Course Name: Canning Technology and Value Addition in Seafood
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Muscle structure of seafood

Welcome to the NPTEL course, Canning Technology and Value Addition of Seafoods. In the last class we have discussed about the composition and nutritional quality of seafood. We discussed about different macro and micro components and the role of these macro components in the food and why seafood is so important. In today's session, we are going to discuss about muscle structure.

Always there's a query can fish be considered as a meat and according to the Cambridge dictionary the definition for meat is a flesh of an animal when it is used as food. Fish does contribute to nourishment and it is also important for sustainability and considering that fish is an animal, the fish meat or fish muscle can be considered as meat. Fish meat has different religious opinions. In case of Muslims, they have strict dietary rules such as halal when they consume meat the rituals have to be followed and that strict dietary rules are followed when consuming the meat. Similarly. in case of Jews, they also have strict dietary rules and this is called kashrut. In case of Muslims, only the scaled fish are considered as halal products and scaleless and shrimp products or octopus they are not considered or they are forbidden from eating and in case of Jews, they don't consume shellfish whereas the other fishes can be consumed. The scaled or scaleless fish are equally important or it can be considered as a meat. But in case of Hindus, they don't have any special preferences only in case of lacto vegetarians; they may avoid meat from animal origin or poultry or fish origin and Christians, as such they don't have any specific regulations. To summarize according to different religions meat has been defined differently and even fish is also considered as meat.

If you look at the figure in the photograph (Fig.1), usually larger animals like a cow, pork are sold in market as different cuts, loins and fillets. These are the terms used for this higher animal but nowadays these are also used in the case of larger fish. So, fish is definitely considered as a meat and these are rich in different macro components and micro components.

Fig.1

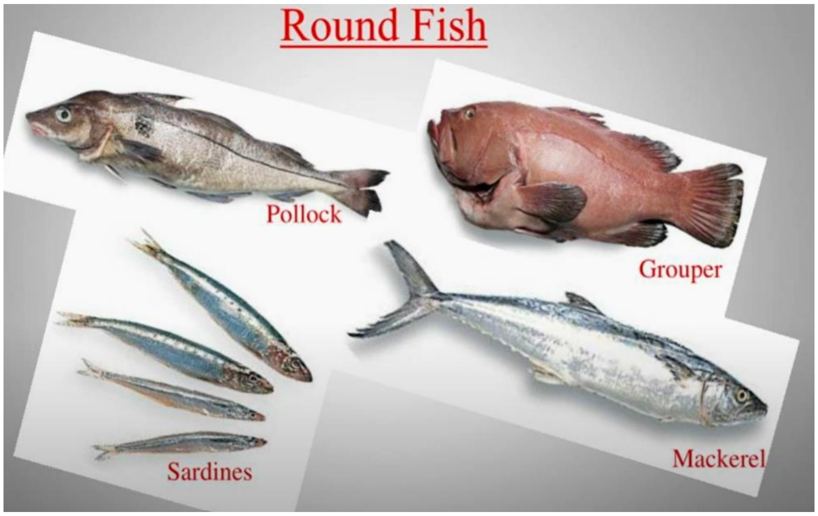
Now, before we further go into the topic let’s understand what is the food pyramid and how it evolved. According to the evolution in 1940, in U.S. they came up with the idea of food wheel. It was not the pyramid which was suggested earlier and all the protein sources they were listed together and these included meat, poultry, fish, eggs, dried beans, peas, nuts and peanut butter and later in 1974, Sweden, they came up with the idea of food pyramid. They again listed the products like meat, poultry, fish, beans and eggs as the sources of protein. This was again redefined in 1992 by U.S. and they rearranged the sources of protein and these included meat, poultry, fish, dried beans, eggs and nuts. Again in 2005, this model was the food pyramid model was redefined and it was again updated in the pictograph model and with this category the meat and beans were put as the choice of protein and they were put together. In 2011, the food pyramid model was replaced by my plate. My plate was recommended as the latest method of food distribution or the nutritional distribution and in this model the protein sources or the source of components or macro components or micro components they are not defined. It is said that the protein sources. So, it can be anything; it may not be meat or bean or the earlier specified ones it can be anything that provides protein that can be included in this category.

