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Meat quality in "in door" and "out door" production systems of poultry and swine

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ABSTRACT

The meat quality can be influenced by many interacting factors before and after the slaughter. Currently more sustainable production systems are targeted in general, whether or not they have any effect on meat quality. The sustainability is a condition of agroecology and necessarily implies on the animal and plant association and succession. A condition for sustainability is to minimize or even eliminate the use of inputs from processes of chemical synthesis. In the case of pigs and poultry, this is feasible by adopting production systems that allows nutriaents recycle directly on the soil at levels that do not involve pollution. Although we have the understanding that the general principles of sustainability to be observed are universal, the solution is not simple. For each situation a viable alternative must be sought, depending on the social, economic, ecological and cultural realities. In tropical and subtropical climates the production of pigs and poultry outdoors can be an appropriate option. This also leads to nutriaents recycle and promotes a better energy balance of the system. Among the alternatives that can be taken to introduce differentiating factors in meat production as food is the type of production system, due to its direct impact on the meat quality. These systems have a direct influence through the consumed food, by the conditions of animal wellbeing, physical activity and the environment provided. The performance and meat quality depend on the interaction of genotypes, rearing conditions, pre-slaughter handling and processing of the meat and the carcass. The influence of the rearing system on the animal performance, on the carcass and finally on the meat is the result of the interactive effects among facilities, feeding level and genotype used in the production systems. The production of poultry and pigs more extensively tend to get a final product with its own organoleptic characteristics, changing the meat default color and content, place of fat deposition and the fatty acid profile deposited on the carcass.

Keywords: Alternative Systems; Meat Quality; Poultry; Swine

1. INTRODUCTION

The technological, nutritional and sensorial meat quality can be influenced by many interacting factors before and after the slaughter. Currently more sustainable production systems are targeted in general, whether or not they have any effect on meat quality.

Following the example of what happens in the world, the alternative rearing of swine and poultry in Brazil has found more supporters among the business makers, which is also an alternative for small and medium producers who aim at a more profitable market niche (Demattê Filho & Mendes, 2001).The main desired characteristics in these farming systems are: health security, the organoleptic quality of the product, the growing concern over the environment, animal welfare and consumers' health (Bastianelli, 2001).

The sustainability is a condition of agroecology and necessarily implies on the animal and plant association and succession. A condition for sustainability is to minimize or even eliminate the use of inputs from processes of chemical synthesis. In the case of pigs and poultry, this is feasible by adopting production systems that allows nutrients recycle directly on the soil at levels that do not involve pollution.

Although we have the understanding that the general principles of sustainability to be observed are universal, the solution is not simple. For each situation a viable alternative must be sought, depending on the social, economic, ecological and cultural realities. In tropical and subtropical climates, such as in Brazil, the production of pigs and poultry outdoors can be an appropriate option. This also leads to nutrients recycle and promotes a better energy balance of the system.

In the past few years it has been consolidated, in many countries, a consumer market willing to pay more for products with "ethical quality" (Warriss, 2000). In Britain, for example, organic pork is twice the price of conventional and the demand is greater than the supply (Edwards, 1999). Also in Brazil there are indications that at least a portion of the consuming public is willing to pay more for organic beef and pork (Machado Filho, 2000).

Among the alternatives that can be taken to introduce differentiating factors in meat production as food is the type of production system, due to its direct impact on the meat quality. These systems have a direct influence through the consumed food, by the conditions of animal wellbeing, physical activity and the environment provided (Dal Bosco *et al.*, 2002).

The performance and meat quality depend on the interaction of genotypes, rearing conditions, pre-slaughter handling and processing of the meat and the carcass. The influence of the rearing system on the animal performance, on the carcass and finally on the meat is the result of the interactive effects among facilities (type of floor, the space, environmental temperature, physical activity), feeding level and genotype used in the production systems (Lebret, 2008).

Some studies indicate increased water retention capacity in meat produced outdoors. On the other hand, the outdoor production may further increase the meat shear force compared to conventional systems (Olsson & Pickova, 2005). The color can be affected in different ways, generating more pigmented or pale meat (depending on the system), structurally affecting the meat (Olsson & Pickova, 2005). The greater unsaturated lipid profile of meat produced in a system that includes foods containing polyunsaturated fatty acids (fodder) is favorable, in relation to the nutritional meat quality, when compared to conventional total confinement (Olsson & Pickova, 2005).

1.1. Implications

So the best knowledge of the organoleptic changes in pork and chicken, through alternative systems of production, could determine the encouragement of agricultural activities that would ensure better welfare of animals through the rationale of improving the quality of the final product. From another viewpoint, these systems would fit better on little farms with family labor, making them more competitive with differentiated products of high added value.

1.2. Muscle Fiber Types and Meat Quality

Understanding the growth and muscle development is one of the most important aspects in animal science, since this is the end product of systems aimed to meat production. There are two types of skeletal muscles, the red and the white. The red is composed predominantly of oxidative fibers and the white muscle is composed predominantly of glycolytic fibers (Lawrie, 2005).

According to Rehfeldt *et al.* (2000), muscle mass is mostly determined by the number of muscle fibers and the size of these fibers. Animals with more moderately sized muscle fibers produce better quality meat. During myogenesis, the number of muscle fibers is determined by genetic and environmental factors. The same authors state that after birth the total number of fibers remains constant in mammals and birds and that the increased skeletal muscle mass is mainly due to hypertrophy of fibers, together with the proliferative activity of satellite cells, which are source of new cores that are going to be embedded in the muscle fiber.

According Lefaucheur & Gerrard (2000), the muscle's weight is a function of the fiber type, relative size and length of the fiber. The growth capacity is related to the number of muscle fibers. The glycolytic fibers have higher relative volume and the increase in the proportion of these could lead to an increase in muscle weight.

To understand the muscle development is essential studying the mechanisms that regulate the number, type and size of muscle fibers. These variations of the muscle fibers are related to several factors that interfere with muscle development in the prenatal and postnatal development periods (Dauncey & Gilmour, 1996). Among these factors it can be cited those intrinsic to the animals (genetic, growth regulators, transcription activators, endocrine status, muscle proteinases and innervation), environmental factors (diet and temperature), motor activity, agents splitters of nutrients (ractopamine in pig feed), age, sex, disease, type and location of muscle fibers in the muscle (Gonzales & Sartori, 2002).

