International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 3, No. 8, p. 1-20, 2013

INNSPUB

REVIEW PAPER

OPEN ACCESS

Conversion of chicken muscle to meat and factors affecting chicken meat quality: a review

Polycarpe Ulbad Tougan[1], Mahamadou Dahouda[2], Chakirath Folakè Arikè Salifou[1], Serge Gbênagnon Ahounou Ahounou[1], Marc T. Kpodekon[1], Guy Apollinaire Mensah[3], André Thewis[4], Issaka Youssao Abdou Karim[1*]

[1]*Department of Animal Production and Health, Polytechnic School of Abomey-Calavi, 01 BP 2009, Cotonou, Republic of Benin*

[2]*Department of Animal Production, Faculty of Agronomic Science, University of Abomey-Calavi, 01 BP 526, Republic of Benin*

[3]*Agricultural Research Center of Agonkanmey, National Institute of Agricultural Research of Benin, 01 BP 884, Cotonou 01,Republic of Benin*

[4]*Animal Sciences Unit, Gembloux Agro Bio Tech, University of Liege, Passage des Déportés, 2, 5030 Gembloux, Belgium*

Article published on August 17, 2013

Key words: Chicken, meat quality, variability factors.

Abstract

Chicken meat results from overall biochemical and mechanical changes of the muscles after slaughtering process. The transformation of muscle in meat is a control point in the determinism of meat quality. Several and complex factors can affect poultry meat quality properties. Therefore, genotype, age, sex, type of muscle, structure of muscle fiber, production system, feeding, feed and water withdrawal, transport, slaughter process, post mortem aging time promote a significant difference in parameters of technological, sensorial and nutritional quality of chicken meat. However, differences in meat quality exist between fast and slow growing chicken genotypes. Furthermore, older chickens present a lower ultimate pH, redder breast meat, higher shear force and drip loss, lower yield and more important intramuscular fat. At equivalent age, the male chickens are less fatty than the females, while crude protein content is higher in males than females. Production systems, such as traditional free range and improved farming, promote differences in color, texture, chemical composition and the fatty acid composition of meat, with the higher protein content, the lower fat content and favorable fatty acid profile reported from chicken of free range system. The motory activity of birds in free range results in tough texture and high cooking loss in the meat during heating (80-100°C). Diet composition affects the fatty acid composition and meat flavor. Higher breast meat redness was found in birds that were transported for a shortest distance or not transported than in those after a longer distance.

* **Corresponding Author:** Issaka Youssao Abdou Karim ✉ iyoussao@yahoo.fr

Introduction

Today, the greatest challenge of the United State Organization for Food and Agriculture (FAO) is food security, and consists on obtaining and guaranteeing an increasing food production of best quality for the population which increase year by year (FAOSTAT, 2010). In the sector of animal production, poultry breeding in general and chicken breeding in particular represents one of the ways on which sub-Saharan Africa countries were committed to increase their production of animal proteins. Avian genetic resources in West Africa are mainly represented by domestic local hen (*Gallus gallus domesticus*), guinea fowl (*Numida meleagris*) and ducks (*Cairina sp.*). These indigenous avian species are mainly exploited by rural families under traditional breeding system (FAO, 2004). In Benin for example, poultry constitutes the second source of meat after cattle with a consumption rate of 21% (Onibon and Sodegla, 2006). Generally, West African indigenous chickens are from a slow-growing type with relatively small body size (FAO, 2004; Missohou *et al.,* 2002).

The development of this avian sector and the importance of the consumption of the chicken meat nowadays worldwide in general and in West Africa in particular requires a better knowledge and control of characteristics of the product. The taste and the texture of this meat meet the requirements of the consumers who generally ignore their implicit needs from meat consumption. Several and complex factors can affect poultry meat quality properties (Jaturasitha *et al.,* 2008a). It is the reason why the present work aims to sum up the factors of variation of chicken meat quality. These factors can be either intrinsic (species, race, type of muscle, sex, genetic origin and slaughtering age) (Mourot, 2008), or extrinsic (conditions of breeding, and slaughtering, feed, technological treatments and *post mortem* biochemical changes). Therefore, a review on the factors that influence the technological, sensorial and nutritional quality of chicken meat is essential to have knowledge for developing research on this way and for promoting this poultry meat in the future. The outcomes of this review should be useful for controlling the fundamental quality factors on further development in chicken production efficiency and processing.

Meat quality concept

According to the standard ISO 8402-94, the quality is the set of characteristics of an entity that give that entity the ability to satisfy the expressed and implicit needs of its user or consumer. This definition reveals the complex character of quality (Touraille, 1994).

As a matter of fact, the meat quality concept is used to add the overall meat characteristics including its physical, chemical, morphological, biochemical, microbial, sensory, technological, hygienic, nutritional and culinary properties (Jassim *et al.,* 2011; Ingr, 1989). In general, the consumers judge meat quality from its appearance, texture, juiciness, water holding capacity, firmness, tenderness, odor and flavor. According to Cross *et al.* (1986), those meat features are among the most important and perceptible that influences the initial and final quality judgment by consumers. Furthermore, the quality of poultry meat gathers quantifiable properties of meat such as water holding capacity, shear force, drip loss, cooking loss, pH, shelf life, collagen content, protein solubility, cohesiveness, and fat binding capacity, which are indispensable for processors involved in the manufacture of value-added meat products (Allen *et al.*, 1998).

According to Touraille (1994), the quality of poultry meat can be defined from a certain number of accurate features: the nutritional quality, the hygienic quality, the technological quality and the sensory quality.

The nutritional quality is tied to the ability of the meat to feed the consumer in proteins, lipids, carbohydrates, as well as many other essential compounds (vitamins, minerals, trace elements...). In addition to the contribution of nutriments, the meat must preserve the consumer's health. It must not content any toxic residue, nor to be the settle of a bacterial development susceptible to produce harmful elements: it's the hygienic quality of meat. This requirement is well evidently recognized by the legislation. Furthermore, the technological quality of the chicken meat corresponds to the ability of meat to undergo the set of the transformations, preservations and packing during an industrial or artisanal process (Boutten *et al.*, 2003). The technological quality of chicken meat is mainly appreciated from the color, the water-holding capacity, and the texture of the meat at raw state or at the time of industrial transformations (Gigaud *et al.*, 2006).

Concerning sensory quality, it is about features discerned by the consumer's senses. They regroup the aspect and the color, the taste and the flavor, the odor and the aroma, as well as the consistence and the texture of a food. They have a fundamental role in the food preference determination (Touraille, 1994; Gigaud et *al.*, 2008). The sensory properties of a food are features that the consumer can discern directly thanks to its senses. These sensations can be qualitative, quantitative, or hedonic. For chicken, the main sensory features are: color, tenderness, juiciness and flavor (Touraille, 1994, Clinquart, 2000; Santé *et al.*, 2001).

Nevertheless, many factors such as genetic (Debut *et al.,* 2005), non-genetic factors (Gigaud, *et al.,* 2008; Boutten *et al.,* 2003), environmental (Berri and Jehl, 2001) and pre-slaughter factors and post mortem changes of muscle (Maltin *et al.,* 2003; Owens *et al.,* 2000; Barbut 1997) can affect the quality of poultry meat.

Conversion of chicken muscle to meat

The conversion of chicken muscle to meat results from the overall biochemical and mechanical changes of the muscles after slaughtering process. This biochemical and mechanical evolution of the muscle after slaughtering that comes progressively to its conversion to meat occurs in two phases: the dissipation of the energy reserves of the muscle during the installation of the *rigor mortis*, and the modification of the organization of muscular proteins structure during the maturation of meat (Santé *et al.,* 2001; Maltin *et al.,* 2003). The transformation of the muscle in meat is a control point in the determinism of meat quality. Stunning and bleeding modify potentially the muscular metabolism (El Rammouz *et al.,* 2003).

The interruption of blood circulation suppresses oxygen and exogenous energy substrata (glucose, amino acids and fatty acids) supplies. However, the mechanisms of homeostasis maintenance continue to function in the cell during a short time. The deprivation of oxygen decrease very quickly the oxidation power of cells, and only the anaerobic reactions persist, essentially the glycolysis (Lawrie, 1966; Bendall, 1973). The muscle, deprived of oxygen, becomes anoxic. The maintenance of the muscular homeostasis requires the synthesis of compound rich in energy such as ATP (Santé *et al.,* 2001). The reactions of ATP synthesis are assured by creatine phosphate utilization and essentially by glycogenolysis and anaerobic glycolysis. Anaerobic glycolysis generates lactate that accumulates, lowering the intracellular pH, so that by 24 h *post mortem,* the pH falls to an ultimate pH (pHu) of about 5.4 to 5.7. Muscle is highly sensitive to both ATP and Ca^{2+}, which are both involved in the contraction–relaxation process. Consequently, as ATP levels are reduced and Ca^{2+} levels increase in post mortem, irreversible link between myosin and actin, and *rigor mortis* occurs in the tissue (Maltin *et al.,* 2003). The reactions of ATP utilization and that of glycogen have been described in detail by Bendall (1973).