If you look at the nutritional profile of fish, it clearly says that fish, whether it is salmon, trout, or any other fish, they are rich in protein sources. Hence, fish can definitely be considered as meat. So, it is right to say that fish is a synonym for meat.

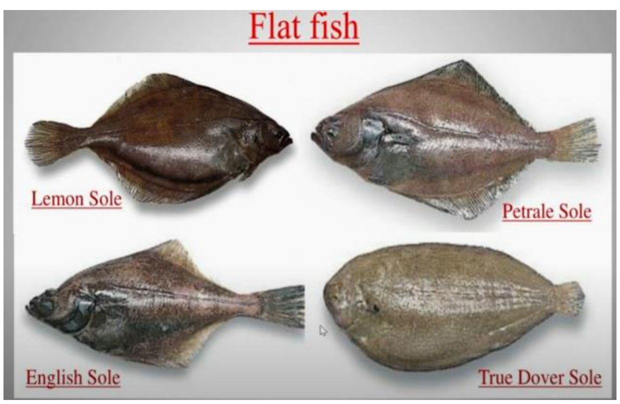
Now, coming to the classification of fish based on their distribution, they can be classified into freshwater fish, brackish water fish, or marine water fish. It is based on the salinity of the water. Fish can also be classified into round fish and flat fish based on their shape. Based on the cooking conditions, they can be classified into lean fish and fatty fish. This is again based on the distribution of oil in the body. In lean fish, the oil is distributed in the liver tissues, whereas in fatty fish, the oil is distributed throughout the muscle tissue.

The fish is protected on the outer side by the skin, which is again protected by scales. The internal organs are protected by the bone cage or the cartilaginous material. If you look at the figure here, you can see that there are fins, and this is a round fish because it has eyes on either side of the head. The internal organs are protected in the bony cage, and in this region, you will find all the internal organs. In the other part or the upper part, you will find only the muscular tissue, with no other organs placed in this upper tissue part.

Now, let's see what is round fish and flat fish. Round fish swim vertically, and they have eyes on either side. They are basically round in shape. Whereas flat fish, they are flat in nature. They are bottom dwellers, basically they survive on the organisms that live on the mud. They have eyes on the top. Since they are bottom dwellers, they have to see or the eyes are placed on the top because they have to see the upper part. They have smaller scales and also the fins. The anal fin and the dorsal fin run along the length of the body. Whereas the same kind of features you will not observe in the round fish.



Now, these are some examples of round fish: sardine, mackerel, groupers, and pollock. You can see that eyes are distributed on either side of the head. And again, the fins are not continuous throughout the body. They have specific dorsal fin or ventral fin or the anal fin. These are flat fishes. So again, it's clear that the eyes are located on the top. So, you can see here on the top, the eyes are located, and these are also called sole fishes.

