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Relationships between technological and nutritional meat quality parameters in local poultry populations (*Gallus gallus*) of Benin

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ABSTRACT

The current work aims at determining relationships between technological and nutritional meat quality parameters in Holli, Fulani, Sahoue, North and South indigenous chicken ecotypes of Benin. Color parameters (L*, a*, b*, hue and chroma), pH, texture, dry matter content, protein content, fat content, and ash content were collected on 52 cockerels of each ecotype slaughtered at 24 weeks old. In Holli chickens, dry matter content was highly and positively correlated with protein content ($P<0.001$; $r = 0.57$), moderately and positively associated to ash content, redness, yellowness and chroma ($P<0.01$), but weakly and negatively correlated with the luminance and hue ($P<0.05$). Fat content was highly and positively correlated with the texture, pH4, pH12, pH24, a* and chroma ($P<0.001$; $0.46 \leq r \leq 0.85$), but highly and negatively correlated with the protein content and luminance ($P<0.001$; $-0.64 \leq r \leq -0.47$). Except dry matter content, protein content was negatively correlated with the others parameters. Correlations between dry matter and the other meat quality traits of North chickens were similar to those of Holli chickens except fat content, pH, L*, b* and hue. Except texture, the correlations between dry matter concentration and the other meat quality traits of South and Fulani chickens were similar to those of Sahoue chickens. South chickens and to a lesser extent Fulani and Sahoue chickens were characterized by higher dry matter, shear force, breast cooking loss, yellowness and pH24, while Holli chickens were characterized by greater protein content, organic matter content, moisture, thigh cooking loss, hue, pH1, pH4, pH8 and pH12. North chickens were characterized by higher ash content, fat content and luminance.

Keywords: Correlation, indigenous chicken, meat quality, principal components analysis.

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INTRODUCTION

In Benin, the indigenous chickens represent 81.3% of the national poultry flock (CountryStat, 2012) and are an important source of animal protein supply for the population and income for producers and poultry sellers (Tougan, 2008). Despite the importance of this poultry flock, local poultry meat production remains below the consumer demand. This shortage created pressure on every form of food supply and lead on increase of meat imports (2.5 times from 2000 to 2010 accordingly to CountryStat, 2012). Despite the low domestic production of local chickens (2,020 tons in 2010), local chicken meat is more appreciated by consumers in comparison with imported chicken meat because of its leanness and relatively lower purchasing price (Mankor, 2009). The lack of religious restriction against indigenous chicken consumption justifies the perennity of its production in Benin (Tougan, 2008).

The local population of poultry of the species *Gallus gallus* of Benin is composed of various ecotypes among which are North, South, Holli, Fulani or Peuhl and Sahoue ecotypes (Bonou, 2006). These indigenous poultry have a remarkable heterogeneity in phenotypical traits (Youssao et al., 2007) and polymorphism trait (Youssao et al., 2009). Several studies were carried out on carcass traits of these local genetic types (Youssao et al., 2009; Youssao et al., 2010; Youssao et al., 2012; Tougan et al., 2013a). The recent studies carried out on the effect of breeding mode, type of muscle and slaughter age on technological meat quality of these local chickens of Benin (Tougan et al., 2013c) on the one hand, and on variation of nutritional quality of meat of local poultry population of *Gallus gallus* specie of Benin (Tougan et al., 2013d) on the other hand showed significant variation of technological and nutritional qualities.

Although the difference between the five ecotypes of local chicken is well known on technological and nutritional meat quality traits, no data exist on the correlations between their technological and nutritional qualities traits.

For accuracy and better judgment of technological and nutritional meat quality traits of indigenous chicken population of Benin, the current study aims at pointing out the relationships between the technological and nutritional meat quality traits of Holli, Fulani, Sahoue, North and South indigenous chicken ecotypes of Benin.

MATERIALS AND METHODS

Area of study

The current 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 (latitude of 6 ° 27' north and at a longitude of 2 ° 21' east) in Atlantic Department from April 2011 to June 2012. The Commune of Abomey-Calavi covers an area of 650 km² with a population of 307,745 inhabitants (INSAE, 2010).

Birds sampling and characteristics of breeding systems

The chickens used in this trial were produced from breeding nuclei of 10 hens and 3 cocks of each genetic type, reared in confinement at the experimental farm of EPAC as described by Tougan et al. (2013a). Two groups of 26 chickens of each ecotype were reared respectively under traditional free range and improved confinement breeding systems and then slaughtered at 24 weeks old.

In free range system, the birds were let scavenge 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. The feeding is not rational and the birds fed themselves by gleaning, but, some grain supplement was distributed to birds occasionally. Their diet was composed of energetic elements (kitchen waste, bran ...), vitamins (green fodder, sprouted grains ...), minerals (salt and pounded shells) and protein from termites and leguminous plants. Water was distributed in rudimentary watering tank. Various discarded containers were often used for drinking. In this type of farming, neither health follow-up nor prophylactic standard were applied.

Concerning confinement breeding system, the birds were bred on a fresh wood shavings litter in buildings of california type. The livestock equipment 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 ME Kcal/kg and 18% of crude protein), growing (2969 ME Kcal/kg and 18% crude protein) and laying (2800 ME 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. 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. The composition and the nutrient contents of each diet are given in Table 1. Habitat, Health and medical prophylaxis used in confinement breeding system were described by Tougan et al. (2013b).

