CHICKEN MUSCLE FIBRES CHARACTERISTICS AND MEAT QUALITY: A REVIEW

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This review endeavours to bring together recent advances in our understanding of muscle fibre relevant to broiler chicken. The physical and biochemical characteristics of muscle fibres can be conveniently defined under three distinct but overlapping categories: fibre number, fibre size and fibre type. In poultry meat production, it has been shown that muscle fibre properties play a key role in meat quantity and quality. Current knowledge indicates that muscle fibre type has a significant role in modulating growth and meat quality. Muscle fibre characteristics are variable and can be influenced by many factors. Muscle fibre size and type can be modified by numerous internal and external factors, such as breed, sex, postnatal nutrition. In addition, histochemical and biochemical characteristics of live chickens can be used to predict meat quality and then applied in selection programs to improve and control meat quality. The correlated responses of growth and meat quality traits to this selection maybe useful studies for better understanding of the significance of muscle fibre characteristics in determining growth performance and meat quality. Feed restriction delays postnatal muscle growth in short term in broiler chickens, but may induce an accelerated myofibre hypertrophy in the long term. It is suggested that promoting the total fibres number, a characteristic established before hatching in broiler chicken, is a promising way to increase muscle mass without increasing fibre size. However, there still is not enough research that definitely demonstrates the deleterious effect of increasing fibre size on meat quality, and some researches showed that breast muscle with largest fibre exhibited high meat quality.

chicken, meat quality, muscle, muscle fibre, nutrition

INTRODUCTION

The major components of muscles are muscle fibres. Muscle fibres are highly specialized cells acting as the structural units of skeletal muscle tissue (Hedrick et al., 1994). It is well known that muscle fibre number, size, and fibre-type composition are closely related to each other (Ryu et al., 2004). It is absolutely clear that biophysical, histological and biochemical characteristics of muscle fibres play a key role of meat quality. So understanding and investigation this characteristic is one of the most practical importance to poultry and meat scientists (Rehfeldt et al., 2000; Wegner et al., 2000; Picard et al., 2006). The purpose of this review is to highlight the importance of muscle fibres in broiler chicken and their relationship with performance and meat quality. We wish also to demonstrate the influence of factors on muscle number and size. Thereafter, we will explain the effects, which can influence meat quality and muscle fibre.

Skeletal muscle fibre is made up of multinucleate, membrane-bound cells. Average fibre size in *pectoralis major*, *biceps femoris*, *extensor hallucis longus* and *gastrocnemius* muscle in broiler chicken are 60, 51.6, 59.8, 60.45 μm (Papinaho et al., 1996; Geyukoulu et al., 2005). In general, the fibre diameter varies from 10 to 100 μm but is dependent on such factors as health, species, breed, sex, age and plane of nutrition (Choi, Kim, 2008). Their lengths can vary from several millimetres to more than 30 cm. Fibre type composition can vary markedly in different muscle types, depending on function. Moreover, there are many factors that contribute to fibre type variation, such as sex, age, breed, hormones and physical activity. Therefore having an understanding of such muscle fibre characteristics is important for the study of overall muscle characteristics and subsequent meat quality. These fibre type variations differ according to their molecular, metabolic, structural, and contractile properties (Choi, Kim, 2008). It is noteworthy that, in broiler chicken the *pectoralis* muscle is composed of only type IIB muscle fibre (Iwamoto et al., 2003; Roy et al., 2006). In contrast, the *biceps femoris* is composed of Type I, IIA and IIB (Papinaho et al., 1996). Type IIIA and IIIB fibres are not found in mammals but are found in muscles such as the *plantaris* and *anterior latissimus dorsi* of the avian species (McKee, 2003).

