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INFLUENCE OF THE MECHANICAL MIXING OF THE HERRING FILLETS IN BRINE ON THEIR RIPENING PROCESS®

Wpływ mieszania mechanicznego filetów śledziowych na proces ich dojrzewania®

Fish is one the most important food groups in terms of nutritional value. They contain significant amounts of proteins and fats, which makes them susceptible to fast spoilage. The most common way to preserve fish is to add salt in high concentration. Following paper presents the influence of the mechanical and manual mixing systems during ripening on the quality of the final product. The changes in proteins and salt concentration, pH level, fillets and brine total acidity were investigated. A TPA test allowed to analyze gumminess, hardness, springiness, and cohesiveness whereas sensory analysis was based on Polish Standards.

Ryby stanowią jedną z najcenniejszych grup produktów pod względem odżywczym. W związku z tym, że zawierają dużo białka i tłuszczy, ulegają szybkiemu psuciu. Najbardziej popularnym sposobem utrwalania ryb jest ich solenie. W niniejszej pracy przeanalizowano, jak sposób mieszania mechanicznego filetów śledziowych podczas ich dojrzewania wpływa na jakość finalnego produktu. Zbadano zmiany zawartości białka i soli, pH oraz kwasowości ogólnej filetów i zalewy. Wykorzystując test TPA przeanalizowano ich żuwalność, twardość oraz spójność. Ponadto wykonano analizę organoleptyczną opartą na Polskiej Normie.

INTRODUCTION

Fish constitute as the source of many valuable nutritients. They are an important component of the balanced diet of the man. Fish contain high quality proteins, iodine, phosphorus, potassium, calcium and vitamins A, and D, as well as the unsaturated fats essential for the correct functioning of the brain.

According to the FAO report fish consumption constantly grows in the EU. In Poland salted and marinated herrings are the most popular appetizer. However, in 2013 herring consumption decreased to 1.94 kg per capita. Until 2000 annual consumption of this fish averaged about 3 kg per capita, but higher prices and the greater species diversity on the market lowered the popularity of herring. Still they are one of most often harvested species. According to statistical data given by the MIR in 2011 in the Baltic Sea almost 30 000 t of herring was harvested, what states for 17% of the entire fishing. From here the production of salted herring fillets states for the 3.2% of the entire fish processing, what gives 10 000 t/year. Even though fish consumption in Poland constantly grows, it is still far behind The European Union [7, 13, 17].

In order to change the situation, not only increase of the assortment of fish products is needed, but also fod companies should improve their taste, as well as make the appearance and the price more attractive. To achieve these purposes modifications and enhancements of the processing technology is needed. Seeking new technologies and solutions is crucial.

During the transportation fish undergo fast rancid, which is a great problem. In order to minimize losses they are frozen, however, this method isn't deprived of defects. Salting is one of the oldest manners of the preservation of foodstuffs. This allows not only to keep a lot of valuable nutrients, but also increases the variety of the products [12, 14, 15].

Herring fillets are mostly subjected to salting, so-called śledzie a'la matias. Such method causes the denaturation of the muscle proteins, what makes meat suitable for direct consumption, as well as it gives the distinctive flavor. Salty solution in the muscular tissue also impedes the development of the micro-organisms as well as stimulates enzymatic ripening of the raw material [12, 15, 19]. An important stage in the production of salted herring fillets is mixing [6]. The purpose is to intensify the mass transfer, chemical and biochemical processes. Moreover, while mixing proteins are extracted into the brine and as the time passes salt drains them more and more until those proteins create undesirable suspension. In order to avoid it fillets should not be mixed in the first twenty-four hours of ripening. With time the some of the proteins would naturally denaturate under the influence of the salt and thus wouldn't migrate to the brine. However, taking the economic side into consideration, mixing is applied in the first twenty-four hours [4, 6]. It is understandable since mixing allows for precipitating ripening, but also enables to achieve regularly salted fillets.

Mixing is most often performed manually by workers. For this a paddle mixer and a plastic container are used (fig.