Slaughtering process and analytical methods

The slaughtering process used in the current study is described by Tougan et al. (2013a). After slaughtering, the cuts of breast and thigh-drumstick were used to evaluate the technological properties (pH, color, hue, chroma and texture) and chemical composition (moisture, protein, fat, and ash) of meat. The pH, the color, the hue value, the chroma value and the texture was determined as described in previous study by Tougan et al. (2013c), while dry matter content, protein content, fat content, and ash content were determined as described by Tougan et al. (2013d). Those different parameters evaluated herein were the mean of the values recorded from both thigh and breast muscles.

Statistical analysis

The data collected on technological and nutritional meat quality parameters (pH, color, hue, chroma, texture, dry matter content, protein content, fat content, and ash content) of the five genetic types of chicken were analyzed with Statistical Analysis System software (SAS 2006). The correlations between the different variables were determined by ecotype using *Proc corr* procedure of SAS (SAS 2006). Principal

Components Analysis (PCA) of technological and nutritional meat quality parameters was carried out for each ecotype and for all ecotypes by the *Proc princompt* procedure of SAS (2006).

RESULTS

Correlations between technological and nutritional meat quality parameters

The correlations between technological and nutritional meat quality parameters were presented by ecotype.

The Table 2 presents on top of diagonal the correlations between technological and nutritional meat quality parameters for Holli ecotype. In Holli chickens, dry matter content was highly and positively correlated with protein content ($P<0.001$; $r = 0.57$), moderately and positively associated to ash content, redness (a*), yellowness (b*) and chroma value ($P<0.01$; $0.34 \leq r \leq 0.37$), weakly and positively associated to the pH recorded 1 hour *post-mortem* (pH1) and 4 hours (pH4) post mortem ($P<0.05$; $0.27 \leq r \leq 0.28$), but weakly and negatively correlated with the luminance (L*) and hue value ($P<0.05$; $-0.3 \leq r \leq -0.28$). The ash concentration was weakly and positively associated to the fat content, shear force, pH24, a*, b* and chroma ($P<0.05$, $0.27 \leq r \leq 0.32$), but weakly and negatively correlated with the luminance ($P<0.05$; $r = -0.27$). Fat content was highly and positively correlated with the texture, extension, pH4, pH12 (recorded 12 hours *post mortem*), pH24 (recorded 24 hours *post mortem*), a* and chroma ($P<0.001$; $0.46 \leq r \leq 0.85$), moderately and positively associated to pH1 and yellowness ($P<0.01$; $0.34 \leq r \leq 0.39$), weakly and positively associated to the pH8 ($P<0.05$, $r = 0.3$), but highly and negatively correlated with the protein content and luminance ($P<0.001$; $-0.64 \leq r \leq -0.47$). Except dry matter content, protein content was negatively correlated with the others technological and nutritional meat quality parameters with the high negative correlations found with the shear force and redness ($P<0.001$; $-0.45 \leq r \leq -0.44$). Furthermore, shear force was highly and positively correlated with the extension, a* and chroma value ($P<0.001$; $0.64 \leq r \leq 0.73$), but highly and negatively associated to the luminance ($P<0.001$; $r = -0.44$). Similarly, high and significant relationships were also found between pH1 and pH4, pH8, pH12, pH24, redness and chroma value ($P<0.001$; $0.43 \leq r \leq 0.76$). Nevertheless, the luminance was negatively associated to all meat quality parameters studied in current study except protein content. The redness was highly and negatively associated to protein content and luminance ($P<0.001$; $-0.56 \leq r \leq -0.45$), but highly and positively correlated with the fat content, shear force, extension, pH1 and pH4 ($P<0.001$; $0.44 \leq r \leq 0.85$). Similar relationships were also observed between the chroma value and the others meat quality traits studied herein.

The correlations between technological and nutritional meat quality parameters for North ecotype are under the diagonal of the Table 2. The correlations between dry matter and the other meat quality traits of North chickens were similar to those of Holli chickens except fat content, pH, L*, b* and hue value. However, ash concentration was weakly and positively associated to the pH24 ($P<0.05$; $r = 0.33$), but weakly and negatively correlated with the extension ($P<0.05$; r = -

0.30). Fat content was highly and positively correlated with the texture, pH8, a* and hue (P<0.001; 0.46 ≤ r ≤ 0.85), moderately and positively associated to pH1, pH4, and pH24 (P<0.01; 0.36 ≤ r ≤ 0.43), weakly and positively associated to the extension and pH12 (P<0.05, r = 0.35), but highly and negatively correlated with the protein content and luminance (P<0.001; -0.78 ≤ r ≤ -0.54). Except dry matter content and luminance, protein content was negatively correlated with the others technological and nutritional meat quality parameters with the high negative correlations found with the shear force, extension, redness, hue and chroma (P<0.001; -0.69 ≤ r ≤ -0.46). As in Holli chickens, shear force in North chicken was highly and positively correlated with the extension, and redness (P<0.001; 0.45 ≤ r ≤ 0.75), but also moderately and positively associated to the chroma value (P<0.01; r = 0.42). The luminance was highly and negatively associated to the dry matter content, fat content, pH8 and pH24 (P<0.001; -0.55 ≤ r ≤ -0.46), moderately and negatively correlated with pH1, pH4 and pH12 (P<0.01; -0.44 ≤ r ≤ -0.43). The redness was highly and negatively associated to protein content and luminance (P<0.001; -0.69 ≤ r ≤ -0.62), but highly and positively correlated with the fat content and shear force (P<0.001; 0.44 ≤ r ≤ 0.85).