The performance of muscle in adult animal largely depends on muscle fibre number and type and therefore on fibre size. The muscle weight is a function of total number of fibres (TNF), fibre cross-sectional area (CSA), and length. Similarly, in chicken selection for overall

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growth has been shown to induce greater muscle weight at the same age by increasing the fibre size, length and number. It is well known that the muscle fibre number in chickens is established before hatching. So, any increase in muscle weight post-hatching depends on the increase in length and diameter of the muscle fibres (Chen et al., 2007). On the other hand, growth of muscle fibre is considered to be controlled by an increase in diameter and an elongation due to the addition of newly formed sarcomeres to the ends. Nonetheless, Scheuermann et al. (2004) suggested that increased muscle fibre number may also participate to improve breast meat yield even though it confirmed that fibre hypertrophy is an essential factor for an increase in muscle volume. Interestingly, males exhibited muscle fibre CSA about 16% smaller than females, whereas their *pectoralis major* muscle weight was less than 4% lower. This suggests a greater muscle fibre number in males broiler chicken**.** Surprisingly, the relationship between muscle mass and CSA is highly controversial. This could be due to the fact that muscle mass is mainly influenced by TNF, a highly variable trait. Most studies report that glycolytic fibres exhibit the largest CSA, suggesting that, for a given TNF, an increase in the proportion of glycolytic fibres must lead to an increase in muscle weight. It is well known that postnatal muscle growth is mainly realized by an increase muscle fibre size and a change in muscle fibre type towards glycolytics type (Chen et al., 2007). Indeed, research shows that selection for growth rate and breast meat yield has led to a shift from type I towards more type IIB muscle fibres which has a major impact on post mortem energy metabolism and thus, on meat quality (Lippens, 2003).

Histochemical characteristics are primarily the result of genetic and environmental factors. Selection for increased breast meat in chicken has no effect on fibre type and fibre diameter or meat quality, whereas in turkeys improvement of growth and breast meat yield is based on an increase of the fibre size with impaired meat quality (Berri, 2000; Iwamoto et al., 2003). Mizuno, Hikami (1971) also reported that differences in muscle volume between the laying type and the meat type in chickens mainly resulted from differences in fibre number. In contrast, Prentis et al. (1984) and Horak et al. (1989) observed that the increase of muscle volume in chickens resulted from enlargement in fibre diameter. Likewise, Aberle and Stewart (1983) reported that muscle fibre of broiler chicken had a greater cross-sectional diameter than those from the laying strain. In poultry, the muscle fibre cross-sectional area increases with age. Fast growing chickens have larger diameter fibre than slow-growing lines. This increase is also associated with an increase in the number of giant fibres, which typically have cross-section area three to five times larger than normal, although this may also result from severe contraction (Dransfield, Sosnicki, 1999). Similarly, Aberle and Stewart (1983) studied fibre characteristics of muscles from meat and laying strain chicks between 3 and 11 weeks of age. Myofibres of meat chicken muscles had a greater cross-sectional diameter than those from the laying strain. Moreover, Scheuermann et al. (2004) evaluated breast muscle development in chicken genotypes and reported that broiler chickens have higher total apparent myofibre number in the breast muscles than Leghorn-type chickens, and high breast yield of broiler strains may be due to increased total apparent myofibre number. Berri et al. (2001) found that selection had no negative impact on meat quality, despite evidence of modified breast metabolism.

Intact males mostly exhibit larger muscle fibre than females or male castrates. Contradictory results have been reported concerning the determination of the number of muscle fibres by gender. A number of differences in total number of muscle fibres seem to exist between female and male muscles in that male muscles exhibit higher numbers than female muscles. Sex-related differences in the number of muscle fibre have been found for chicken *extensor hallucis longus*. Differences in fibre number and size are primarily under the control of sex hormones, and differences in fibre number between males and females can arise by hormonal action if differences in androgen hormones are sufficiently high during periods of prenatal fibre formation (Rehfeldt et al., 2004; Choi, Kim, 2008). Chiang et al. (1995) found that sex of chickens had no influence on either the proportion of muscle fibre types or areas. Dransfield and Sosnicki (1999) reported that fast growing male chickens had *pectoralis* muscle fibres three to five times wider than slower growing chickens and an increase in the number of giant fibre. Scheuermann et al. (2004) reported that male broiler chicken had higher muscle fibre density in *pectoralis* muscle than female broiler chicken. In addition, testosterone treatment in later postnatal periods can stimulate muscle hypertrophy in a direct or indirect manner. Additionally, differences in fibre number and size have been related to differences in physical activity between the sexes. Differences in muscle fibre characteristics have been found between breeds. Burke and Henry (1997) showed that muscle fibre numbers in *semimembranosus* muscle broiler chicken were significantly more than muscle fibre numbers in the same muscle Bantam chicken. Burke and Henry (1997) reported that at posthatch, commercial broilers had twice as much muscle fibre number in *semimembranosus* muscle than Bantam chickens. Similarly, it is reported (Remignon et al., 1994, 1995) that fast-growing chicken lines have 15 to 20% more myofibres in the muscle red oxidative *anterior latissimus dorsi* than slow-growing chicken lines. Commercial broiler chicken strains seem also to have enhanced myofibre cross-sectional area (Iwamoto et al., 1993; Remignon et al., 1994, 1995; Burke, Henry, 1997), thus different myofibre density (MFD; myofiber number in a given cross-sectional area of the muscle)**.**