1). Workers should be specially trained on how to use the mixing tool so the process will be accurate [3]. To achieve highest quality constant control of the mixing process is required. Another important aspect is keeping constant low temperature for ripening, around 5°C [14].

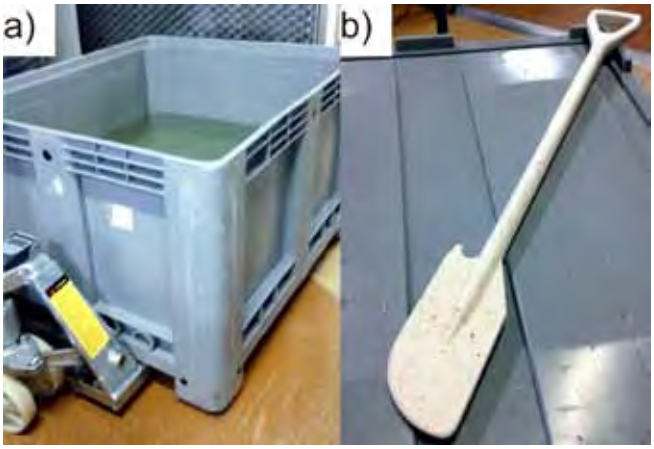

Fig. 1. Tools for manual mixing: a) plastic container, b) paddle mixer.

Rys. 1. Narzędzia do mieszania ręcznego: a) zbiornik z tworzywa sztucznego, b) mieszadło w kształcie wiosła.

Source: Own study

Źródło: Opracowanie własne

The food product must have appealing appearance, proper consistency and rich taste. The majority of processes are applied to change the texture of the raw material. Mainly to soften the structure so the mastication is much easier. In some cases changes of the texture are the secondary effect of technological processing, sometimes these are undesirable, however they are advantageous. As the example, softening and loosening of the structure of the raw material while freezing and after defrosting, and food subjected to the sterilization in tins [2].

The analysis of the texture is usually conducted with the help of the TPA test (texture profile analysis). According to the dictionary of the food technology a TPA test is an analysis of the texture of the food product in terms of mechanical and geometrical properties, and the fat and moisture content during the mastication [5]. The TPA test was created in the 60's of the last century, in order to examine the connection between mechanical properties and the texture of food products [10]. Replacing people with instrumental test lowered price, heightened the efficiency, accuracy and the repetitiveness of the examinations. Texturometer generates a graph of the relation of the force to the time, so-called profile of the texture (fig. 2).

Graphs for various products will differ in the height and the widthof the curvature. For food products the second peak will always be lower than first – it is a result of the imperfect springiness of the raw material [6].

THE PURPOSE OF THE WORK

The analysis of the influence of the mixing system on the quality of herring fillets is a subject of this work. Herring fillets mixed traditionally by hand and mixed mechanically were compared. Mechanical mixing was performed with the use

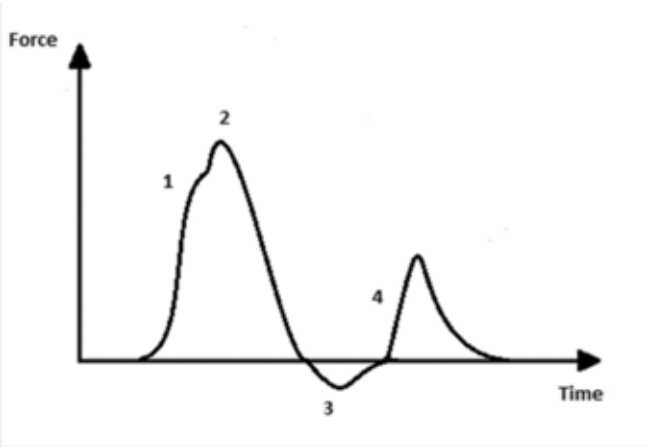

Fig 2. TPA graph overview, 1 – fragility, 2 – hardness, 3 – adhesiveness, 4 – springiness.

Rys. 2. Poglądowy wykres TPA, 1 – łamliwość , 2 –twardość, 3 – spójność, 4 – sprężystość.

