ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol., Technol. Aliment. 9(4) 2010, 425-441
ISSN 1644-0730 (print) ISSN 1889-9594 (online)

INFLUENCE OF METHOD OF PACKING ON PHYSICOCHEMICAL AND TEXTURAL CHANGES IN ATLANTIC HERRING DURING FROZEN STORAGE

Grzegorz Szczepanik, Krzysztof Kryża, Marta Ostrowska
West Pomeranian University of Technology in Szczecin

Background. Cooling and freezing were used as one of the most important and widely used methods of fixation of the food. However, it must be stressed that low temperatures should not be applied to stock up bakery goods, but to improve production organisation, balance demand and supply, as well as to provide consumers with a wide range of fresh fish.
Material and methods. Raw Atlantic herring was packed in polyethylene (PE) bags: in air or in vacuum and then frozen and stored at –25°C. The quality of fresh fish and of carcasses and fillets after 1, 2, 3 and 4 months of storage was estimated by determination of weight change, pH, moisture and fat content, hardness, cohesiveness, springiness, resilience, gumminess, and chewiness.
Results. Weight of the air-packed herring samples decreased along with frozen storage time, due to changes in moisture content in the muscle tissue. The vacuum-packed raw material did not demonstrate weight changes. Moisture content was correlated with cohesiveness of the fish packed in air. Strong correlations were found between hardness and gumminess / chewiness regardless of the packing method, springness and pH / fat content of vacuum-packed fillets, and cohesiveness and springness / resilience of the vacuum-packed carcasses. Additionally, significant correlation coefficients were obtained between coherence and resilience for carcasses packed in air, as well as between gumminess and chewiness regardless of the packing method. Significant correlation occurred also between cohesiveness and resilience for carcasses packed in air, as well as between gumminess and chewiness regardless of the packing method. The packing method, as well as raw fish processing were found to have a major impact on cohesiveness and springiness, and in the case of carcasses also on resilience. No significant differences in hardness, gumminess and chewiness were found for samples obtained from different sections of the same fish, either fillets or carcasses. Significant differences were found in textural properties between the fresh and stored samples. Only hardness, gumminess and chewiness of fish samples did not show any significant changes throughout the storage period.
Conclusions. Frozen storage of air-packed material resulted in fluctuations of lipid content, while vacuum packing reduced lipid extractability from fish muscle along with storage time. In the vacuum-packed fish, textural parameters of fillets changed less, and of car-

© Copyright by Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu

Corresponding author – Adres do korespondencji: Dr inż. Grzegorz Szczepanik, Department of Dairy Technology and Food Storage of West Pomeranian Technological University in Szczecin, Papieża Pawła IV/3, 71-459 Szczecin, Poland, e-mail: grzegorz.szczepanik@zut.edu.pl

casses changed more compared with the air-packed fish. In both: fillets and carcasses, textural parameters changed most in section A, next in section B, and the less in section C.

Key words: fish, hardness, TPA (texture profile analysis), vacuum

INTRODUCTION

Fish meat is a source of proteins, but also of iron, zinc and vitamins. Fish and seafood products are especially sensitive to quality changes due to thigh content of unsaturated lipids, proteins and enzymes, and occurrence of specific micro-flora [Rywotycki 2005 b]. Raw fish require strict applying of low storage temperature to eliminate the risk of growth of pathogenic spore-forming bacteria. Therefore temperature is a key factor in preservation of fish raw material [Rywotycki 2005 a].

Freezing of raw fish is widely used to preserve raw material intended for further processing. Although freezing process was proved to destroy cell structure of all meat products (the slower freezing, the stronger destructive effect), freezing is commonly regarded to fulfil the main purposes of food processing as it prolongs food products' shelf-life at minimum changes of their initial qualities [Rywotycki 2005 b].

Texture is one of the most important characteristics, as well as appearance, colour, odour and taste. Texture determines food product quality and consumers' approval. It is both sensory and psychological feature, which depends on chemical and physical structure and rheological properties of the product [Morkore and Einen 2003, Marzec 2007].

Stodolnik et al. [2007] determined the rate of lipid oxidation and changes in water-holding capacity in the muscle tissue of striped catfish (*Pangasius hypophthalmus*) and escolar (*Lepidocybium flavobrunneum*) during storage at –21°C temperature for 79 days. They reported that muscle tissue consistency, measured by a compression coefficient, was similar for both fish species and varied from 4.5 to 4.9 cm^2/g. Escolar meat hardness slightly decreased, while striped catfish meat hardness did not change significantly during storage. The study revealed that freezing methods had significant impact on the textural properties of defrosted meat. The results have lead to conclusion that low temperature storage not always increases hardness of fish meat.