Nutrition in broiler chicken growth is a complex subject of major importance. Adequate nutrition is undoubtedly a key for normal skeletal muscle growth. Feed restriction in quantity and quality leads to decreased muscle fibre diameter (Rehfeldt et al., 2004). It is known that muscle fibre formation is completed at hatching in avian species. Early feed restriction has been reported recently to delay the slow to fast *gastrocnemius* muscle fibre conversion as an immediate effect, but would result in a lower percentage of slow fibres owing to compensatory growth in long term. In other word, feed restriction delay postnatal *gastrocnemius* muscle growth in short term in broiler chickens, but may induce an accelerated myofibre hypertrophy in the long term (Li et al., 2007). In summary, whether postnatal malnutrition is able to induce muscle fibre loss seems to depend both on the intensity and on the time period (developmental stage and duration) of dietary restriction. Only severe restriction (starvation, 75% restriction of ad libitum intake) seems to cause fibre loss, whereas moderate undernutrition exclusively affects fibre hypertrophy by means of reduced nuclear and protein accumulation. Das et al. (2008) reported that feed restriction increased the size of the hind limb muscle relative to wing muscle as a result of greater depression of muscle development in the wing than in the hind limb. Roy et al. (2006) found that high density diets enhanced growth of the *pectoralis* muscle and accompanied by hypertrophy of the fibre type IIB chicken. Geyukoulu et al. (2005) reported that the IIIB fibre population in avian *latissimus dorsi* in broiler chicken significantly decreased upon 500 mg Cu/kg water. On the other hand, they showed that application 500 mg Cu/kg have no effect on muscle fibre type IIIA population. Franco et al. (2008) found that delayed placement affected of negative linear form **(**$P < 0.05$) muscle fibre size in broiler chicken. They also showed that increased upon 1.143% of lysine level dietary had no effect on feed conversion ratio and muscle fibre size in broiler chicken. Thyroid hormones play an important role during muscle development and maturation. There are marked differences in histochemical characteristics both between and within muscles muscle development and maturation. In general, hypothyrodism causes fast-to-slow fibre transitions, while hyperthyroidism elicits transitions in the reverse (Choi, Kim, 2008). The use of β-adrenergic agnonists provides an excellent model for studying changes in muscle growth. Recent studies have dealt with the effect of cimaterol (CIM), a β-adrenergic agonist, on various carcass traits of meat animals. Growth-promoting effect on muscle by stimulating fibre growth is also known to be exerted by β-adrenergic agnonists in various species. As for growth hormone (GH), β-adrenergic agnoists are able to increase lean growth and to decrease fat deposition in poultry. Muscle fibre hypertrophy seems to be achieved mainly by reduction of proteolytic activity after long-term application. Consistent with GH action, the number of muscle fibres was not increased in response in broiler chicken. Gwartney et al. (1992) observed that muscle fibre size in breast meat and thigh meat increased in CIM-fed chicken than in control broiler chicken. According to Rehfeldt et al. (1999) β-adrenergic agonists (clenbuterol) increase diameter in *extensor hallucis longus* but not in *gastrocnemius* muscle. This increase was more pronounced in female. Sartori et al. (2001) reported that environmental temperature affected the performance of broiler but not the number, frequency and size of the myofibres in the *flexor hallucis* muscle.