To understand the importance of the factors that affect growth and protein deposition in muscle, one must consider the impact of these factors on the quality of the muscle that will be transformed into food for human. But the meat quality is not only determined by the intrinsic (physiological) and extrinsic (environment) influences on the bird's muscle in the period preceding his death. Once the muscle tissue is dynamic, it also responds to environmental influences during and after the animal's death. The type of processing, considering the slaughter and the carcass treatment, interacts with the muscle's characteristics and, together, will determine the meat quality (Pearson & Young, 1989).

Both in birds and mammals, three types of muscle fibers can be identified based on their metabolic and contractile characteristics: Type I - slow twitch and oxidative (SO), type IIA-fast twitch oxidative (FOG) and type IIB / X- fast twitch glycolytic (FG) (Macari *et al.* 2002; Lawrie, 2005).

The type I fibers are small, have many mitochondria, myoglobin pigment in abundance and are well vascularized, which gives them their red color. The mitochondria are large and have numerous cristae. The storage of oxygen by myoglobin prevents fatigue. The type IIA fibers are medium sized with oxidative and glycolytic energy metabolism, having numerous mitochondria and myoglobin, high vascularization and are resistant to fatigue, while the type IIB fibers are large, with few mitochondria and myoglobin, with glycolytic energy metabolism and poor vascularization , besides being easily fatigable and easily accumulate lactic acid (Macari *et al.* 2002; Lawrie, 2005).

The predominant muscle fiber type is especially important for the carcass quality of pigs. Due to the generally higher content of glycogen in type II fibers compared to type I, there would be a great anaerobic glycollytic potential on those during the *post mortem*. This results in sharp drop in pH, resulting in a meat called PSE (*pale*, *soft and exudative*) (Lawrie, 2005).

Swines of the Piétrain breed have greater genetic tendency to higher prevalence of such a failure, both due to the presence of the halothane gene and the predominance of type II fibers (Lawrie, 2005). However other factors may influence the formation of the fibers, thereby changing their characteristics, such as exercise and the animal's age (Lawrie, 2005). In general physical training (long term) may increase the myoglobin content of muscle fibers. In this way there is a change in their initial physical characteristics, making the fibers more likely to express aerobics features, since myoglobin becomes an intracellular oxygen reserve (Lawrie, 2005).

Also Sosnicki *et al.* (1996) reported the importance of the presence of white fibers, affecting the meat quality, due to change in meat pH, making it acidic after slaughter, due to the glycogen content of the cells that form the white muscle fibers. This implies on a loss in industrial yield from certain carcass cuts of pork, especially ham, when cooked without the addition of phosphate.

Another determining factor in swine carcass quality is the content of intramuscle fat (marbling), affecting the meat appearance and taste. This has been identified as an important factor in determining the consumer preference for the consumption of pork (Plastow, 2000).

In birds the chest muscle, white colored, has predominantly FG and FOG fibers and histologically presents low density of blood capillaries and contain few mitochondria. The red muscles, from the thigh and drumstick, on the other hand, are richly vascularized and contain a large number of mitochondria in the fibers which are mainly of the SO and FOG types (Macari *et al.*, 2002).

According to Gonzales & Sartori (2002), the distribution of muscle fibers in a certain type of muscle is a functional adaptation from its various kinds of activities. Thus, the rate of different muscle fibers types in a muscle is directly correlated with its function in the bird's body. In agreement, Remignon *et al.* (1994) reported that the frequency of different types of muscle fibers in broilers is primarily related to the muscle function. The breeding of broiler chickens for increasing muscle mass and speeding growth reduced the muscle's oxidative capacity, resulting in a more anaerobic muscle (Soike & Bergmann, 1997). Therefore, the meat of broiler chickens has lighter color due to the muscles being more anaerobics.

According to Macari *et al.* (2002), after the bird's death, the tissues are deprived of oxygen, resulting in anoxia. In this situation, with the continuity of their metabolic activity, the muscle fibers rely solely on the anaerobic mechanisms for the ATP production. Thus, using the glycogen that is quickly consumed. Concomitantly, occurs an accumulation of lactic acid, the end product of anaerobic metabolism, due to its non-removal via the bloodstream. The anaerobic metabolism reduces sarcoplasmic pH level which inhibits glycolysis, ceasing the ATP production. But the ATP consumption continues, reaching critical mass, so that the dissociation of the actin-myosin system is not performed. Due to the formation of the actin-miosin complex, the muscle loses its plasticity and gets unable to relax; hence the *rigor mortis* takes place (Gonzales & Sartori, 2002).

The time to develop the process of *rigor mortis* depends on the muscle type, the frequency of fibers types in the muscle, the speed of pH tissue fall and the environmental factors before and after slaughter that the animals were submitted (Gonzales & Sartori, 2002). Changes in the establishment of the *rigor mortis* may increase the meat pallor and its ability to reduce fluid retention, worsening the quality of the processed products (Dransfield & Sosnicki, 1999).

2. FORAGES

The replacement of part of the concentrate feed (diets based on corn and soybean meal) for fodder (forages), is one of the causes of the production system influence on pigs' and poultry's carcass. The animals when begin to eat forage have a greater development of the gastrointestinal tract as an adaptation to increased dietary fiber. This is due mainly to the production of volatile fatty acids by allozyme processes (bacterial activity), especially in the cecum of these animals. However only a small portion of the energy required for both maintenance and production is resulting from such sources, being essential the concentrate feeding to not compromise the production index. Also due to the low protein content of these sources and low nutritional contribution of bacterial protein in the nutrition of monogastric animals, it becomes necessary the protein nutrition almost in its entirety coming from the concentrated feed.

One of the main influences is the lipid type contained in these forages and how they are deposited on the carcass. The total lipids content in forages is variable (4% - 12% of the dry matter), being greater the younger they are, with the highest proportion in the leaves, and from these the majority are chloroplast lipids. The latter may have an impact mainly on aspects related to the meat color.

The fatty acid composition of forages is characterized by a high percentage of polyunsaturated acids, particularly linolenic acid (C18: 3 Ω-3), which represents over 50% of total fatty acids, followed by linoleic acid (C18: 2 Ω-6, 10% - 20%).They present a relationship Ω-6/Ω-3 of 0.20, whereas the content of saturated fatty acids (10% - 20%) and monounsaturated fatty acids (1% - 17%) is low.

