UKRAINIAN JOURNAL OF VETERINARY SCIENCES

2023. Volume 14, No. 1. P. 26-38

Received: 03.11.2022 Revised: 23.01.2023 Accepted: 22.02.2023

DOI: 10.31548/veterinary1.2023.26

UDC: 637.56.04/.05: 639.2

Microstructural analysis of frozen and salted fish and seafood meat

Nadiya Dyshliuk*

Doctor of Veterinary Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-4753-9356

Svitlana Usenko

PhD in Veterinary Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-3418-5421

Nataliia Slobodyanyuk

PhD in Agricultural Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-7724-2919

Tetiana Mazurkevych

Doctor of Veterinary Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-1294-5939

Zhanna Stehnei

PhD in Veterinary Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-0801-0751

Suggested Citation:

Dyshliuk, N., Usenko, S., Slobodyanyuk, N., Mazurkevych, T., & Stehnei, Z. (2023). Microstructural analysis of frozen and salted fish and seafood meat. *Ukrainian Journal of Veterinary Sciences*, 14(1), 26-38. doi: 10.31548/veterinary1.2023.26.

**Corresponding author*

Abstract. To evaluate the quality and safety of fish and seafood meat, along with generally accepted methods, new histological research methods are used, which allow establishing microscopic changes in fresh, spoiled, and canned foods. The purpose of this study is to examine the microscopic structure of salted fish meat (Herring, Pollock) and seafood (squid, mussels) by freezing. It was confirmed that fish meat is composed of skeletal muscle, fibrous connective (endo-, perimysium) tissues with blood, lymphatic vessels, and nerves. Muscle tissue fibres have the appearance of cylindrical formations, with well-defined transverse striation and numerous nuclei. The basis of seafood meat is smooth muscle tissue with layers of loose fibrous connective tissue, blood vessels, and nerve fibres. Smooth muscle cells are fusiform in shape, without transverse striation and with a single nucleus. During freezing of fish meat at a temperature of -18ºC, ice crystals are small and well-defined in the endo- and perimysium, and at a temperature of -23ºC – in muscle fibres. When fish is re-frozen, large ice crystals form in both the muscle fibres and the endomysium and perimysium of the muscles, the muscle fibres are fragmented and have cracks. In frozen seafood meat, there is a deformation of bundles of smooth muscle cells and their fragmentation. During the salting of fish meat, in the dehydration phase, a decrease in the diameter of muscle fibres and the width of the endo- and perimysium is noted, the transverse striation and nuclei of muscle fibres are well expressed, and in the dehydration phase, the reverse processes occur. Meanwhile, the fibres become straight with cracks and crevices, and graininess is noticeable in the endomysium and perimysium. Based on the results obtained, it is possible to evaluate the microstructure of frozen and salted fish and seafood meat, which is important when monitoring the suitability of food products for consumers

Keywords: fishing industry; canning; histological methods; muscle tissue; skeletal muscles

Introduction

Fish and seafood have long been consumed by humans and used as affordable and tasty food products. Currently, the value of fish products has been substantiated based on the quantitative and qualitative evaluation of proteins, fats, carbohydrates, vitamins, microelements, and other substances contained in them, and the technologies for their production and canning have been developed to preserve natural properties and improve quality (Abraha *et al*., 2017; Alimon *et al*., 2018; Volkhova & Holembovska, 2021).

By chemical composition, muscle tissue contains a considerable amount of protein and is a source of essential fatty acids (omega-3) and minerals (phosphorus, calcium, magnesium, zinc, iron, etc.). In particular, fish protein is easily absorbed in the human body, which creates conditions for lowering cholesterol levels. Fish meat also contains vitamins (A, D, E, K, B_1, B_2) and other biologically active substances that prevent the development of metabolic disorders and the occurrence of various diseases, in particular atherosclerosis. They have a positive effect on the functioning of the brain, cardiovascular and endocrine systems (Abraha *et al.*, 2017).

Fat obtained from fish has a positive effect on the human body. In addition, sea fish contains much more fat than river fish. It contains polyunsaturated fatty acids and fat-soluble vitamins that promote the formation of prostaglandins. The latter compounds increase the body's immunity and resistance to infections and have an anti-inflammatory effect (Duarte *et al.*, 2020).

Recently, some producers often falsify fish (Semenov *et al.*, 2020). Due to the above, the fish is of improper quality and becomes a source of human diseases, in particular, salmonellosis, botulism, etc. (Pohrebnyak, 2015). Quite often, to notably increase the mass of fish and seafood, manufacturers add water during freezing and, as a result, freeze a large amount of it, and also freeze fish that has begun to spoil or is already spoiled. Moreover, fish products can be treated with a variety of stabilisers (preservatives, antibiotics), including hydrogen peroxide, to freshen the corresponding products. The consumer must be protected from counterfeiting and consume high-quality and safe products to preserve their health. Therefore, veterinary and sanitary expertise of fish and seafood meat is particularly relevant (Pohrebnyak, 2015; Semenov *et al.*, 2020).