The Table 3 presents on the top of diagonal the correlations between technological and nutritional meat quality parameters for Fulani ecotype. The relationships between dry matter and the others quality traits in Fulani chickens were similar to those recorded in South chickens. Contrary to Sahoue and South chickens, ash content in Fulani chicken was weakly and negatively associated to the pH4, pH8, pH12 and pH24 (P<0.05; -0.33 ≤ r ≤ -0.29). Fat content was highly and positively correlated with the texture, extension, a* and chroma (P<0.001; 0.54 ≤ r ≤ 0.81), moderately and positively associated to pH4, pH8 pH12 and hue (P<0.01; 0.37 ≤ r ≤ 0.39), weakly and positively associated to the pH1 and pH24 (P<0.05, 0.3 ≤ r ≤ 0.31), but highly and negatively correlated with the protein content and luminance (P<0.001; -0.68 ≤ r ≤ -0.61) as found in the others genotypes. Except dry matter content, ash content and protein content, luminance was negatively associated to all meat quality parameters in Fulani chickens. Similarly, protein content was negatively correlated with the others technological and nutritional meat quality parameters except dry matter content, luminance and yellowness.

Correlations between technological and nutritional meat quality parameters for Sahoue ecotype are shown under the diagonal of Table 3. In Sahoue chickens, dry matter content was highly and positively correlated with yellowness (P<0.001; r = 0.55), moderately and positively associated to the fat content, protein content, and chroma (P<0.01; 0.37 ≤ r ≤ 0.43), weakly and positively associated to the redness (P<0.05, r = 0.35). Fat content was highly and positively correlated with the texture, a*, extension and chroma (P<0.001; 0.54 ≤ r ≤ 0.81), moderately and positively associated to dry matter content, pH4, pH8 and pH12 (P<0.01; 0.37 ≤ r ≤ 0.39), weakly and positively associated to the pH1 and pH24 (P<0.05, 0.30 ≤ r ≤ 0.31), but highly and negatively correlated with the protein content and luminance (P<0.001; -0.68 ≤ r ≤ 0.61) as found in the others genotypes. Except dry matter content and luminance and yellowness, protein content was negatively correlated with the others technological and nutritional meat quality parameters. Furthermore, shear force was highly and positively correlated with the fat content, extension, a* and chroma value ($P<0.001$; $0.46 \leq r \leq 0.81$), moderately and positively associated to the pH4 and hue ($P<0.01$; $0.4 \leq r \leq 0.42$), weakly and positively associated to the yellowness, but weakly and negatively associated to the luminance and protein content ($P<0.05$; $-0.79 \leq r \leq 0.68$).

Correlations between technological and nutritional meat quality parameters for South ecotype are showed in Table 4. Except shear force and extension, the correlations between dry matter concentration and the other meat quality traits of South chickens were similar to those of Sahoue chickens. However, the correlations between ash content and the other meat quality in South ecotype were not significant. The correlations between fat content and the other meat quality in South ecotype were comparable to those of North chicken. However, protein content was highly and positively associated to dry matter content and luminance ($P<0.001$; $0.44 \leq r \leq 0.53$), but negatively correlated with the shear force, redness and chroma value ($P<0.001$; $-0.6 \leq r \leq -0.52$). The shear force was highly and positively correlated with a* and chroma value ($P<0.001$; $0.53 \leq r \leq 0.59$), but moderately and negatively associated to the luminance ($P<0.01$; $r = -0.42$).

Overall, fat content was more associated with the other meat quality traits in chicken of all ecotypes studied. Furthermore, technological meat quality parameters were more associated to nutritional meat quality parameters in Fulani and Holli, chickens than Sahoue, South and North chickens.

Principal components analysis of technological and nutritional meat quality parameters

The Figure 1 presents the principal components analysis of technological and nutritional meat quality parameters of the five genetic types of chicken studied. Indeed, principal components analysis of technological and nutritional meat quality parameters discriminated the five ecotypes according to their meat quality. The first axis explains 46.09% of the variation and opposed meat quality traits of Holli chickens to those of South chickens and to a lesser extent to Fulani and Sahoue chickens. The second axis explains 35.54% of the variation and opposed technological and nutritional meat quality parameters of North chickens to those of Holli and South chickens.

South chickens and to a lesser extent Fulani and Sahoue chickens were characterized by higher moisture, shear force, breast cooking loss, yellowness, extension and pH24, while Holli chickens were characterized by greater protein content, organic matter content, dry mater, thigh cooking loss, hue value, pH1, pH4, pH8 and pH12. North chickens were characterized by higher ash content, fat content and luminance.

Table 1: Composition and nutrient content of the starting, growing and laying diets.