The forages are rich in linoleic acid and low in saturated lipids when young and rich in oleic acids in vegetative stages more advanced (Morand-Fehr & Tran, 2001). Moreover, the quality of the adipose tissue in relation to its nutritional value, organoleptic characteristics and conservation is related to its fatty acid composition (Lizardo *et al.*, 2002).

The composition of lipids in the carcass of pigs and poultry is influenced by several factors, such as genotype, sex, age, animal's weight (Girard *et al.*, 1988), the location of fat deposition in the carcass (Miller *et al.* 1990), environmental temperature (Katsumata *et al.* 1995) and especially nutrition. The latter is mainly influenced by the energy and fat content in the diet, fatty acid composition and daily fatty acids consumption (Wiseman & Agunbiade, 1998).

In their study, Ponte *et al.* (2008), broilers of the RedBro Cou Nu X RedBro M genotype were fed on a cereal-based diet in portable floorless pens located either on subterranean clover (Trifolium subterraneum) pastures and without access to pasture. Unlike the imagined, the pasture intake had a low impact on the fatty acid and vitamin E homologue profiles of meat from free-range broilers. However, breast meat from birds with free access to pasture presented lower levels of the n-6 and n-3 fatty acid precursors linoleic acid (18:2n-6) and α-linolenic acid (18:3n-3), respectively. In the same work, contrary to other results, the levels of eicosapentaenoic acid (20:5n-3) in breast meat were significantly greater in birds consuming pastures, which suggests greater conversion of α-linolenic acid into eicosapentaenoic acid in these birds.

3. SWINE PRODUCTION

The production of pigs outdoors offers a greater variety of environments for animals and greater freedom of behavior, but poses challenges for the breed adaptation, management control, biosafety and ambience. Each of these has potential implications for the real and perceived quality of the product.

According to Edwards (2005) in most conventional production systems of northern Europe only adult animals and infants remain in the pasture. However, in the Mediterranean traditional systems and in organic production systems, animals can be kept throughout his life outdoors. Influences on the organoleptic quality of products derive from the choice of breeds better suited to outdoor systems, changes to the rate of growth and increased proportion of roughage on the diet.

According to Honeyman (2005) recently in the United States the production of pigs outdoors using tents has been used for finishing pigs and gestating sows. The seasonal outdoor lambing and indoor (winter/summer) in some systems, along with lactation group has also been used, as the example of the French system (*plein air*). Most of the meat markets, mainly in Europe, has required adjustments in order to encourage the use of outdoor systems or straw, the withdrawal of subtherapeutic doses of antibiotic growth promoters and there are still a encourage to a family environment agricultural production (Honeyman, 2005).

Indirect consequences would have positive and negative influences on the physiological responses to stress during pre-slaughter (Edwards, 2005). Although some aspects of animal health and hygiene can be improved, in broader conditions, the exposure to parasites and contact with wild animals may increase the risk of zoonotic infection (Edwards, 2005). Product quality attributes can be influenced positively or negatively, depending on the consumers' opinion, the quality of management and the creation of units of pigs outdoors visible to the public as marketing, reiterating the argument of the ethical quality of the product.

4. GENETIC FACTORS

Currently, the goal to continue increasing the content of meat in the carcass is becoming more complex, since there is a trend of increase in slaughter weight of pigs which decreases the rate of lean deposition at the expense of a higher rate of fat deposition (Moreira, 1998). Also, the intense genetic selection for production of pig carcass with less fat content has caused a negative effect on meat quality (Terra & Fries, 2000; Rübensam, 2000), besides contributing for the reduction of food intake, thereby affecting the animals growth rate.

Especially, animals selected for muscle deposition have low rate of feed intake and lower growth rate and are associated with the presence of the halothane gene whose effect is related to the metabolic changes that leads to the intense and accelerated decrease of pH that, in turn, affects the color and the ability to retain water, besides affecting the organoleptic properties of meat such as tenderness, juiciness and flavor.

The **Table 1** shows the heritability values for color, marbling, water holding capacity, tenderness, pHu (pH after 24 hours of slaughter) and the genetic correlation among these meat quality characteristics with the daily weight gain, backfat thickness,% carcass meat and the intramuscle fat content (Sosnicki *et al*. 1996).

Thus the improvement to the amount of carcass meat results in an adverse effect on color, intramuscle fat content, water holding capacity, tenderness and meat's pHu.

5. PRODUCTION SYSTEMS

According to Lebret (2008), the environmental enrichment (more space, straw bedding) generally increases the rate of growth, carcass fat and can improve the juiciness of the meat and taste due to the increased intramuscular fat. The outdoor criation and organic production systems have different effects on growth rate and carcass fat, depending on the weather conditions and the feed (Lebret, 2008).

The influence on meat quality is also controversial: higher drip, smaller pHu and more tender meat systems were reported in "*indoor*" (confinement), while some studies show better meat juiciness through outdoor creation (Lebret, 2008). The discrepancies could probably be due to differences among studies in the creation of conditions and the physiological responses of pigs to pre-slaughter treatment.

Specific systems of production in the Mediterranean area based on local breeds (low growth rate, high fat) and finishing systems "*Free Range*" (pastures, forests), which allow the animal to express its genetic potential for intramuscle fat deposition, clearly demonstrate the positive effects of the interaction "genetic *VS* production system" in the quality of pork and its derivatives.

In Brazil, there are few studies reporting the differences of systems indoor and outdoor on pork quality. Bridi *et al.* (2003a) verified that pigs housed in the outdoor system showed lower performance and carcass characteristics (carcass weight, warm and cold) compared to the conventional system and housed in bunk beds (**Tables 2** and **3**). Similar results were observed by Sather *et al.* (1997) in the Canadian summer conditions. However, on the cold season, the pigs raised in confinement on a bed of wood shavings had similar warm carcass weight to the outdoors. According to Heyer *et al.* (2006) outdoor pigs also had lower dressing percentage than the pigs indoor.

To Bridi *et al.* (2003b), the rearing system have not affected the values of initial and final pH or water hold-

Table 1. Heritability and genetic correlations among meat quality traits, carcass traits, and growth rate.