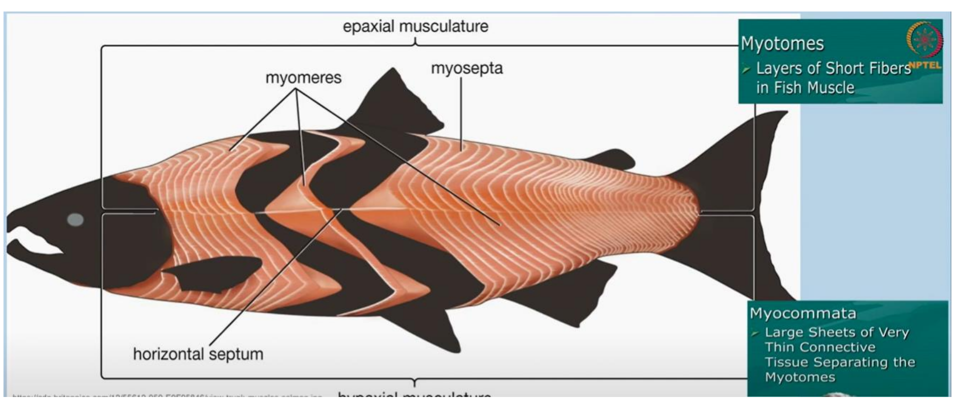


Now, there is another class called shellfish. These include mollusks and crustaceans. Mollusks, they are soft, un-segmented, and they don't have any internal skeleton. But they do have hard shells. And they are again classified into three types: univalve, bivalve, and cephalopods. Univalve, they have only one shell. And bivalves, they have two shells. Within these two shells, the organism will be well protected. In this category, cephalopods mean they have the appendages attached to the head region. So mainly, these include squid, cuttlefish, and octopus. They have pens or the cuttlebone, which is the hard part or the hard shell found in the mollusk.

Crustaceans, they have an outer skeleton, exoskeleton, which is hard in nature, and jointed appendages. Crustaceans include lobsters, crab, and shrimp. They fetch a lot of economic value. So, these are the major animals or the higher animals which are sold or marketed for their meat. So, from cattle, we get beef; pigs, they are known for pork; and sheep, they provide lamb. So, the cuts you can see here, some of the cuts like loin, which you can see in beef and in the case of lamb or in the case of pork. And also, the fillet, they have been adopted in the case of fish also where the sizes can be of the same nature.

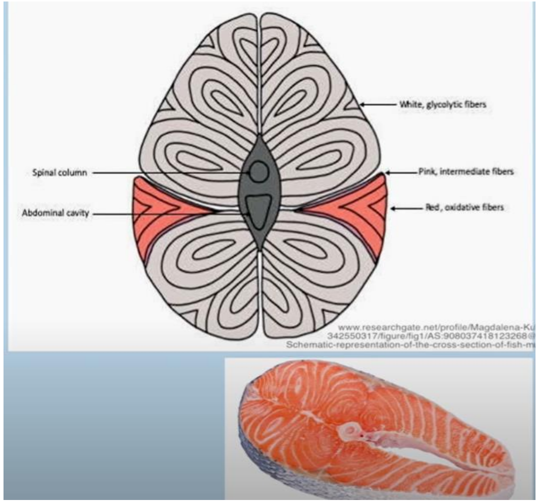
Coming to the nutritional composition, we have seen this in the last class. Fish muscles contain water in huge amounts, followed by protein, lipids, minerals, vitamins, and sterols. Of course, myoglobin is again an important component of the meat. And the muscle tissue of animals are generally lean in nature because the meat doesn't contain fat. The fat is distributed in the liver tissue. The muscle fibers in animals, they are made up of many fibers together and they are held together by the connected tissue. So, there is a connected tissue surrounding each muscle bundle. In higher animals, these muscles are joined together with tendons and ligaments. These connective tissues, which envelop the muscle fiber, comprise collagen and elastin. However, in fish, you find collagen in proportionately large numbers. Elastin is almost not available. This collagen, on heating, is converted to gelatin, which results in soft, soluble protein. It's a broken-down structure. The secondary and tertiary structures are denatured, and they are broken down to a digestible form of gelatin. Again, elastin is also elastic in nature. That's why it gets the name elastin. It is yellow in color and it becomes tough on cooking. Elastin also helps in connecting ligaments. Then muscle fibers, it comprises of actin and myosin. Both these actin and myosin filaments are important for the contraction and relaxation of the muscles.

If you look at the figure here, if you draw an axis along the length of the body, this is a longitudinal axis.

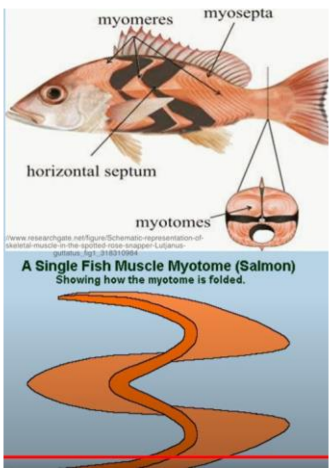


If you draw an axis along the length of the body, through the middle, the upper half of the muscle can be called as apaxial musculature and the lower half can be called as hypaxial musculature. And each myotome or myomere, it's a bundle of muscle. It is separated from each other by a septum. That septa will be myo septa and it is basically collagenous in nature or connective tissue proteins. And myomeres are made up of myofibrillar proteins.