Fresh fish muscle is firm, elastic and pale. However, texture undergoes changes during cool and frozen storage. Post mortem changes of textural properties are a direct or indirect result of physicochemical changes in myofibril proteins and extracellular structures, i.e. clustering of relaxed fibres, increase of extracellular space among fibres [Herrero et al. 2004].

Sigurgisladottir et al. [1999] studied textural properties of raw Atlantic salmon (Salmo salar) fillets on different locations of the fillets. They used three instrumental methods for evaluation of textural properties. Two methods were based on puncture tests, using flat-ended cylinder or spherical probes measuring the hardness of the fillet. The third method was based on cutting the fillet with a blade and measuring the shear force. The authors reported that hardness and shear force increased from head to tail, while fat, pigments and collagen were irregularly distributed along fish body. Lipid content ranged from 9.6 to 38%, being a factor considerably influencing the results of textural properties measurements.

According to Godiksen et al. [2009], post-mortem softening of fish tissue often results in low yield and decreased product quality. The authors studied textural properties of trout stored 5 days on ice. They examined the link between protein band intensities

and firmness of trout fillets through a correlation study, and simultaneously, they evaluated the effect of cathepsins on the texture-related proteins. They observed that most changes induced by cathepsin D were unfavourable to firmness. Therefore they concluded that cathepsin D is likely to be involved in textural change of trout, due to the breakdown of the muscle structure.

Marked differences in textural properties were reported by Morkore et al. [2008] in farmed Atlantic salmon fed to satiation or starved for 35 d, and subjected to acute pre-slaughter stress or careful handling before slaughtering. Their study revealed that nutritional status and acute pre-slaughter stress resulted in serious physiological responses that influenced texture quality, colour or water-binding capacity. Pre-slaughter stress was observed to stimulate lactate formation through post-mortem glycolysis, contributing to muscle softening. The fish subjected to long pre-slaughter starvation turned out to be more resistant to acute stress, compared with the fish subjected to short starvation.

As illustrated by trends of the last several years, distribution of fish products and seafood shows considerable development of wrappings and increasing complexity of their appearance. At present, various packaging technologies meet requirements of fish distribution, hygiene during processing and product's innovativeness. Formerly, fresh fish were available only in near-shore regions what resulted from inadequacy of logistics. Therefore packaging is an important element of industry's response to both: trade demand and logistics limitations. Vacuum packing, which depends on air removal from the pack, stands out among various packaging techniques. The aim of this type of packaging is achieving an optimum stability of food products. Air-less environment considerably reduces growth of aerobic bacteria that are the main reason of early fish spoilage [Goussault and Leveau 2006].

Regarding the above, we examined changes of textural properties of muscle tissue in carcasses and fillets of Atlantic herring during 4 months of freeze storage in air-tight packs or in air-containing packs.

MATERIAL AND METHODS

The studied material was Atlantic herring (*Clupea harrengus*). The raw material (50 specimens) was bought at retail, as fresh fish stored on ice. The study was conducted in the Department of Dairy Technology and Food Storage, West Pomeranian University of Technology in Szczecin.

Preliminary measurements of raw material were based on evaluation of:

Parameter	Average*
Fish weight, g	333.67 (36.09)
Total length of fish, cm	31.00 (1.00)
Fish thickness, cm	3.43 (0.15)
Carcass weight, g	239.67 (23.03)
Carcass length (excluding tail), cm	20.67 (0.58)
Carcass length (including tail), cm	23.33 (1.15)
Skinned fillet thickness, cm	1.33 (0.06)
Female to male ratio	1 to 3
Gonad maturity stage	6^{th} in the Maier's scale

*Standard deviation presented in parentheses.

Raw fish intended for further examination were wrapped in polyethylene (PE) bags. Samples were packed without deaeration or by vacuum packing using a TURBOVAC SB 420 vacuum packer. Operating conditions of vacuum packing: suction 15 millibar (mbar), additional vacuum OFF, degassing 100 mbar, sealing 2 seconds (s), soft air OFF. The packed fish were frozen and stored at –25°C for 1, 2, 3 or 4 months. Each month, samples for analysis were thawed in a freezer (at 4°C) till attained internal temperature of 4°C, and next processed to carcasses and fillets. So prepared material was further analysed.