To evaluate the quality and safety of fish meat and seafood, histological research methods based on microstructural analysis are gaining popularity (Abraha *et al.,* 2017; Popova *et al.*, 2020). They are used by veterinary medicine doctors who work in accredited laboratories and supermarkets, based on various types of food production and processing facilities and possess the technique of manufacturing histological preparations, which is one of their professional competencies. Using a light microscope, histological methods make it possible to establish microscopic changes in fresh and spoiled food products, including canned products. Histological methods allow veterinary doctors to finally confirm the suitability of meat fish and seafood for food purposes, namely, the proper quality and safety of the food product for human consumption.

The purpose of the study is to examine microscopic qualitative changes in fish and seafood meat under various canning methods (freezing and salting).

Literature Review

The fishing industry is a branch of the food industry, the enterprises of which are engaged in catching fish and seafood and producing various products from them. The latter are a source of many nutrients for humans, which are necessary for strengthening bones, increasing immunity, and preventing the development of diseases of various organ systems and apparatuses (Mahmud *et al.,* 2018; Standal *et al.*, 2018).

To prevent spoilage of fish and extend its shelf life, it is necessary to preserve products. These methods are designed to inhibit bacterial activity and metabolic changes that lead to loss of fish quality (Boziaris *et al.,* 2013; Semenov *et al., 2020*). One of the main methods of preserving the freshness of fish is its freezing (applying cold), which is used to extend the long-term storage time.

According to Kong *et al.* (2008), physical changes occur in frozen fish meat, during which frozen water in the tissue forms ice crystals, which lead to partial destruction of the sheath of muscle fibres and leakage of tissue fluids due to deformations.

Alizadeh *et al.* (2007) note that physical changes are considerably affected by the freezing rate and the condition of raw materials. In their opinion, fish should be frozen quickly and at a low temperature. During rapid freezing, small ice crystals are formed, which on histological preparations look like voids, they are evenly distributed in the tissues and do not disturb their structure. The concentration of tissue fluids almost does not change and the proteins retain the ability to swell during defrosting. Moreover, the lower the freezing temperature, the smaller the size of the crystals. When frozen slowly, large ice crystals form, mainly in fibrous connective tissue, which on histological preparations have the appearance of significant

voids, since some of the water moves there from muscle fibres. Large crystals deform muscle fibres, destroy fibrous connective tissue and during defrosting, liquid flows out of the fish's tissues, and therefore it loses its original taste and appearance.

Khomych & Bal-Prylypko (2018) indicate that fish is better preserved if it is frozen immediately after catching when the shell of the muscle fibres of its meat is elastic, has considerable elasticity, and there is no damage so that the resulting ice crystals do not destroy this shell. As the freezing point decreases, this process occurs faster and the structure of body tissues changes microscopically less.

According to Popelka *et al.* (2012), during long-term storage of fish, microscopic changes occur, which are characterised by loss of muscle fibres, swelling and destruction of their nuclei, the appearance of numerous voids that are formed by ice crystals, and loosening of the endomysium and perimysium.

In addition, another common method of preserving fish is salting, which uses salt crystals or brine Dal Bello *et al.* (2020). Sodium chloride diffuses into the muscles from the outside due to the difference in osmotic pressure between the internal environment of the muscle fibres and the brine.

According to Dal Bello *et al.* (2020) during the dry method, the moisture content in the muscles, as well as bacterial and enzymatic activity, is notably reduced. Therewith, the muscle fibres are located denser and acquire a smaller length and width. The duration of the salting period and the salt concentration depend on the expected final product.

Horner (1997) considers that the main disadvantage of the dry method of salting is the dehydration of meat products, as a result of which they become hard. In this case, the distribution of salt is quite uneven.

Materials and Methods

The study was conducted during 2020-2022 in the scientific laboratory of the Department of Anatomy, Histology, and Pathomorphology of Animals of V.G. Kasyanenko National University of Life and Environmental Sciences of Ukraine (Kyiv). Samples of frozen and salted fish and seafood meat were taken for histological studies. According to external signs and organoleptic parameters, all samples of frozen fish met the regulatory requirements of DSTU 4868:2007 (2009).

The process of making histopreparations included a series of sequential steps: sampling, fixing, washing the fixed samples with water, dehydration, sealing the samples with paraffin, making sections from the compacted material, staining the sections, and embedding the sections in balsam.