Parameter	Value	Color	Intramuscle Fat	Water retention capacity	Tenderness	pHu
H2	Average	0.3	0.50	0.20	0.30	0.20
	Amplitude	0.10/0.60	0.25/0.65	0.05/0.65	0.20/0.40	0.10/0.40
Rg Weight Daily Gain	Average	–0.15 (U)	0.40	0.00		–0.15 (U)
	Amplitude	–0.5/0.15	0.15/0.60	–0.80/0.50		–0.40/0.50
Rg Backfat Thickness	Average	0.20 (F)	0.20	0.20 (F)	0.20 (F)	0.15 (F)
	Amplitude	–0.20/0.60	–0.20/0.60	–0.20/0.80	–0.20/0.40	0.40/0.50
Rg % carcass meat	Average	–0.25 (U)	–0.20 (U)	–0.35 (U)	–0.20 (U)	–0.10 (U)
	Amplitude	–0.60/0.20	–0.50/0.40	–0.80/0.25	–0.60/0.20	–0.70/0.35
Rg Intramuscle Fat	Average	–0.20 (U)		–0.05 (U)	0.25 (F)	0.00
	Amplitude	–0.10/0.35			0.20/0.30	–0.20/0.40

H^2 - Herdability Values; R_g - Genetic Correlation; pHu - Meat's pH 24 hours after slaughter; F - Value of Favorable Correlation; U - Value of Unfavorable Correlation; Source: Sosnicki *et al.* 1996.

Table 2. Effect of the production system type on the carcass parameters of pigs.

Production System	Warm carcass weight (kg)	Cold carcass weight (kg)	Carcass yield (%)	Cooling loss (%)
"Indoor" no bed	74.5 [ab]	72.6 [ab]	75.5	2.62
"Indoor" with bed	75.0 [a]	73.3 [a]	75.0	2.26
"Outdoor"	71.1 [b]	69.4 [b]	74.9	2.48

[ab]Means followed by different letters in the same column show significant difference ($P < 0.05$), Source: Bridi *et al.* (2003a).

Table 3. Effect of the production system type on the quantitative carcasses characteristics of pig obtained by the Hennessey Grading Probe.

Production System	Fat thickness (mm)	Muscle depth (mm)	Percentage of lean meat (%)	Amount of carcass meat (kg)
"Indoor" with bed	17.2 [a]	56.6	53.8 [b]	40.1
"Outdoor"	13.3 [b]	56.6	56.2 [a]	40.0

[ab]Means followed by different letters in the same column show significant difference ($p < 0.05$); Source: Bridi *et al.* (2003a).

ing capacity of pork. The higher incidence of PSE meat (pale, soft and exudative) was observed in the carcasses of pigs reared under confined systems compared to outdoor animals.

However, in a previous study comparing the carcasses of pigs reared outdoors with the confined, Bridi *et al.* (1998) verified no significant difference for the variable warm carcass weight. Whereas, Hoffman *et al.* (2003), working with crossbred (Landrace X Large White) observed lower carcass fat deposition and greater percentage of lean meat in animals raised in outdoors rearing systems when compared to the conventional system. However, the creation type did not affect the distribution of commercial cuts, expressed in percentage of cold carcasses.

Comparing carcasses with the same weight, Van der Wal *et al.* (1993) verified that pigs raised outdoors tended to have more subcutaneous fat and lower amount of lean meat. However, Jones *et al.* (1993), Enfält *et al.* (1997) and Sather *et al.* (1997) found that pigs reared outdoors had a higher amount of lean meat and lower fat ratio than pigs finished in confinement. In the work developed by Jones *et al.* (1993) and Bridi *et al.* (1998), there were no significant differences among the means of fat thickness and depth of back muscles from pigs reared outdoors and in confinement. However on the study conducted by Bridi *et al.* (2003a) have been detected differences.

Butko *et al.* (2007), working with Black Slavonian pig breed, reared outdoors and fed with natural pastures and crop residues, compared to conventional (ending with the 137 kg BW), verified higher proportion of leg and lower proportion of ribs when the weight of these were compared with the total weight of the carcass. Furthermore, it was verified a bigger amount of meat on the carcass of pigs reared outdoors compared to the system indoor, concluding that there would be a greater value in the carcass of pigs reared outdoors.

Large White pigs reared outdoors also had a higher content of lean meat and lower content of intramuscle fat on the carcass. However, the intramuscle fat in *Longissimus* and *Rectus femoris* muscles was greater in these than in pigs raised in the conventional system (Bee *et al.*, 2004).

Strudsholm & Hermansen (2005), working with animals originated from the crossing type tricross (matrices "Large White X Landrace", mated by Duroc boars), reported that the animals kept in confined system had a lower content of lean meat (2.3%) and higher fat thickness (1.1 mm), however there were those who consumed less feed (5 MJ ME/ kg gain) compared to the farming system outdoors.

Another issue to be related to carcass quality of pigs in the near future is not only the content but also the profile of fatty acids present on it. According to Basso *et al.* (2007) the growing and finishing pigs in outdoor systems with pasture, presented better meat quality than the confined system, introducing more favorable characteristics to human health (less teratogenic). In the fatty acid composition of intramuscle fat there were more C18: 1, C18: 2 and C18: 3 in animals reared outdoors (**Table 4**). Moreover, the level of C18:3 in intramuscle fat was higher in animals fed forage, than in animals reared outdoors and confined without food bulky.

Studies of Lebret & Mourot (1998), regarding the rearing conditions of pigs, showed higher levels of omega-3 fatty acid and vitamin E in backfat and intramuscle fat of animals raised in extensive systems. On pigs' lard from Cinta Senese breed reared outdoors, Pugliese *et al.* (2005), reported a higher percentage of monounsaturated fatty acids (MUFA) (55.1% vs. 53.3%) and polyunsaturated (PUFA) (13.2% vs.10.4%). The pigs raised in outdoors systems also showed higher relation polyunsaturated fatty acid (PUFA)/stearic fatty acid (SFA) (0.43 vs.0.29).

