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# INFLUENCE OF THE TRANSVERSE STRIATIONS OF SKELETAL TISSUES ON THE GROWTH OF FARM ANIMALS (review)

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## ABSTRACT

The number and the thickness of muscular fibres together with the content of interstitial tissues determine the quantitative and qualitative mass and value of the skeletal muscles and meat. The growth of the transverse striations of the skeletal muscular tissues is under the influence of the variable factors. In this article the factors with the biggest tendency to influence the growth of the skeletal muscles are discussed. First of all there are genetic influences and the influence of nutrition. Next it is describing the influence of sex, movement, age, weight and last but not the least the ethological influence.

**Key words:** Skeletal tissues, influence of genetic factors, nutrition, sex, movement, age, weight, ethology

The realisation of the growth potential of live organisms depends on the quantitative and qualitative biochemical processes and on the performance of specific physiological functions in cells, tissues and organs. All the above mentioned processes are genetically determined as well as they are determined by other factors. The transverse striations in the skeletal muscles continue to grow in postnatal period in length as well as in thickness. The whole process is influenced by factors as mentioned above. The effectiveness of the individual factors is on one side dependent on the ability to change the natural processes in the organisms whilst this is being done on the basis of the ability and intensity to cause the change in the natural algorithm of growth.

## Genetic influences

The genotype influences the utility of animals, the growth, maturity, live weight and in a certain sense the behaviour. Rybanská et al. (2001) states the meat yield is influenced by the animal genotype, and the fattening of the animals depends on the genotypes as well.

According to Tóthová (2001) there are ubiquitous genes in the muscle and they influence the synthesis of meat by their regulation. Among them belongs the genes of MYOD family and they influence the muscle development in the process of myogenesis.

Lin et al. (2002) are stressed on the synthesis of growth factors in the cells themselves and they either affect the same cells or the neighbouring ones. These growth factors such as cytokines influence the cell differentiation, the growth, the agility and the gene expression.

Tesfaye et al. (2003) stated that the group of growth factors is created by the rank-family transforming growth factors (TGF). They are glycoproteins originally described as the products of cells transformed by viruses and they change the phenotype of the normal cells in to the neoplasmic phenotype. Myostatin is specifically found in the developing somites and in the skeletal muscles and at the same type is functioning as a negative regulator in the process of control of the muscle development and growth in mice and in cattle (Potts et al., 2003). In the case of myostatin belonging to TGF group "beta" the attenuation of the muscle growth is observed. The identification of the genes with quantitative traits and the mutual relationship with the candidate genes for the growth intensity and the meat quality gives us the possibility to create the animals with the genotypic combinations ensuring the high productivity and the healthy individuals (Gerhard et al., 2001; Trakovická ae al., 2002).

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Tesfaye et al. (2003) also reported that myostatin is created in the cells of the skeletal muscles at the beginning of embryogenesis in the myotonic parts of somites and in the case of adult individuals it is created mainly in the cells of the skeletal muscles and it is also created but on a considerably lower amount in the fat ligaments. The gene is responsible for the coding of myostatin – the protein is responsible for the suppression of new muscle cell formation. The creation of new muscle cells is influenced by the decrease or inhibition of myostatin gene. On the other hand, inactivation of myostatin prolongs the proliferation of muscular fibres. This can bring the mitotic increase in the creation of new myoblasts maturing in myocytes which are transformed in myotubes and they form the new muscular fibres. The volume of muscle mass grows analogically with the growing number of muscle cells (Hungs, 2001; Mc-Pherron et al., 1997).

Mutation in the coded genetic sequences of myostatin (GDF8) in cattle leads to hyperplasia and this results in its inhibitory function with regards to myoblast proliferation (Cieslak et al., 2003). According to Dvořák and Vrtková (2001), it is possible to use the candidate genes effectively directly in the selection process; by this we can achieve the increase in the selection intensity and shortening of the generation interval. If one of the alleles of the candidate gene influences considerably the expression of the effective trait then the analogue will increase the frequency of that particular allele, which is capable of improving the breeding value of population, family or line and thus to influence the meat quality (Haegeman et al., 2002).