This is a cross-section of fish.

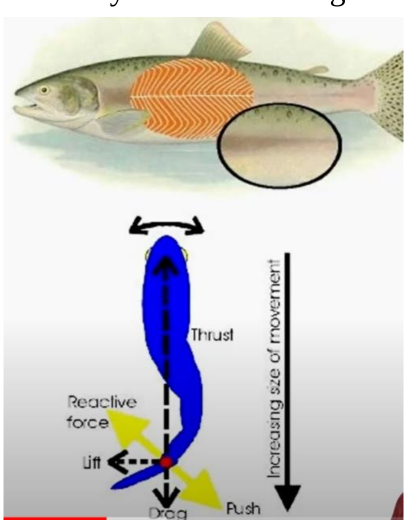


In cross-section, again, you can see the septa and the upper half is the apaxial region and the lower half is the hypaxial region. And here you can see on either side, that tissues are darker in color. And this is because of the presence of myoglobin, and they are called red muscles. Whereas in the upper region, that is white in color. The bottom figure is a cross-section of salmon fish. Here you cannot see the dark meat and it's a mosaic nature. And if you look at the structure here, the muscles, they have a 3D structure. hey are folded and



the narrow ends they face towards the front portion of the fish. And whereas the outermost edge it faces towards the tail. It has a shape of W and many such W's they are placed or they are overlapping each other. And this way, the myomeres are developed. So longitudinally, it is like several layers of myomeres are arranged from head to the caudal region. If you cut it along the longitudinal axis, you are cutting all the myomeres.

If you look at the figure here, the correct W's can be seen. And the number of W's



are stacked one over another. So that this is how the muscles are arranged in the fish. And this muscular arrangement helps in the movement of fish in the water. It is also responsible for the contraction and relaxation and not only during the movement but also during the post-mortal changes.

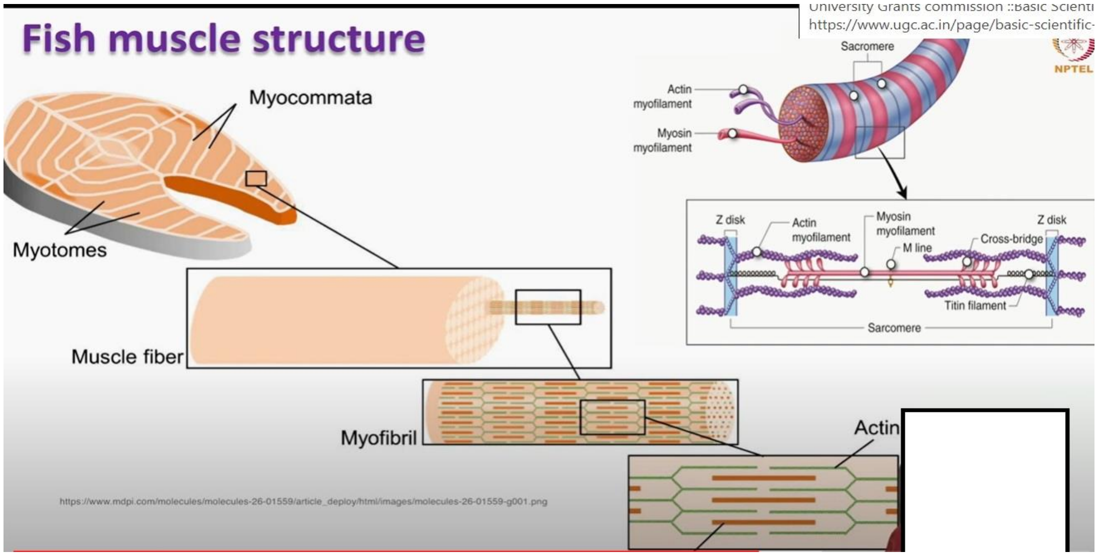
Fish muscle is classified into red, pink, and white. Most of the fish you will find red and white, but in some fish, you also find these three combinations. In salmon, it is a mosaic-type distribution. There is no clear-cut discrimination. Red and white, they are mixed together to form a mosaic-type muscle. And the color difference is mainly because of the myoglobin. Red muscle has a high amount of myoglobin, whereas white has very little amount of myoglobin. In some fish, like crustaceans and salmonids, they get their red color because of the feed they take, which are rich in carotenoids. So, it is the same in the case of flamingos where they also get the pink color because of the crustaceans they eat.