Composition	Starting diet	Growing diet	Laying diet
Soy cakes (g/kg)	12	7.5	15.5
Wheat bran (g/kg)	10	17.5	7
Corn (g/kg)	60	59	59
Cotton cakes (g/kg)	8	6.5	6
Fish meal (g/kg)	7	7	9
Lysine (g/kg)	0.2	0.2	0.2
Methionine (g/kg)	0.2	0.2	0.2
Salt (g/kg)	0.2	0.2	0.2
Oyster shell (g/kg)	2	1.5	2.5
Premix 0.25 (g/kg)	0.25	0.25	0.25
Total (g/kg)	**100**	**100**	**100**
Metabolisable energy (kcal/kg)	2880.5	2969.6	2800.0
Crude protein (g/kg)	18.6	17.2	20.1
Lysine (g/kg)	0.91	0.78	0.92
Methionine + Cystine (g/kg)	0.63	0.58	0.72
Calcium (g/kg)	1.11	0.91	1.35
Digestible phosphate (g/kg)	0.28	0.27	0.35

Tableau 2: Correlations between technological and nutritional meat quality parameters in Holli (above diagonal) and North chickens (below diagonal).

Variables	Dry Matter	Ash	Fat	Protein	Shear force	Extension	pH1	pH4	pH8	pH12	pH24	L*	a*	b*	Hue	Chroma
Dry Matter	1	0.37 **	0.25 ^{NS}	0.57***	0.20 ^{NS}	0.09 ^{NS}	0.28*	0.27*	0.10 ^{NS}	0.11 ^{NS}	0.13 ^{NS}	-0.30*	0.35**	0.34**	-0.28*	0.38**
Ash	0 .44**	1	0.32 *	-0.06^{NS}	0.31 *	0.23 ^{NS}	0.02 ^{NS}	0.15 ^{NS}	0.08 ^{NS}	0.16 ^{NS}	0.27*	-0.27*	0.31*	0.28*	-0.15^{NS}	0.32 *
Fat	0.35*	0.05^{NS}	1	-0.64***	0.7***	0.6***	0.39**	0.53***	0.3*	0.46***	0.49***	-0.47***	0.85***	0.34**	0.04 ^{NS}	0.8 ***
Protein	0.29*	0.14^{NS}	-0.78***	1	-0.44***	-0.41**	-0.1 ^{NS}	-0.24^{NS}	-0.17 ^{NS}	-0.3*	-0.3*	0.16 ^{NS}	-0.45***	-0.04^{NS}	-0.24^{NS}	-0.4 **
Shear force	-0.23^{NS}	-0.15^{NS}	0.54***	-0.69***	1	0.73***	0.25 ^{NS}	0.35**	0.16 ^{NS}	0.33 *	0.3 *	-0.44 ***	0.67***	0.26^{NS}	0.13 ^{NS}	0.64***
Extension	-0.32*	-0. 30*	0.35*	-0.55***	0.75***	1	0.07 ^{NS}	0.23 NS	0.06 ^{NS}	0.22 ^{NS}	0.18 ^{NS}	-0.26 ^{NS}	0.5 ***	0.17 ^{NS}	0.1 ^{NS}	0.47***
pH1	0.09^{NS}	0.21^{NS}	0.36**	-0.35*	0.25^{NS}	0.04^{NS}	1	0.76***	0.46***	0.58***	0.44***	-0.27*	0.44***	0.14 ^{NS}	0.09 ^{NS}	0.43***
pH4	0.18^{NS}	0.18^{NS}	0.43**	-0.34*	0.26^{NS}	0.07^{NS}	0.81***	1	0.69***	0.72***	0.55***	-0.37**	0.54***	0.16 ^{NS}	-0.1 ^{NS}	0.52***
pH8	0.35*	0.25^{NS}	0.46***	-0.25^{NS}	0.22^{NS}	0 .05^{NS}	0.72***	0.81***	1	0.66***	0.61***	-0.21 ^{NS}	0.15 ^{NS}	-0.19 ^{NS}	-0.1 ^{NS}	0.11*
pH12	0.22^{NS}	0.26^{NS}	0.35*	-0.24^{NS}	0.20^{NS}	0.03^{NS}	0.82***	0.76***	0.83***	1	0.86***	-0.49***	0.42**	-0.08 ^{NS}	-0.03 ^{NS}	0.37**
pH24	0.33*	0.33*	0.37**	-0.19^{NS}	0.12^{NS}	-0.05^{NS}	0.73***	0.80***	0.81***	0.83***	1	-0.43***	0.38**	-0.15 ^{NS}	0.0004 ^{NS}	0.32*
L*	-0.47***	-0.25^{NS}	-0.54***	0.26^{NS}	-0.22^{NS}	-0.01^{NS}	-0.43**	-0.44**	-0.55***	-0.43**	-0.46***	1	-0.56***	0.05 ^{NS}	-0.18 ^{NS}	-0.47 ***
a*	0.39**	0.16^{NS}	0.85***	-0.62***	0.45***	0.23^{NS}	0. 34*	0.41**	0.44**	0.37**	0.38**	-0.69***	1	0.54***	0.01 ^{NS}	0.98***
b*	0.21^{NS}	0.03^{NS}	0.25^{NS}	-0.13^{NS}	0.17^{NS}	0.12^{NS}	-0.10^{NS}	0.02^{NS}	-0.10^{NS}	-0.06^{NS}	-0.04^{NS}	-0.11^{NS}	0.43**	1	-0.33*	0.67***
Hue	0.15^{NS}	0.17^{NS}	0.54***	-0 .46***	0.23^{NS}	0.04^{NS}	0 .37**	0.41**	0.50***	0.41**	0.38**	-0.59***	0.62***	-0.23^{NS}	1	-0.07
Chroma	0.40**	0.15NS	-0.78***	- 0.55***	0.42**	0.24^{NS}	0.26^{NS}	0.35^{NS}	0. 35**	0.29*	0. 30*	-0.63***	0.97***	0.64***	0.47***	1

NS: Non Significant; *: P<0.05; **: P<0.01 ; *** : P<0.001 ; pHi : pH recorded i hours *post mortem* ; L*: Luminance; a*: redness; b*: yellowness..