Source: Own study on the basis of the [2]

Źródło: Opracowanie własne na podstawie [2]

of specially prepared agitator. Following quality indicators were chosen: nitrogen content, salt concentration, the pH level and total acidity. In order to determine the influence of the mechanical mixing changes of the protein content were investigated in the course of processing. Finally, texture of the meat was analyzed with the use of TPA test and the sensory analysis was performed.

Paper presents the results of research on the effect of mechanical mixing of herring fillets on their ripening process.

MATERIALS AND METHODS

Frozen herring fillets constituted as the research material. Polish Standard PN-A- 86770 defines fillet as the flesh of a fish which has been cut away from the bone lengthwise along one side of the fish parallel to the backbone, without the shoulder belt, fins and ribs and membranes of the peritoneum. Raw material was stored in the temperature -21°C for the period of 3 months. Defrosting took place in the defrosting chamber.

The laboratory conditions were applied for the research. The first test bench constituted of the glass container, where thawed herring fillets were dipped into the brine, in the proportion of 2.5 kg of fillets in 2.5 dm^3 of the brine. An agitator connected to the direct-current motor was installed to achieve rotary motion.

The engine had a transmission gear PM-33123000-540k with rated voltage 12 V. After setting the tension given to the engine at 2.7 V, 1 rpm was received. The structure of the agitator and the rotation speed allowed for a low share mixing. The container with mixture was situated in the refrigerator, in which for the entire period of examinations temperature was kept at 7°C.

The second test bench consisted of the plastic container, in which thawed herring fillets were dipped into the brine, in the proportion of 2.5 kg of fillets and 2.5 l of the brine. Manual mixing was performed with the help of the mixing tool for 15 minutes once a day, the first twenty-four hours were omit-

ted. The container along with mixture was situated in the refrigerator, in which for the entire period the temperature was also kept at 7°C. Herring fillets ripened for 4 days. Every day one fillet from each stand was taken for the analyses.

Mohr's method according to PN-ISO 9297: 1994 was used to investigate the changes of the concentration of the salt. The presented method is intended to indicate concentrations of soluble chlorides in the water in the scope 5 mg/l up to 150 mg/l. For the analysis 10 g of the fragmented sample of fillet was weighed out as well as 1 ml of the brine was measured.

The value of the pH of the fish meat and the brine were measured with the Microcomputer Multifunction Meter CX-551 pH meter, Elmetron. For the analysis 5 g of the fragmented sample of the meat and 5 ml brines were taken, then 5 ml of the distilled water was added and it was mixed for about 1 minute. Next the pH value was measured with the use of an electrode of the pH meter calibrated with model buffers.

Sensory evaluation was based on Polish Standards and was performed as a description in words in accordance with the requirements. Following basic characteristics of the quality of salted fish were evaluated: the smell of fish and brines and the taste. Also, changes on the surface of fillets were compared between test benches: layering of the meat, meat loss and the color changes. An evaluation was performed on finished products.

The examination of the texture of the meat of herring fillets was performed with the help of texturometer TMS-Pro Food Technology Corporation Companies. It enables to perform tests of stretching, crushing, compression and breaking along with the measuring sensors and measurement software for the result analysis.

The tested sample was compressed twice with the help of the flat tile, with the diameter greater than the diameter of the sample. Measured values of powers were recorded.

The texture was measured each day for both tech benches. Sizes of analyzed samples were about 1 cm/1 cm/8 mm, it was important to keep them perfectly identical to previous, because used device is very sensitive and any deviations of the size could affect the result. Samples were cut crosswise to the direction of the fibers in the examined muscle. Cartilage, bone elements and a skin could not appear in the sample. On the texturmeter's stand samples were put so that muscle fibers were placed along the direction of the compression [9].

RESULTS

The results of protein content changes in the meat of fish and in the brine are shown in figure 3. The initial concentration in both cases was the same and amounted to the 16%. In the course of ripening natural depletion of the protein in fillets took place to about 11%. Mechanical mixing caused greater loss and the final content amounted to the 9%. It was associated with intensifying the process of the change of mass by permanent mixing. Total losses of proteins amounted to 5-7 %. As proteins are the most important component its content in finished products should be similar to of the one in the raw material. At the beginning of the experiment there were no proteins in the brine, and at the end of ripening of fillets its content amounted to the 2.08% for manual mixing, and for mechanical mixing as far as 3.54%. Since the brine isn't being used by consumers such losses are not advantageous.