Determination of sublimation loss

After 1, 2 and 3 months of frozen storage, the samples were taken out, unpacked, and weighed electronically, to an accuracy of 0.01 g, to determine differences in weight resulting from storage (sublimation). Then the samples were defrosted by air at 4°C until the product reached 4°C. Until the following texture test, the samples were stored in a freezer at 4°C. Changes resulting from sublimation (B) were calculated according to the formula:

B = raw material weight – frozen material weight after frozen storage

Lipid extraction from muscle tissue

Lipids were extracted by a chloroform-methanol mixture (2:1) according to Linko [1967]. Quantification results are expressed as g total lipids kg^{-1} wet muscle.

Determination of lipid content in herring muscle tissue

From the flask containing the chloroform extract, subsamples of 10 cm^3 were transferred to previously dried and weighed to the nearest 0.0001 g conical flasks of 100 cm^3 capacity. The solvent was distilled off on a water bath, under reduced pressure, and at temperature of about 40°C. The residues left in the flasks were dried in a dryer at 80°C for 1 h, next cooled down in a desiccator for 20 min and weighed. All samples were analysed in triplicate. Percentage lipid content in muscle tissue was calculated according to the following formula:

$$x = \frac{(b-a)\cdot 10\cdot 4}{c},\ \%$$

where:

x – percentage lipid content,
a – flask weight, g,
b – weight of flask with lipid residue after drying, g,
c – weight of minced sample, g.

Determination of moisture content

An amount of 1.5 g of minced material was placed into a glass weighing bottle filled with sand and with a short rod inserted, previously dried at 105°C for 30 min, cooled

down in a dessicator and weighed to the nearest 0.0001 g. The whole was weighed again with the same accuracy. The sample added was carefully mixed with the sand using the glass rod. So prepared weighing bottles were placed in a dryer and kept in 105°C for 3 h. Next the samples were cooled down in a desiccator and weighed to the nearest 0.0001 g. Percentage moisture content was calculated according to the following formula:

$$x = \frac{(b-c)\cdot 100}{b-a}, \%$$

where:

x – percentage moisture content,
a – weight of the bottle with sand and rod, g,
b – weight of the bottle with sand, rod and sample prior to drying, g,
c – weight of the bottle with sand, rod and sample after drying, g.

Determination of pH

Measurements of pH were conducted using electronic pH-meter IQ240 from Scientific Instruments Inc.

Rheological analysis

Rheological tests were performed using a TA.XT texture analyzer (Stable Micro Systems Ltd., England) using a cylinder shaped aluminum tenon with a diameter of 6 mm (Part code P/6). The test parameters were as follows: Pre-Test Speed – 1.0 mm·s^{-1}, Test Speed –2.0 mm·s^{-1}, Post-Test Speed – 5.0 mm·s^{-1}, Distance – 5 mm, Time – 15 s, Trigger Force – 5 g.

The herring carcasses measured about 20 cm. This length was divided into 10 sections, and the first section was excluded from examination. Two subsequent sections of 4 cm total length constituted first measured part of the fish (A), next two subsequent sections (4 cm) formed part B, and next two sections (4 cm) – part C (Fig. 1).

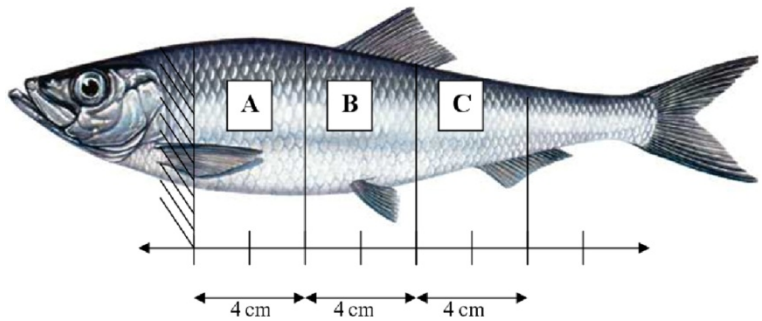


Fig. 1. Diagram of distribution in herring of the three studied sections subjected to the TPA assay

In each section, 4 measurements were made in 0.5 cm intervals, always about 0.5 cm above the lateral line.

Statistical analysis

The obtained data were statistically analysed using the Excel and Statistica 8.0 software. Significant differences were determined with the Tukey's test at the significance level $p \leq 0.05$. Additionally, the Pearson's correlation coefficient was determined to find linear correlation between random variables.