Samples were taken from fish and seafood carcasses using various canning technologies: freezing (herring, pollock, squid, mussels) and salting (herring). Two samples with a thickness of 2-3 cm were obtained from one carcass. Samples obtained from one carcass were numbered with the same number, placed in a glass jar, and fixed in a 10% neutral formalin solution. The minimum period of fixing the material was 24 hours.

The samples were washed with cold running water for several hours, after which they were dehydrated with ethyl alcohol of increasing strength (60%, 80%, 96% and absolute alcohol). Samples were kept in each of these alcohols for 12 to 24 hours. Paraffin was used to seal the dehydrated samples. Before compaction, the material was kept in two portions of chloroform for 2.5-3 hours. Samples from chloroform were transferred to a mixture of chloroform and paraffin and placed in a thermostat at 37°C for two hours. Subsequently, all samples were kept in paraffin at a temperature of 56°C. Then the paraffin samples were transferred to containers

and filled with hot paraffin. Paraffin blocks containing samples were obtained.

Subsequently, histological sections with a thickness of 6-11 microns were made on an MPS-2 microtome (Kharkiv plant "Tochmedprylad", Ukraine). Sections were stained with Karatsi's hematoxylin and eosin to establish the general microstructure of fish and seafood meat. The stained sections were placed in a Canadian balsam and examined using an Olympus CX 43 light microscope (Olympus, Japan). Individual histopreparations and their fragments were photographed with a Nikon Coolpix S3100 (Nikon, Japan).

Results and Discussion

Composition of fish and seafood meat

According to the data obtained, the composition of fish meat (herring, pollock) and seafood (squid, mussels) was not the same. The composition of fish meat included skeletal muscles, the basis of which is composed of skeletal muscle tissue, dense fibrous connective tissues, blood vessels, nerve fibres, and endings. In addition, muscle tissue was quantitatively superior to other tissues.

The skeletal muscles of fish are formed by muscle fibres, which are symplastic structures. On the longitudinal sections, they had the appearance of cylinders, the ends of which are rounded, jagged, or bevelled. The length of such fibres was 1.5-3.5 mm, and the diameter was 10-70 microns. The overall microstructure of the muscle fibre of fish meat is similar to that of mammalian meat (Stasishen, 2009; Dubinina *et al*., 2010; Khomych & Bal-Prylypko, 2018).

The fibre consisted of numerous nuclei, sarcoplasm (viscous protein solution), and sarcolemma (shells). The nuclei were rod-shaped or elongated-oval in shape and were located on the periphery of the muscle fibre, directly under the sarcolemma. There were from several dozen to several hundred of them. In the nuclei, their components were well distinguished: the nuclear envelope, chromatin (a small amount), the nucleolus, and karyoplasm (nuclear juice). A significant volume of the sarcoplasm of muscle fibres was occupied by hyaloplasm, which is a colloidal structure and, accordingly, its rarest part. The sarcoplasm contains special organelles-myofibrils, which provide contraction of muscle fibres. They were located along the muscle fibre and occupied the central part of it. Myofibrils consisted of myofilaments and had characteristic alternating dark and light stripes. As noted in the literature (Khomych *et al.,* 2013), since the light and dark stripes are located at the same level, the muscle fibre looks striated.

Individual muscle fibres were thin layers of loose connective tissue (endomysium), in which a network of hemocapillaries and nerve fibres were located. Muscle fibres were combined into bundles, between which thicker layers of loose connective tissue (perimysium) were located. Loose fibrous connective tissue consisted of cells and intercellular substance. The latter included a basic (amorphous) substance and fibrous structures. The cellular composition of this tissue was represented mainly by fibroblasts, which produce components of the intercellular substance, and in much smaller quantities, there were histiocytes, plasma cells, mast cells, etc. (Khomych & Bal-Prylypko, 2018). A considerable number of adipocytes or fat cells were found in the loose fibrous connective tissue of herring. The latter had a pear-shaped appearance and a significant diameter on histopreparations. The nucleus in such cells was shifted to the plasmolemma (shell) and had an elongated oval shape. The loose fibrous connective tissue of pollock contained notably fewer adipocytes, which were arranged in small groups.

According to the results of research, part of the fish's muscles began or ended with tendons. The latter were formed by dense fibrous connective tissue with a significant cellular content

of fibrocytes. Tendons turned into septa, which are formed by loose fibrous connective tissue (Fig. 1). Septa divided the fish muscles into myomeres, which had the appearance of concentrically arranged semicircles and circles. Fat cells were visible in individual myosepta.