Tableau 3: Correlations between technological and nutritional meat quality parameters in Fulani (above diagonal) and Sahoue chickens (below diagonal).

Variables	Dry Matter	Ash	Fat	Protein	Shear force	Extension	pH1	pH4	pH8	pH12	pH24	L*	a*	b*	Hue	Chroma
Dry Matter	1	-0.07^{NS}	0.37**	0.42**	0.27^{NS}	0.25^{NS}	-0.13^{NS}	0.01^{NS}	-0.06^{NS}	-0.05^{NS}	-0.06^{NS}	-0.22^{NS}	0.35*	0.55***	-0.09^{NS}	0.43**
Ash	-0.07^{NS}	1	0.11^{NS}	-0.26^{NS}	-0.07^{NS}	-0.13^{NS}	0.004^{NS}	-0.3*	-0.33*	-0.29*	-0.29*	0.18^{NS}	0.13^{NS}	-0.05^{NS}	-0.01^{NS}	0.09^{NS}
Fat	0.37**	0.11^{NS}	1	-0.68***	0.65***	0.54***	0.30*	0.37**	0.37**	0.39**	0.31*	-0.61***	0.81***	0.24^{NS}	0.39**	0.76***
Protein	0.42**	-0.26^{NS}	-0.68***	1	-0.42**	-0.32*	-0.38**	-0.30*	-0.35*	-0.38**	-0.30*	0.41**	-0.53***	0.19^{NS}	-0.45***	-0.42**
Shear force	0.27^{NS}	-0.07^{NS}	0.65***	-0.42**	1	0.73***	0.16^{NS}	0.40**	0.44***	0.52***	0.46***	-0.79***	0.81***	0.34*	0.42**	0.79***
Extension	0.25^{NS}	-0.13^{NS}	0.54***	-0.32*	0.73***	1	-0.04^{NS}	0.27^{NS}	0.16^{NS}	0.17^{NS}	0.14^{NS}	-0.50***	0.55***	0.20^{NS}	0.35*	0.53***
pH1	-0.13^{NS}	0.004^{NS}	0.30*	-0.38**	0.16^{NS}	-0.04^{NS}	1	0.49***	0.41**	0.44***	0.33*	-0.33*	0.20^{NS}	-0.08^{NS}	0.21^{NS}	0.15^{NS}
pH4	0.01^{NS}	-0.3*	0.37**	-0.30*	0.40**	0.27^{NS}	0.49***	1	0.77***	0.6***	0.60***	-0.42**	0.28*	0.12^{NS}	0.17^{NS}	0.28*
pH8	-0.06^{NS}	-0.33*	0.37**	-0.35*	0.44***	0.16^{NS}	0.41**	0.77***	1	0.80***	0.81***	-0.63***	0.37**	0.03^{NS}	0.31*	0.34*
pH12	-0.05^{NS}	-0.29*	0.39**	-0.38**	0.52***	0.17^{NS}	0.44***	0.6***	0.80***	1	0.79***	-0.67***	0.43**	0.02^{NS}	0.32*	0.38**
pH24	-0.06^{NS}	-0.29*	0.31*	-0.30*	0.46***	0.14^{NS}	0.33*	0.60***	0.81***	0.79***	1	-0.58***	0.34*	0.04^{NS}	0.26^{NS}	0.32*
L*	-0.22^{NS}	0.18^{NS}	-0.61***	0.41**	-0.79***	-0.50***	-0.33*	-0.42**	-0.63***	-0.67***	-0.58***	1	-0.77***	-0.23^{NS}	-0.52***	-0.73***
a*	0.35*	0.13^{NS}	0.81***	-0.53***	0.81***	0.55***	0.20^{NS}	0.28*	0.37**	0.43**	0.34*	-0.77***	1	0.46***	0.46***	0.98***
b*	0.55***	-0.05^{NS}	0.24^{NS}	0.19^{NS}	0.34*	0.20^{NS}	-0.08^{NS}	0.12^{NS}	0.03^{NS}	0.02^{NS}	0.04^{NS}	-0.23^{NS}	0.46***	1	-0.46***	0.61***
Hue	-0.09^{NS}	-0.01^{NS}	0.39**	-0.45***	0.42**	0.35*	0.21^{NS}	0.17^{NS}	0.31*	0.32*	0.26^{NS}	-0.52***	0.46***	-0.46***	1	0.33*
Chroma	0.43**	0.09^{NS}	0.76***	-0.42**	0.79***	0.53***	0.15^{NS}	0.28*	0.34*	0.38**	0.32*	-0.73***	0.98***	0.61***	0.33*	1

NS: Non Significant; *: P<0.05; **: P<0.01 ; *** : P<0.001, ; pHi : pH recorded i hours *post mortem* ; L*: Luminance; a*: redness; b*: yellowness.