Now, what is myoglobin and hemoglobin? Both are proteins which help in carrying oxygen. In myoglobin, it's a single subunit of protein with heme. Whereas in the case of hemoglobin, it is four units, that is two alpha and two beta. If you take the difference between hemoglobin and myoglobin, hemoglobin is found in blood whereas myoglobin is found in heart, and skeletal muscles. Skeletal muscles are very important in fish because that is what we are going to consume and that is usually processed and consumed in different forms. So, hemoglobin consists of four heme and four globin chains whereas myoglobin contains one heme and one globin.

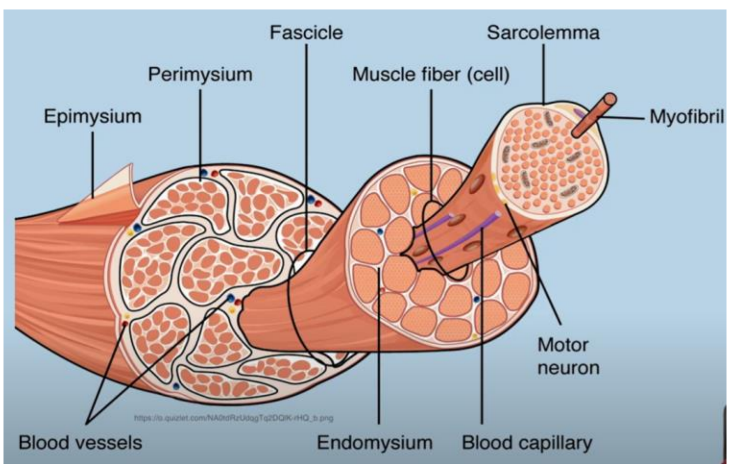
Hemoglobin carries oxygen and carbon dioxide throughout the body, but myoglobin is a reservoir and carries only oxygen. Hemoglobin has high affinity towards oxygen, whereas myoglobin has low affinity towards oxygen. If you look at the musculature, red muscle is also called a slow muscle or a dark muscle. It is used particularly in regular swimming for continuous movement. The red muscle is used because it is rich in energy and it also has a high amount of vasculature, meaning blood circulation is high in red muscle, which helps in continuous movement. So, it is also called bloodline. Twenty percent of the fish's total muscle mass is made up of red muscle.

The white muscle has thick fibers but it has less vasculature, meaning reduced blood flow. Because of that, the oxygen availability is also less. Further, it is used for short periods of action. If there is an immediate response required. These white muscles take part in that kind of activity. The activity is anaerobic, where glycogen is converted to lactate. It is usually the spontaneous release of energy where such kind of action is used. The white muscles will be found abundantly. Pink muscle is a combination of both white and red, and it is good for continued swimming, where it lasts for 10 minutes to longer distances, and also speed is involved.

Now, coming to the structure of fish muscle, you can see here myotomes, that is the muscle fibers. It is otherwise called myomeres. Each myomere is encapsulated by myocommata or collagenous tissue. Each myomere or myotome is a bundle of several muscle fibers. Several muscle fibers come together to form myotome. And if you take one muscle fiber, it will comprise of several muscle myofibrils. Several myofibrils together, they form one muscle fiber. And if you look at one myofibril, it will be comprising of several myofilaments. And these myofilaments, they are basically actin myofilaments. So, the myofilaments, they are made up of units of sarcomere.