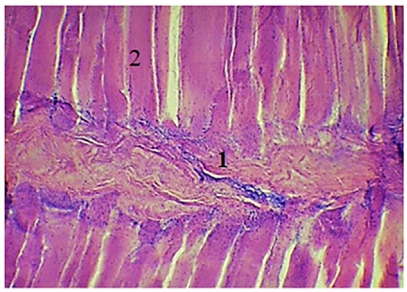

Figure 1. Skeletal muscle of fish (herring). Hematoxylin and eosin, ×90

Note: *1 – septa; 2 – muscle fibres*

Depending on the colour, fish meat is divided into white with different shades and pink-red. White muscle fibres are thicker and contain less of pigment-protein myoglobin, while red ones are the opposite (Horner, 1997; Doe, 2002). In the studied meat of herring and pollock, muscle fibres had a white colour with different shades.

According to the obtained results, the basis of the meat of invertebrate seafood is composed of smooth muscle tissue, loose fibrous connective tissue (endomysium, perimysium), vessels, nerve fibres, and endings (Fig. 2). The muscle tissue of squid was white, while mussels were white and pink in colour with different markings. It was formed by smooth muscle cells that had a microscopic structure similar to the smooth muscle tissue cells of aquatic mammals (Khomych *et al.,* 2013). These are fusiform cells with a single, centrally located oval-shaped nucleus. Their length was about 100 microns, while in aquatic mammals these cells can reach up to 200 microns (Khomych *et al.,* 2013), and the thickness is 3-10 microns. In the nucleus of smooth muscle cells, insufficient heterochromatin was noted and one, less often two nucleoli were found. There was no transverse striation in these cells, which indicates the absence of myofibrils. Smooth muscle cells were combined into bundles consisting of 8-12 cells, and the bundles formed layers.

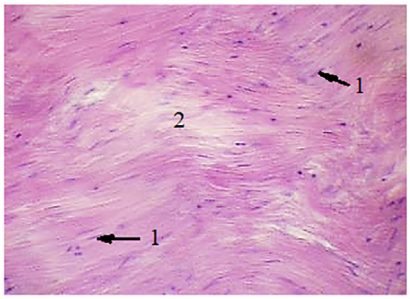

Figure 2. Smooth muscle tissue of seafood (squid). Hematoxylin and eosin, ×90

Note: *1 – smooth muscle cells; 2 – loose fibrous connective tissue*

Frozen fish meat

The microstructure of frozen fish meat depends on its condition, temperature, speed, and multiplicity of freezing. Fish is considered frozen if the temperature in its thickness is below 6°C. Usually, unassembled and disassembled fish are frozen until their posthumous conjuration. In industrial production, the freezing temperature can range from -5 to -80°C. As a rule, fish is frozen at a temperature of -5 and -20°C (Alizadeh *et al.*, 2007).

The results of the research confirmed that the tissue liquid (water) of frozen fish meat (herring and pollock) turns into ice crystals. They caused changes in the microstructure of meat. Ice crystals melted in thawed meat, and in histological preparations, their locations had the appearance of cavities of various configurations and sizes. The size of the ice crystals depended on the freezing rate of the meat.

It was confirmed by Alizadeh *et al.* (2007) and Duarte *et al.* (2010) that large ice crystals are formed during slow freezing, and much smaller crystals are formed during fast freezing. The authors believe that the size and location of ice crystals are the most important factors affecting the texture quality of frozen food. From the surface to the deeper layers, the rate of freezing of meat decreased. In addition, ice crystals were smaller in the surface areas of the meat than in the deep ones.

At a temperature of -18°C, ice crystals in frozen fish meat were found in connective tissue layers (endomysium and perimysium) (Fig. 3).

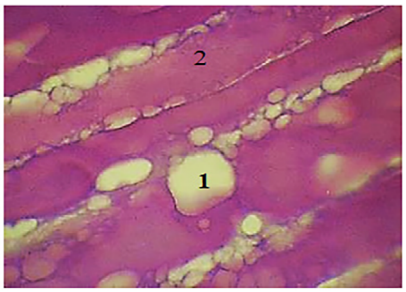

Figure 3. Ice crystals in the endomysium of herring meat. Hematoxylin and eosin, ×100
Note: *1 – ice crystals; 2 – muscle fibres*

Large ice crystals with appendages stuck into muscle fibres, leading to their destruction or deformation. The endomysium and perimysium in ice crystals had a slightly expanded appearance. Transverse striation was well expressed in the muscle fibres, and some of the nuclei in the places of their deformation were marked by destruction.

In fish frozen at -23°C or lower, ice crystals were found in the endomysium, perimysium, and muscle fibres (Fig. 4).

These crystals were small in size, oval and rounded in shape. The muscle fibres that contain ice crystals were deformed in some places, but not destroyed, with a weak transverse striation. Some of their nuclei were in a state of destruction. The endomysium and perimysium showed notable extensions.