Tableau 4: Correlations between technological and nutritional meat quality parameters in South chicken.

Variables	Dry Matter	Ash	Fat	Protein	Shear force	Extension	pH1	pH4	pH8	pH12	pH24	L*	a*	b*	Hue	Chroma
Dry Matter	1															
Ash	0 .03^{NS}	1														
Fat	0.28*	-0.02^{NS}	1													
Protein	0.44***	-0.05^{NS}	-0.73***	1												
Shear force	-0.06^{NS}	0 .01^{NS}	0.55***	-0.56***	1											
Extension	0 .27^{NS}	-0.06^{NS}	0.35*	-0.14^{NS}	0.33*	1										
pH1	0.08^{NS}	0.10^{NS}	0.36**	-0.29*	0.38**	0.01^{NS}	1									
pH4	0.21^{NS}	0.13^{NS}	0.27*	-0.12^{NS}	0.32*	0.09^{NS}	0.78***	1								
pH8	0.17^{NS}	0.12^{NS}	0.34*	-0.22^{NS}	0.29*	0.09^{NS}	0.74***	0.89***	1							

pH12	0.14^{NS}	0.01^{NS}	0.24*	-0.12^{NS}	0.25^{NS}	0.11^{NS}	0.67***	0.77***	0.79***	1						
pH24	0.17^{NS}	0.13^{NS}	0.39**	-0.25^{NS}	0.32*	0.05^{NS}	0.61***	0.68***	0.56***	0.67***	1					
L*	-0.24^{NS}	-0.15^{NS}	-0.73***	0 .53***	-0.42**	-0.31*	-0.53***	-0.50***	-0.53***	-0.38**	-0.51***	1				
a*	0 .32*	0.11^{NS}	0.87***	-0.60***	0 .59***	0.35*	0.47***	0.42**	0.44**	0.30*	0.53***	-0.76***	1			
b*	0.37**	-0.07^{NS}	0.18^{NS}	0.10^{NS}	-0.00^{NS}	0.14^{NS}	-0.005^{NS}	0.10^{NS}	0.14^{NS}	0.07^{NS}	-0.02^{NS}	0.01^{NS}	0.34*	1		
Hue	0.11^{NS}	-0.05^{NS}	0 .38**	-0.27^{NS}	0.30*	0.30*	0.11^{NS}	0.12^{NS}	0 .10^{NS}	0 .07^{NS}	0 .31*	-0.36**	0.43**	-0.12^{NS}	1	
Chroma	0.37**	0 .01^{NS}	0.82***	-0.52***	0.53***	0 .53***	0.42**	0.39**	0 .42**	0 .27*	0.48***	-0.68***	0.98***	0 .52***	0.37**	1

NS: Non significant; *: $P<0.05$; **: $P<0.01$; *** : $P<0.001$; ; pHi : pH recorded i hours *post mortem* ; L*: Luminance; a*: redness; b*: yellowness...