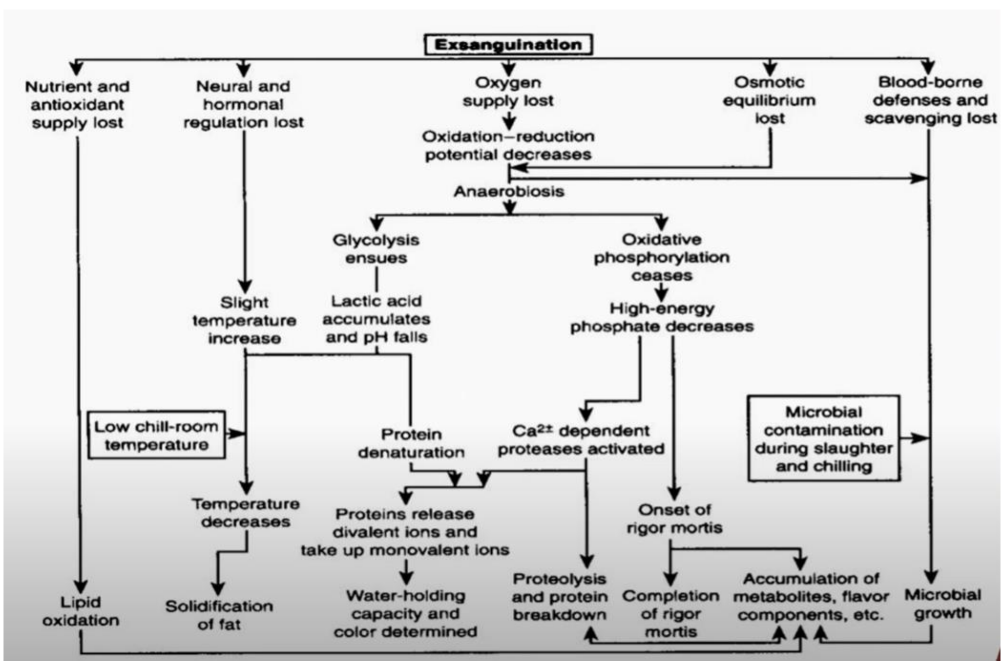
If you take a myofilament, you can find a number of sarcomeres. Each is being differentiated from another by the Z-disc, which is the lightened part. So, the light part, called the Z line, delineates one sarcomere. From here to the other end, there's a Z line, so this is called one sarcomere. The lighter band is called the I band, and the darker band is called the A band. In this A band region, we will find actin and myosin. When it contracts, it forms actomyosin, and they help with contraction and relaxation. So, all these parts of the sarcomere participate equally in contraction and relaxation. This is how the proteins are distributed in the fish.



In this figure, you can find a lot of muscle fibers. Muscle is made up of muscle fibers and they are made up of myofibrils and then fibrils are made up of filaments. So, each filament is protected by a sheet that is called endomysium. Together with the muscle fibers, they are covered by perimysium and on outermost layer you will find epimysium. So, it's like bundles are protected each bundle is protected so innermost bundle it is protected by endomysium and number of muscle fibers they are protected by perimysium and for on the outermost it will be epimysium. So, these epimysium, perimysium and endomysium together contribute to the collagenous part and in between the myofibrils you will find distribution of sarcoplasm. So, this is how the proteins are distributed in the fish.