The fall in post mortem pH is characterized by its speed and its amplitude. The speed of the fall is mainly determined by the ATPasique activity, whereas the amplitude of fall in post mortem pH depends mainly on glycogen reserves of the muscle at the time of slaughtering (Santé *et al.,* 2001). According to Stewart *et al.* (1984), and Schreurs (1999), the *post mortem* biochemical reactions of broiler breast (Pectoralis major) meat of 7 to 9 weeks of age submitted to refrigeration stops between six and eight hours after slaughtering.

The kinetics and the intensity of these reactions influence strongly the technological, sensory and hygienic qualities of meats (Valin, 1988).

Factors affecting chicken meat quality

Intrinsic factors

The genotype

Genetic studies on meat quality traits in poultry are more recent. At the present state of knowledge, the genetic type, the breed, the line or the strain can affect strongly several properties of chicken meat qualities.

The speed and the amplitude of pH post mortem decline depend on the genetic type. Indeed, Berri *et al.* (2001) and Le Bihan-Duval *et al.* (2001) observe some differences in the post mortem biochemical evolution between different genotypes of chickens at equal age. These authors show that the selection for growth and / or muscular development leads for this species on a slowdown of pH *post mortem* decline, and on the other hand, an increase of ultimate pH of muscle. Furthermore, Debut *et al.* (2003) showed significant differences in most of the meat quality indicators between a slow-growing French Label-type line and a fast-growing standard line of chickens exposed to different pre-slaughter stress condition when estimating breast and thigh meat quality (pH decline, color, drip loss and curing-cooking yield). It comes out from their study that the breast muscle of Label chickens had more important reserves in glycogen at the time of slaughtering than the standard chickens. This difference can be due to the variability of muscle fiber structure among genetic types. Indeed, Jaturasitha *et al.* (2008b) showed that slow-twitch oxidative (STO), fast twitch oxidative-glycolytic (FTO) and fast twitch glycolytic (FTG) fibers diameters varying among genotype. Moreover, the speed of pH decline of slow-growing chicken lines is faster than in fast growing chicken lines (Debut *et al.,* 2003). In contrast, the study of Youssao *et al.* (2009) in Benin on Label Rouge and indigenous chickens of North and South ecotypes showed no significant difference among genotype in pH recorded 1 hour and 24 hours *post mortem*.

The chicken meat quality comparison carried out by Lonergan *et al.* (2003) on chickens from 5 genetic groups (inbred Leghorn, inbred Fayoumi, commercial broilers, F5 broiler-inbred Leghorn cross, and F5 broiler-inbred Fayoumi cross) showed high differences in breast meat composition and quality. Their results indicated that the Leghorn inbred line breasts were a more pure and more intense red color than the crossbred contemporary whereas Kramer shear force (kg/g of sample) was higher in breasts from broilers than in breasts from the inbred lines.

It has been reported that selection for fast growth and high yield affects the sensory and functional qualities of the meat (Dransfield and Sosnicki, 1999; Le Bihan-Duval et *al*., 2001; Le Bihan-Duval, 2003); therefore, differences in meat quality may exist between fast- and slow-growing broilers. Fast-growing chickens selected for their breast yield present a slow speed and amplitude of pH decline comparatively to slow-growing chickens (Berri, 2000). Thus, more the live weight and therefore the one of the breast increases, more the glycolytic potential of the *Pectoralis major* decreases (Berri and Jehl, 2001). The important differences of *post mortem* metabolism between different genetic types reverberate on their water-holding capacity in raw state but also on their properties during transformation process (Jehl *et al.,* 2001). Important exudation water loss of raw meat leads on faster pH *post mortem* decline (Debut *et al.*, 2003).

Hector (2002) mentions that the breast of feather sexable line of chicken present a higher pH than the breast of non-feather sexable line at different period *post mortem* (15 minutes, 4 hours and 24 hours *post mortem*). By the same way, El Rammouz *et al.* (2004) showed breed differences in the biochemical determinism of ultimate pH in breast muscles of broiler chickens. Moreover, Xiong *et al.* (1993) and Fernandez *et al.* (2006) reported significant differences between the ultimate pH among genetic types of chickens. According to Le Bihan-Duval *et al.* (1999), the pHu of selected line chicken meat is higher than that of control lines (5.78 *vs* 5.68). Culioli *et al.* (1990) observed a faster post mortem metabolism in the Label Chicken breasts than in those of the Standard ones. According to Larzul *et al.* (1999), Le Bihan Duval *et al.* (2001), Le Bihan Duval *et al.* (2008), the rate and the extent of decrease in pH post-mortem in chicken are under the control of different genes. These genetic results in short show that Glycolytic Potential and pHu of chicken meat have close genetic control and can be modified by selection. The slow-growing chicken meat tends to have a longer time of rigor inset with lower ultimate pH compared to broiler meat resulting in lower water holding capacity.

he investigations of Fanatico *et al.* (2005) on the meat quality evaluation of slow-growing broiler genotypes indicate that the drip loss and cooking loss (%) were significantly affected by genotype, with the highest losses occurring with the slow-growing genotype and the lowest losses occurring with the commercial fast-growing genotype and the medium-growing genotype. These results confirm the report of Debut *et al.* (2003), who found a higher drip loss in breast from slow-growing broilers than in fast-growing broilers. Lonergan *et al.* (2003) also showed a higher cooking loss in slow-growing broilers compared with fast-growing broilers. By the same way, Jaturasitha *et al.* (2008b) showed, when studying carcass and meat characteristics of male chickens from Thai indigenous, improved layer breeds and their crossbred that the water holding capacity in terms of drip, thawing and cooking (boiling and grilling methods) losses of breast and thigh muscle was significantly different among genotypes.

Furthermore, quite significant levels of heritability (ranging from 0.35 to 0.57) were obtained for meat pH, color and water-holding capacity in two studies conducted on the same experimental broiler line slaughtered under experimental conditions (Le Bihan-Duval *et al.*, 1999; Le Bihan-Duval, 2001). More moderate heritability values (ranging from 0.12 to 0.22) were reported for the same meat traits measured in turkeys slaughtered under commercial conditions (Le Bihan-Duval *et al.*, 2003). A study performed in quails by Oguz *et al.* (2004) also reported moderate to high levels of heritability (0.22–0.48) of ultimate meat pH and color indicators.

As for the technological quality, genotype greatly affected the physico-chemical and sensory characteristics of chicken meat. Castellini *et al.* (2006), when making comparison of two chicken genotypes (Ross 205 and Kabir) reared according to the organic farming system, showed that the meat from Ross chickens showed the higher Thiobarbituric Acid Reactive Substances values and these higher Thiobarbituric Acid Reactive Substances values were negatively correlated to lightness and yellowness. Stronger differences in the meat color were found when comparing commercial strains with experimental lines selected or not selected for increased body weight and breast yield (Berri *et al.,* 2001). Furthermore, Quentin *et al.* (2003) and Kisiel and Ksiazkiewicz (2004) reported in chicken that lightness (L*), redness (a*) and yellowness (b*) of breast and thigh meat differ significantly 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). The slow growing birds had lower redness (a*) values compared with the fast-growing birds. Other authors have found that slow-growing birds are redder and darker than fast-growing or high-performance birds (Le Bihan-Duval *et al.*, 1999; Berri and Jehl, 2001; Debut *et al.*, 2003). This difference in meat color among genotype can be due to the difference of their slaughter age which can affect the content of myoglobin in muscle. According to Gordon and Charles (2002), older (slower-growing) birds have redder meat due to a higher content of myoglobin. Lonergan *et al.* (2003) believed that difference in redness among genotypes was due to a difference in muscle fiber type.

Nevertheless, the effect of genetic type on nutritional chicken meat quality is controversial. Fanatico *et al.* (2005) reveal that *Pectoralis* muscle dry matter, fat, and ash contents were largely unaffected by genotype.