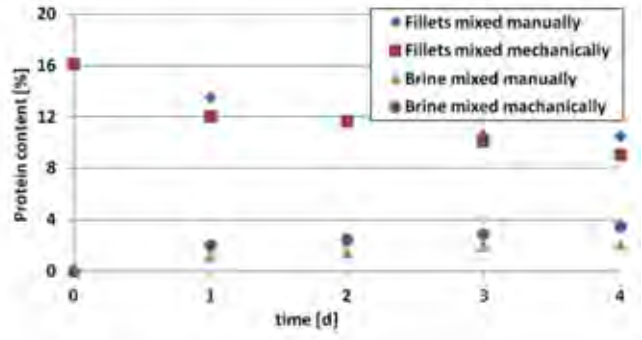

Fig. 3. Protein content in the fillets and in the brine mixed both by hand and mechanically.
Rys. 3. Zawartość białka w filetach oraz w solance mieszanych mechanicznie i ręcznie.
Source: Own study
Źródło: Opracowanie własne

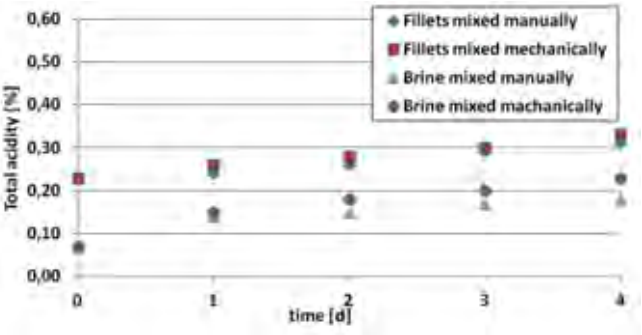

Fig. 4. Total acidity of the fillets and in the brine mixed both by hand and mechanically.
Rys. 4. Kwasowość ogólna w filetach oraz solanki mieszanych mechanicznie i ręcznie.
Source: Own study
Źródło: Opracowanie własne

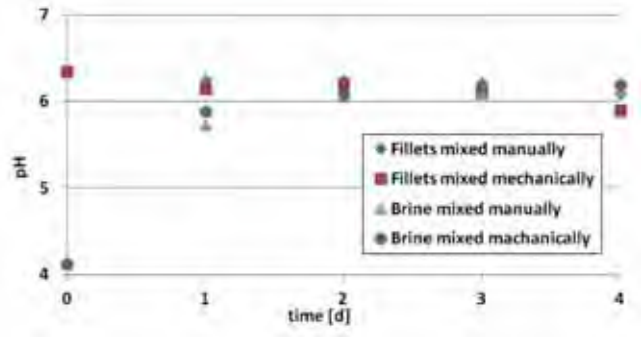

Fig. 5. Changes of pH value of the fillets and the brine mixed manually and mechanically.
Rys. 5. Zmiany pH filetów oraz solanki mieszanych mechanicznie i ręcznie.
Source: Own study
Źródło: Opracowanie własne

Fig. 4. shows the results of the analysis of changes of the total acidity of the fillets mixed manually and mechanically and changes of the total acidity of the brine. In consecutive days of ripening the acidity grew from the 0.23% up

to the 0.31% for fish mixed manually. Fish mixed mechanically had a greater increase of the acidity, up to 0.33%. The salt causes the diffusion of water from cells to the intercellular space, and acetic acid forming during ripening increases the acidity. Moreover anions of chlorine block positive groups of peptides which form in the course of the denaturation of the proteins. The acidity is connected with the proteolysis of the proteins which causes the increase of the acidity of the meat [1,4,12, 18].

A pH value was the next examined parameter, fig. 5 shows changes of pH value of the fillets and of the brine mixed by hand and mechanically.