The Subcutaneous fat from pigs of Nero Siciliano breed reared outdoors showed a higher percentage of monounsaturated fatty acids (MUFA) (53.3% vs. 47.2%), but lower percentage of polyunsaturated fatty acids (PUFA) (10.85 % vs.14.45%) (Pugliese *et al.* 2004). No differences were found in omega-3 content between the two groups, though the meat of animals reared outdoors

Table 4. Fatty acids profile of intramuscle fat of pigs under different production systems.

Fatty acids	Indoor system	Outdoor system		RSD
		With forage	Without forage	
Palmitic C16:0	24.84	24.67	24.56	0.145
Palmitoleic C16:1	3.19	3.33	3.16	0.058
Estearic C18:0	12.65	12.17	16.66	0.142
Oleic C18:1	39.88 b	42.62 a	41.28 ab	0.293
Linoleic C18:2	10.93 a	8.81 b	10.32 ab	0.281
Linolenic C18:3	0.41 b	0.57 a	0.44 b	0.017
CFA+21:0	0.11 b	0.28 a	0.13 b	0.014
Arachidonic C20:4	2.00	1.81	1.89	0.107
Eicosapentaenoic C20:5	0.09 b	0.13 a	0.08 b	0.008
Docosahexaenoic C22:6	0.03	0.05	0.04	0.002
SFA	40.12	39.36	39.52	0.244
UFAM	45.23 b	48.03 a	46.52 ab	0.328
UFAS	14.62	12.58	13.98	0.39
n6/n3	23.67 a	14.26 b	21.03 a	1.751

Different letters in the same row indicate significant differences ($p < 0.05$). Source: Basso *et al.* (2007).

showed lower rates of teratogenicity (0.48 vs. 0.53) and thrombogenicity (1.03 vs. 1, 21), related to the development of cardiovascular diseases.

The content of fatty acid stearic (C18: 0) was lower, while the content of linoleic acid (C18: 2Ω-6) and polyunsaturated fatty acids (PUFA) was higher in meat from pigs (Landrace X Large White) from outdoor systems when compared to the pigs from the indoor system (Hoffman *et al.* 2003). Enfält *et al.* (1997) and Bridi *et al.* (1998), found no difference in loin eye area of pigs raised confined and outdoors. Sather *et al.* (1997) verified that pigs reared outdoors produced loin and ham heavier than those raised in confinement on wood shavings, being these differences more pronounced in summer than in winter. To Bridi *et al.* (2003a) the rearing systems induced differences in loin eye area (**Table 5**). Pigs raised in confinement on a concrete ground produced loin with larger area than those kept outdoors. On the other hand, Gentry *et al.* (2004) commented that there are no differences between the parameters of carcass of animals raised "in" and "outdoor". The animals produced in "outdoor" systems had more fibers to the darker gray type (IIB) that the animals reared in conventional, in yours *Semimembranosus* muscles, but the cross section of these fibers no differ significantly (**Figures 1** and **2**).

Table 5. Effect of the production system type on the loin eye area and weight of ham and carrè.

Production system	Loin eye area (cm^2)	Ham weight (kg)	*Carrè* weight (kg)
Indoor no bed	53.8^{a}	10.4	4.2
Indoor with bed	51.2^{ab}	10.3	4.2
Outdoor	50.1^{b}	9.9	4.1

[ab]Means followed by different letters in the same column show significant difference ($p < 0.05$). Source: Bridi *et al.* (2003a).

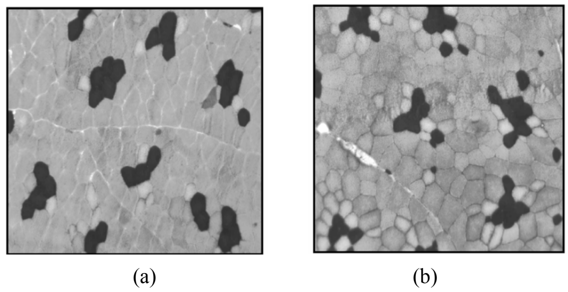

Figure 1. Photomicrograph of muscle *Semimembranosus* of: (a) pigs reared in conventional system and (b) pigs reared outdoors. The darker fibers are of the type I (SO), the lighter gray center of the type IIA (FOG), around the type I, and the darker gray are of the type IIB (FG) (Gentry *et al.* 2004).

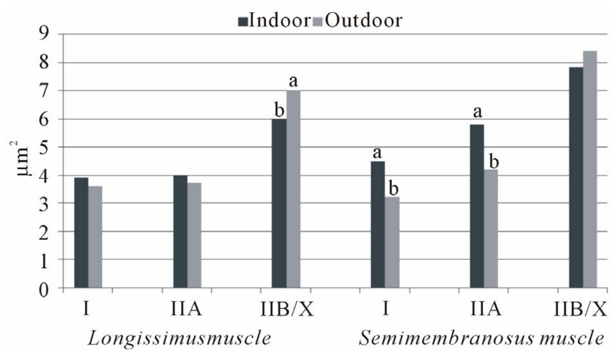

Figure 2. Cross section of muscle fibers in Longissimus and Semimembranosus of pigs reared outdoor and indoor: Type I - slow twitch and oxidative (SO), type IIA - fast twitch and oxidative (FOG) and type IIB / X - fast twitch and glycolytic (FG). Charts of paired columns, having different letters differ significantly ($P < 0.05$) (Gentry *et al.* 2004).

In Cinta Senese pig breed, Pugliese *et al.* (2005) reported that pigs raised in outdoor systems, when compared to indoor systems, demonstrated a lower percentage of the *Longissimus lumborum muscle* (46% vs. 48%) and higher percentage of intermuscle fat (7.2% vs.4.7%) and bones (20.9% vs. 19.2%). Also on this muscle from pigs raised billboard was verified a higher percentage of intramuscle fat (4.04% vs. 3.29%) and crude protein (23.5% vs. 22.8%) and lower drip loss and when subjected to baking in an oven (0.66% vs. 2.14% and 28.6%

vs. 32.3% respectively) and under a high pressure in autoclave (30.3% vs. 26.6%).