Experiments conducted by Kocamis and Killefer (2002) aimed at damaging the myostatin led to the dramatic increase in the skeletal muscle while the weight of the individual muscles almost doubled in comparison to the undamaged myostatin muscles. Taking this into consideration the possible interventions in the production, the receptor links or the myostatin signal transfer process could lead to the end of the myostatin inactivity and to the increased muscle growth. These facts could be realized in two ways. The first one represents the myostatin gene regulation by means of genetic engineering and in the second case we have to take into consideration the neutralization properties of the protein myostatin.

The speed of muscle growth in the individual stages of ontogenesis is influenced by the genetic structure, then by the time of the homeocreative process and the functional disposition in the antenatal and postnatal periods. The character, intensity and the growth period of the various young animals and different breeds are rather varied and therefore there is no same influence of non-genetic factors on the growth inclusive of the nutritional differences.

There are different opinions about the breed and species differences on the growth and quality of the muscular fibres. Uhrín (1986) and Kulíšek (1976) are have described the interspecific influences.

The significant differences are often described in the same muscles of various breeds. Renand et al. (1994) studied the evident influence of the farm animal breeding on the growth of muscular tissue. Even Aass and Vangen (1998) observed the increase in the growth of muscular tissues in interbred farm animals. Uhrín (1997) noted that the breeding and selection of animals result in increase in the proportion of fast growing white fibres whilst the white fibres had the highest value of thickness as well as their growth intensity was at the highest. The end result of this hidden phenomenon results in parallel decrease of the intramuscular fat.

## Influence of nutrition

The effective production of farm animals is influenced by the provision of quality and quantity of a sufficient amount of food, by animal health and by certain other factors. The intensity of farm animal growth for meat production is influenced by the food consumption in regards to the growing weight in the condition of the maximum implementation (Cherepanov, 2001; Nardone and Valfre, 1999). In general this process is described as the nutrient conversion and this is represented by intensive and effective metabolism of the consumed food. There are a lot of experiments of various significance and character in the area of mutual correlation of the growth of the transverse striations of skeletal muscle and the nutrition.

Nicastro and Maiorano (1994) studied the influence of high calorific food on the skeletal muscle growth. The histochemical analysis proved that the surface of muscular fibres was enlarged and that the red fibres are represented in higher proportion while the fat cells were enlarged.

The influence of the live weight and the intensity of growth as the selected indicators of meat utility of bulls of Holstein breed was quantified by Chládek and Ingr (2003). According to them, the higher intensity of growth in bulls goes in hand with higher proportion of kidney fat and finally constitute a smaller share of some parts of slaughtered animal bodies.

As Uhrín and Uhrín (1989) reports the creation of albumens can be increased by various ingredients and very often these are of hormonal origin and they are called biostimulators.

Very high correlation was found in the relationship of nutrition and the muscular fibre thickness (Kulíšek, 1980). Stickland et al. (1975) found out that the energy deficit in nutrition has far more reaching impact at the thickness of muscular fibres than the protein deficiency.

Cornejo and Pokniak (1983) reported that after the deficit in the energy and protein storage in MPM *musculus psoas major* the thickness of the muscular fibres decreases and in the meantime there is decrease in the number of fibre nuclei in *m. gastrocnemius*. On normalisation of nutrition compensation hypertrophy is observed in *m. psoas major* while there is hyperplasia in *m. gastrocnemius*.

As a result of total starvation the rats registered a weight loss of 40 %, reports Hegarty and Kim (1980). They also observed that the reduction in muscle mass was caused by decrease in the fibre numbers as well as their thickness. They explained the decrease in the number of muscular fibres on the basis of unspecified fusion. Once the feeding was established again the muscle mass increased in weight as well as their thickness at the control level.

In spite of this fact, Timson et al. (1983) suggested that the growth of chicken slows down under insufficient nutrition but there is no reduction in muscle mass. Moody et al. (1969) mentioned that starvation influenced the size of internal muscular fat cells far more than the size of muscular fibres. There was a reduction of their diameter and the change of the round shape into the elongated one. The complete starvation is evidently reducing the thickness of the muscular fibres (Kulíšek, 1980).