This observation confirms the results of Latter-Dubois (2000), who found no significant differences in dry matter or ash in the breast meat (with skin) among 5 crosses of fast-, medium-, and slow-growing chickens. Nevertheless, Lonergan *et al.* (2003) found that breast meat from fast-growing broilers had higher lipid content than from slow-growing ones. Furthermore, Havenstein *et al.* (2003) found that *the modern 2001 strain* had more carcass fat than an *older 1957 strain* of chicken. In Thaïland, Jaturasitha *et al.* (2008a), Wattanachant *et al.* (2004), Wattanachant and Wattanachant (2007), and Chuaynukool *et al.* (2007) found that genotype (breed and strain) of chickens plays a major role in carcass fatness and meat quality (table I). In Nigeria, the study carried out by Oluwatosin *et al.* (2007) reveals very significant effect of genetic factors on the nutritional quality of the breast and thigh of cockerels of the Nera, Bovan, Harco and nigerian local strains. Their results showed that local chickens of Nigeria were nutritionally better than exotic cockerels. Crude protein values from the thigh and breast muscles of nigerian local strains were 63.58% and 63.32 ± 0.03% respectively, while the least crude protein contents of thigh and breast muscles were obtained respectively from Bovan exotic cockerels (60.72 %) and Nera exotic cockerels (42.37 %). The same tendency was observed for the ash content but not for the ether extract content. The nigerian local strains had the lowest lipid content (Oluwatosin *et al.*, 2007). Similary, in Thaïland, Jaturasitha *et al.* (2008b) reported that the indigenous chickens of Thaïland were nutritionally better than the crossbreeds and the exotic strain (Bresse and Rhode Island Red). These reports confirm the result of Brunel *et al.* (2006) who showed that protein and lipid rates of chicken meat depend on the genetic type.

Last decades, much effort has been spent on obtaining knowledge about quantitative trait loci (QTL) in several species including chicken (Van Kaam *et al.* (1999). Usually, information from genetic markers is used for detecting QTL on chromosomes. In the chicken, a large number of genetic markers were generated, which enabled QTL detection. Van Kaam *et al.* (1999) showed when studying the whole genome scan in chickens for quantitative trait loci affecting carcass traits and meat quality that the most significant QTL was located on Chromosome 1 at 466 cM and showed an effect on carcass percentage. The other QTL, which affected meat color, was located on Chromosome 2 and gave a peak at 345 and 369 cM. Similarly, Nadaf *et al.* (2007) had recently identified most significant QTL controlling the redness and the yellowness in broiler breast meat. Number QTL were also identified for the growth performance and carcass composition in relation with the metabolism by Nadaf *et al.* (2009). Moreover, Le Bihan-Duval *et al.* (2009) confirm that several QTL areas were detected for yellowness of breast meat (on the chromosomes 2, 4, and 11). They also showed a pleiotropic effect of QTL detected on the chromosome 4, of which allele increasing the live weight also has a positive effect on the ultimate pH but negative on fattening, pH at 15 minutes *post mortem* and yellowness (b *).

Overall, chicken meat quality is stongly affected by breed or genotype. However, other intrinsic factors, such as type of muscle and muscle fibers, sex, age, live weight may influence chicken quality.

- **The type of muscle and muscle fibers**

The breast and thigh muscles of chicken represent the highest proportion of chicken carcass and differ in their chemical composition and technological and sensory quality (Oluyemi and Roberts, 2000). Indeed, Oluwatosin *et al.* (2007) revealed that the thigh muscle is relatively more nutritive (crude protein, ether extract, dries matter, organic matter, nitrogen free extract) than the breast muscle in all cockerel strains. This influence of the type of muscle on the quality of meat is also reported by several authors such as Oluyemi and Roberts (2000), Berri *et al.* (2007), Jaturasitha *et al.* (2008a) and Latter-Dubois (2000) on the chicken and Baeza (2006), Woloszyn *et al.* (2006) and Huda *et al.* (2011) on duck meat.

However, according to Scheuermann *et al.* (2003), selection in chicken can induce greater muscle weight at the same age by increasing the fiber size and number. These authors concluded that increased muscle fiber number may also participate to improve breast yield. Now, according to Berri *et al.* (2007), increased breast weight and yield were associated with increased fiber cross-sectional area, reduced muscle glycolytic potential, and reduced lactate content at 15 min *post mortem*. Therefore, P. major muscle exhibiting larger fiber cross-sectional area exhibited greater pH at 15 min *post mortem* and ultimate pH, produced breast meat with lower L* and reduced drip loss, and was potentially better adapted to further processing than muscle exhibiting small fiber cross-sectional area. Moreover, when *post mortem* time increases during storage (between 4 and 12°C), the lightness (L*) and the yelowness (b*) of chicken breast meat increase but the redness (a*) decreases (Zanusso *et al.*, 2001; Petracci and Fletcher, 2002). This variation of color with *post mortem* aging time may be resulted from the variation of concentration of pigments, the chemical state of pigments, and the way light is reflected off the meat (Abdullah and Matarneh, 2010). The higher myglobin content in *biceps femoris* muscle of the indigenous chicken contributed to higher a* value and lower L* value compared to that of the lower myoglobin content in *pectoralis* muscle (Wattanachant and Wattanachant, 2007; Abdullah and Matarneh, 2010).

On the basis of their biochemical and functional properties, Brook and Kaiser (1970) classified the muscle fibers into three groups: slow-twitch oxidative (STO), fast twitch oxidative-glycolytic (FTO) and fast twitch glycolytic (FTG). Jaturasitha *et al.* (2008b) reported that no significant difference in the percentage of each breast muscle fiber type among Thai native chickens, Thai native x Bar Plymouth Rock, Bar Plymouth Rock and Shanghai chickens was observed. Dark muscles contain predominantly STO, while light muscles contain primarily FTG. Lengerken Von *et al.* (2002) reported that the FTG content of *pectoralis* muscle of broiler and turkey was respectively 99.5 and 99.8 %; whereas Jaturasitha *et al.* (2008b) found the type IIB between 82.2-95.0 %. Moreover, Jaturasitha *et al.* (2008b) showed that the STO, FTO and FTG diameters varying among genotype. In conclusion, difference between genotypes is not only related to the different proportions of muscle, but also to their different diameter.

- **The Sex**

The sex has an influence on several parameters of the chicken meat quality (Le Bihan-Duval *et al.*, 1999; Mehaffey *et al.*, 2006; Jaturasitha *et al.*, 2008a).

At 24 h *post mortem*, the pH values on breast meat between sex found by Lopez *et al.* (2011) when studying broiler genetic strain and sex effects on meat characteristics showed female broilers having a lower pH24 (5.87). This difference in pH value can be due to the glycogen content in the muscle. Gigaud *et al.,* (2007) had observed a sex effect on glycogen rate; this rate in glycogen was more important at the females with a lower pH.

Moreover, this author reported that females broilers exhibited a higher yellowness (b*) than males. This influence of the sex on the color of chicken meat had also been observed by Fanatico *et al.* (2005). Furthermore, the meat of female is less exudative and tenderer than that of the male (Debut *et al.*, 2004; Berri *et al.,* 2000). The study of Abdullah and Matarneh (2010) on the influence of carcass weight, bird sex, and carcass aging time on meat quality traits of *pectoralis major* muscles in broiler birds showed that cooking loss was affected by bird sex with the highest value recorded in females (27.8%) than males (26.7%), while the carcasses of male birds exhibited higher thawing loss values than those from female birds. The highest thawing loss found in male by these authors may have resulted from the excess amount of moisture picked up by carcasses from male birds because of differences in breast thickness or the space between muscle fibers. In contrast, these authors found no effect of sex on water-holding capacity, color, and chemical composition of meat. Similarly, Lopez *et al.* (2011) reported on the same broiler birds that no difference existed for sex for mean shear force. Indeed, in their study, all shear force values of breast were lower than 30 N, and then suggesting that meats were sufficiently tender and therefore would be highly accepted by consumers (Owens *et al.*, 2000; Schilling *et al.*, 2003; Corzo *et al.*, 2009).

Table 1. Chemical composition and some quality characteristics of different genotypes of chicken muscles.

Parameters	Chicken genotype							
	Shanghai[1]	Bar Playmouth Rock [1]	Broiler[2]	Black Bone[3]	Northern Thai[3]	Southern Thai[3]	Naked Neck[3]	Kai Dang[3]
Breast muscle Chemical composition								
Moisture (%)	73.3	73.3	73.733	72.10	72.9	73.4	73	72.8
Protein (%)	23.9	24.2	23.72	24.4	24.7	24.2	24.1	23
Fat (%)	0.59	0.56	1.96	0.53	0.51	.2	0.22	2.88
Collagen (mg/g)	17.1	14.8	-	28.3	26.20	7.15	8.5	7.76
Shear value (N)	21.9	30.9	-	41.7	51.20	2.4	1.8	2.7
Cooking loss (%)	21.07	14.93	-	22.08	18.99	20.78	20.28	24.04
Meat Color								
L*	59.1	55.8	-	50.70	54.90	67.3	61.7	53.6
a*	-0.08	1.86	-	1.66	1.27	4.22	1.04	-0.6
b*	11.9	9.9	-	10.5	13.60	8.8	3.2	9
Thigh muscle Chemical composition								
Moisture (%)	74.5	73.2	73.502	74.10	75.7	74.8	74.2	80.80
Protein (%)	19.8	21.3	19.50	21.7	20.4	21.4	20.7	17.4
Fat (%)	5.55	3.83	6.29	2.81	2.94	0.48	0.56	1.14
Collagen (mg/g)	22.2	22.1	-	36.3	42.2	13.12	14.05	10.33
Shear value (N)	39.2	35.8	-	36.1	44.3	3.2	2.4	4.2
Cooking loss (%)	25.78	20.04	-	20.12	23.38	20.46	21.05	19.66
Meat Color								
L*	57.9	54.3	-	45.90	51.9	61.4	57.1	48.5
a*	3.92	3.47	-	3.87	5.27	8.84	3.16	0.16
b*	6.32	5.13	-	3.40	7.8	8.8	5.1	5.30

Note: - backyard production system and 1.3 kg of carcass weight was noted for naked-neck chicken while intensive rearing system and 1.0 - 1.1 kg of carcass weight noted for the Black Bone, Northern Thai, Southern Thai and Kai Dang. All types of chicken studied by Wattanachant (2008) were males and females slaughter age at 16 weeks old. Breast muscle: *pectoralis major*, Thigh muscle: *biceps femoris*. **Source :** Adapted from [1]Jaturasitha *et al.* (2008b), [2]Bogosavljevic-Boskovic *et al.* (2010) and [3]Wattanachant (2008).

