the times except the first hour after slaughter. At these times, the effect of additional psychological stress is not significant on the thigh pH, which is also not improved by this rest duration. Furthermore, at 12 hours, the not transported chickens and those transported and slaughtered after 4 hours of rest had similar thigh pH lower than those of the other two groups which were equal. This similarity indicates that the 4-hour rest has improved the thigh meat acidity of chickens that underwent 2 hours of transport stress at 12 hours after slaughter.

According to Giloh *et al.* (2012), rest normalizes the body's homeostasis by activating neurogenic and nervous systems related to muscle lactic acid content. Acidification restoration is not noticed at all times in the two muscles because the 4-hour rest is not entirely sufficient to completely correct this parameter of technological quality of meat from the transport stress conditions in our study. Results of pH according to rest duration close to those in the present study had been obtained by other authors. For example, Gonzalez *et al.* (2007) reported lower initial and final thigh pH values in quails having undergone 4 hours of rest compared to those immediately slaughtered after a 95-minute transport. Zhen *et al.* (2014) observed a beneficial effect of a two-hour rest on the breast pH measured at 10 minutes after slaughter in ducks transported for two hours. In their case, this 2-hour rest increased pH to be similar to that of the controls. Tamzil *et al.* (2019) also mentioned a beneficial effect of 12-hour rest on pH of broilers having undergone 3 hours of transport in Indonesia. An improving effect of rest on the pH meat of local chickens stressed by another close stress factor like pre-slaughter catching was also recorded. In fact, according to Bonou *et al.* (2025), control chickens had breast pH similar to those of 2 and 4 hours of rest chickens at 1, 4, 8, 12, 16 and 20 hours after slaughter. In the thigh at 24 hours, they recorded that same tendency. However, the rest durations observed by the authors could be more appreciated if all of them have included pH of the two muscles and their evolution as in our study.

Furthermore, the high nature of the pH values observed in our study in the most stressed birds, namely those transported and slaughtered immediately and those transported and slaughtered after 2 hours of rest, has also been reported by several authors. This is the case of Bonou *et al.* (2017a and c) during works on the effect of transport and its duration on the quality of meat. This is explained by the depletion of glycogenic reserves following their use for energy production during stress events. According to Tesseraud *et al.* (2014) and Berri (2015), the ultimate pH depends on the glycogen concentration in the muscles at the time of slaughter. A transport of chickens for 3 hours before slaughtering decreases plasma glycogen concentration in broilers (Zhang *et al.*, 2014).

In the breast at one hour after slaughter, males' pH was higher than that of females in control chickens ($p<0.001$) and two-hour rest chickens. An opposite trend between the two sexes was observed at certain times in chickens slaughtered without rest and those of 4 hours of rest.

These variations between sexes are not related to stress or rest because they are observed in both transported and non-transported groups. They must be explained by the determinism of sex in chicken meat pH variation. More in-depth studies will give a better understanding.

Results of higher pH in males were, for example, reported by Bonou *et al.* (2017a). Schneider *et al.* (2012) also reported a higher ultimate breast pH in males than in females (5.96 vs 5.87).

Drip loss from chickens transported and slaughtered immediately and those slaughtered after a 4-hour rest were similar to drip loss from control chickens. This equality proves that the practiced transport duration did not significantly affect the breast drip loss of chickens and thus, no improvement effect can be expected from the rest duration. Bonou *et al.* (2017c) also observed no effect of stress from a transport duration of 30 minutes, 1 hour and 2 hours on this meat quality's parameter. However, in the present study, chickens transported and slaughtered after 2 hours of rest had a lower drip loss than control chickens. At 24 hours after slaughter where the drip loss was determined, these chickens had the highest pH values compared to the other three groups. This observation, attributable to additional psychological stress, is the cause of the low recorded drip loss. Schneider *et al.* (2012) and Zhang *et al.* (2014) also reported lower drip loss when stressed chickens had high pH values.

Color of Pectoralis major and Iliotibialis superficalis muscles according to rest duration in local chickens stressed by transport

The lightness was higher in control chickens, in the thigh, on the slaughter day and in the breast, at 24 hours after slaughter, followed by that of chickens slaughtered without rest and with 4 hours of post-transport rest which had a similar value. The lowest value was observed in chickens transported and slaughtered after 2 hours of rest. The difference between the lightness of control and that of stressed chickens is due by a stress effect on which the corrective effect of the 4-hour rest was insignificant. The two-hour rest, for its part, have worsened the initial effect of transport stress by increasing the lightness difference with chickens of the control group. This aggravating effect is the consequence of psychological stress. Furthermore, in the breast on the slaughter day and in the thigh at 24 hours after slaughter, the lightness was similar in control and 4 hours of rest chickens. Thus, the 4-hour rest improves the lightness of the breast on the slaughter day and that of the thigh the next day. An effect of stress on meat lightness similar to that in our study was reported by Bonou *et al.* (2017a and c). They had also recorded low lightness in local chickens from southern Benin stressed by preslaughter transport.