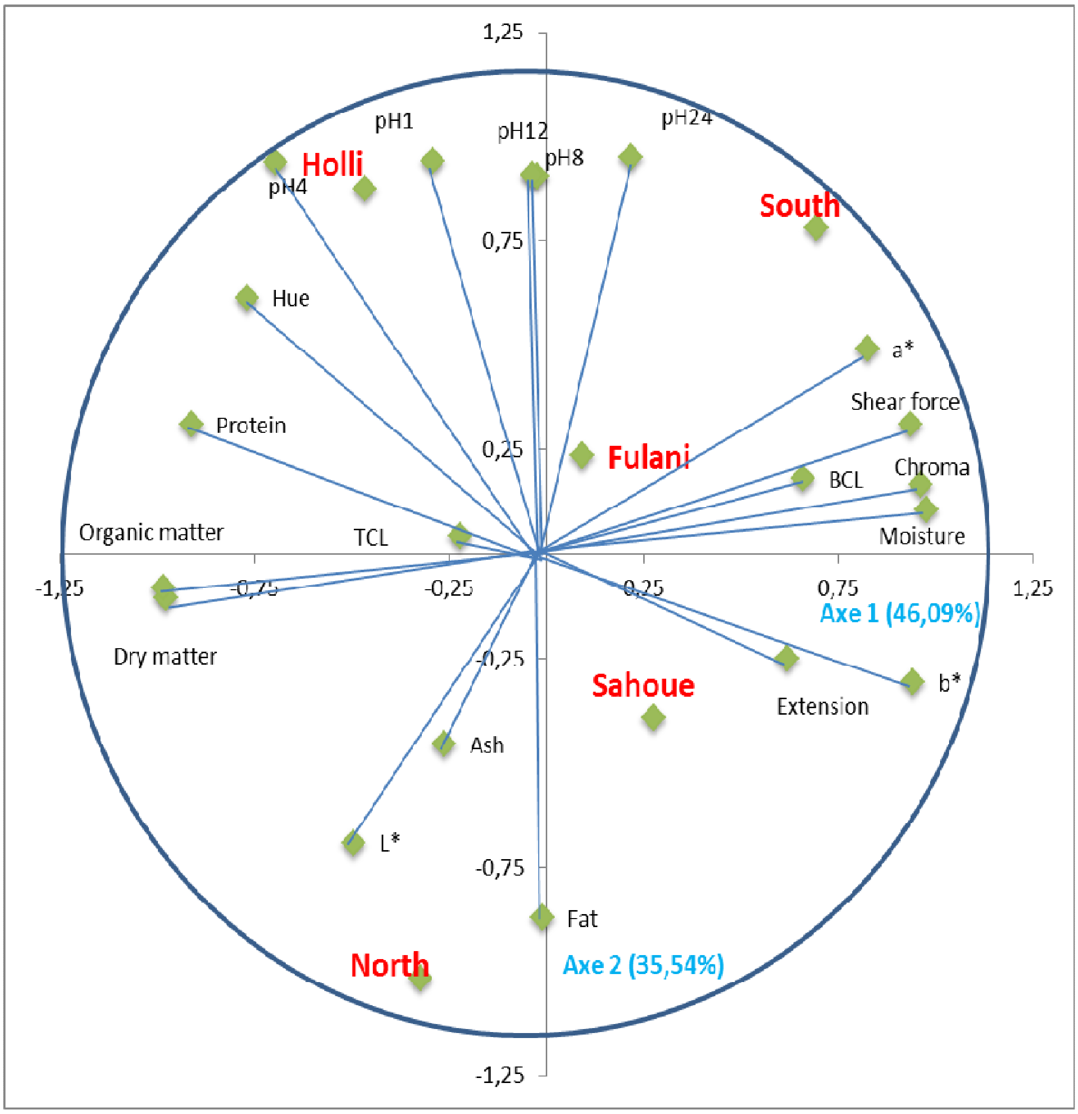

Figure 1: Principal Components Analysis (PCA) of indigenous chicken technological and nutritional meat quality parameters of Holli, Fulani, Sahoue, North and South ecotypes of Benin
; **TCL:** Thigh-drumstick cooking loss; BCL: Breast Cooking loss; ; **;** pHi : pH recorded i hours *post mortem* ; L*: Luminance; a*: redness; b*: yellowness..

DISCUSSION

Correlations between technological and nutritional meat quality parameters

The correlations between technological and nutritional meat quality parameters obtained herein differ among chicken genetic types. Technological meat quality parameters were more associated to nutritional meat quality traits in Fulani and Holli, chickens than Sahoue, South and North chickens. The observed differences in the relationships between meat qualities traits among genotype could be related to the genetic variability of carcass traits that exist among those studied ecotypes (Tougan et al., 2013a). This result confirms the finding of Youssao et al. (2010) who showed that indigenous chicken populations of Benin are characterized by a great genetic diversity than that reported for commercial lines chicken (Granevitze et al., 2007; Muchadeyi et al., 2007; Berthouly et al., 2008). In accordance with Havenstein et al. (2003a, 2003b), technological and nutritional meat quality depend on genotype. Franco et al. (2012, 2013) also found great difference in meat quality traits between Mos and Sasso T-44 roosters.

Overall, dry matter content was positively correlated with protein content, redness (a*) chroma value and to a lesser extent fat content, but negatively correlated with the luminance (L*). This result indicated that an increase in dry matter content led to significant increases in protein, redness (a*) chroma value and to a lesser extent fat content, but to significant decrease in meat lightness. According to Oluwatosin et al. (2007), an increase in the level of dry matter led to significant increases in organic matter and ether extract, suggesting that an increase in dry matter content would result to toughness of muscles rather than to higher carcass quality. This difference between the results obtained herein and those of Oluwatosin et al. (2007) in the relationship between dry matter content and fat content could be explained by the lower fat content recorded in the local chickens of Benin (1.83-2.09% of raw meat) comparatively to the fat content (4.75 to 6.44% of raw meat) of chicken strains used by Oluwatosin et al. (2007), and the genetic variability of those chicken breeds.

However, Oluwatosin et al. (2007) found that as the moisture content in the cockerels' muscles increased, significant ($P<0.05$) increases in crude protein and ash content occurred in disagreement with the current results. This difference in relationships between moisture content and protein content could be due to the weak slaughter weight and lower fat content in indigenous chicken meat of Benin compared to those of 28-weeks old cockerels of Nera, Bovan, Harco and Nigerian local strains used by Oluwatosin et al. (2007).

Fat content was more associated with the other meat quality traits in chicken of all ecotypes studied herein. This finding corroborates the results of Chabault et al. (2012) who reported positive genetic correlation between intramuscular fat content and luminance (r_g= 0.42) as well as the shear force (r_g=0.57) in free range naked-neck chickens, a slow-growing line selected by the SASSO breeding company. Previous studies had reported positive genetic correlations of abdominal fat weight and abdominal fat percentage with carcass weight in chickens (Deeb and Lamont, 2002; Musa et al., 2006). Furthermore, except dry matter content, ash content, luminance and yellowness, protein content was negatively correlated with the others technological and nutritional meat quality parameters with the high negative correlations found with the shear force and redness in all genetic types studied in the present work. As found herein, Chabault et al. (2012) found strong negative genetic correlations between the ultimate pH and the lightness, yellowness and drip loss of the meat. Similarly, Fletcher (1999) had reported high negatives correlations between pH and lightness ($P<0.001$; r = –0.636) and yellowness ($P<0.01$; r = –0.2). These results are consistent with those previously reported for turkey breast meat (Barbut, 1993). In the same way, Berri et al. (2007) found high significant negative correlation between the ultimate pH and the lightness ($P<0.001$; −0.61). In short, when pH decreases, lightness, yellowness and drip loss of the meat increase. However, Contreras-Castillo et al.