According to Uhrín and Uhrín (1989), insufficient nutrition causes thinning of muscular fibres; even though the animal is still potentially capable of synthesizing the higher albumens but the animal is unable to do so because of the nutritional deficit. The selection process in order to increase the growth and the weight often leads to the increase in the fat content and not proteins. The saccharides and proteins can change in the organism into fat but the reverse process from fat into albumens is far more complicated as the control of the fat synthesis and therefore the protein synthesis is far more difficult to influence. The animals selected for fast growth need more food and this is why the organism once satisfying the need for energy and nutrients required for the development of the muscles and the other organs and the normal body functions stores the extra energy in the form of fat.

An important study in this field was done by Slánský (1993). The restricted nutrition in pigs weighing 48–66 kg registered a decrease in weight by 20 % in three weeks. They found out that in smaller weight there was a considerable loss in fats while the fat losses were small in the other group but there was a decrease in muscle mass weight and also in some organs. After feeding *ad libitum* for a period of 90 days they found out that the first group of animals was greedier and fatter than the second group. This group did not have the higher food intake as the specimen group and the differences in the fat content were not considerable.

According to Field et al. (1985), there is a possibility that during the malnutrition of mothers there are changes in the proportion of muscular fibres. It is because the red beta-Red fibres are differentiated as first. Thus the increase in the number of thinner beta-Red fibres and the decrease in the numbers of alpha-Red and alpha-White could influence the process of growth of muscle mass because the types of fibres developing at later stage (alpha-Red, alpha-White) enlarge more quickly than the beta-Red fibres at the time of muscle hypertrophy.

The impact of selection on the high and low weight in relation to the thickness and size of muscular fibres was studied by Hanrahan et al. (1973). They found out that the differences in the muscle weight of mice are in correlation to the number of fibres but often there is a relationship with the differences in fibre thickness.

Luff and Goldspink (1970) noticed that the mice selected for larger increase have the bigger muscles and this is influenced by higher number of fibres with thicker muscular fibres. They considered the number of fibres in a muscle as the main responsible factor. This is also supported by Penney et al. (1983) as they found out almost 30 % more muscular fibres in the muscles of mice of bigger size.

## Influence of sex and movement

The growth of the skeletal muscular tissue in conjunction with its qualitative parameters was the focus of several studies. Apart from the hereditary influences of its own embryonic genotype affecting the weight of animals there is also the maternal influence and the influence of sex (Frickn et al., 2002; Juhás and Zimmermann, 2002; Rybanská et al., 2001).

Uhrín and Uhrín (1989), in another study found that the sexual differences are less significant with regard to the thickness of the muscular fibres even though as a rule the females have thinner fibres in the muscle than the males.

The relationship between the parents and F2 generation with regards to the growth of skeletal muscular fibres was studied by Kulíšek (1976) and he described various sexual influences on the thickness of the muscular fibres and even admitted the possible age relationship. According to Kulíšková et al. (1984), the sex differences on the observed indicators are varied and rather lack uniformity.

Červenka (2003) noted the significant differences in the thickness of the muscular fibres in different sexes whilst the biggest variability was found in *m. cleidocephalicus* and *m. adjuctor* in different sexes and in the achieved live weight. The differences in the protein levels in the growing muscles from the point of view of the sex variability were noticed by Huff-Longergan et al. (1995).

Pulrábek (2002) observed 2–3 % higher proportion of muscles in sows. Čuboň et al. (2003) stated that the bulls grow faster than the cows. The majority of authors concluded the fact than various muscles of the same animal have different thickness in their muscle fibre (Kulíšek, 1976; Uhrín, 1997). These factors are the results of various functions as well as variable topographic anatomic muscle structure.

The structure of the individual muscles itself is under different angles and different degrees and shape. This leads to different microscopic structure in different parts of the muscle. There are several literary resources (Kulíšek, 1976; Uhrín, 1997) proving that the muscle is not homogenous in regards to the real thickness of the muscular fibres but it contains the fibres of different thickness. On the other hand, the muscular fibre does not have the same thickness alongside its length. The muscular fibre is the thickest in its middle and it is narrower at its ends (Gomboš and Gombošová, 1976; Gray, 1988; Kresan et al., 1990; Najbrt et al., 1980).