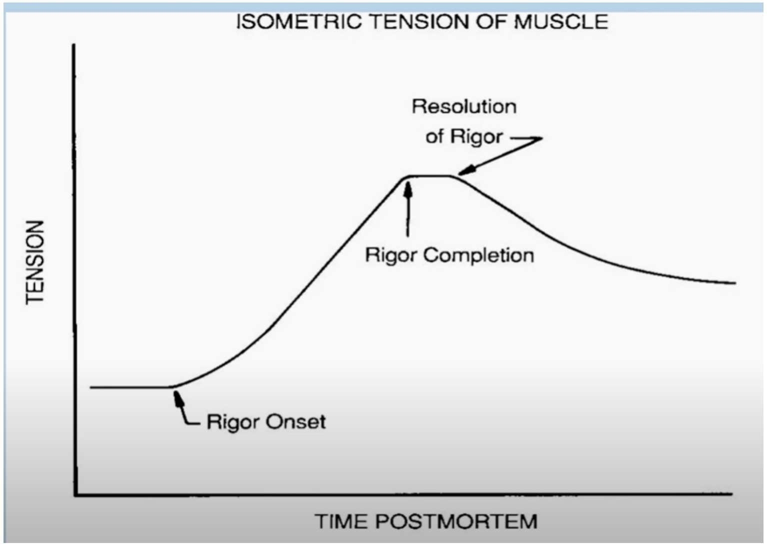
The conversion of muscle to meat involves a number of physical and chemical changes. When the animal is captured or killed, it is in the muscle form, and from there to meat, it undergoes a number of changes. This is because of the change in homeostasis; homeostasis is lost once the animal is killed. It happens because of changes in temperature, pH, and oxygen, and also because of the shift from aerobic to anaerobic respiration, oxygen depletes, glycogen is converted to lactic acid, which again reduces the pH, and pH comes down to 5.6. Creatinine phosphate, which supplements, phosphorylates the ADP molecules. The creatinine phosphate is lost because of that, and then ATP molecules also decline because of its utilization. Myosin heads bind tightly to the actin, forming actomyosin. Again, all this induces rigor motifs, that is stiffness of death. We will observe proteolysis and muscle tenderization.

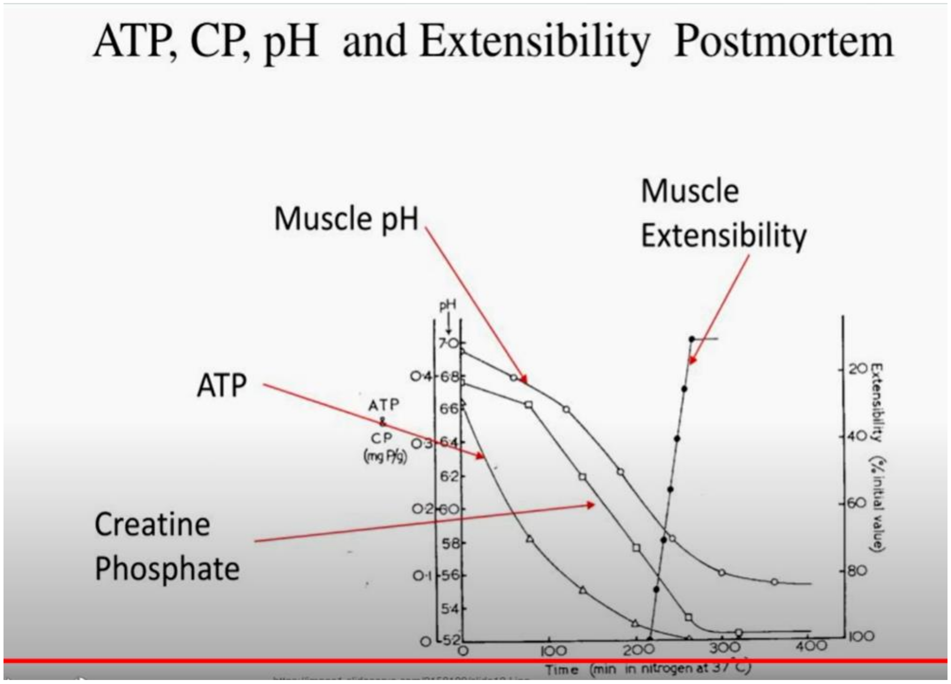
These are the changes observed when muscle is converted to meat. Usually, in case of higher animals, the rigor onset happens in 6 to 12 hours, whereas in fish, it takes less than one hour for the rigor to start. Once the rigor starts, the muscles are very stiff and the extensibility is less. But as rigor goes off, the muscle extensibility is reduced.