Changes in the pH value of the meat attribute of the ripening process. During the first twenty-four hours the pH value decreased notably for fillets mixed mechanically from 6.5 to 6.15. It was associated with the amount of the absorbed salt and increased intensity of mass transfer. In order to stop the development of pathogens the pH value about 5 should be achieved, for that purpose an acetic acid is often added to the brine. Value about 6 of the pH impedes the development of the halophilic bacteria, however halophilic mold tolerates the scope of pH value 3.3 to 7.4 [14.18]. Final pH values reached 6.1 and 5.9 for fish mixed by hand and mechanically, respectively. The increase of pH value of the brine can be associated with passing negative anions to the meat. Changes of brine's pH value are similar and increased from 4.16 to 6.15 (in the brine mixed by hand) and to 6.19 (brine mixed mechanically).

In fig. 6 changes of the of the salt concentration in fillets of fish and in the brine are shown.

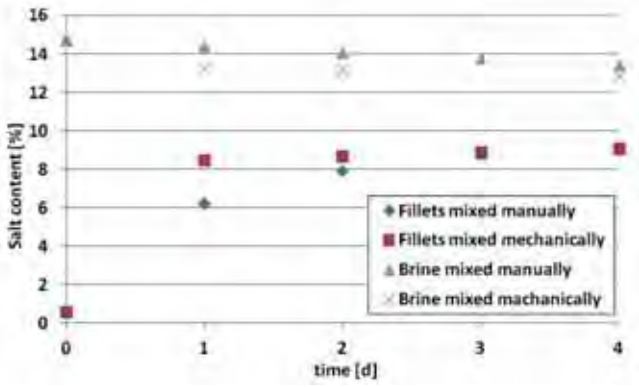

Fig. 6. Salt content in the fillets and in the brine mixed manually and mechanically.
Rys. 6. Stężenie soli w filetach oraz w solance mieszanych mechanicznie i ręcznie.

Source: Own study
Źródło: Opracowanie własne

In case of mechanical mixing on the first day the amount of the absorbed salt increased considerably - from the initial content of the 0.61% up to the 8.5%. In consecutive days the concentration of the salt did not undergo great changes and stabilized on the value about 8.7%. For manual mixing the concentration of the salt grew gradually, all the way to the concentration characteristic for light-salted fillets. For light-salted herring the concentration of the salt, according to the Polish Standards, is between 6 and 10 %. Fish mixed mechanically reached the upper limit on the second day of ripening [14.18]. Finally, the salt concentration for both stands reached 9.1%.

Salt concentration drop in the brine is relative to the rise of it in the meat of fish. The initial mass concentration of the salt in brines amounted to the 14.74%. For mechanical mixing in the first twenty-four hours the concentration dropped about 1.3%, and finally achieved the value of the 12.9%. In the brine mixed manually a gradual permanent fall in the content of the salt was observed, from the 14.74% up to the 13.46%. It is a result of diffusion of the salt from solution to the muscular tissue of fillets, and mechanical mixing considerably precipitated this process.

The analysis of mechanical properties of herring fillets was performed with the consideration of parameters with significant influence on the meat texture. These are: hardness, springiness, gumminess, and cohesiveness.

In case of salted fish changes of the texture are due to salt diffusion deep in the muscles. As it penetrates the tissue it destabilizes the proteins and reduces their solubility. Also the outflow of water due the osmosis gives harder structure of the final product. These changes are more visible for heavy-salted fish, the lihgt-salted are more similar to the raw material [16].

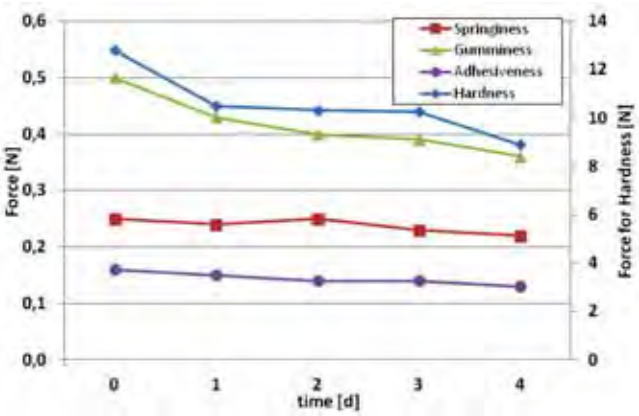

Fig. 7. Texture analysis of the fillets mixed manually.
Rys. 7. Analiza tekstury filetów mieszanych ręcznie.