The influence of the movement was mainly analysed in the correlation with the thickness of the muscular fibres. A whole series of authors have confirmed than the movement is a significant factor in this sense. But it is necessary to differentiate the intensity and the muscle workload, as Uhrín (1971) points out. The cytological studies of the transverse striated skeletal muscles proved unanimously that hypertrophy is closely related to the increase in myofibril mass (Kulíšek, 1980). The number of mitochondria and the sarcoplasm proteins increases under certain conditions. The representation of the muscular fibres has the variable differences in the framework of intensive movement. The intensive systematic activity lowers the proportion of white fibres which change in to intermediary ones. Similarly, some other experiments have also showed the same effect as the chronic muscle electro-stimulation, denervation, cross muscle intervention with various fibre types and the synergic muscles tenotomy (Uhrín, 1986).

The influence of free pasturing of cattle on the growth of the muscular tissue was studied by Dufrasne et al. (1995) and he did not find any enormous change, not even in the augmentation.

According to Uhrín and Uhrín (1989), it is possible to change the muscular types from white to intermediary and intermediary to red by the intensive training. But the complete immobilisation of animals has considerable influence (Uhrín, 1971).

Sidor (1983) observed the impact of very limited space on the cattle and he found out that while the animals were in cages the intensity of growth was higher only in the first three months and then the animals became depressed which showed in the lower food consumption. In case of the application of cage system in cattle there would probably be the need to find the suitable biological material as with poultry.

Uhrín and Uhrín (1989) reported that the cutting of the nerve results in considerable muscle atrophy and this happens equally in the fast and slow muscular fibres. Then they also stated that immobilisation by means of plaster causes muscle atrophy, too. But the situation is different depending on the type of muscle fixation – extension or flexion type. After muscle immobilisation the thickness of red fibres decreases and the share of the intermediary fibres increases. The muscle immobilisation influences the slow types of fibres more than the fast ones.

## Influence of age and weight

There is difference of opinions in the influence of age, weight and the size of animals on the thickness of the muscular fibres. Sidor (1983) and Monson et al. (2004) found out that the age has a considerable influence on the usage of animals in various stable types. Halban (1984) observed that the muscles are growing from the embryo development to the adulthood almost with mathematical precision. The types of the muscular fibres are homogenised at the late age (Uhrín, 1986).

Uhrín and Uhrín (1989), Kaman (1993) and Schenkel et al (2004) observed the uneven dependency of growth of muscular fibres on age, weight and size.

The work of Ashmore and Doer (1971) points at the differential speed of postnatal growth of the muscular fibres in their thickness in various muscles. This is determined by the degree of differentiation and the development of individual muscles. The selection for larger weight was caused by the increase in the muscle mass and this reflected in the increase in the number and size of muscular fibres (Kulíšek, 1976).

In connection with this, Knight et al. (1999) drew attention to the issue of castration, whereby they studied the influence of castration on the type of muscular fibres. They concluded that the time of castration of farm animals is exceptionally important with regards to the intensity of growth of muscular fibres. Similarly, Cosgrove et al. (1997) paid attention to the issue of the time of castration from the point of view of growth intensity.

Ijačky et al. (1997) observed in the muscles of pigs in age 6 to 12 months age the completion of formation of muscle bundles with majority of intercellular spaces; this histological observation is similar to the one made at the individual's age of 1–3 months.

Sidor (1983) considers the age factor as exceptionally important aspect in the choice of animals for various breeding purposes. The younger animals react better to the new environmental conditions and they adapt faster, he concludes.

According to Uhrín and Uhrín (1989) and Solomon (2004), the younger animals with more intensive growth and higher weight can have thicker fibres in the transitional period than the older animals with lower intensity of growth.

Cicalo et al. (1997) confirmed this finding on the basis of histological and histochemical analysis that the share of connective tissue grows in direct proportion with the age of bulls while the muscular fibres could occasionally diminish. According to the research by Pulkrábek's research (2002) emphasises that with the weight growth of pigs there is a possibility of decrease in the skeletal muscle and also confirmed the formula that a weight increaseof slaughtered animal in 10 kg is accompanied by a decrease of the muscle mass in 1.0 – 1.5 %. Mersmann et al. (1987) showed that the muscle structure changes with age from the point of view of percentage content of water and proteins.