One of the arguments for such differences in the carcass of these animals are the types of muscle fibers developed during their lifetime. Pigs are born with a predominance of type I fibers (red-SO), due to their development, these fibers change to the type IIA (FOG) and IIB / X (FOG), usually of lighter pigmentation. In general, physical activity leads to a shift of muscle fibers from the IIA, to IIB / X and from these to the type I; reduced levels of activity lead to a reversal of this path (Lefaucheur and Gerrard, 2000). According to Petersen *et al.* (1998) the spontaneous physical activity signifycantly increases the proportion of fiber type IIA to IIB/X in *the Longissimus muscle*.

In relation to muscle fiber types found in the carcass, Gentry *et al.* (2004) verified a higher percentage of type I fibers (SO) and lower of type IIA (FOG) in the *Longissimus* muscle of pigs reared outdoors. In the same study were found lower percentage of fibers type IIB/X (FG) in *Longissimus* and *semimembranosus* of pigs reared outdoors compared to pigs raised in confinement system (indoor). However, there were negative correlations between the number of fibers and the size their cross-section, being their number of greater significance for the evaluation as a whole.

According Bee *et al.* (2004) in the *Rectus femoris* and *Longissimus* muscles of Large White pigs reared outdoors were found greater quantity of the type IIA (FOG) fibers and lower fiber content of type IIB/X (FG), when compared to traditional system confined.

Moreover, other features related to consumer acceptance are attributed to meat in general. Among these the meat color, brightness and luminosity must be cited once it may stimulate the purchase by the consumer.

According to Heyer *et al.* (2006), pigs reared outdoors had the glycogen content and the values of L * (lightness) in *Longissimus dorsi* higher, while values of b * (yellow pigmentation) were lower in the meat of pigs reared in the indoor system. In Cinta Senese pig breed, Pugliese *et al.* (2005), reported that in *Longissimus lumborum* muscle of pigs raised in outdoor systems had lower L * values (brightness) (45.8 vs. 50.1) and higher values of a * (red pigmentation) (14.9 vs. 11.8) and Chroma (15.9 vs.12.8). In Addition, according to Pugliese *et al.* (2004), pigs reared outdoors (Nero Siciliano breed) showed significantly higher lightness (L^* = 50 vs.46.7) and yellow pigmentation (b^* = 5.84 vs.4.88) in the meat. Gentry *et al.* (2004) commented that there were higher values of L * (lightness) and b * (yellow pigmentation) in chops from pigs born and reared outdoors.

Meat from pigs crossbred (Landrace X Large White) reared outdoors showed higher a * (red pigmentation) than those raised in confinement system (Hoffman *et al.* 2003).

A very important factor and often overlooked in research on meat quality is the acceptance of the final consumer. Aparicio *et al.* (2007) investigated these factors in meat from Iberian pig breed Valdesequera raised in confined systems, semi-confined (5 m^2/animal) and extensive (16,800 m^2/20 animals) (**Table 6**). These researchers concluded that there was more texture and firmness in the meat of animals raised in extensive systems when compared to other systems. These characteristics influenced the public's assessment, having greater acceptance ofof meat originated from more extensive systems.

Broiler Production

The conventional chicken is generally known for its lack of taste and the soft and white aspect of its meat. Some consumers prefer firmer meat and with more pronounced flavor, features that correspond to older animals, near to the sexual maturity (Bastianelli, 2001), birds that have not suffered intense breeding (redneck strains) or the birds subjected to physical exercise (free range or semi-confined).

According to Castellini *et al.* (2008), in Europe, alternative systems can be a viable production method, especially if suitable changes in EU Regulation. 1804/99 are made. The market opportunity for both organic and free range poultry products does not yet seem to be fully developed.

Age at slaughtering, genetic strains (fast- and slow-growing), physical activity, and pasture intake are key factors in determining meat quality. In conventional farming, fast-growing chicks are generally used, but these are not suitable for alternative systems, since they may develop health and welfare problems, the most recurrent of which are leg disorders and lameness (Castellini *et al.* 2008). Conversely, use of slow-growing strains in alternative systems has positive repercussions on both animal welfare and product qualitative characteristics (eating quality and appearance) perceived by consumers (Castellini *et al.* 2008).

Table 6. Indexes of consumer's taste and preference of pork originated from different production systems.

Production system	Flavor		Preference
	Average	Standard deviation	
Confined	2.82 b	±0.90	9.1%
Semi-confined	3.53 a	±0.96	36.4%
Extensive	3.68 a	±0.94	54.5%

Different letters in the same column indicate significant differences ($p < 0.05$). Source: Aparicio *et al.* (2007).

In Brazil, the creation of alternative chickens then emerges as an option to consumers, in which the term *alternative certificated chicken* is to designate the chicken of intensive farming raised without antibiotics, anticoccidial, growth promoters, chemotherapeutic agents and animal ingredients in the diet, besides a lower stocking density (birds / m²) and other requirements and standards adopted and made official in the Alternative Poultry Industry Association AVAL (Demattê Filho & Mendes, 2001).

The redneck chicken or "brazilian colonial" is the chicken in which its feed is exclusively composed of ingredients of plant origin, being forbidden the use of growth promoters of any kind or nature. The creation is made in sheds until the 25 days old. After this age, the birds are released into the field, being now their rearing extensive, recommending 3 m ^{2} of pasture per bird. The slaughter is performed with a minimum age of 85 days. The strains used must be suitable for this purpose, being forbidden strains specific for commercial broiler (Circular of the Ministry of Agriculture and Supply MAPA, DOI / DIPOA No 007/99 of 19.5.1999, supplemented by the Circular DOI / No 014/2000 of 11.5.2000 DIPOA).

To serve this market, several colonial strains are created in Brazil, highlighting the Naked Neck Label Rouge of French origin; Embrapa 041, produced by the National Research Center of Embrapa Swine and Poultry in Concordia, SC; Paradise *Pedrês*, produced by the Birds Grange of Paradise in Itatiba, SP and *Caipirinha*, produced by ESALQ / USP in Piracicaba, SP (Takahashi, 2003).

According to Gessulli (1999), it should be noted that the redneck chicken does not compete in scale of production and the cost with the poultry industry, but does in the meat quality, serving a market niche that can pay more for these characteristics.

6. GENETIC FACTORS

The strains of chicken produced commercially, although belonging to a single specie *(Gallus gallus)* show marked differences in conformation, size and color as its output destination. Greater peculiarities can still be detected by comparing these strains with their breeds of origin, once these differences are reflected in the skeletal muscles.