RESULTS AND DISCUSSION

The study on Atlantic herring enabled evaluation of the packaging method and raw material processing on changes of its quality during 4-month frozen storage. According to Błoński [2006], quality changes and considerable mass losses in frozen meat result from freezer burn. Surface character of sublimation together with practically unchangeable water distribution in frozen products prevents compensation of moisture losses through water migration from the inside of the product. This way, an external layer of porous structure and deprived of moisture is formed, which promotes oxidation processes and absorption of foreign odours. The scale of natural losses is the outcome of multiple factors, e.g., temperature and time of freezing, temperature and time of storage, temperature stability, or the type of wrapping used.

In our study, sublimation-derived mass changes of air-packed herring demonstrated an increasing tendency along with frozen storage duration (Table 1). The longer storage time, the higher mass losses occurred. On the contrary, no such losses were observed in the vacuum-packed samples. Goussault and Leveau [2006] indicated advantages of vacuum packing of raw material prior to freezing. This technique prevents weight losses from evaporation during cooling down and protects the product from spoilage resulting from surface degradation and freezing. Their observations revealed that packing method significantly influenced sublimation-derived mass changes during frozen storage.

Table 1. Sublimation-derived weight changes of Atlantic herring packed in air during frozen storage

Time of frozen storage months	Sublimation-derived weight reduction %
1	0.41
2	0.60
3	0.89
4	1.54

Post-slaughter changes in meat should be submitted to technological control, as muscle tissue undergoes structural changes typical to all cells with stopped metabolism. Muscles, initially relaxed and elastic, gradually become hard and stiff, till attaining complete stiffness. As oxygen is no longer supplied, accumulation of carbon dioxide and lactic acid occurs, increasing hydrogen cations concentration, so that muscle pH

gets reduced from 7.4 to 5.5. Such reduced pH restricts anaerobic processes and inhibits enzymes involved in these processes. All the described changes create new configuration of anions and cations, conditioning water absorption capacity of muscles. Due to activation of proteolytic enzymes, meat becomes soft and tender [Błoński 2006]. This explains why muscle pH decreased along with frozen storage duration (Table 2), and why significant correlations occurred between pH and resilience or springiness.

Table 2. Changes of pH in Atlantic herring during frozen storage

Time of frozen storage months	Method of packaging	Type of raw material	Average value pH
0			8.6 (0.05)
1	air	fillet	6.7 (0.06)
		carcass	6.6 (0.01)
	vacuum	fillet	6.9 (0.20)
		carcass	6.4 (0.02)
2	air	fillet	6.6 (0.01)
		carcass	6.5 (0.04)
	vacuum	fillet	6.4 (0.12)
		carcass	6.9 (0.03)
3	air	fillet	6.6 (0.02)
		carcass	6.6 (0.02)
	vacuum	fillet	6.6 (0.01)
		carcass	6.7 (0.02)
4	air	fillet	6.5 (0.02)
		carcass	6.4 (0.03)
	vacuum	fillet	6.3 (0.02)
		carcass	6.3 (0.04)

Standard deviation presented in parentheses.

Gruda and Postolski [1999] revealed that fish lipids are very susceptible to changes. Lean fish have longer storage life compared with fat fish, while uneviscerated fish have longer storage life compared with fillets. Fat content is species-dependent, however considerable intra-species fluctuations occur with regard to fishing time and fishing ground.

In our study, lipid extractability from the air-packed herring muscle fluctuated during frozen storage between 17.1% and 18.9%, while in the vacuum-packed herring lipid extractability decreased from initial 17.1% in fresh fish to 14.7% after 4 months of frozen storage.

Phase transition of tissue juices during freezing contributes to negative physical and chemical effects. Its range depends on the rate of heat transfer and on chemical composition of food, especially moisture and fat content. Crystallization of tissue juices changes cell membrane properties, leading this way to plasmolysis and modifications in the structure of proteins. Modified protein structure, in turn, reduces water-binding capacity after thawing and during thermal processing [Stodolnik et al. 2004]. Our study

revealed significant correlation between moisture content and cohesiveness in carcasses of air-packed herring. Moisture content in herring muscle fluctuated during frozen storage, regardless of the packing method.

Koy et al. [2008] revealed significant effect of both storage time and package method on changes in quality of salted herring during storage. They proved that vacuum packing prolonged shelf-life of salted herrings for 6 to 9 days, on average.