Source: Own study
Źródło: Opracowanie własne

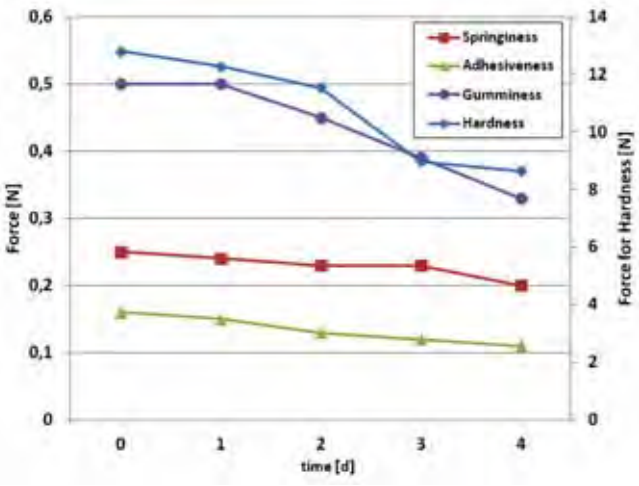

Fig. 8. Texture analysis of the fillets mixed mechanically.
Rys. 8. Analiza tekstury filetów mieszanych mechanicznie.

Source: Own study
Źródło: Opracowanie własne

In fig 7. and 8 results achieved during analisis are presented. There was 8 repetitions, graphs represent average values.

As can be seen on graphs in both experience a considerable decrease of the hardness and gumminess of the meat was obtained. In case of fillets mixed mechanically these two features have greater values than for those mixed by hand. It could be caused by absorbing more salt. The initial value of the hardness was 12.8 N, and of the gumminess 0.5 N. For fillets mixed mechanically final values of these features amounted to resepctively 8.64 N and 0.33 N. And for fillets mixed manually the hardness achieved the value 8.89 N and gumminess 0.36 N. These features are the one that directly influence the process of mastication. The final product should be easy to chew, but cannot be too soft, the sliminess is not pleasant. During ripening ions of calcium and magnesium can penetrate into the tissue what can cause softening of the meat's structure. It is an undesirable effect. Changes in the texture of fish mainly depend on endopeptidase. The most important enzyme that creates appropriate texture and the aroma is cathepsin-d which causes the disintegration of proteins into peptides and amino acids [11].

The cohesiveness of the raw material amounted to 0.16 N. The value of this feature dropped systematically and achieved value of 0.13 N for fillets mixed by hand, and 0.11 N for mechanical mixing. Filets mixed mechanically have a smaller cohesion than the ones mixed by hand, because the mechanical agitator caused loosening and disintegration of the structure of muscles. The springiness in both attempts did not differ considerably and from the initial value of 0.25 N dropped to about 0.2 N.

In fig. 9 fillets after 4 days of ripening are shown. Fish mixed mechanically sustained considerable damages, it is an undesirable outcome. Fillets were mixed throughout all the time of ripening what turned out to be too intense. Even though the disintegration of fillets did not cause the loss of the nutritients, it is unattractive and mechanical damages of the food products should be avoided.

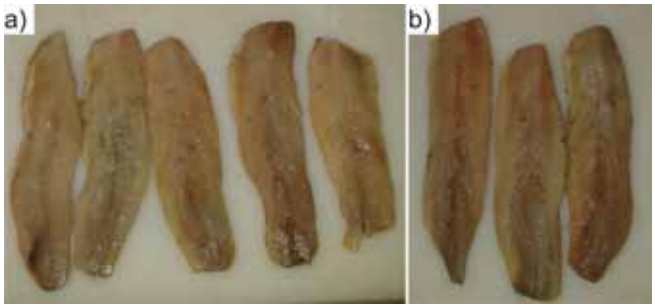

Fig. 9. Fillets mixed: a) manually, b) mechanically.
Rys. 9. Filety mieszane: a) ręcznie, b) mechanicznie.
Source: Own study
Źródło: Opracowanie własne

A cross-section of the filets was analized. Fig. 10 shows cuts through fillets both after manual and mechanical mixing. Fillets mixed by hand sustained much less damage to the structure so meat was firm and springy. Moreover, there was little leakage of the brine from the meat. Fillets mixed mechanically, on the other hand, were flatter, much less elastic and there was great leakage.