Relation between muscle fibre and meat quality

The size and number of muscle fibre are factors that influence muscle mass and meat quality. During postnatal development, when the number of muscle fibres is high, fibre generally grows more slowly. Conversely, fibre grow more rapidly when the number of fibre is low in poultry (Choi, Kim, 2008). Thus, fibre number is negatively correlated with fibre area, whereas both fibre number and area are positively correlated with muscle mass in broiler chicken (Gille, Salomon, 1998; Rehfeldt et al., 2004). Papinaho et al. (1996) found that there was a significant correlation between final meat quality and biochemical and histological properties of breast muscle such as fibre cross-sectional area, pH and so on. Furthermore, muscle fibre size is an important factor in determining meat tenderness. As broiler chickens age, the cross-sectional area of muscle fibre increases in size. For example in broiler chicken muscle with a larger fibre size exhibits tougher meat than muscles of smaller fibre size (Chen et al., 2007). Choi, Kim (2008) and Bünger et al. (2009) reported that animals with greater numbers of muscle fibres of moderate size produced a higher quantity and quality of meat. In contrast, Berri et al. (2007) reported that increased fibre size was associated with higher pH and darker meat. The authors suggest the meat from broiler chickens with larger fibre would therefore be better adapted to further processing compared to broiler chickens with smaller fibre. Likewise, Duclos et al. (2007) found that breast muscles with the largest fibres exhibited the highest pH, lower drip loss, darker lightness value and greater tenderness after cooking than breast muscle with smallest fibre. It has been clearly shown that both extreme fibre hypertrophy and the occurrence of giant fibres in pigs correlate with poor meat quality in terms of the pale, soft, exudative (PSE) condition (Schubert-Schoppmeyer et al., 2008). Muscle fibre from fast growing lines of chickens have twice as large fibre diameters than slow growing lines and larger fibre diameters are often associated with an increased number of giant fibres (Le Bihan-Duval, 2003). For the majority, giant fibres are considered to arise from hypercontraction of individual fibres. Muscles consisting of higher proportion of IIB fibres have more giant fibre (Chiang et al., 1995). Miraglia et al. (2006) found that Ross and Kabir hybrid have giant fibre. They also showed that the percentage of giant fibres in the *pectoralis major* muscle is higher ($p < 0.001$) in the Ross, while there are no significant differences in the *ileotibialis lateralis* and *semimembranosus* muscles. The greater fibre diameter observed in the Ross chickens, in spite of the younger age of the animals at slaughter, can be easily explained by the faster growth speed typical of this hybrid. The presence of more giant fibres in the muscles of animals selected for fast meat production could be considered as one of the side effects of genetic selection. As far as the giant fibre percentage is concerned, the most significant difference ($p < 0.001$) was found in the *pectoralis major* muscle that, interestingly, is the muscle that genetic selection mainly aims to increase because of its commercial value (M i r a g l i a et al., 2006). Some of the meat quality traits are especially affected by muscle fibre types. As we expressed breast muscle chicken are entirely type IIB fibre (glycolytic), capable of short burst of activity for the fight or flight response. According to B a r b u t et al. (2008) showed that metabolism of the breast muscle could contribute to pale, soft and exudative (PSE) chicken meat. These authors propose that breast meat involves enormous glycogen stores with a high trend to produce lactic acid and therefore the potential for a rapid drop in pH. White fibres are more susceptible to PSE due to their greater dependence on anaerobic/glycolytic metabolism and phasic contractile action in other word, white fibres have higher glycolytic potential, higher amounts of glycogen, lower oxidative metabolism and lower hem pigments compared to red fibres (S o l o m o n et al., 1998). R y u and K i m (2005) reported that the accelerated metabolic rate and poor quality of meat in PSE in pig are explained by an increase in the percentage of type IIB fibre. Intramuscular fat (IMF) content is an important factor that influences sensory quality, including tenderness, juiciness, and flavour, and is influenced by genetics and environmental factors, such as genotype, gender, feeding system, age and so on. L e B i h a n - D u v a l (2003) reported that fast-growing chicken had more IMF in breast meat, which was usually associated with higher tenderness. However, F a n a t i c o et al. (2007) found that breast meat from slow-growing chicken was more tender than meat from fast-growing chickens. Likewise, C h e n et al. (2007) reported that higher breast meat shear force was found in broiler chicken compared to the crosses and leghorns.

