

BIOLOGY AND BIOCHEMISTRY OF POST-MORTEM MUSCLE

STATUS AND CHALLENGES

by

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INTRODUCTION

An examination of the published proceedings of past EMMRW and ICoMST meetings reveals that a review paper on biochemistry, post-mortem change or fundamental science is invariably included. These papers range in format from broad and extensive reviews of the literature to quite specific analysis of rather narrowly defined problem areas. We have the pleasure, this year, of contributing our thoughts and have decided to examine the evolution of what has occurred; this will allow us to define the current status and, in turn, set forth the challenges to be met.

The post-mortem period is critical because it is then that muscle is converted to meat. It is well known from very early work that the post-mortem changes influence, to some extent, properties of the meat. Many of the classical papers in meat science have described the metabolic and physical processes which occur. These works have been so important in forming the basis of what we know now as Meat Science that we almost automatically think of post-mortem biochemistry as Meat Science.

We emphasize that two other important areas are now also recognized--the pre-mortem phase and the processing phase. Knowledge about post-mortem properties remains the central and important issue. But, we must appreciate that the pre-mortem phase influences the post-mortem properties, and processing can be designed to utilize to best advantage those properties.

In the first case--the pre-mortem phase--there are two considerations. The first is that the handling of the live animal itself has a major influence on the meat produced from it. Genetics is important, as illustrated by the PSE problem in pigs. Likewise, genetics and management techniques determine composition of the meat. And now, genuine concern is being expressed about what changes may be affected in the meat by applying to the animal modern techniques of biotechnology and regulation of growth controlling factors. The second consideration is the control which can be exerted influencing immediate preslaughter stress to the animal, stunning and slaughter techniques, chilling conditions and use of techniques such as electrical stimulation.

In the second case--that is what can be done with the meat once it is meat--has evolved into another area known as "processing". Here we have seen the old and well-known techniques of sausage making converted to highly refined and automated production of numerous varieties of processed meat. Packaging has been a key consideration. In this phase also, a knowledge of post-mortem properties of meat has been of benefit to those developing new processes and procedures.

JUSTIFICATION

We turn now to a topic extremely important, but, unfortunately, often overlooked. In order to conduct research, which is done to accumulate knowledge so that problems can be solved, funds are required. In a given area of science, the initial descriptive work comes rather rapidly, but then, when effort is focused on working out and explaining mechanisms the work becomes more difficult and slows. In the case of post-mortem properties of muscle, the situation is complicated because of the recognized strong impact of the biology of the animal on the post-mortem conversion process. Post-mortem muscle cannot just be treated as static meat, but it must be recognized as resulting from dynamic biology of the animal and potentially subjected to harsh mechanical treatment if it is converted to processed meat. So, it appears to us to be extremely important to define carefully the status of knowledge about post-mortem muscle and then consider the challenge for the future--that is, what further information is required to maintain and improve consumer acceptance of meat?

In our opinion, there are three factors influencing the perception consumers have of meat. They are: quality, safety and value. Quality is primarily what the consumer sees, and then subsequently realizes as the meat is prepared and consumed. So, properties such as color, composition and palatability are important. Even though some say quality is difficult to define, the concept of safety is much more nebulous. The consumer may consider the safety of meat from the positive aspect of it being a nutritious commodity. More likely today, however, is the fear of the consumer that the meat may present some human health problem due to residues, composition or food borne disease. Value is purely a commercial aspect--what does it cost and how much is it worth?

Quality of meat is important to consumers. Quality is a reflection of post-mortem properties of muscle, and scientific knowledge and understanding allows some regulation of quality of the meat. Therein lies the justification for research on post-mortem muscle.

RESTATEMENT OF PROBLEM.