During the observation of domesticated farm animals and wild animals the age differences were studied and Yan et al. (2000) described the differences in the growth and the development. Their observation was based on the study of sperm production of wild bulls. They found out that the sperm was formed for the first time in the 12$^{th}$ month and that the wild bulls achieved their sexual maturity at 24 months.

## Ethological influences

The health and the reproduction abilities of the animals depend 30 % on the endogenous factors and 70 % on the environmental factors. The factoe considered to be the most important include temperature, relative humidity, air cirkulation, purity of air and light. But injuries of farm animals are the primary stressors. Muscle regeneration during injuries can have considerable impact on the utility of farm animals. It is evident that together with the yield of meat that the injured animals also suffer from pain and therefore they lose their weight and they cease to be socially active and utilisable.

However, Boľ and Boľ (1954) noticed that the regeneration of transverse striated muscles usually takes place very slowly depending on the gravity of the muscle damage. As Stanek et al. (1955) observed the muscular fibres are ceasing to exist in various pathological spots by complete decomposition (sarcolysis) whilst they remain only as nuclei with the cytoplasmic squares imitating the cells (sarcolytes). Later we find only the ligaments at the places of disappearance of muscles. If both the sarcolemma as well as the sarcoplasm is preserved with partial nuclei it is possible to have the complete regeneration. Totally damaged muscular fibres fall apart by means of the cell fermentation and the remnants are drained via the system of veins. At this point the interstitial muscle multiplies thereby replacing the muscular tissue. There is a possibility of partial or complete muscle dysfunction in considerable muscle damage. Probably under the influence of stress in mildly damaged muscles the nuclei start to divide and the sarcoplasm increases in volume. Inside the damaged channel of sarcolemma there are multinuclear cytoplasmic islands growing in their size till they create the syncytium. The dead muscular fibres are dissolved by means of fermentation. Then the preserved muscular nuclei divide and the surrounding sarcoplasm increases in volume. The next development is the differentiation of myofibrils and nuclei move to the periphery of the muscular fibres (Mahon et al., 1999).

Debrecéni et al. (2001) suggested that unsuitable manipulation with animals gives rise to stressors, which decrease the productivity of animals. Stressors manifest in physical, chemical and the stress caused by illness and last but not the least the psychogenic stressors.

Sidor (1983) observed it to be necessary to approach the study of animal behaviour from two main aspects - from the point of view of physiology and psychology. As these aspects were significant at the end result Sidor (1983) defined the external and internal, physical, biochemical and ethological stress symptoms in cattle and he paid attention to the induced stressors too.

The selection of pigs for the lean slaughtered meat together with high daily increment specified the high nitrogen retention ability of pigs, the ability to synthesise albumens and the high activity of growth hormone (STH) which is antagonistic to the production of adreno-corticotrophin hormone and corticosteroid hormone of suprarenal glands. The preference of the individuals with those abilities caused reduction in their ability to respond effectively to stress situation Debrecéni et al. (2001).

The nutritional influence in winter and summer time on the growth of the skeletal muscular tissue of cattle was analysed by Keane et al. (1999) and Lebret et al. (2002). They studied the influence of warm temperature on the growth of muscular tissues in farm animals. The temperature in summer was 24˚C and in winter 17˚C. There was relatively lower rate of growth of skeletal muscular tissue in summer than in winter but in the end the system of farming did not influence the growth of skeletal muscular tissue and did not influence the end pH in the meat of animals post mortem.

The changes in the muscular fibres are caused also by thereduced activity of farm animals and this can be brought about by various causes (Uhrín and Uhrín, 1989). In this sense it is mainly about the reduction of the thickness of muscular fibres, upto by 5–10 %.

## CONCLUSION

The postnatal growth of skeletal tissues refers to the process of thickness and elongation of muscular fibres. These processes are under the influence of many factors from external and internal surroundings. The most important are the genetic and nutrition influences. Others include sex, movement, age, weight and also ethological influence. This paper gives information about the influences on growth of transverse striations of skeletal tissues of animals.

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