MORPHOLOGY AND PHYSIOLOGY OF MUSCLE FIBERS AND THEIR INFLUENCE ON THE MEAT QUALITY (SHORT VERSION)

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Biologically speaking meat is skeleton musculature, and the cellular constituents of a muscle are muscle fibres, fat cells, and connective tissue. The meat and fat layer, which are especially interesting to the breeder, are the result of the growth of these microstructural components. The constitution of the meat is dependent on the qualitative composition and the condition of the cellular components.

That is why the examination of the muscular tissue with the help of micriscopic methods has taken up an important place within the meat research internationally as well as in our institute.

1. MICROSTRUCTURE OF THE MUSCLE

With the naked eye, we see the so-called grain size at the cut part of the meat, which, looked at in longitudinal direction, a.g. at cooked meat, becomes visible as meat fibre. Here, however, we are not dealing with muscle fibres. The grain size of the meat ensues from the bundle structure of the muscle tissue. The often very thick cords of the connective tissue, which run through the whole muscle in cross-section like the holes of a net, and cause the bundle structure, have, among others, the function of transmitting power from the muscle to the bone, and in the meat they are of importance for the tenderness. The larger blood vessels run through the connective tissue which support the muscle. This is also where the storage of intramuscular fat takes place. Without doubt, the intramuscular fat is of major importance for the taste and the juiciness of the meat.

Muscle fibers are the major components of the muscular tissue making up 90% of the tissue. They are highly specialized cell compounds with a cross-section of 10-150 μm and a varying length of several centimetres. Another exceptional feature of the muscular tissue is the existence of different types of muscle fibres which vary in their metabolic and contractile qualities. Muscle fibres, for example, are classified into white, red, and intermediate, or slowly or quickly contracting fibres. The detection of the muscle fibre type is carried out at the cut preparation through various histochemical reactions which cause different colourings.

The muscle fibre has several marginally positioned nuclei. The relationship of the number of nuclei per surface of a fibre cross-section is an important feature of the muscle structure. Each muscle fibre is supported by blood capillaries. The oxidative, red muscle fibres have more capillaries per fibre surface than the glycolytic, white muscle fibres. The capillary-fibre relationship is one of the features for the oxygen and nutriment provision. With a strong microscope enlargement, one can see that the muscle fibre consists of numerous myofibrils. The distance between the Z-lines of the myofibrils within the myosin parts is called sarcomere length. The sarcomere length is a measure of the state of contraction of the muscle and is regarded as a feature of the tenderness of cattle meat.

2. METHODOLOGY OF THE EXAMINATION OF MICROSTRUCTURAL CHANGES DURING THE GROWTH AT THE LIVING ANIMAL

In the past, processes of growth were examined especially because of sequential slaughtering. With the help of shot biopsy and the microscopic examination of the biopsy samples it is possible to study changes of growth already at the living animal and a repeated biopsy at the same animal. The shot biopsy equipment fulfills all requirements with regard to a quick and uncomplicated extraction of the samples in the shed as well as in the slaughter-house. There is no fixation of the animals and no anesthesia or local anesthesia necessary. The healing of the wound takes place after dressing the wounds with an antibiotic spray without any complications. In the course of the last few years, more than 2000 biopsies on pigs and cattle of different ages have been carried through by our researchers. The animal experiments by shot biopsy have to be approved of by the committee for animal protection of the province.

3. MYOGENESIS AND POSTNATAL MUSCLE GROWTH

The process of the embryonic and foetal myogenesis is an important precondition for the later growth of the individual, in which the development and differentiation of the skeletal muscle tissue from the mesodermal blastema takes place.

The principle of the myogenesis is based on the fusion of myoblasts with one nucleus to myotubes with several nuclei which, again, develop into the mature skeletal muscle fibre. The formation of the muscle fibres takes place in two phases in the cause of the embryonic development. With some animal species it reaches up to the early postnatal phase. Further myoblasts are taken up by the so-called primary fibres, which then amalgamate and form secondary fibres.

The postnatal growth of the skeleton musculature is, under normal conditions, only an extension of the existent muscle fibres, which, for its part, is physiologically limited. Thus, the total number of muscle fibres is an important factor for the growth potential of a muscle.

The difficulty of using this fact for the breeding is that it is hardly possible to determine the total number on a living animal. Currently, examinations are in process which try to solve this problem with the help of computer tomography and biopsy.

The postnatal differentiation of the muscle fibre types is different for the animal species mouse, cattle, and pig. While animals that stay a long time in their nests, especially mouse, do not have different histochemically differentiable muscle fibre types, cattle, as an animal that leaves the nest early, does have all three fibre types, which are easily detectable. In the further cause of growth a fibre transformation takes place in the juvenile stage from the red over the intermediate to the white muscle fibre type.

4. GROWTH STIMULATION

Aiming at the promotion of growth, numerous experiments for the determination of the effects of exogenically supplied substances have been carried out on laboratory and working animals in the seventies.

Especially interesting are such active substances that stimulate the protein formation in the muscular system, hinder the fat growth, and use the offered nutrients as well as possible.

The ß-adrenic agonists (Cimaterol, Clenbuterol a.o.) and Somatotropic or growth hormone, for example, belong to the so-called "repartitioning agents" which cause a redistribution of the food energy in favour of the fat formation with better feed efficiency. The effects, on the whole, are relatively uniform: more meat - less fat.