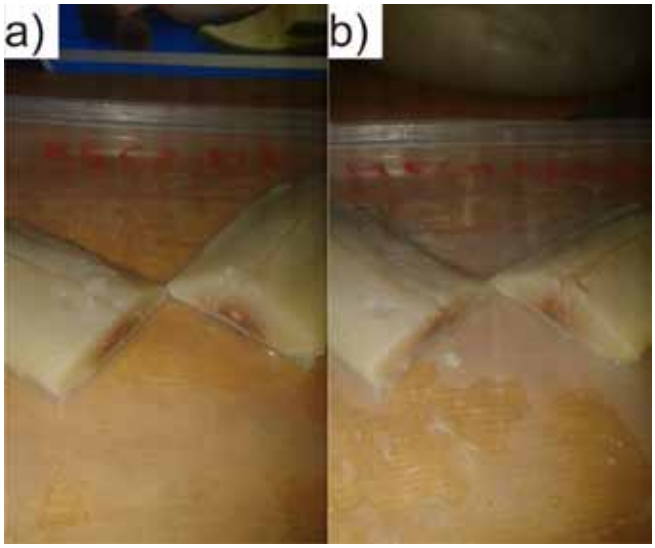

Fig. 10. Cross-section of the fillets after mixing: a) manual, b) mechanical.
Rys. 10. Przekrój filetów po mieszaniu: a) ręcznym, b) mechanicznym.
Source: Own study
Źródło: Opracowanie własne

Apart from the analysis of the texture an organoleptic evaluation of the final products was conducted. For that purpose Polish Standards were used. The meaty smell of salted fish should not be sweet, become rancid, or bitter, because such smells are indicators of the process of ongoing rancidification of fats contained in the meat of fish. The smell of the brine is determined as unusual if it is a sour or putrid smell, which appoints for bacterial and putrefactive changes. Opacity of the brine most often accompanies such smells. Moreover bacterial and putrefactive changes cause change of the color of the meat [8].

Organoleptic examining of herring fillets mixed mechanically and manually did not show rancidification of the product. The color and the taste were specific, characteristic in both stands. No unusual sour scent or changes of the color of the brine and meat was present. Fillets mixed by hand showed little yellow discolorations however, these are acceptable. It is possible that during manual mixing microbiological pollution of the product occurred. Applying such mixing method hygiene rules should be strictly followed, because lack of it can lead for destroying the entire manufactured unit. Also the color of the brines from both stands did not vary from standards. On the surface of the brine mixed mechanically appeared fat, which looked like thick grease. The cause could be the destroyed muscular tissue which led to dissolving of the fat. Whereas brine mixed by hand did not show any signs of opacity. It is obvious, that the opacity of the brine is undesirable. Even if the cloudiness of the brine is a side effect of mixing rather than putrefactive processes, for the consumer it will be discouraging.

The meat tissue of fillets mixed by hand did not undergo any the distortion. Some layering of the meat appeared, but it is characteristic for salted fillets, however, it did not have the influence on the general appearance of the fillets. The consistency was coherent and resilient, typical of the desired product.The meat tissue of fillets mixed mechanically

underwent the distortion and a large extent of damage. The large portion of fillets was broken or completely destroyed, and their consistency was greasy.

CONCLUSIONS

Fillets mixed mechanically soon after the first twenty-four hours achieved the appropriate concentration of the salt in the tissue, that is 9%. It is the determining value (according to PN) of technological maturity of fillets. Further parameters did not differ between both stands. In case of fillets mixed mechanically it is possible to notice larger differences between finished product and the raw material.