Much of the research we recognize as classical Meat Science and Muscle Biology has, in fact, been directed at elucidating the post-mortem conversion of muscle to meat. Well-described are metabolic changes, the process of rigor mortis and the properties of proteins participating in muscle contraction. This work has led to an understanding of important phenomenon such as tenderness, water-holding and pale, soft, exudative muscle. In the quest for basic knowledge about post-mortem properties of muscle, the Meat Scientist has developed an appreciation of the role of the biology of the animal as well as the potential for altering properties of the meat by processing techniques. The outlook then is that basic knowledge about post-mortem muscle has been useful, and as changes and improvements are made on either side--i.e. in the live animal and in processing procedures--a greater need for knowledge is evident for the future. Such information is prerequisite not only for solving problems which will arise but also to improve the quality of the meat. Our

objective is to comment on the status and future of research dealing with post-mortem muscle. We believe such research is not only easily justifiable but also critically required as the meat industry faces new challenges stemming primarily from consumer perceptions about quality and safety of meat.

STATUS

In this section, we will analyze several areas of research which impact upon our knowledge base about properties of post-mortem muscle.

THE LIVE ANIMAL

It was established nearly 30 years ago (Briskey, 1964) that the PSE problem was indeed a consequence of the physiological status of the animal. Even though the problem was manifested as a condition of the meat during post-mortem change, it originated because of a genetic condition present in the animal. At present, there must be renewed interest regarding the role of the live animal in determining quality of the meat. There is a great deal of animal experimentation on testing various agents to promote growth or repartition nutrients more into protein than fat; also, some scientists are involved in actually manipulating the genetics of the animal in order to alter growth patterns (see Campion et al 1989 for recent review). This work is proceeding at an extremely rapid pace, and it is evident that the meat produced must be subjected to experimentation to assure that properties have not been altered in an unexpected way. As animal production practices are altered the consumer will demand to know if the properties of the meat are changed.

As a means to illustrate how changes in the animal may result in alterations of the meat produced, we will use the turkey as an example (Sosnicki et al, 1988, 1989). By means of quantitative, genetic selection, great progress has been made in improving the feed efficiency as well as the proportionate mass of muscle produced in the modern turkey. Morphological study of a number of different muscles from birds of different ages has revealed the presence of degenerative characteristics. Individual fibers varied greatly in size and muscle fiber nuclei were often shrunken and pyknotic. Hyaline degeneration, infiltration by mononuclear cells and necrotic fibers were observed. Attempts at fiber typing revealed often a more or less uniform reaction for various histochemical tests. Motor end plates appeared normal. These degenerative changes were more frequent in the older birds. It is important to note that there was no apparent correlation between the degenerative symptoms observed and the gross morphology of the muscle or the quality of the meat. It was suggested that because of the selection pressure and resulting improvement in muscle growth and mass there was developed an ischemia of the muscle. While as mentioned above, the degenerative changes had no gross affect on the muscle, it may be taken as an early warning sign that changes in the properties of the muscle are indeed occurring.

PROTEOLYSIS

It is well accepted that some natural tenderization occurs during post-mortem aging of muscle. This is undoubtedly the result of action of the Ca^{2+} -dependent proteinase system known to be present in muscle. Tenderization by this system occurs to different extent in different animals and in different muscles. In order to understand how the system works it will be necessary to determine how it is controlled and regulated. Once the mechanism is known it may be controlled. This is an active area of research with effort being focused on determining the extent of tenderization under different conditions and also on locating the enzymes (primarily u-calpain and m-calpain) as well

as the inhibitor (calpastatin) so that the mechanism of action can be determined. For detailed information see Goll et al, 1990 and Ouali et al, 1983.

PROTEINS

The proteins, especially the contractile proteins, are often thought of as the most valuable part of the muscle. They are present in large quantity, they are responsible for the primary function of muscle which is contraction and they are the functional component in manufacture of processed meats. The numerous proteins were isolated, identified, characterized and their mechanism of action (i.e. contraction) was worked out in detail. An enormous amount of early work resulted in information which we generally accept for granted today.