Our study confirmed that fillets and carcasses of vacuum packed herring demonstrated smaller changes in textural properties than those of air-stored fish (Fig. 2).

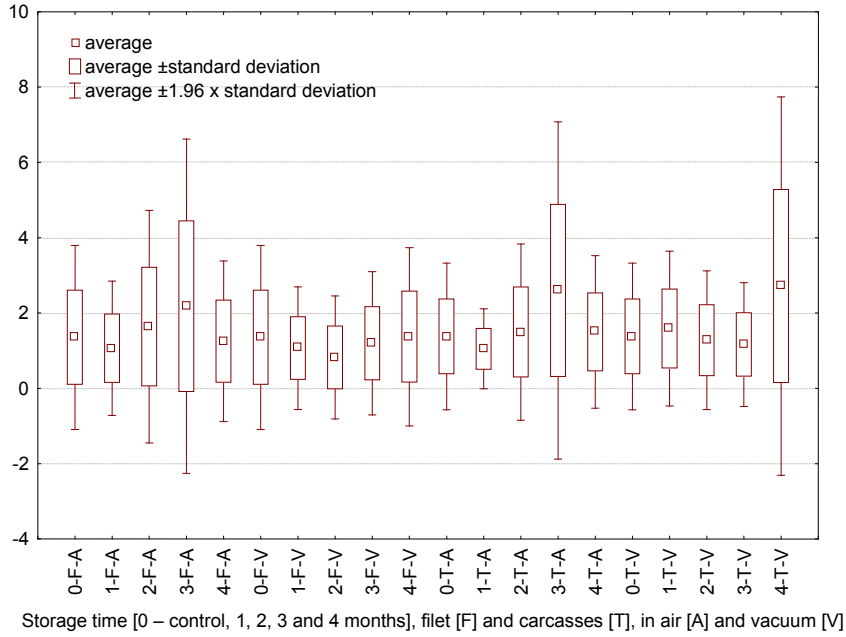


Fig. 2. The results of all TPA tests for filets and carcasses of fresh fish and fish stored in air or vacuum

Hardness changes in the air-packed herring tended to increase till the 3rd month of storage, while after 4 months the parameter's values decreased and were comparable with the initial values measured in the fresh fillets and carcasses (Fig. 3). According to Zhou and Li-Chan [2009], changes of textural properties may be imperceptible during long-term frozen storage and shortly after thawing, however, post-mortem softening of fish tissue often results in low yield and decreased product quality [Godiksen et al. 2009]. Vacuum packaging used in our study maintained hardness of fillets and carcasses on a stable level (Fig. 4). Through the whole study period, hardness of vacuum-packed fish meat decreased from section A, through B, to C (Fig. 3, 4), similarly as for the air--packed samples. Stodolnik et al. [2007] indicated significant effect of freezing method on textural properties of thawed raw material, however, they concluded that hardness of fish meat stored at low temperatures (–20°C) not always changes and meat of some fish species is relatively resistant to freezing temperatures.

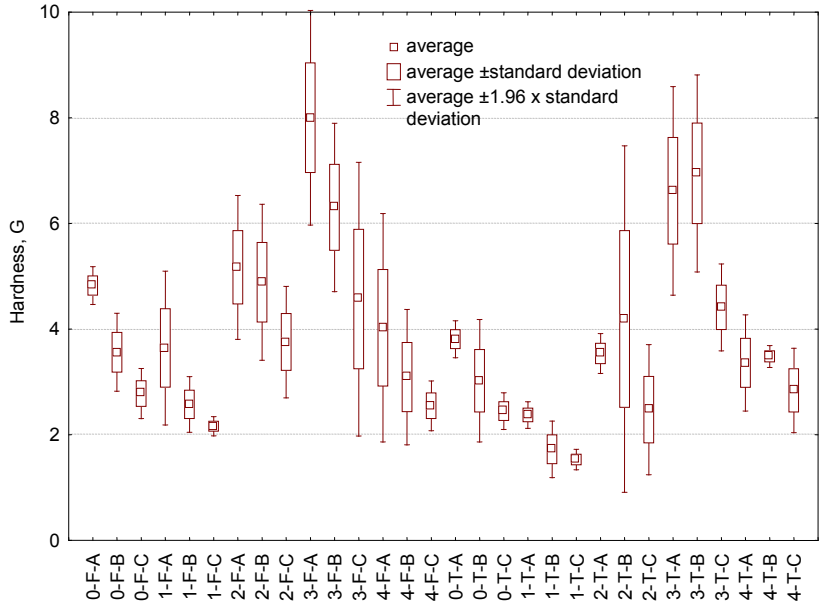


Fig. 3. The results of TPA hardness test (fish storage in air)