Based on the results it can be stated that the mixing system has an influence on the ripening process. The selection of the mechanical method can not just intensify and fasten their ripening, but also also gives the possibility to automate the process. Taking only on this perspective, mechanical mixing is very advantageous.

Values of gumminess and hardnesses were lower for fillets mixed mechanically and with the sensory analysis it was recognized as beneficial changes. Also the drop of the cohesiveness value was great and it caused the disintegration of the tissue.

The salt absorption is much more intensified with mechanical mixing, and it shortens the time of ripening. Keeping high hygiene standards is also much easier for the mechanized process.

Inasmuch as chemical aspects of fillets did not differ notably, the appearance of fish mixed mechanically was highly undesirable. Further analysis should determine the time and intensity of mechanical mixing as well as the choice of a proper agitator. This should be followed by issuing problems of scaling up. Results from laboratory analyses cannot be directly applied for industrial scale. This part poses great challenge and should be thoroughly considerate.

The automation of a process is beneficial and desired, however much thought should be given while setting the parameters of the process so that the final product is of the best quality.

REFERENCES

[1] **BHAT R., ALIAS A. K., PALIYATH G. 2012.** Progress in Food Preservation. Oxford, Wiley-Blackwell.

[2] **BOURNE M. 2002.** Food Texture and Viscosity, Second Edition: Concept and Measurement (Food Science and Technology), New York, Academic Press.

[3] **FELLOWS P. 2000.** Food Processing Technology: Principles and Practice. Cambridge, CRC Press LLC.

[4] **HALL G. M. 1997.** Fish Processing Technology. London, Springer.

[5] **International food information service. 2009.** Dictionary of food science and technology. Oxford, Wiley-blackwell.

[6] **KOŁAKOWSKA A., KOŁAKOWSKI E. 2007.** Postępy w technologii solenia i marynowania ryb. Szczecin, Akademia Rolnicza.

[7] **KOŁODZIEJCZYK M. 2007.** „Spożycie ryb i przetworów rybnych w Polsce – analiza korzyści i zagrożeń". Roczn. PZH, 58, (1): 287-293.

[8] **KREŁOWSKA-KUŁAS M. 1993.** Badanie jakości produktów spożywczych. Warszawa: PWE.

[9] **LAWLESS H. T., HEYMANN H. 2010.** Sensory Evaluation of Food: Principles and Practices. London, Springer.

[10] **MOCHIZUKI Y. 2001.** Current protocols in food analytical chemistry. Oxford, Wiley, unit H2.3 5.

[11] **RAO M. A., RIZVI S. S. H., DATTA A. K. 2005.** Engineering Properties of Foods. Boca Raton Florida, CRC Press.

[12] **SEN D.P. 2005.** Advances in Fish Processing Technology. New Delhi, Allied Publishers (P) Ltd.

[13] **SEREMAK-BULGE J. 2009.** Rynek i spożycie ryb w latach 2009-2010 dostępne na www.sprl.pl/userfiles/files/pdf/rynek.pdf (24.06.2015).

[14] **SIKORSKI Z.E. 1971.** Technologia żywności pochodzenia morskiego. Warszawa: WNT.

[15] **SIKORSKI Z.E. 2004.** Ryby i bezkręgowce morskie. Warszawa: WNT.

[16] **SIMPSON B. K., NOLLET L. M. L., TOLDRA F., BENJAKUL S. 2012.** Food biochemistry and food processing. New Jersey, Wiley-Blackwell.

[17] **SZOSTAK S. RAKOWSKI M., BYDNY T. 2012.** Morska gospodarka rybna w 2011 r. Gdynia, Morski Instytut Rybacki – Państwowy Instytut Badawczy, Zakład Ekonomiki Rybackiej.

[18] **SZYMCZAK M., KOŁAKOWSKI E., TOKARCZYK G., FELISIAK K., KRZYWIŃSKI T. 2009.** Wpływ stężenia soli na proces marynowania świeżego śledzia bałtyckiego. Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech. 274 (12): 63-74.

[19] **TOUSSAINT-SAMAT M. 2008.** A History of Food, The influence of mixing technic during ripening of herrings filets. New Jersey, Wiley-Blackwell.