Recent progress in immunohistochemistry has allowed specific localizations which in turn have aided in the solving of more practically related problems. For example, Ringkob et al (1988) have reported on use of a monoclonal antibody to titin which when used on 3-hour post-mortem muscle showed 2 bands, but when used on 48-hour post-mortem muscle showed 4 bands. They interpreted the results as meaning that the shape of the titin might have been altered during post-mortem time or alternatively a proteolysis had occurred.

Another important property of the muscle proteins is their ability to form gels (see for example Yasui et al, 1982; Foegeding, 1988) when heated. Recent interest in refined fish muscle protein, known as surimi (Lanier, 1985), and its strong gelling properties has probably stimulated renewed interest in learning more about gelling properties of muscle proteins.

MORPHOLOGY

Morphology is included in these comments about biochemistry because it has played an important role in biochemical studies of muscle. Now, a new technique is emerging which promises to allow better interpretation of some immunohistochemical localizations. Confocal scanning optical microscopy (CSOM) can be used non-invasively to obtain optical sections in biological specimens. The views are free from out-of-focus blur and the data obtained can be processed into three dimensional images. Velinov et al (1990) have demonstrated that CSOM can be used on meat products to determine fat globule distribution within the protein matrix undisturbed by sectioning and also to determine if bacteria actually exist within the depth of the thick section.

COLOR

The color of fresh meat is the major factor consumers use in making purchase decisions--it is, therefore, a critical characteristic of quality. Color depends upon the ratio of the two pigments oxymyoglobin (red) and metmyoglobin (brown), and numerous factors influence which pigment predominates. Metmyoglobin is the oxidized form; the two strategies for maintaining a good color are to prevent oxidation or reverse it if it has occurred. Two recent works have provided a possibility for each strategy.

Faustman et al (1988) studied a partially purified metmyoglobin reductase prepared from bovine cardiac muscle. The preparation was active but required either partially purified cytochrome b_5 or potassium ferrocyanide as reaction mediators. Further work will be required to determine if the system could actually be used in a meat system to reduce oxidized pigment.

Probably a better alternative is to prevent oxidation of pigment. This may actually be accomplished by vitamin E supplementation of animals. Faustman et al (1989) used Holstein animals and reported that supplementation

with vitamin E stabilized the redness and color intensity of the meat compared to meat from control animals.

CHALLENGES

The premier challenge at present is to be able to deal successfully with problems which are a result of perception of the consumers. This is not written facetiously. The consumer has some legitimate concerns and raises some real questions which must be solved and answered. For example, they wish to have genuine answers about nutrition and safety. There are two difficulties in responding to such circumstances. First, there are pseudoscientist who are more than willing to give an opinion that is not backed up by data or established information. Second, questions that are raised may require a long time to answer whereas an almost immediate response is expected.

In order to be effective in today's environment, the scientific community must anticipate problems, must have a vast storehouse of factual knowledge and must learn from previous experiences how to plan, execute and respond. A case history of a typical food safety problem (nitrite cured meat) has been used by Cassens (1990) to illustrate what can be learned in dealing with such issues.

We suggest that information about the biochemistry of post-mortem muscle (or meat) is the foundation upon which the field of Meat Science has been built. It remains critical, in our opinion, that efforts continue to build our storehouse of basic information about post-mortem muscle. Such information has allowed solving of practical problems in the past, and it will also allow solving of problems which will arise in the future.

While post-mortem biochemistry of muscle is the cornerstone upon which to build, recognition must be made of two areas which impinge directly upon that classical biochemistry. At present, many manipulations are being attempted on the production animals in an attempt to improve efficiency and growth. The consumer has legitimate questions about what this does to the quality of the meat taken from the animals. Also at present, the value-added industry is busy at work developing new products, improved packaging and altered distribution. Again, the consumer has legitimate questions about what these changes do to the quality of the meat.

The best way to be able to answer questions and solve problems in the future is to increase our fundamental knowledge about the biochemistry of post-mortem muscle.

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