It is recognized that the males are less fatty (at equivalent age) than the females. Sunday *et al.* (2010) found that lipid content of chicken meat was higher in females than males, whereas crude protein content was significantly higher in males than females. Moreover, these authors found also that the interaction between genotype and sex significantly affected crude protein and lipid contents. Similarly, Bogosavljevic-Boskovic *et al.* (2010) observed that at equal age, male broilers in both rearing systems had higher protein content in leg muscle than females, while the fat content and dry matter was significantly higher in females than in males. The results obtained by Holcman *et al.* (2003) also confirmed a significant effect of sex on broiler meat quality (females having more fat than the males of the same age). However, Konràd and Gaàl (2009) found that sex has a significant impact only on ash content of thigh meat of Yellow Hungarian Cockerel and Pullet kept in free range for 84 days with the highest ash content recorded in pullet (0.98% *vs* 0.89%).

Furthermore, the sex of the chicken influences the profile in fatty acids of the chicken muscles (Brunel *et al.,* 2006). De Marchi *et al.* (2005) found that female Padovana breed of chicken had most important rate of C16:0, C18:3w3 fatty acids than male, while had the highest content in C18:1w7t and C20:4w6 fatty acids than female.

The Slaughter age

The composition of chicken muscle and technological quality of its meat change as the animal gets older. When slaughter age decreases the flavor of meat decreases whereas the tenderness and the juiciness increase (Gigaud *et al.,* 2008; Fletcher *et al.,* 2002). Moreover, Berri *et al.* (2005) reported that the content in glycogen of *Pectoralis major* chicken muscle seems to decrease with the age of the animals apart from their speed of growth. This reduction of glycogen content in breast muscle is associated to the increase of the fiber cross-sectional area. According to the study of Berri *et al.* (2007) carried out on consequence of muscle hypertrophy on characteristics of *pectoralis major* muscle and breast meat quality of broiler chickens revealed that increasing muscle fiber cross-sectional area and thus muscle weight in chicken was linked to a number of changes in muscle and meat characteristics. Indeed, as the fiber cross-sectional area increased, the muscle postmortem pH fall slowed down and its glycolytic potential decreased, whereas breast meat ultimate pH increased. The chickens bred during a long period will have a higher pH.

Furthermore, it had been noticed an increase of the quantity of collagen and decrease of its solubility with the age of the animals (Fiardo, 2003). The decrease of tenderness in chicken meat during muscle growth can thus due to the structural changes of collagen (Nakamura *et al.*, 2004). According to Fletcher (2002), differences in tenderness can be due to the fact that older birds are more mature at the time of harvest and have more cross-linking of collagen. A similar effect of the age on the flavor, the tenderness and the juiciness were observed on the turkey meat by Owens *et al.* (2000).

Castellini *et al.* (2002) attributed poor water-holding capacity in slow-growing birds to a less mature age than fast-growing birds at a slaughter age of 81 days. Indeed, the slow-growing birds had a higher percentage of moisture in the meat. Moreover, the breast muscle skin (L*, a* and b*) color coordinates increased while b* value of muscle decreased with increasing age. Poultry breast meat, typically, tends to become darker and redder as bird age increases because of highest contents of myoglobin in the muscles (Fletcher, 2002). Janish *et al.* (2011) reported that the electrical conductivity, lightness, grill loss, and shear force values increased but the drip loss and a* values decreased with the age of the broiler.

Moreover, the age of the chicken influences strongly nutritional quality of its meat through the profile in fatty acids of the muscles (Brunel *et al.,* 2006). Similarly, dry matter content of chicken meat can be affected by the age of animal. In Thaïland, the studies of Wattanachant and Wattanachant (2007) and Wattanachant (2008) on changes in composition, structure, properties of muscle protein and meat quality of Thai indigenous chickens during growth from 6 to 24 week old confirm that moisture content in muscle decreased from 77.8 to 71.6%, whereas fat and protein contents increased from 1.35 to 3.90% and 21.5 to 24.0%, respectively. The same observation was made by Suchy *et al.* (2002) on chemical composition of muscles of hybrid broiler chickens during prolonged feeding. Similarly, De Marchi *et al.* (2005) found significant difference for protein content of Padovana breed of chicken slaughtered at 150 and 180 days of age with the highest protein concentration recorded at 180 days old.

In short, older chickens present a lower pHu, redder breast meat, higher drip loss and protein content, lower yield and more important intramuscular fat.

The live weight

At the same age, the live weight can affect the chicken carcass composition and the meat quality properties (INRA, 2008). The weight variability of the chickens can be very important within a batch (Gigaud and

Berri, *2007*). This variability can be tied to individual variability but also to the sexual dimorphism. Thus, some differences in *post mortem* metabolism of chicken muscle could be explained by the difference in growth rate. The investigation of INRA (2008) indicated that heavier chickens present a lower pHu, redder breast meat, higher drip loss, lower yield and more important intramuscular fat. Furthermore, a study conducted to determine the influence of genotype, market live weight, transportation time, holding time, and temperature on broiler breast fillet color under commercial processing in Italy by Bianchi *et al.* (2006) reveals that with regard to the market live weight of broilers, the heavier birds (>3.3 kg) produced a darker breast meat (L* = 51.67) than did the lighter birds (<3.0 and 3.0 to 3.3 kg; L* = 52.63 and 52.84, respectively) ($P < 0.001$). Nevertheless, the influence of carcass weight, bird sex, and carcass aging time on meat quality traits of *pectoralis major* muscles was studied in broiler birds by Abdullah and Matarneh (2010) and it comes out from their study that lighter carcasses had a higher thawing loss percentage in breast muscle while higher shear force values were recorded in breast muscle from heavier carcasses. This could have been due to a greater denaturation of muscle protein in the lighter carcasses compared with heavier ones. Carcass weight in chicken is then critical to meat quality characteristics.

Extrinsic factors

Production system

The breeding mode of chicken affects the characteristic of their meat quality. The study of Fanatico *et al.* (2005) on the meat quality evaluation of slower-growing broiler genotypes with or without outdoor access indicated that meat quality differences exist among production systems particularly on the sensory quality. Indeed, it comes out from their study that the principal effect of outdoor access was to make the meat yellower in the case of the slow-growing genotype ($P < 0.05$), but not in the commercial fast-growing genotype (F) ($P > 0.05$). Mikulski *et al.* (2011) found that color of the breast and thigh muscles of chickens bred with outdoor access was significantly darker, compared with birds raised in confinement. Changes in the color of meat in their study were accompanied by a better water-holding capacity of breast muscles and lower juiciness of breast from free-range chickens. Moreover, Fanatico *et al.* (2005) showed that when the slow-growing genotype chickens had access to the outdoors, their drip loss increased significantly; when they hadn't outdoor access, there was little impact from production system on water-holding capacity.

The shear force of the meat also varied significantly according to the production system. The study of Castellini *et al.* (2002) on the effect of organic production on broiler carcass and meat quality showed that the production system affected the shear force value, which was higher in either the breast or drumstick of the organic animal, presumably as a consequence of their motory activity. The same tendency was observed by Santos *et al.* (2005) in free range broiler chicken strains raised in confined or semi-confined systems, Husak *et al.* (2008) for the breast meat from chickens reared under a lower stocking density and Wattanachant (2008) for Thai indigenous chickens bred with or without outdoor access. Thus, rearing systems, such as intensive and extensive farming, promote differences in meat texture.