The skeletal muscles of broiler chickens reared in intensive system in comparison to those created in semi-intensive (redneck chicken) presents greater muscle mass, composed by muscle fibers of size and length superior and with more DNA (Souza, 2005). The faster growing and the larger size of muscles of industrial chickens in relation to the rednecks are occasioned by the greater number of myofibers and their rapid hypertrophy. But there could be influence of the production system in these results.

According Fanatico *et al.* (2005b), fast growth genotype birds has greatest breast yield (%) and the lowest wing yield (%), while slow growth genotype birds exhibit lowest breast yield (%) and the greatest leg quarter yield (%) in the same production systems. These results suggests that the genetic strain is more significant that system of rearing. Drip loss and cook loss (%) were affected by genotype, with the highest losses occurring with the slow growth genotype and the lowest losses occurring with the fast growth genotypes (Fanatico *et al.* 2005a).

Selection for high growth rate led to a relative increase on the number and total cross-sectional area of myofibers. This may explain the greater weight of the muscles of animals of high growth rate. Madeira et al, (2006) evaluating the morphological aspects of skeletal muscle fibers types of the flexor *Hallucis longus* of four strains of broiler chickens raised in confined systems (Ross) and semi-confined (Naked Neck Label Rouge, *Caipirinha* and Paradise *Pedrês*) observed that Ross presented greater muscle mass (**Table 7**). These results indicate that the growth rate is related to the increase in the area of the three muscle fiber types (SO, FOG and FG) in birds selected for increased body growth. In relation to the rearing system no significant difference was observed between the two genetic groups.

Similarly, Sartori *et al.* (1999) also observed a greater area of FG and SO fibers in the flexor *Hallucis longus* muscle of broilers when comparing strains of high growth (Hubbard and Ross) to another of slow growth (Naked Neck). According to these authors, the greater muscle mass of broilers selected can be characterized by

Table 7. Mean values of area (mm²) of the glycolytic fibers type (FG), intermediate (FOG) and oxidative (SO) from the flexor hallucis longus muscle of broilers at 56 days old, according to the strain and rearing system.

Strain	Area		
	FG	FOG	SO
Ross	7104.51 a	4915.77 a	4860.84 a
Paradise *Pedrês*	4442.22 b	4270.18 a	2735.20 b
Caipirinha	3067.20 c	3308.73 b	2677.56 b
Naked Neck	3062.76 c	3148.09 b	2199.20 b
Production system	FG	FOG	SO
Confined	4466,29	4014,99	3087,65
Semi-confined	4597,96	3778,25	3093,33

[a,b]Means in column followed by different letters differ ($P < 0.05$) by Tukey test. Source: Madeira et al, (2006).

the increase of the muscle fibers area, principally glycolytic, indicating that the major selection pressure for weight gain is manifested in the hypertrophy of the muscle fibers.

The selection for high growth rate in broilers has promoted structural and metabolic changes in muscles and changed the meat quality. High growth rates leads to injuries, larger diameter of muscle fibers, greater proportion of glycolytic fibers and reduced muscle proteolysis. These changes results in faster *rigor mortis*, which increases the meat pallor and diminish their capacity to fluid retention, worsening the quality of the processed products. The decrease in muscle proteolysis increases the hardness of the poultry meat (Dransfield & Sosnicki, 1999).

To evaluate the smoothness can be used subjective methods like tasters in a taste test and equipment that measure the force required to shear the samples, such as methods of Allo-Kramer and Warner-Bratzler. Another indirect measure of this characteristic is the pH, which is related to the *rigor mortis*. To determine the *rigor mortis* is also made the evaluation of the glycogen level (Smith *et al.*, 1992).

Fanatico *et al.* (2006) working with fast, medium and slow growing strains of broilers, found that the breasts of the medium growing birds were more tender than other genotypes, however, all treatments scored "slightly to moderately tender". The thigh meat of the medium development birds was more flavorful than that of slow growing birds, and the flavor of the slow growing broilers thigh meat was less liked than other genotypes.

Analyzing the characteristics of meat quality in four strains of broiler chickens, being one of them commercial (Ross) and the other specific to the colonial production (*Caipirinha*, Naked Neck and Paradise *Pedrês*), Takahashi (2003) verified that Ross showed less weight loss due to cooking and greater shear force of breast muscle fibers compared to colonial birds (**Table 8**).

Coelho, *et al.* (2007) verified that only two of eight genetic groups of broilers reared under semi-intensive system (*Caipirão* and Embrapa 041) presented a shear force of the *Pectoralis major* muscle fibers lower than the control group (Ross) reared under intensive system (**Table 8**).

However, Rajar *et al.* (1999) and Lima (2005) obtained lower values of shear force to the fibers of the flexor *Hallucis longus* muscle of conventional broiler breeds (1.97 and 2.94 kgf.cm^{-2}, respectively) in relation to redneck broiler breed (2.46 and 3.39 kgf.cm^{-2}, respectively).

According to Souza (2005), these different results may be related to muscle physiology, since the breast muscle glycolytic metabolism decreases the effects of the difference between conventional rearing systems and semi-confined (redneck), in addition of this muscle do not be required to the birds' movement, unlike what happens to the *Flexor hallucis*. Additionally, Magalhães (2004) stated that the location and function of the muscle are important factors that influence the shear force of the muscle fibers (**Table 9**).

According to Cothenet (1998), the meat of redneck broilers Label Rouge reared under the semi-confined system when compared to commercial broilers of intensive farming, obtained in the taste test lower tenderness and juiciness. However, the Label Rouge broiler had higher scores for flavor and preference. Other important features related to the meat quality are determining the chemical composition, fatty acid profile, the color and the sensory analysis.

According to Scheuermann (2004), with the selection pressure for high growth in broiler chickens, have been observed greater susceptibility to PSE meat (pale, soft and exudative), due to the high glycolytic potential and especially to the size of muscle fibers. These fibers derive energy for contraction through the glycolytic pathway and, under stress conditions with high energy demand (such as stirring pre-slaughter), the metabolism contributes to the rapid drop in the pH consequently raising the lactic acid production, which cannot be removed at *post mortem*. Concerning the increase in the fiber size, this may negatively affect the meat quality, leading to a greater tendency to PSE.