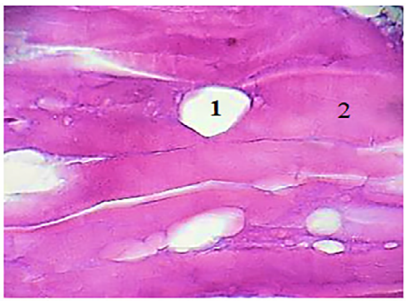

Figure 4. Ice crystals in the muscle fibres of herring meat. Hematoxylin and eosin, ×100
Note: *1 – ice crystals; 2 – muscle fibres*

Substantial destructive changes occur in fish meat when it is re-frozen (Fig. 5), manifested by the formation of large ice crystals in the endomysium, perimysium, and muscle fibres with noticeable cracks, while some of the fibres are fragmented, which is consistent with the findings of Popelka *et al.* (2012). These authors also consider unstable temperature conditions as a factor that increases lipid oxidation. Preventing temperature fluctuations during storage is important to preserve the quality of frozen fish meat.

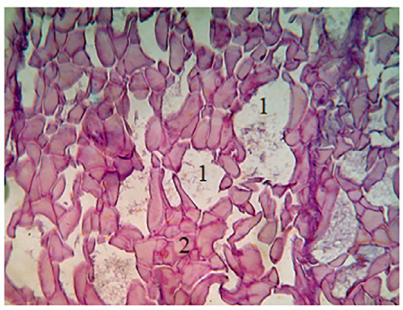

Figure 5. Muscle tissue of pollock when re-frozen. Hematoxylin and eosin, ×100
Note: *1 – ice crystals; 2 – muscle fibres*

When fish meat is re-frozen, the transverse striation of muscle fibres is almost invisible, a significant part of their nuclei is destroyed, lysed, or deformed. The endomysium and perimysium are considerably expanded and loosened. They contain a fine substance of pink colour.

Frozen seafood meat

In industrial conditions, seafood (squid and mussels) is frozen at a temperature of 30°C (shock freezing). It is also allowed to freeze these products at a temperature of -5 °C and below (Nagarajarao, 2016).

According to the results of studies, extremely pronounced destructive changes were noted in frozen squid and mussel meat. They were best expressed in perimysium, which had a loose appearance and significant expansions. Ice crystals of various shapes and sizes, noticeable pink granularity and fibrous structures were found in perimysium. Deformation of smooth muscle cell bundles was observed, which were oriented differently. In some areas, they formed grid-like formations (Fig. 6).

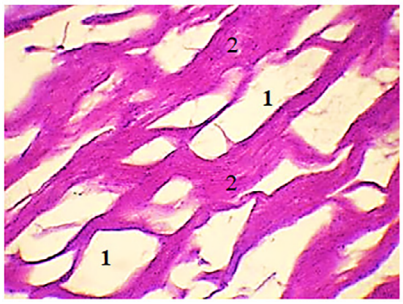

Figure 6. Locations of ice crystals in frozen squid meat. Hematoxylin and eosin, ×90

Note: *1 – ice crystals; 2 – bundles of smooth muscle cells*

The nuclei of smooth muscle cells, which are located near ice crystals, were not expressed, and the cell bodies looked fragmented and deformed. In some places, ice crystals were found in bundles of smooth muscle cells, which lead to their fragmentation and destruction. Furthermore, the destruction of individual smooth muscle cells in bundles with ice crystals was observed. Similar changes were recorded in the meat of frozen mussels (Fig. 7).

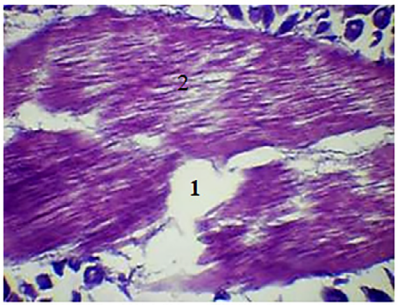

Figure 7. Location of ice crystals in frozen mussel meat. Hematoxylin and eosin, ×100

Note: *1 – ice crystals; 2 – bundles of smooth muscle cells*

Meat of salted fish

The microscopic structure of salted fish meat depends on the methods of salting and is based on the penetration of a solution of table salt into fish meat, while tissue liquid (water) and water-soluble substances are displaced from it (Kong *et al.*, 2008).

For wet salting, the duration of which is from 4 to 8 days, fish (disassembled or not disassembled) is placed in a solution (brine) containing up to 40% table salt (Varlet *et al.*, 2007). Within a few days, fish meat is considerably dehydrated (compacted), as the tissue fluid from the meat diffuses into the salty solution (dehydration phase).

According to the results of studies in the phase of dehydration of fish (herring), there was a decrease in the diameter of muscle fibres and the width of endomysium and perimysium, the fibres fit snugly together (Fig. 8).