In term of nutritional value, fat content variation can be tied to the production system since the organic system reduces by three times the lipid content of chicken breast meat (Brunel *et al.*, 2006). Indeed, the conventional production system and the organic production system were compared on the chickens of 56 and 81 days old by Castellini *et al.* (2002) and it comes out from their study that a fat content of 2.37% was observed for conventional production system *vs* 0.74% for the organic chickens at 81 days old. Thus, the organic production system is then very interesting in term of nutritional quality of meat since it allows not only obtaining less fatty meat (Konràd and Gaàl, 2009) but rich in heme iron and protein (Bogosavljevic-Boskovic *et al.*, 2010). Furthermore, dry matter content of chicken meat can be affected by the breeding system (Brunel *et al.*, 2006). According to the finding of Mikulski *et al.* (2011) when studying growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access, the breast meat of free-range chickens contained significantly more dry matter and protein than the breast meat of chickens raised without outdoor access. Similarly, according to Fletcher (2002), differences in dry matter content and juiciness of meat, may be due to the fact that free-range birds have a greater motor activity than indoor confinement chickens without outdoor access. However, Fanatico *et al.* (2005) reveal that Pectoralis muscle dry matter (%), fat (%), and ash (%) were largely unaffected ($P > 0.05$) outdoor access (production system).

In short, the meat of free-range chickens may be darker in color, with higher protein content and a better water-holding capacity, but it may be less juicy than the meat of birds raised indoors.

Feeding

The feeding mode is very important factor of meat quality since the feed composition can affect or change strongly the characteristics of chicken meat (Jaturasitha *et al.*, 2004 and 2008a), including the fatty acid profile (Brunel *et al.*, 2006).

The sensory characteristics of chicken meat depends on the specific raw materials used in the feed composition such as vitamin, oil, fish flours … (Sauveur, 1997). For example, Mellor *et al.* (1958) showed that fasted broilers have been observed to have higher glycogen stores than broilers fed with a diet supplemented with sugar. These authors also found that meat from sugar-fed broilers was more tender than meat from their control counterparts. The study of Garcia *et al.* (2005) on the inclusion of sorghum replacing corn in broiler feeds shows not only a significant negative correlation between meat pH decrease and corn replacement but sorghum inclusion also affected meat color, promoting paler meat. Baracho *et al.* (2006) reported that diet supplementation with different level of vitamin E (α-tocopheryl acetate) led on significant difference in chemical composition and sensory quality of meat. According to these authors, HPLC analyses showed that muscle α-tocopherol levels of the chickens fed with the supplemented diet were 6-7-fold higher than those of the chickens fed with the control diet. Moreover, they showed that vitamin E supplementation had a beneficial effect on sensorial data, and on oxidative stability of the meat, as measured by thiobarbituric acid. GC-MS analyses also showed from their study that the concentration of aldehydes, which are considered responsible for rancid off-flavors, was much more important in the control samples as compared to the supplemented samples.

Furthermore, diet composition affects the fatty acid composition of every fatty depot. The investigation of Shen and Du (2005) on effects of dietary α-lipoic acid on the pH value, AMP-activated protein kinase (AMPK) activation and the activities of glycogen phosphorylase and pyruvate kinase in *post mortem* muscle revealed that dietary α-lipoic acid supplementation can significantly reduce prevalence of quality default of pale, soft, and exudative (PSE) meat. The work carried out by Guillevic *et al.* (2010) on the effect of flax seed supply in diet of fast growing chicken and turkey on nutritional quality of meat showed that the proportion of mono saturated fatty acid in thigh meat of chicken fed with diet supplied with flax seeds decreases significantly ($P<0.05$) compared to the one recorded in chicken feed with the control diet (without flax seeds). The content in poly-unsaturated fatty acid (PUFA) was also significantly affected by the type of diet, with an increase of poly-unsaturated fatty acid in meat of chicken fed with diet supplied with flax seeds. Moreover, the content in n-3 PUFA increases 2.3 times in thigh and 2.1 times in breast meat in chicken fed with diet supplied with flax seeds than thigh and breast meat of birds fed with the control diet ($P<0.001$). Similar results were reported by Shen *et al.* (2005) on chicken meat, when they were studying performance, carcass cut-up and fatty acids deposition in broilers fed with different levels of pellet-processed flaxseed.

Groom (1990) showed that increase the level of lysine in chicken diet may lead on more important breast yield, higher abdominal and visceral fat contents. Similarly, high nutrient density diets (high energy + protein) increase breast meat but also abdominal fat, but by altering energy: protein ratio; narrow ratios reduce fat content.

Transportation

During transportation, several stress factors such as high or low temperature, high moisture, noise, feed and water withdrawal… occur in animal. These factors influence strongly the properties of final meat quality. It has been suggested that transportation may affect meat quality because of the chickens' hormonal and metabolic response to the stressor, with the resulting loss of body equilibrium. Fortunately, birds recover from stress relatively quickly, but even brief stress may account for varying meat quality. Preslaughter stress may affect the acidity, color and water binding properties of the meat (Northcutt, 2001a). Bianchi *et al.* (2006) reported a significant effect of transport on the color of the meat; the breast fillets from birds transported for the shortest distance (<40 km) exhibited a higher breast meat redness (a*= 3.59) when compared with transport distances of 40 to 210 or >210 km (a* = 3.28 and 3.04, respectively). But Debut *et al.* (2003) found no differences in breast meat color between transported and non-transported broiler chickens. Moreover, Savenije *et al.* (2002) reported that chicken transport during 75 minutes before slaughter process doesn't affect the *post mortem* pH evolution in the muscle.

Pre-slaughter temperature and holding time

According to Gordon and Charles (2002), temperature fluctuations can cause variation in carcass quality. Heat may increase abdominal fat, and in cold temperatures, less fat and meat are deposited. A study conducted to determine the influence of genotype, market live weight, transportation time, holding time, and temperature on broiler breast fillet color under commercial processing in Italy by Bianchi *et al.* (2006) revealed that the holding temperature significantly affected meat color. Breast fillets from birds held at <12°C were darker (L* = 51.32) than fillets from birds held at 12 to 18°C (L* = 52.85) or >18°C (L* = 53.11) (*P* <0.001). Moreover, when holding temperature increases, the breast meat a*, b*, C*, and H* decrease. The shortest holding time (<6 h) produced the highest (*P* <0.05) L* values (52.84) compared with holding periods of 6 to 9 h and more than 9 h (L* = 52.12 and 52.04, respectively). Furthermore, an increase of both meat a* and saturation (C*) was observed with the advance in holding time. Moreover, Petracci *et al.* (2001) also reported significantly lower breast meat a* (2.48 vs. 3.04) in broilers held at higher temperatures (34 *vs.* 25°C).

Water and feed withdrawal and pre-slaughter stress

The energy stock available at the end of fasting of chicken before slaughtering influences the kinetics of pH reduction in chicken meat (Immonen *et al.,* 2000). Feed is normally withdrawn for several hours before catching in order to reduce the danger of microbial (*Salmonella, Campylobacter*) contamination of carcass. Feed withdrawal before slaughter allows emptying of the digestive system and reduces the likelihood of faecal contamination during processing (Shawkat *et al.,* 2008). The effects of fasting on meat quality of poultry are particularly important because feed withdrawal periods of 8 to 12 hours before slaughtering are common. This practice has been shown to accelerate *rigor mortis* and final product quality by decreasing the amount of glycogen available for energy production prior to the onset of *rigor mortis*. Feed withdrawal from broilers prior to slaughter significantly reduces muscle energy stores that could be used during *post mortem* metabolism (Sams and Mills, 1993). Moreover, Savenije *et al.* (2002) reported that there is no influence of feed withdrawal (5 hours of fasting) on the color (L *, a * and b *) of the chicken meat at 96 hours after slaughtering. However, according to Hector (2002), the stability of the color is very variable and it is influenced by several factors as the fasting or feed withdrawal.

According to Berri and Jehl (2001), stresses before slaughter in chicken like fasting, manipulations, transportation, crating and extreme temperatures accelerates the fall of the pH while increasing the ATPasique activity of the muscle. The same impact of stress on the meat quality was reported in turkey by McKee and Sams (1998) who reported that breast meat from heat stressed turkeys exhibited lower initial and ultimate post mortem pH and higher rates of *post mortem* pH decline when compared to non-stressed birds.

Post mortem aging time

The pH and cooking loss increase with the aging time while color (L*, a*, b*, C*, and H*) and Warner-Bratzler shear force decrease (Northcutt *et al.*, 2001b; Bianchi *et al.*, 2006). Qiao *et al.* (2001) and Petracci and Fletcher (2002) reported that aging time had a significant effect on broiler breast meat color.

However, the influence of aging time on meat quality traits of *pectoralis major* muscles was studied in broiler birds by Abdullah and Matarneh (2010) and it appears that Water-holding capacity, color, and chemical composition were not affected by this factor, whereas thawing loss percentage decreased significantly with an increase in aging time. Moreover, shear force values were significantly higher for breast fillets aged for 0 and 2 h. However, a major improvement in tenderness resulted after 4 h of aging, with tenderness being comparable among carcasses of all weights. It is undeniable that post chilling carcass aging duration is critical to chicken meat quality characteristics (Abdullah and Matarneh, 2010).