Now you can see the changes that have been described earlier in this figure. Everything has been compiled together. As the meat continues, microbial growth can also be observed in the post-mortem muscle, and rigor mortis will also onset, and accumulation of other metabolites happens.

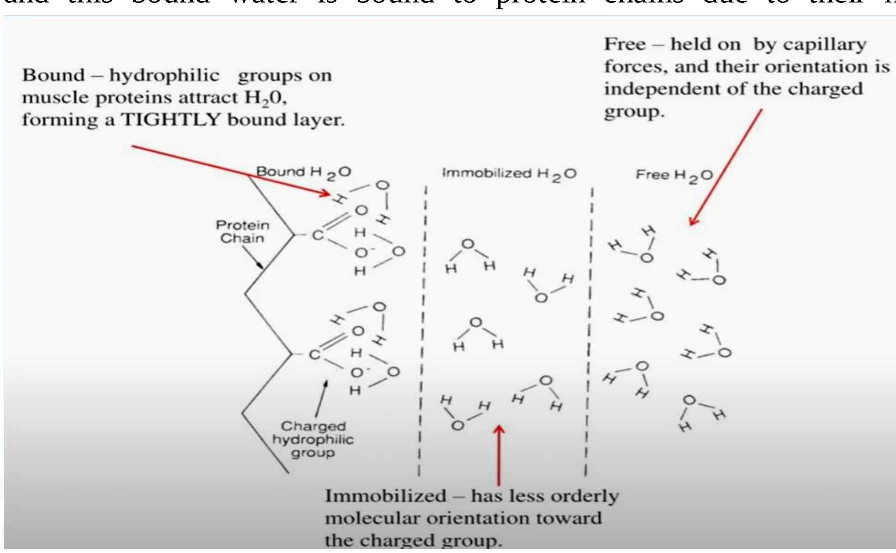
So, if you plot the post-mortem against time and tensions, the major post-mortem changes, like rigor, the fish entering into the rigor state after death, the stiffness happens in the body, can be plotted against time. In rigor, when the rigor starts, there is only a limited amount of time, and once it starts, it stays on for a longer period. The time of rigor will depend upon the size of the animal, and after some time, it gets resolved, during which the extensibility increases.





During this period, if you look at the muscle components or the other components, creatine phosphate, for example, is utilized for the production of ATP molecules. So, one phosphate will be contributed to ADP, and because of that, the level of creatine phosphate will come down with the rigor or the time. Again, ATP molecules are utilized for anaerobic respiration, so again, the amount of ATP molecules is also coming down. Similarly, because anaerobic respiration happens and lactate is formed, the pH is reduced, so it becomes acidic in nature. At the same time, muscles get extended, so it is the extensibility of the muscle which increases.

Now, in this figure, I have put this figure to show that in the last class, I had told you that the water can be divided into free water, bound water, and intermediate water, and this bound water is bound to protein chains due to their hydrophilic charges.



The charges are

available on the functional groups of protein, they help in holding the water molecules. So, once these are tightly bound, actually, but once the denaturation happens and physiological changes are observed, this water gets freed off, and the water molecules are moving away from the protein chains. Complete denaturation releases the water molecules, and these water molecules, they are free enough to be squeezed out of the mood. So, this shows that muscle is not able to hold the water intact with the increased period of storage or as it enters into the rigor continues.

With this, we'll stop for today's class, and to conclude this session, today we discussed about the muscle tissue of the fish. Each muscle tissue has myotomes or myomeres, and these myomeres in turn are made up of several myofibers, and myofibers they are made up of filaments. So, at each level, you will find collagen tissue which is enveloping or encasing the bundles so that it can be held together. And when you cook the product, these tissues they get degenerated or they are converted to gelatin, the soft tissue, and because of which the muscle bundles they get separated.