Transverse striation and muscle fibre nuclei were well defined. The dehydration phase is quickly replaced by the dehydration phase, due

to the accumulation of salt in muscle fibres. In addition, water enters the fish meat from the brine, which led to an increase in the width of the endomysium, perimysium, and the diameter of muscle fibres (Fig. 9).

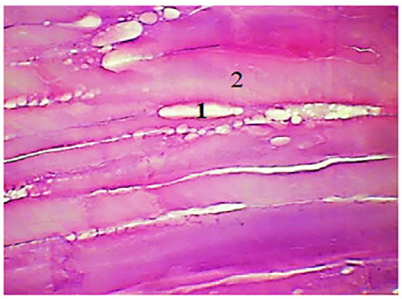

Figure 8. Dehydration phase of muscle tissue of pre-thawed salted herring. Hematoxylin and eosin, ×100

Note: *1 – ice crystals; 2 – muscle fibres*

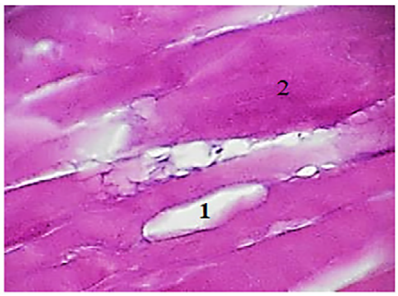

Figure 9. Hydration phase of muscle tissue of previously thawed salted herring. Hematoxylin and eosin, ×100

Note: *1 – ice crystals; 2 – muscle fibres*

Microscopic changes were observed in the muscle fibres. Some of the rectilinear fibres were fragmented and had cracks and crevices, and the striation was not visible. Some of the nuclei were destroyed. In the endomysium and perimysium, pink graininess was noted. When brine was introduced into fish meat by syringing, there was no dehydration phase for this type of wet salting. Microscopic changes in the fish meat are similar to the hydration phase, however, destruction of individual muscle fibers was noted at the sites of brine injection.

During dry salting (mixing fish with salt crystals), the duration of which is from 5 to 7 days, the fish is rubbed with salt and placed in a container in layers (rows). Layers of fish in containers were also sprinkled with salt. On the surface of the fish's body, salt dissolves in mucus, sodium ions enter the meat, and tissue fluid is released from it, that is, only dehydration of fish meat occurs, which is manifested by its compaction (Montero *et al.*, 2003). Microscopic changes in this meat were similar to the dehydration phase in the wet salting method. Thus, muscle fibers had a dense arrangement, and their length and diameter were reduced. Transverse striation and nuclei in muscle fibres were preserved. Using the mixed salting method, the fish is sprinkled with table salt and then dipped into the brine. This method of salting fish meat first dehydrates and compacts it, followed by rehydration (Goulas & Kontominas, 2005). As noted in this paper, this method is the most common and allows obtaining products of standard quality.

In the compacted fish meat, the layers of endomysium and perimysium were weakly expressed, muscle fibres acquired an elongated appearance, their diameter decreased, while nuclei and striation were preserved. Brine that penetrates into fish meat (hydration) caused reverse changes, in which the epimysium and perimysium were expanded and loosened, the diameter of muscle fibres looked enlarged, and their striation was not noted. Most of the fibres were fragmented.

Conclusions

The basis of fish meat (herring, pollack) is composed of skeletal muscles, the muscle fibres of which are symplastic structures with pronounced transverse striations and a large

content of cytoplasm and nuclei. Most skeletal muscles start and end with tendons, which are built from dense fibrous connective tissue. A characteristic feature of fish muscles is the presence of well-expressed myosepta (bridges) on histopreparations, where muscle fibres begin and end. Myosepta are loose fibrous connective tissues and are located across the muscles. They divide the fish's muscles into myomeres. Seafood meat (squid, mussels) is composed of spindle-shaped mononuclear cells of smooth muscle tissue, which do not have transverse striations. Muscle fibres of fish meat and smooth muscle cells of seafood are layers of fibrous connective tissue (endomysium and perimysium) with blood vessels and nerves.

In histopreparations made from frozen fish meat, ice crystals have the appearance of cavities of various sizes, which at a temperature of -18°C are found in layers of fibrous connective tissue and are absent in the muscle fibres, while at temperatures of -23°C – also appear in muscle fibres. In the frozen meat of invertebrate seafood, the smooth muscle cells are deformed and fragmented, while fibrous structures and a pink substance are visible in the perimysium.

During the salting of fish meat, qualitative changes in its microscopic structure occur. Thus, in the dehydration phase, fish meat is considerably compacted, and the muscle fibres retain striation and well-defined nuclei. In the rehydration phase, there is an increase in the diameter of muscle fibres and the width of endomysium and perimysium. The striation of muscle fibres disappears, cracks appear in them, and a pink substance is found in the endomysium and perimysium.