Conclusion

Chicken meat quality is affected by several factors such as breeds or genotypes, age, sex, breeding systems, feed, muscle pH, type of muscle, live weight, *post mortem* aging, feed withdrawal, pre-slaughter stress…. These factors influence not only meat quality but muscle metabolic capabilities. This review shows a determinative role of the hours preceding and succeeding the death at the chicken. Better understanding of these factors will help the chicken breeding sector to obtain large scale and good quality products.

References

Abdullah AY, Matarneh SK. 2010**.** Broiler performance and the effects of carcass weight, broiler sex, and postchill carcass aging duration on breast fillet quality characteristics. Journal of Applied Poultry Research **19**, 46–58.

Allen CD, Fletcher DL, Northcutt JK, Rusell SM. 1998**.** The relationship of broiler breast color to meat quality and shelf life. Poultry Science **77**, 361-366.

Baéza E, Jehl N, Jégo Y, Duclos MJ, Le Bihan-Duval E. 2006**.** Variations in chicken breast meat quality: implications of struggle and muscle glycogen content at death. British Poultry Science **46**, 572-579.

Baracho MS, Camargo GA, Lima AMC, Mentem JF, Moura DJ, Moreira J, Nääs IA. 2006**.** Variables Impacting Poultry Meat Quality from Production to Pre-Slaughter: A Review. Brazilian Journal of Poultry Science **8 (4),** 201 – 212.

Barbut S. 1997**.** Problem of pale soft exudative meat in broiler chickens. British Poultry Science, **38**, 355-358.

Bendall JR. 1973**.** Post-mortem changes in muscle. In: Academic Press 2nd Ed. The structure and function of muscle. New York. **2**, 243-309.

Berri C, Jehl N. 2001**.** Facteurs de variation de la qualité technologique et organoleptique des viandes de poulet. In : 4ème Journées de la Recherche Avicole 27-28-29 mars 2001, Nantes, France.- Paris INRA, 245-252.

Berri C. 2000. Variability of sensory and processing qualities of poultry meat. World's Poultry Science Journal **56**, 209-224.

Berri C, Debut M, Santé-Lhoutellier V, Arnould C, Boutten B, Sellier N, Baéza E, Jehl N, Jégo Y, Duclos MJ, Le Bihan-Duval E. 2005. Variations in chicken breast meat quality: implications of struggle and muscle glycogen content at death. British Poultry Science **46**, 572-579.

Berri C, Le Bihan-Duval E, Debut M, Santé-Lhoutellier V, Baéza E, Gigaud V, Jégo Y, Duclos MJ. 2007**.** Consequence of muscle hypertrophy on characteristics of Pectoralis major muscle and breast meat quality of broiler chickens. Journal of Animal Science 85, 2005–2011.

Bianchi M, Petracci M, Cavani C. 2006**.** The Influence of Genotype, Market Live weight, Transportation, and Holding Conditions Prior to Slaughter on Broiler Breast Meat Color. Poultry Science **85**, 123–128.

Bogosavljevic-Boskovic S, Mitrovic S, Djokovic R, Doskovic V, Djermanovic V. 2010**.** Chemical composition of chicken meat produced in extensive indoor and free range rearing systems. African Journal of Biotechnology **27**, 9069-9075.

Boutten B, Picard M, Bouvarel I, Mekhtiche L, Larroudé P, Barrier-Guillot B, Roffidal L. 2003**.** Relation entre le pH, la couleur et le comportement en transformation du blanc de poulet en pièces cuites saumurées. Cinquièmes Journées de la Recherche avicole, Tours, 26 et 27 mars 2003, 4p.

Brunel V, Jehl N, Drouet L, Portheau M-C. 2006. Viande de volailles : Sa valeur nutritionnelle présente bien des atouts. Viandes Prod. Carnés **25 (1),** *18-22*.

Castellini C, Dal Bosco A, Mugnai C, Pedrazzoli A. 2006**.** Comparison of two chicken genotypes organically reared: oxidative stability and other qualitative traits of the meat. Italian Journal of Animal Science **5**, 355-363.

Castellini C, Mugnai C, Dal Bosco A. 2002**.** Effect of inorganic production system on broiler carcass and meat quality. Meat Science **60**, 219-225.

Chuaynukool K, Wattanachant S, Siripongvutikorn S. 2007**.** Chemical and properties of raw and cooked spent hen, broiler and Thai indigenous chicken muscles in mixed herbs acidified soup (Tom Yum). Journal of Food Technology **5**, 180-186.

Clinquart A, Leroy B, Dottreppe O, Hornick Jl, Dufrasne I, Istasse L. 2000. Les facteurs de production qui influencent la qualité de la viande des bovins BBB. L'élevage du Blanc Bleu belge – Journée CESAM, 26 mai 2000, 19p.

Corzo A, Schilling MW, Loar II RE, Jackson V, Kin S, Radhakrishnan V. 2009**.** The effects of feeding distillers dried grains with solubles on broiler meat quality. Poultry Science **88**, 432–439.

Cross HR, Durland PR, Seideman SC. 1986. Sensory qualities of meat. In: Bechtel, P.J., ed. Muscle as food. Academic Press, New York, 279-320.

Culioli J, Touraille C, Bordes P, Girard JP. 1990. Caractéristiques des carcasses et de la viande du poulet "label fermier". Arch. Geflugelk **53,** 237-245.

De Marchi M, Cassandro M, Lunardi E, Baldan G, Siegel PB. 2005**.** Carcass characteristics and qualitative meat traits of Padovana breed of chicken. International Journal of Poultry Science **4 (4)**, 233-238.

Debut M, Berri C, Baéza E, Arnould C, Guémené D, Santé-Lhoutellier V, Boutten B, Jégo Y, Chapuis H, Beaumont C, Le Bihan Duval E. 2005**.** Variabilité génétique de la qualité de la viande en relation avec les caractéristiques du muscle et la réponse au stress dans une lignée lourde de poulet. Sixièmes Journées de la Recherche Avicole, St Malo, 30 et 31 mars 2005 ; 524-528p.

Debut M, Le Bihan-Duval E, Berri C. 2004. Impact des conditions de pré-abattage sur la qualité technologique de la viande de volaille. Sciences et Techniques Avicoles **48**, 4-13.

Debut M, Berri C, Baéza E, Sellier N, Arnould C, Guémené D, Jehl N, Boutten B, Jego Y, Beaumont C, Le Bihan-Duval E. 2003**.** Variation of chicken technological meat quality in relation to genotype and preslaughter stress conditions. Poultry Science **82**,1829–1838.

Dransfield E, Sosnicki AA. 1999**.** Relationship between muscle growth and poultry meat quality. Poultry Science **78**, 743–746.

El Rammouz R, Berri C, Le Bihan-Duval E, Babilé R, Fernandez X. 2004**.** Breed differences in the biochemical determinism of ultimate pH in breast muscles of broiler chickens: A key role of AMP deaminase? Poutry Science **83 (8)**, 1445-1451.

El Rammouz R, Berri C, Le Bihan-Duval E, Babilé R, Fernandez X. 2003**.** Biochemical determinism of ultimate pH in breast muscle of broiler chicken. In: Proceedings of XVI European Symposium on the Quality of Poultry Meat, Saint-Brieuc, France, p. 60-65.

Fanatico AC, Cavitt LC, Pillai PB, Emmert JL, Owens CM. 2005**.** Evaluation of Slower-Growing Broiler Genotypes Grown with and Without Outdoor Access: Meat Quality. Poultry Science **84**, 1785–1790.

FAO. 2004. Production en aviculture familiale.131p.

FAOSTAT. 2010. Bases de données statistiques de la FAO, Food and Agriculture Organization of the United Nations, Rome.

Fernandez X, Santé V, Baeza E, Lebihan-Duval E, Berri C, Rémignon H, Babilé R, Le Pottier G, Astruc T. 2002**.** Effects of the rate of muscle post mortem pH fall on the technological quality of turkey meat. British Poultry Science **43**, 245–252.

Fiardo S. 2003**.** La qualité technologique du filet de poulet transformé en blanc de poulet. Mémoire de fin d'études d'Agriculture, Ecole supérieure d'agriculture d'Angers, Angers, France, 40p.

Fletcher DL. 2002**.** Poultry meat quality. World's Poultry Science Journal **58(2)**, 131-145.

Garcia RG, Mendes AA, Costa C, Paz ICLA, Takahashi SE, Pelícia KP, Komiyama CM, Quinteiro RR. 2005**.** Desempenho e qualidade da carne de frangos de corte alimentados com diferentes níveis de sorgo em substituição ao milho. Arquivo Brasileiro de Medicina Veterinária e Zootecnia **57(5)**, 634-643.