(2007) found that correlation between L* and pH values was not significant in male Cobb broilers.

In the present study, the values for a* were inversely related to the L* values in all ecotypes used suggesting that the higher the level of lightness, the lower the redness of the chicken meat. This finding is consistent with those of Askit et al. (2006) in Ross 308 broiler, Contreras-Castillo et al. (2007) in male Cobb broilers, and de Jesus Silva (2011) in broiler meat. According to Le Bihan-Duval et al. (2001), the redness and yellowness of chicken are linked, such that meat with higher redness tends to present higher levels of yellowness, similar to the association found in this study.

Contrary to the findings of Contreras-Castillo et al. (2007) in male Cobb broilers who pointed out that the correlation between L* and pH values was not significant, luminance was highly and negatively associated to pH8 and pH24, moderately and negatively correlated with pH1, pH4 and pH12 in the current study. Our results were consistent with the reports of Askit et al. (2006) in Ross 308 broiler and Chabault et al. (2012) in free range naked-neck chickens. Franco et al. (2013) also found a negative correlation ($r = -0.38$; $p < 0.01$) between L* and pH was found in Sasso T-44 line and Mos breed chickens. Similarly, this finding is in accordance with that reported by Le Bihan-Duval et al. (2008) and de Jesus Silva (2011). These significant inverse correlations found between L* and pH24 suggests that the meat of the studied ecotypes tends to present greater lightness when the pH is smaller, indicating the occurrence of protein denaturation 24 hours after slaughter. This is in agreement with the results of Le Bihan-Duval et al. (2003), who reported that the greater the degree of protein denaturation, the less the amount of light transmitted through the fibers and the more light that is dispersed, which makes the meat pale. Debut et al. (2003) also found negative and moderated correlations between the lightness of the meat and the pH 24 hours after slaughter.

Non-significant correlations or to a leaser extend weak and positive relationships were found between shear force and pH values in the current study indicating that meat with a low pH is less tender. This observation is in disagreement with the finding of Barbut (1993) and Contreras-Castillo et al. (2007) in broiler who found that shear values were highly inversely correlated with pH. These discrepancies in relationships between shear force and pH values could be related to the difference in genotypes of chickens used and their slaughter age. Indigenous chicken populations of Benin are of slow-growing type slaughtered at 24 weeks old, while Cobb broilers used by Contreras-Castillo et al. (2007) are heavier and fast-growing chicken line slaughtered at 6 weeks old. According to Anadón (2002), the texture of the meat is closely related to the amount of intramuscular water and, thus, inversely associated to the dry matter content of the meat, similar to the correlations found herein.

Overall, the obtained results showed that all the meat quality traits measured were good indicators of fat content.

Principal components analysis of technological and nutritional meat quality parameters

Principal components analysis of technological and nutritional meat quality parameters discriminated the five ecotypes according to their meat quality. Similar principal components analysis results were reported by Tougan et al. (2013d) when studying relationships between carcass traits and offal components in local poultry of Benin. This finding confirms that there is a gene linkage effect operating on technological and nutritional meat quality as found by several authors in carcass quality traits in chicken (Muhiuddin 1993; Olawumi 2013).

South chickens and to a lesser extent Fulani and Sahoue chickens were characterized by higher moisture, shear force, breast cooking loss, yellowness, extension and pH24, while Holli chickens were characterized by greater protein content, organic matter content, dry matter, thigh cooking loss, hue value, pH1, pH4, pH8 and pH12. North chickens were characterized by higher ash content, fat content and luminance. This variability in technological and nutritional meat quality characteristics among birds may be related to the genetic variability of chickens used in the present study since they were reared under the same breeding system and environmental conditions. These findings corroborate the observations of Tougan et al. (2013d) on the principal components analysis of carcass characteristics and offal component of the same indigenous chicken ecotypes of Benin. In the same way, Debut et al. (2003) showed that principal components analysis (PCA) of meat quality traits of slow-growing and fast growing strains of chicken discriminated both genotypes according to their meat quality. These authors showed that PCA opposed slow-growing and fast growing chickens with the slow-growing chickens characterized by higher thigh pHu, breast redness, thigh technological yield, breast pHu, thigh pH15 and thigh redness, while fast growing chickens were characterized by higher breast water loss, breast yellowness, breast lightness, thigh lightness, thigh yellowness, thigh redness and breast pH15.

Conclusion

The current work on phenotypic correlations between technological and nutritional meat quality parameters in indigenous chicken populations of Benin showed that fat content was the most associated with the other meat quality traits in chicken of all ecotypes studied. Furthermore, technological meat quality parameters were more associated to nutritional meat quality parameters in Fulani and Holli, chickens than Sahoue, South and North chickens. The principal components analysis of technological and nutritional meat quality parameters discriminated the five ecotypes according to their meat quality properties. South chickens and to a lesser extent Fulani and Sahoue chickens were characterized by higher dry matter, shear force, breast cooking loss, yellowness, extension and pH24, while Holli chickens were characterized by greater protein content, organic matter content, moisture, thigh cooking loss, hue value, pH1, pH4, pH8 and pH12. North chickens were characterized by higher ash content, fat content and luminance. Therefore, improve one meat quality trait will improve the other traits as a correlated response.

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