Factors which influence meat quality and muscle fibre

F a n a t i c o et al. (2007) found that selection for fast growth and high yield have negatively impacted the sensory and functional qualities of the meat, pushing muscle fibres to their maximum functional size constraints. D u c l o s et al. (2007) reported that there was no evidence of any antagonism between growth rate or muscle development and breast meat quality. These authors expressed that there was low genetics correlation between growth and meat quality. There is a positive genetic correlation between histochemical characteristics, growth and meat quality and the coefficient of heritability for histochemical and meat quality, growth traits varied from 0.25 to 0.49 (L e B i h a n - D u v a l et al., 2008). As we previously expressed, animals with greater numbers of muscle fibres of moderate size produce a higher quantity and quality of meat. Feed restriction in quality or quantity leads to decreased muscle fibre diameter (R e h f e l d t et al., 2004). Controversially, S a r t o r i et al. (2001) found that early feed restriction can be utilized as management tool without changing the performance at slaughter age and the fibre composition of *flexor hallucis longus* muscle of male broilers. Similarly, F a n a t i c o et al. (2007) found that there were no meat quality advantages from using a low nutrient feed in broiler chicken. Likewise, R i s t i c (1988), M o r i t z et al. (2005), C h a r t i n et al. (2006) and G r a s h o r n (2006) reported that feed restriction did not have a significant impact on meat tenderness and texture. In contrast, L i et al. (2007) reported that feed restriction delay postnatal *gastrocnemius* muscle growth in short term in broiler chickens, but may induce an accelerated myofibre hypertrophy in the long term.

CONCLUSION

Meat quality has become a major concern for poultry market. Meat quality traits are very complex and are influenced by many internal and external factors. The histochemical and biochemical characteristics of skeletal muscles are primarily the result of genetic and environmental factors such as gender, muscle type, postnatal nutrition, breed, hormone, growth promoters, etc. Considering the fact, muscle fibres are the major component of muscle tissue, many studies have attempted to understand the muscle fibre characteristics. The histochemical and biochemical characteristics of skeletal muscle are primarily the result of genetics and environmental factors. Furthermore, the histochemical and biochemical characteristics of live chickens can be used to predict meat quality and then applied in selection programs to improve and control meat quality. Feed restriction postpones postnatal muscle growth in short term in broiler chickens, but may induce an accelerated myofibre hypertrophy in the long term. Although many studies have reported relationships between histochemical and biochemical characteristics and meat quality, opinion among scientists on this point remain divided. For example, although majority of studies show a negative correlation between muscle fibre size and meat quality. Some studies showed a positive correlation between muscle fibre size and meat quality. And still, the relations between muscle fibre size, number, type and meat quality are not yet fully understood. Therefore more information is needed on how the muscle fibre characteristics affect meat quality, in order to practically apply this knowledge to improve and control meat quality, to understand better the physiological mechanisms of muscle, and to evaluate the sometimes controversial conclusions regarding the roles of these traits in practical chicken breeding.

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Charakteristika svalových vláken a kvalita masa kuřat: přehled literatury.

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Přehled literatury shrnuje poslední údaje o svalových vláknech u brojlerových kuřat. Fyzikální a biochemické vlastnosti svalových vláken jsou běžně definovány ve třech kategoriích: počet svalových vláken, jejich průměr a typ svalového vlákna. Je zřejmé, že při produkci drůbežího masa mají svalová vlákna rozhodující roli ve vztahu k množství i kvalitě masa. Typ svalového vlákna má významnou úlohu v řízení růstu a v kvalitě masa. Charakteristiky svalových vláken jsou proměnlivé a ovlivněné mnoha faktory. Průměr a typ svalového vlákna závisí na vnitřních a vnějších vlivech, jako jsou genotyp, pohlaví, výživa. Kromě toho histochemické a biochemické charakteristiky živých kuřat mohou pomoci při odhadu kvality masa, a tím být využity v selekčních programech zaměřených na kvalitu. Vztah mezi růstem a kvalitou masa závisí na svalových vláknech. Například restrikce krmiva u kuřat krátkodobě sníží růst svalů, ale dlouhodobě vyvolá zvětšení průměru svalového vlákna. Zvýšit množství svalstva je možné ovlivněním nárůstu počtu svalových vláken ve svalu v období embryonálního vývoje bez následného zvětšení průměru vláken. Na druhou stranu je poměrně málo údajů o vlivu většího průměru svalového vlákna na kvalitu masa. Tyto výsledky jsou popisovány především u prsního svalstva, kde se častěji vyskytují vlákna s velkým průměrem.

kuře; kvalita masa; sval; svalové vlákno; výživa

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