In the *Iliotibialis superficalis*, the red index was lower and similar in control chickens and those transported and slaughtered after 2 hours of rest on the slaughter day and also in 4 hours of rest chickens at 24 hours postmortem. However, the values recorded in the three transported chickens' groups were similar. The lower value observed in controls compared to those slaughtered immediately after stress reflects a transport stress effect also reported in several studies. Bonou *et al.* (2017a) also obtained redder breast meat from local chickens stressed by one hour of preslaughter transport by motorcycle. The slightly redder color is provoked by an increase in hemoglobin rates after higher blood flow in the active muscle.

The red indices similarity between control and 2 hours of rest birds on the first day, and between control and 4 hours of rest chickens the next day is the result of a positive effect of the rest durations at these times. However, this improving effect on the red index observed with the rest durations is insufficient and this explains the non-existence of statistical difference recorded.

In the breast, the yellow index b* was more abundant in control chickens than in those transported and slaughtered immediately or after a rest time which had similar values. Therefore, the stress of 2 hours of transport affected the yellow index of the breast by reducing it. This effect of stress on breast meat is not eliminated by the rest but it was removed with the 4 hours of rest with the thigh where the yellow index was similar in control and 4 hours of rest chickens.

The analysis of pH and meat color results from local chickens in the present study reveals that meat from chickens transported and slaughtered without rest and those slaughtered after 2 hours of rest have high pH values which are associated with low lightness. Additionally, chickens slaughtered without rest also had higher thigh red index values. A similar relationship between pH, lightness and red index has been reported in several studies. Thus, Gigaud *et al.* (2007 and 2008), Sheard *et al.* (2012), Harford *et al.* (2014), Xing *et al.* (2015) and Bonou *et al.* (2017a, b and c) observed that in poultry, meat yellow index is negatively and significantly correlated with ultimate pH. The trend of association observed between lightness and yellow index was also recorded in the results of Bonou *et al.* (2017a, b and c).

Tougan *et al.* (2016) studying the influence of feed withdrawal on meat quality also observed that when lightness and yellow index increase, the red index of meat decreases. Harford *et al.* (2014) made a similar observation indicating that selection for high lightness resulted in an increase in the yellow index.

In both muscles, the lightness in males was higher than that in females on the slaughter day in the thigh of two hours of rest chickens and in the breast of those of 4 hours of rest after transport. This same trend was observed for the red index on the slaughter day in the thigh of chickens slaughtered without rest and after 2 hours of rest then, at 24 hours after slaughter in the breast of the controls.

Just like pH, these color variations between sexes are not related to stress nor to rest because they are observed in both transported and non-transported animals. They must be explained by sex determinism in chicken meat color variation. More in-depth studies will give a better understanding. Beyond that, color variations are related to relationships between pH and meat color indices. For example, a negative correlation between pH and meat lightness has been reported (Sheard *et al.*, 2012; Harford *et al.*, 2014; Xing *et al.*, 2015; Bonou *et al.*, 2017a).

Sensory analysis of Pectoralis major according to rest duration in local chickens stressed by transport

The tenderness of female meat was lower in control chickens than in chickens slaughtered immediately after transport, while chickens that had been rested after stress had intermediate values similar to those of chickens from the first two groups. This observed difference in tenderness must be due to the effect of the 2-hour transport stress. As for the statistical similarities, they can be explained by the beginning of a positive effect of rest times but which nevertheless remains insufficient. In addition, the effect of stress on meat tenderness recorded in the present study was not observed by Bonou *et al.* (2017a and c).

Conclusion

The work on the influence of rest duration on carcass and meat quality of local chicken stressed by preslaughter transport revealed a positive effect of 4 hours of rest and a negative effect of that of 2 hours. Indeed, the 4 hours of rest starts to improve meat organoleptic and technological quality. It improves the acidity of the thigh at 12 hours, its lightness at 24 hours and its yellow index. Concerning the breast, the 4 hours of rest only corrects the lightness. Furthermore, trends of positive effect of this rest duration are observed at other times but they remain insignificant. On the other hand, the rest of 2 hours worsens the meat acidification and color defects of local chicken and this is attributable to additional psychological stress.

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