Table 8. Effect of the broiler strain on the meat quality pa- rameters (pectoralis major muscle) at 56 days old.

Strain	Weight loss due to cooking (%)	Thickness (cm)	Width (cm)	Lenght (cm)	pH	Shear force (Kgf/cm^2)
Ross	14.93 b	2.57 a	8.57 a	18.76 a	5.92 a	3.44 a
P. Pedrês	18.22 a	1.42 b	7.12 b	16.10 b	5.85 ab	2.46 b
Caipirinha	19.03 a	1.29 bc	6.34 c	14.85 c	5.80 b	2.79 b
N. Neck	18.75 a	1.25 c	6.45 c	14.99 c	5.84 ab	2.64 b

Means followed by different letters in columns differ by Tukey test ($P < 0.05$). Source: Takahashi (2003).

Table 9. Comparison of means to shear force, tenderness and flavor of the meat among strains of broilers reared under intensive and semi-confined systems.

Strains	Shear force ($kgf.cm^{-2}$)[1]	Softness[2]	Flavor[2]
Ross (control)	4.02 a	4.75 a	4.32 a
Redneck	3.07 b	3.82 b	3.68 a
7P	3.30 a	4.56 a	4.00 a
Paradise *Pedrês*	3.16 a	3.97 b	3.55 b
Embrapa 041	2.67 b	4.26 a	3.37 b
Label Rouge	3.19 a	3.66 b	3.81 a
Naked Paradise	3.37 a	3.33 b	3.31 b
Caipirinha	3.58 a	4.33 a	3.97 a
Carijó Barbado	3.45 a	4.51 a	3.91 a
Overall Mean	3.31 a	4.13	3.77

[1]Means followed by different letters differ from control by Dunnett test ($P < 0.05$). [2]Means followed by different letters differ from control by X^2 test ($P < 0.05$). Source: Magalhães (2004).

According to Olivo (2004), fillets of PSE broilers are also characterized by high levels of exudate, due to its low water retention capacity, compromising its nutriational properties. This occurs primarily in products injected with brine and cooked in the *cook-in system-bags*, due to release of moisture during the slicing and, also, the pre-cooked steaks tend to be dry, fibrous and rancid, when reheated, compromising their sensorial and nutriational qualities.

In the other hand, the appearance of the meat and carcass seems affected by the interaction between genotype and production systems of the birds. The meat and skin of the slow growth birds become more yellow when the birds had outdoor access; however, this did not occur when the fast birds has outdoor access (Fanatico *et al.* 2007). In addition, the breast meat of the slow birds has more protein and α-tocopherol than the fast growth broilers and half the amount of fat (Fanatico *et al.*, 2007).

7. PRODUCTION SYSTEMS

The extensive production system differs from the traditional system relying primarily on two characteristics, diet and the animals' physical activity. Although there is the inclusion of roughage in the most extensive systems of broilers production, the vast majority of nutrients are provided by the concentrated feed. In addition, the increase in physical activity is crucial for the amendment of the meat color and texture aspects.

The effects of the exercise on the histochemical pattern of skeletal muscle and, therefore in its fiber composition, are complex and variable and depend of several factors including the exercise type (strength or resistance), the intensity and duration, the status of individual training, the muscle studied and possibly, the genetic makeup. Associated to these changes, we observe the weight increase, measure and conformation of the muscle subjected to exercise (Gonzales & Sartori, 2002). The physical exercise can promote biochemical changes in the skeletal muscle, like increased capacity for oxidation of pyruvate and long-chain fatty acids; increased respiratory capacity, which varies with the intensity and duration of the exercise; increased activity of a large number of mitochondrial enzymes, which seems to be the result of raising the concentration of enzyme proteins; the concentrations of cytochromes and myoglobin in the muscle and the increase of the number and size of mitochondria (Gonzales & Sartori, 2002).

According to Gonzales & Sartori (2002), the duration of exercise can cause some modulation of white fibers into red, since, in histochemical studies, it was observed a decrease in the percentage of muscle fibers with white character and an increase in the fibers with red character. The changing pattern of fibers is accompanied by an increased muscle vascularization, with a higher capillary density and rate of capillaries per fiber. There are also indications that certain forms of mechanical overload (stress, exercise, compensatory hypertrophy) may promote an increase in the number of muscle fibers in several animal species (Kelley, 1996).

In broiler chickens, Khaskiye *et al.* (1987) observed an increase in the physical muscle characteristics (such as weight and diameter) and modulation of its fibers due to the exercise. The authors also verified that the pattern of physical activity influences the intensity of muscle differentiation, and that both the placement of barriers and ramps in conventional boxes are crucial for obtaining heavier muscles, after three or four weeks of exposure to the new situation. The production system also interferes with bone formation in birds. Birds given outdoor access has greater bone strength in the tibia that animals reared in intensive system (Fanatico *et al.*, 2005b).

Rearing broilers in sheds with ramps Sandusky & Heath (1988), verified an increase in chest growth rate and greater size of the *Pectoralis major*, *Supracoracoideo*, *Gastrocnemius* (inside) and *Femorotibial* muscles in birds reared in boxes with simple ramps, however in boxes with dual ramps it was found an increase in the growth of fibula long and *Femorotibial* muscles of broilers. Based on these considerations, it is verified that the birds' physical activity leads to adaptive changes that elevate the oxidative capacity of skeletal muscles, similar to those that have been observed in mammals.

Studding broilers from fast and slow growing strains, reared in outdoor and indoor systems, Fanatico *et al.* (2005a), found that the principal effect of outdoor access was to make the meat more yellow in the case of the slow growing strain genotype, although not the fast growing birds. In the same work was observed that the tenderness was affected by production system, but only in the fast growing strain birds. The pectoralis dry matter (%), fat (%), and ash (%) were largely unaffected, both the production system and genotype (Fanatico *et al.*, 2005a). However, the outdoor access did not impact flavor of the thigh and breast meat of the birds in the sensorial test (Fanatico *et al.*, 2006). These data indicate that differences in sensory attributes may exist among geno- types with different growth rates and reared with or without outdoor access.

8. CONCLUSIONS

The production of poultry and pigs more extensively tend to get a final product with its own organoleptic characteristics, changing the meat default color and content, place of fat deposition and the fatty acid profile deposited on the carcass.

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