Further studies should examine the histological structure of fish meat and invertebrate seafood using other methods of preserving them (smoking, drying, frying, etc.).

Acknowledgements

None.

Conflict of Interest

None.

References

[1] Abraha, B., Samuel, M., & Mohammud, A. (2017). A comparative study on quality of dried anchovy (Stelophorus heterolobus) using open sun rack and solar tent drying methods. Turkish Journal of Fisheries and Aquatic Sciences, 17, 1107-1115. doi: 10.4194/1303-2712-v17_6_04.

[2] Alizadeh, E., Chapleau, N., & De Lamballerie, M. (2007). Effect of different freezing processes on the microstructure of Atlantic salmon (*Salmo salar*) fillets. Innovative Food Science and Emerging Technologies, 8(4), 493-499. doi: 10.1016/j.ifset.2006.12.003.

[3] Boziaris, I.S., Stamatiou, A.P., & Nychas, G.J. (2013). Microbiological aspects and shelf life of processed seafood products. *Journalof the Science of Food and Agriculture,* 93(5), 1184-1190. doi: 10.1002/jsfa.5873.

[4] Dal Bello, F., Aigotti, R., Zorzi, M., Giaccone, V., & Medana, C. (2020). Multianalyte MS based investigation in relation to the ilicit treatment of fish products with hydrogen peroxide. *Toxics*, 8(1), 1-12. doi: 10.3390/toxics8010002.

[5] Doe, P.E. (2002). Fish drying. In: Bremmer H.A. (ed.). *Safety and quality issues in fish processing*. Cambridge: Woodhead publishinglimited, (pp. 350-359).

[6] DSTU 4868:2007. (2009). Frozen fish. Specifications. Kyiv: Technical standardization committee "Fisheries".

[7] Duarte, A.M., Silva, F., Pinto, F.R., Barroso, S., & Gil, M.M. (2020). Quality assessment of chilled and frozen fish–mini review. *Foods*, 9(12), 1-26. doi: 10.3390/foods9121739.

[8] Dubinina, A.A., Ovchinnikova, I.F., & Dubinina, S.O. (2010). *Methods for determining counterfeiting of goods*. Kyiv: Professional.

[9] Goulas, A.E., & Kontominas, M.G. (2005). Effect of salting and smoking–method on the keeping quality of chub mackerel (Scomber japonicus): biochemical and sensory attributes. Food Chemistry, 93(3), 511-520. doi: 10.1016/j.foodchem.2004.09.040.

[10] Horner, W.F.A. (1997). Preservation of fish by curing (drying, salting and smoking). In: Hall G.M. (eds). Fish processing technology (pp. 32-73). 2nd ed. UK: Blackie Academic and Professional publishers.

[11] Khomych V.T., & Bal-Prylypko L.V. (2018). *Microstructural analysis of meat and meat products*. Kyiv: NULES of Ukraine.

[12] Khomych, V.T., Dyshliuk, N.V., & Byrka, V.S. (2013). *Histology and embryology of aquatic animals*. Zhytomyr: PP "Ruta".

[13] Kong, F., Oliveira, A., Tang, J., Rasco, B., & Crapo C. (2008). Salt effect on heat–induced physical and chemical changes of salmon fillet (O. gorbuscha). Food Chemistry, 106(3), 957-966. doi: 10.1016/j.foodchem.2007.07.008.

[14] Mahmud, A., Abraha, B., Samuel, M., Mohammedidris, H., Abraham, W., & Mahmud, E. (2018). Fish preservation: A multi-dimensional approach. *Food Processing and Technology*, 6, 303-310. doi: 10.15406/mojfpt.2018.06.00180.

[15] Malimon, Z.V., Kukhtyn, M.D., & Perkiy, Y.B. (2018). Contamination of frozensh with mesophilic and psychrotrophic microorganisms depending on biochemical quality indices. *Theoretical and Applied Veterinary Medicine*, 6(3), 39-43. doi: 10.32819/2018.63008.

[16] Montero, P., Gómez–Guillén, M.C., & Borderias, A.J. (2003). Influence of salmon provenance and smoking process on muscle functional characteristics. Journal of Food Science, 68(4), 1155-1160. doi: 10.1111/j.1365-2621.2003.tb09617.x.

[17] Nagarajarao, R.C. (2016). Recent advances in processing and packaging of fishery products: A review. *Aquatic Procedia*, 7, 201-213. doi: 10.1016/j.aqpro.2016.07.028.

[18] Pohrebnyak, O.O. (2015). Methods of processing products in modern food production. *Medicines of Ukraine*, 4(190), 20-26.