Gigaud V, Debut M, Berri C, Le Bihan-Duval E, Travel A, Bordeau T. 2006. Influence des facteurs ante-mortem sur la qualité technologique des filets de poulet de type standard et label. 11èmes Journées des sciences du muscle et technologies des viandes (Clermont-Ferrand, France, 10/04/2006). Viandes et Produits carnés, **numéro hors-série**, 213-214.

Gigaud V, Berri C. 2007**.** Influence des facteurs de production sur le potentiel glycolytique musculaire : impact sur la qualité des viandes. Office 2006-2007, 44 p.

Gigaud V, Geffrard A, Berri C, Le Bihan-Duval E, Travel A, Bordeau T. 2007**.** Conditions environnementales ante-mortem (ramassage-transport-abattage) et qualité technologique des filets de poulet standard. 7ème Journées de la Recherche Avicole (Tours, France), 470-474.

Gigaud V, Bordeau T, Le Bihan-Duval E, Berri C. 2008**.** Impact du pH ultime sur les qualités bactériologiques et gustatives des filets de poulet. 12èmes Journées des sciences du muscle et technologies des viandes (Tours, France, 08 et 09/10/2008), 61-62.

Gordon SH, Charles DR. 2002**.** Niche and Organic Chicken Products. Nottingham University Press, Nottingham, UK, 11p.

Guillevic M, Kouba M, Mourot J. 2009. Un apport en graines de lin extrudees chez le poulet et la dinde participent à l'amélioration de la qualité nutritionnelle de la viande. Meat Science **81**, 612-618.

Groom GM. 1990. Factors affecting poultry meat quality. Options Méditerranéennes, Série A_1 **7**, 6p.

Havenstein GB, Ferket PR, Qureshi MA. 2003. Carcass composition and yield of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry Science **82**, 1509–1518.

Hector L. 2002**.** Biological, nutritional, and processing factors affecting breast meat quality of broilers. Ph.D. thesis. of Faculty of Virginia, Polytechnic Institute. 181p.

Holcman A, Vadnjal R, Zlender B, Stibilj V. 2003. Chemical composition of chicken meat from free range and extensive indoor rearing. Archiv für Geflügelkunde, **67(3)**, p. 120-124.

Huda M, Putra AA, Ahmad R. 2001**.** Potential application of duck meat for development of processed meat product. Current Research in Poultry Science **1(1)**, 1-11.

Husak RL, Sebranek JG, Bregendahl KA. 2008**.** Survey of commercially available broilers marketed as organic, free range, and conventional broilers for cooked meat yields, meat composition and relative value. Poultry Science **87**, 2367-2376.

Immonen K, Ruussumen M, Puolanne E. 2000**.** Some Effects of Residual Glycogen Concentration on the Physical and Sensory Quality of Normal pH Fall. Meat Science **55**, 33-38.

Ingr, I. 1989**.** Meat quality: Defining the term by modern standards. Fleisch **69**, 1268p.

ISO. 1994**.** Norme 8402. Quality management and quality assurance-Vocabulary. International Organisation for Standardization, Geneva, Switzerland, 1994.

Janisch S, Krischek C, Wicke M. 2011**.** Color values and other meat quality characteristics of breast muscles collected from 3 broiler genetic lines slaughtered at 2 ages. Poultry Science **90**, 1774–1781.

Jassim JM, Riyad KM, Majid HA, Yanzhang G. 2011. Evaluation of physical and chemical characteristics of male and female ducks carcasses at different ages. Pakistan Journal of Nutrition 10 (2): 182-189. ISSN 1680-5194.

Jaturasitha S, Khiaosaard R, Pongpaew A, Leowtharakul A, Saitong S, Apichatsarangkul T, Leaungwunta V. 2004**.** Carcass and indirect meat quality of native and Kai Baan Thai chickens with different sex and slaughter weight, in: Proceedings of the 42nd Annual Conference. Kasetsart University, Bangkok, Thailand, 116-126.

Jaturasitha S, Srikanchai T, Kreuzer M, Wicke M. 2008a**.** Differences in carcass and meat characteristics between chicken indigenous to Northern Thailand (Blackboned and Thai native) and improved extensive breeds (Bresse and Rhode Island Red). Poultry Science **87**, 160-169.

Jaturasitha S, Kayan A, Michael W. 2008b**.** Carcass and meat characteristics of male chickens between Thai indigenous compared with improved layer breeds and their crossbred. Archives of Animal Breeding (Arch. Tierz.), Dummerstorf **51(3)**, 283-294.

Jehl N, Boutten B, Le Bihan-Duval E, Berri C, Monin G, Deschodt G, Jego Y , Allain L. 2001. Qualité technologique de la viande de poulet : Adaptation des qualités technologiques de la viande de poulet aux nouvelles demandes des transformateurs : étude des possibilités d'amélioration offertes par la génétique et de l'impact du stress avant abattage. Centre Technique de la Salaison, de la Charcuterie et des Conserves de Viandes **11(4)**, 229-230.

Konrád SZ, Gaál KK. 2009. Effect of genotype, sex and keeping technology on the chemical compounds of breast and thigh meat. Lucrări ştiinţifice Zootehnie şi Biotehnologii of Timişoara **42 (2)**, 7p.

Larzul C, Le Roy P, Gogué J, Talmant A, Jacquet B, Lefaucheur L, Ecolan P, Sellier P, Monin G. 1999. Selection for reduced muscle glycolytic potential in Large White pigs: Correlated responses in meat quality and muscle compositional traits. Genet Sel Evol **31**, 61-76.

Latter-Dubois. 2000. Poulets Fermiers: Leurs Qualités Nutritionnelle et Organoleptique et la Perception du Consommateur. Master of Science Thesis. Faculté des Sciences de l'Agriculture et de l'Alimentation, Université Laval, Quebec, Canada, 117p.

Lawrie RA. 1966. Metabolic Stresses Which Affect Muscle. In: Briskey, E. J., Cassens, R. G., and Trautman, J. C., ed. The Physiology and Biochemistry of Muscle as Food. University of Wisconsin Press, Madison, p. 137-164.

Le Bihan-Duval E, Berri C, Baéza E, Millet N, Beaumont C. 2001 Estimation of the genetic parameters of meat characteristics and of their genetic correlations with growth and body composition in an experimental broiler line. Poultry Science **80**, 839-843.

Le Bihan-Duval E, Millet N, Rémignon H. 1999. Broiler meat quality: effect of selection for increased carcass quality and estimates of genetic parameters. Poultry Science **78**, 822-826.

Le Bihan-Duval E, Berri C, Baéza E, Santé V, Astruc T, Rémignon H, Le Pottier G, Bentley J, Beaumont C, Fernandez X. 2003 Genetic parameters of meat technological quality traits in a grand-parental commercial line of turkey. Genet Sel Evol **35,** 623-635.

Le Bihan-Duval E, Debut M, Berri CM, Sellier N, Santé-Lhoutellier V, Jégo Y, Beaumont C. 2008. Chicken meat quality: genetic variability and relationship with growth and muscle characteristics. BMC Genetics **9(53)**, 6p.

Le Bihan-Duval E, Berri C, Pitel F, Nadaf J, Sibut V, Lagarrigue S, Duclos MJ. 2010. A la croisée de la génomique positionnelle et fonctionnelle : application à l'identification d'une mutation chez le poulet et perspectives de recherches en qualité de la viande. 13èmes Journées des sciences du muscle et technologies des viandes (Clermont-Ferrand, 19 et 20 Octobre 2010), France, P. 201-207.

Lengerken Von G, Maak S, Wicke M. 2002. Muscle metabolism and meat quality of pigs and poultry. Veterinarija Ir Zootechnika **20**, 82-86.

Lonergan SM, Deeb N, Fedlet CA, Lamont SJ. 2003. Breast meat quality and composition in unique chicken populations. Poultry Science **82**, 1990–1994.

López KP, Schilling MW, Corzo A. 2011. Broiler genetic strain and sex effects on meat characteristics. Poultry Science **90**, 1105–1111.

Maltin C, Balcerzak D, Tilley R, Delday M. 2003. Determinants of meat quality: tenderness. Proceedings of the Nutrition Society **62**, 337–347. © Rowett Research Institute 2003.

McKee SR, Sams AR. 1998. Rigor mortis development at elevated temperatures induces pale exudative turkey meat characteristics. Poultry Science **77**, 169-174.

Mehaffey, JM, Pradhan SP, Meullenet JF, Emmert JL, Mckee SR, Owens CM. 2006. Meat quality evaluation of minimally aged broiler breast fillets from five commercial genetic strains. Poultry Sciences **85**, 902–908.

Mikulski D, Celej J, Jankowski J, Majewska T, Mikulska M. 2011. Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. Asian-Australian Journal of Animal Science **24(10)**, 1407 – 1416.