However, histological and biochemical examinations have shown that this result is reached differently. ß-agonists as well as Somatropin cause a stimulation of the muscle fibre growth with a constant total number of muscle fibres. The nucleus-plasma relationship of the muscle fibres as well as the DNA-concentration and the DNA-protein relationship remain unchanged at longtime treatment with STH, however, they increase after the treatment with ß-agonists. That means that the nucleus reproduction (satellite cell profilation) by STH is increased to the same extent as the protein accumulation. This could be an advantage of the STH-effect over the ß-agonist-effect, as the large increase of a DNA-supply unit possibly leads to bad functions in the muscle metabolism.

There is another difference in the reaction of the "repartitioning agents" in the distribution of the fibre types. While there are generally no changes in the metabolic and contractile fibre type pattern after STH-treatment, ß-agonists cause a distinctive increase of the quickly contracting glycolic muscle fibres.

Recently, we received an interesting result in our laboratory after the treatment of pregnant sows with porcine Somatropin. After a treatment of two weeks at the early pregnancy considerably more muscle fibres were found in the M. Semitendinosus of the newly-born piglets. Thus, the muscular system of such animals would have a comparatively high growth potential.

The growth of muscle fibres and fat cell of cattle was examined after the implantation of zeranol (commercial preparation: RALGRO).

Zeranol is a growth promoter which is used in cattle farming in numerous countries. Besides estrogen effects, zeranol also shows effects in other ways, whose mechanisms are not settled in every detail, yet. Thus, it causes an increased distribution of growth hormones in the hypophysis. The anabolic effect on bullocks shows especially in an increased protein formation, decreased fat formation, and quicker growth.

Our examinations on bulls showed cellular changes in the direction of an increased protein and fat formation, which can be very well observed by using the shot biopsy method.

5. GENETIC FEATURES OF THE MUSCLE FIBRE QUALITIES, THEIR RELATIONSHIPS TO THE MEAT QUALITY, AND POSSIBILITIES FOR USING IT FOR BREEDING

The task to show relevant relationships between microstructural features of the musculature and criteria of meat quality has been scientifically worked on intensively for some time. After phenotypical relationships between features of the muscular structure and relevant qualities have been proven, the suitability of the features of the muscle structure for the increase of the precision of the breeding esteem should be examined.

However, before new criteria, based on the knowledge of the muscle structure, can be used, their genetic basis must be known, and a save proof of their efficiency for breeding must be available.

This proof is found through reports about the genetic variability, the heritability of the features, as well as about the genetically- founded relationships to important efficiency features.

As only very high spot check scopes guarantee the necessary statistical reliability for such examinations, various experiments were carried out first on the experimental animal laboratory mouse. They showed relatively high phenotypical and genetic variabilities, appealing success in the selection, heritabilities in the lower sphere, and few maternal influences concerning the thickness and number of muscle fibres.

Genetic relationships to growth, protein formation, and maximum resilience could be proved through the calculation of genetic correlation coefficients and through the determination of correlative successes in the selection of the muscular structure after the selection of more than 40 generations of laboratory mice. The results showed the incompatibility of a good maximum resilience and an extreme muscle fibre hypertrophy.

The results found through the experiments with laboratory mice provided positive starting-points for a specific treatment of this problem on the working animal pig. The genetic relationships between the muscular structure and the meat capacity of pigs are of special interest. A divergent selection by features of the muscular structure leads to considerable changes of the sensitivity of the maximum resilience and the meat quality already after three generations.

The results stress the causal correlation between the structure of the musculature and its maximum resilience.

The features of a total of 1990 animals have been used by the way of comparison in an experiment with pigs for the population-genetic analysis for the estimation of the genetic relationships of pigs. Nearly all features show, with coefficients of more than 10%, a variability high enough for selection. The white muscle fibres are an exception, as their results are 7.6% for the diameter and 3.5% the portion. This low phenotypical and genetic variability has absolutely to be taken into consideration for the construction of possible selection criteria. The h-values for the features of the muscular structure lie between 0.22 and 0.65 and can be well compared with results from the literature. By estimation of the genetic correlation coefficients it was revealed that the fibre diameters show the closest relationships to the drip loss.

For the fibre portions, the portion "white" shows the closest correlation to colour brightness and the fibre portion "red" to the pH-value. The relationship between the total number of fibres and the criteria of meat quality is very low, compared to them, the portion of giant fibres shows close relationships to all three features. With these results, the following genetic-physiological correlation becomes obvious.

Large fibre diametres in the muscle have bad consequences on the capability of meat to produce water. High portions of white or low portions of red fibres result in a reduced oxidative potential of the muscle for the production of energy, which limits the adaptability of the animals at maximum resilience and, post-mortem, leads to unfavourable values of colour-brightness and pH of the meat.

6. CONCLUSIONS FOR THE CATTLE BREEDING AND FURTHER BASIC RESEARCH

The methodology of the extraction of samples, of the histological-histochemical preparation technique, and of the quantitative-microscopical muscle fibre analysis has developed so far that the methods can be used in a routine way. The muscle biopsy, when used in practice, however, requires the acceptance on the part of the protection of animals.

The phenotypical and genetic relationships between the features of the muscle fibres and the meat quality as well as the maximum resilience found on laboratory mice and pigs allow a sensible use in pig breeding. However, they are not applicable to cattle without further examinations.

The meat quality of cattle is not as much determined by the size of the muscle fibres and their type correlation, but mainly by the microstructural components intramuscular fat and connective tissue, that is juiciness, taste, and tenderness. In regard to these complexes, microstructural basic research will be necessary in the future.

The increase of the meat portion in the body for slaughter can, if not desired by oxigene growth stimulation, be reached by an increase of the total number of muscle fibres. As the total number cannot be determined on the living animal, yet, and can thus not be influenced by the breeder, the regulation by endogenous factors, starting with the myogenesis, should be researched in further basic examinations.