[19] Popelka, P., Luptáková, O., Marcinčák, S., Nagy, J., Mesarčová, L., & Nagyová, A. (2012). The effect of glaze and storage temperature on the quality of frozen mackerel fillets. *Acta Veterinaria Brno*, 81(4), 397-402. doi: 10.2754/avb201281040397.

[20] Popova, V., Syromiatnykova, N., Vasylieva, Y., & Leppa, A. (2020). Experimental study of the influence of different types of smoking wood on the quality of hot smoked mackerel. *Veterinary medicine, Animal Husbandry Technologies and Nature Management*, (5), 121-126. doi: 10.31890/vttp.2020.05.22.

[21] Semenov, V., Petryankin, F., Kosyaev, N., Nikitin, D., Nikitina, A, Tikhonova, G., & Grigorieva V. (2020). Veterinary-sanitary evaluation of fish when applying the Akwa-Biot-Norm nutrient feed additive. *Earth and Environmental Science,* 433, 1-6. doi: 10.1088/1755-1315/433/1/012030.

[22] Standal, I.B., Mozuraityte, R., Rustad, T., Alinasabhematabadi, L., Carlsson, N.-G., & Undeland, I. (2018). Quality of filleted atlantic mackerel (Scomber Scombrus) during chilled and frozen storage: changes in lipids, vitamin D, proteins, and small metabolites, including biogenic amines. *Journal of Aquatic Food Product Technology*, 27(3), 338-357. doi: 10.1080/10498850.2018.1436107.

[23] Stasishen, M.S. (2009). High product quality is the basis of economic and ecological development of fisheries. *National Economy of Ukraine: Theory and Practice of Management,* 199-206.

[24] Varlet, V., Prost, C., & Sérot, T. (2007). Volatile aldehydes in smoked fish: Analysis methods, occurrence and mechanisms of formation. *Food Chemistry*, 105(4), 1536-1556. doi: 10.1016/j.foodchem.2007.03.041.

[25] Volkhova, T.V., & Holembovska, N.V. (2021). State and prospects of fish market development in Ukraine. *Scientific World Journal*, 1(07-01), 44-50. doi: 10.30888/2663-5712.2021-07-01-013.

Мікроструктурний аналіз замороженого і солоного м'яса риби та морепродуктів

Надія Володимирівна Дишлюк

Доктор ветеринарних наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-4753-9356

Світлана Іванівна Усенко

Кандидат ветеринарних наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-3418-5421

Наталія Михайлівна Слободянюк

Кандидат сільськогосподарських наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-7724-2919

Тетяна Анатоліївна Мазуркевич

Доктор ветеринарних наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-1294-5939

Жанна Георгіївна Стегней

Кандидат ветеринарних наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-0801-0751

Анотація. Для оцінки якості та безпечності м'яса риби і морепродуктів поряд із загальноприйнятими методами використовують нові гістологічні методи досліджень, які дають можливість встановити мікроскопічні зміни у свіжих та зіпсованих харчових і консервованих продуктах. Мета цієї роботи полягала у дослідженні мікроскопічної будови м'яса соленої риби (оселедець, минтай) і морепродуктів (кальмар, мідії) за заморожування.

Підтверджено, що м'ясо риби утворене скелетною м'язовою, волокнистою сполучною (ендо-, перимізій) тканинами з кровоносними, лімфатичними судинами та нервами. Волокна м'язової тканини мають вигляд циліндричних утворень, з добре вираженою поперечною посмугованістю і численними ядрами. Основу м'яса морепродуктів формує гладка м'язова тканина з прошарками пухкої волокнистої сполучної тканини, судинами та нервовими волокнами. Гладкі м'язові клітини веретеноподібної форми, без поперечної посмугованості і з одним ядром. Під час заморожування м'яса риби за температури -18°С, кристали льоду дрібні та добре виражені у ендо- і перимізії, а за температури -23°С – є у м'язових волокнах. Під час повторного заморожування риби формуються великі кристали льоду як в м'язових волокнах, так і в ендомізії і перимізії м'язів, м'язові волокна фрагментовані та мають тріщини. У замороженому м'ясі морепродуктів спостерігається деформація пучків гладких м'язових клітин та їх фрагментація. Під час соління м'яса риби у фазі обезводнення відзначається зменшення діаметру м'язових волокон і ширини ендо- та перимізію, поперечна смугастість і ядра м'язових волокон добре виражені, а у фазі оводнення відбуваються зворотні процеси. При цьому, волокна стають прямолінійними з тріщинами і щілинами, а в ендомізії та перимізії помітна зернистість. За отриманими результатами можна оцінити мікроструктуру замороженого і солоного м'яса риби та морепродуктів, що важливо під час контролю придатності харчових продуктів для споживачів

Ключові слова: рибна промисловість; консервування; гістологічні методи; м'язова тканина; скелетні м'язи