Missohou A, Dieye PN, Talaki E. 2002. Rural poultry production and productivity in southern Senegal. Livestock Research for Rural Development **14 (2).**

Mourrot J, Chesneau G. 2008. Modification de la qualité nutritionnelle des produits animaux. 3ème journée CEREL, Rennes, 3 et 4 juillet 2008, p. 14-23.

Nadaf J, Gilbert H, Pitel F, Berri CM, Feve K, Beaumont C, Duclos MJ, Vignal A, Porter TE, Simon J, Aggrey SE, Cogburn LA, Le Bihan-Duval E. 2007. Identification of QTL controlling meat quality traits in an F2 cross between two chicken lines selected for either low or high growth rate. BMC Genomics **8**, 155p.

Nadaf J, Le Bihan-Duval E, Dunn IC, Berri CM, Beaumont C, Haley CS, De Koning DJ. 2009. EAAP – 60th Annual Meeting, Barcelona, p138.

Nakamura YN, Iwamoto H, Shiba N, Miyachi H, Tabata S, Nishimura S. 2004. Growth changes of the collagen content and architecture in the *pectoralis* and *iliotibialis lateralis* muscles of cockerels. British Poultry Science **45(6),** 753-761.

Northcutt J, Burh RJ. 2001. Pre-slaughter factors affecting poultry meat quality. Chapter 2. In: Alan R. Sams ed., Poultry meat processing. 345p

Northcutt JK, Buhr RJ, Young LL, Lyon CE, Ware GO. 2001. Influence of age and postchill carcass aging duration on chicken breast fillet quality. Poultry Science **80**, 808–812.

Oguz I, Aksit M, Önenc A, Gevrekci Y, Özdemir D, Altan Ö. 2004. Genetic variability of meat quality characteristics in Japanese quail (*Coturnix coturnix japonica*). Arch Geflügelk **68**, 176-181.

Oluwatosin O, Olawoyin E, Agiang A, De Neji C, Iso E. 2007. Nutritional evaluation of the thigh and breast muscles of four cockerel strains. African Journal of Animal and Biomedical Sciences **2(2),** 26-31.

Oluyemi JA, Roberts FA. 2000. Poultry production in warm wet climates. 2nd edition, Ibadan, Spectrum book limited **2 (2)**, 57-62.

Onibon P, Sodegla H. 2006. Etude de la sous filière aviculture moderne au Bénin. Rapport intégral. p. 5-51.

Owens CM, Hirschler EM, McKee SR, Martinez-Dawson R, Sams AR. 2000. The characterization and incidence of pale, soft, exudative turkey meat in a commercial plant. Poultry Science **79,** 53-558.

Petracci M, Fletcher DL. 2002. Broiler skin and meat color changes during storage. Poultry Science **81**, 1589–1597.

Petracci M, Fletcher DL, Northcutt JK. 2001. The effect of holding temperature on live shrink, yields and breast meat quality of broiler chicken. Poultry Science **80**, 670–675.

Qiao M, Fletcher DL, Smith DP, Northcutt JK. 2001. The effect of broiler breast meat color on pH, moisture, water holding capacity, and emulsification capacity. Poultry Science **80**, 676–680.

Quentin M, Douvarel I, Berri C, Le Bihan-Duval E, Baeza E, Jego Y, Picard M. 2003. Growth, carcass composition and meat quality response to dietary concentrations in fast-, medium- and slow-growing commercial broilers. Animal Research **52**, 65-77.

Roy IO, Miyachi H, Nishimura S, Tabata S, Iwamoto H. 2007. Effects of nutritional level and carcass weight on the different anatomical body parts and muscle weights of male broilers Bimol Chandra. Journal of Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan, **52(1)**, 43–48.

Sams AR, and Mills AD. 1993. The effect of feed withdrawal duration on the responsiveness of broiler pectoralis to Rigor mrtis acceleration. Poultry Science **72**, 1789-1796.

Santé V, Fernandez X, Monin G, Renou JP. 2001. Nouvelles méthodes de mesure de la qualité de la viande de volaille. INRA Productions animales **14 (4)**, 247-254.

Santos AL, Sakomura NK, Freitas ER, Fortes CMS, Carrilho ENM. 2005. Comparison of free range broiler chicken strains raised in confined or semi-confined systems. Revista Brasileira de Ciência Avícola **7(2)**, 85-92.

Sauveur B. 1997. Les critères et facteurs de la qualité des poulets "label rouge." INRA Productions Animales **10**, 219–226.

Savenije B, Lambooji E, Gerritzen MA, Venema K, Korf J. 2002. Effects of feed deprivation and transport on preslaugter blood metabolites, early postmortem muscle metabolites, and meat quality. Poultry Science **81,** 699-708.

Scheuermann GN, Bilgili SF, Hess JB, Mulvaney DR. 2003. Breast muscle development in commercial broiler chickens. Poultry Science **82**, 1648–1658.

Schilling MW, Schilling JK, Claus JR, Marriott NG, Duncan SE, Wang H. 2003. Instrumental texture assessment and consumer acceptability of cooked broiler breast evaluated using a geometrically uniform-shaped sample. Journal of Muscle Foods **14**, 11–23.

Schreurs FJG. 1999. Post Mortem Changes in Chicken Muscle. Ph.D. Thesis. Wageningen Agricultural University, Wageningen, Netherlands, 185p.

Shawkat A, Geun-Ho K, Seon Tea J. 2008. A review: influences of pre-slaughter stress on poultry meat quality. Asian - Australasian Journal of Animal Sciences **21(6)**, 912 – 916.

Shen Y, Feng D, Fan Ming Z, Chavez Eduardo R. 2005. Performance, carcass cut-up and fatty acids deposition in broilers fed different levels of pellet-processed flaxseed. Journal of the Science of Food and Agriculture **85,** 2005-2014.

Stewart MK, Fletcher DL, Hamm D, Thomson JE. 1984. The effect of hot boning broiler breast muscle on postmortem pH decline. Poultry Science **63**, 2181–2186.

Suchý P, Jelínek P, Straková E, Hucl J. 2002. Chemical composition of muscles of hybrid broiler chickens during prolonged feeding. Czech Journal of Animal Science **47(12)**, 511–518.

Sunday OP, Olusegun MOI, Brilliant OA, Raphael OE, Adeboye OF. 2010. Genotype and Sex Effect on Gastrointestinal Nutrient Content, Microflora and Carcass Traits in Nigerian Native Chickens. International Journal of Poultry Science **9(8)**, 731-737.

Touraille C. 1994. Influence of muscle characteristics on sensory properties of meat. Renc. Rech. Ruminants **1**, 169 – 176.

Valin C. 1988. Différenciation du tissue musculaire : conséquences technologiques pour la filière viande. Reproduction Nutrition Développent **28(3B),** 845-856.

Van Kaam JB, Groenen MA, Bovenhuis H Veenendaal A, Vereijken ALJ, Van Arendonk J. 1999. Whole genome scan in chickens for quantitative trait loci affecting carcass traits. Poultry Science **78**, 1091–9.

Wattanachant C, Songsang A, Wattanasit S, Adulyatham P, Wattanachant S. 2004. Carcass quality, chemical composition, physical properties and textural characteristics of meat from naked-neck chicken and common Thai indigenous chicken. Prince of Songkla University. Songkhla, Thailand, 158p.

Wattanachant S. 2008. Factors affecting the quality characteristics of Thai indigenous chicken meat**.** Suranaree Journal of Science and Technology **15(4)**, 317-322.

Wattanachant S, Wattanachant C. 2007. Chemical composition, properties and microstructure of Thai indigenous chicken muscles as influenced by age and rearing systems. Research report, Prince of Songkla University. Songkhla, Thailand, 77p.

Wołoszyn J, Książkiewicz J, Skrabka-Błotnicka T, Haraf G, Biernat J, Kisiel T. 2006. Comparison of amino acid and fatty acid composition of duck breast muscles from five flocks. Arch Tierz **49**, 194-204.

Xiong XL, Cantor AH, Pescatore AJ, Blanchard SP, Straw ML. 1993. Variations in muscle chemical composition, pH, and protein extractability among different broiler crosses. Poultry Science **72**, 583-588.

Youssao AKI, Senou M, Dahouda M, Kpodekon TM, Djenontin J, Idrissou N-D, Bonou AG, Tougan PU, Assogba HM, Bankole E, Rognon X, Tixier-Boichard M. 2009. Genetic improvement of local chickens by crossing with the Label Rouge (T55XSA51): growth performances and heterosis effects. International Journal of Poultry Science **8 (6)**, 536-544.

Zanusso J, Rémignon H, Auvergne A, Molette C, Manse H, Babilé R. 2001. Caractéristiques Zootechniques et Qualités de la Viande du Poulet : Comparaisons entre Mâles, Femelles et Chapons. In: Quatrième Journées de la Recherche Avicole, Nantes, France, 269-272.