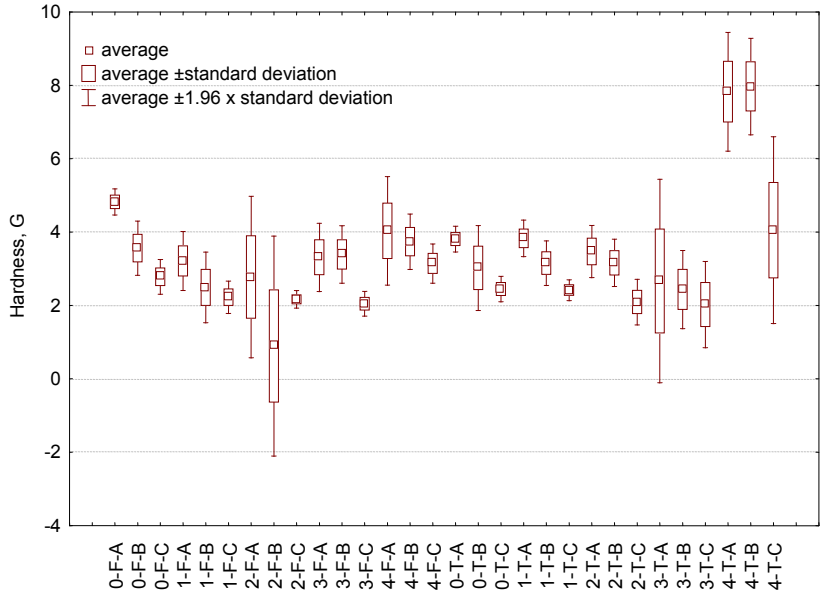


Fig. 4. The results of TPA hardness test (fish storage in vacuum)

Post-mortem changes in textural properties were found to derive directly or indirectly from physicochemical changes on myofibrillar proteins and extracellular structures among fibres, such as clustering of relaxed fibres, increase in extracellular space among fibres [Herrero et al. 2004]. Actin degradation leads to structural changes and causes tissue softening. A study of Godiksen et al. [2009] revealed that cathepsins may cause actin hydrolysis. Our study gave results consistent with these findings, as significant correlation between gumminess and chewiness were detected, regardless of the packaging method or method of fish processing (Tables 3-6).

Table 3. The correlation coefficients between texture parameters, pH, moisture content, fat content and weight changes in Atlantic herring fillets packed in air during frozen storage

Parameters	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	pH	Moisture content	Fat content	Weight change
Hardness	0.431	0.139	0.997*	0.992*	0.281	–0.145	–0.451	–0.150	0.582
Springiness	–	0.421	0.453	0.515	–0.486	–0.793	–0.583	0.412	0.641
Cohesiveness		–	0.216	0.242	–0.267	–0.168	0.375	0.143	–0.365
Gumminess			–	0.997*	0.248	–0.160	–0.404	–0.155	0.538
Chewiness				–	0.189	–0.225	–0.428	–0.128	0.566
Resilience					–	0.861*	–0.136	0.174	–0.045
pH						–	0.332	0.030	–0.525
Moisture content							–	–0.527	–0.941*
Fat content								–	0.245

*Correlation coefficient statistically significant ($p \leq 0.05$).

Table 4. The correlation coefficients between texture parameters, pH, moisture content, fat content and mass changes in Atlantic herring carcasses packed in air during frozen storage

Parameters	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	pH	Moisture content	Fat content	Weight change
Hardness	0.813	–0.203	0.991*	0.965*	–0.318	–0.119	–0.246	–0.129	0.107
Springiness	–	–0.607	0.753	0.767	–0.690	–0.251	–0.445	0.430	0.443
Cohesiveness		–	–0.095	–0.207	0.952*	0.537	0.883*	–0.727	–0.959*
Gumminess			–	0.976*	–0.238	–0.129	–0.134	–0.246	0.018
Chewiness				–	–0.383	–0.342	–0.201	–0.240	0.170
Resilience					–	0.720	0.754	–0.589	–0.935*
pH						–	0.341	0.020	–0.698
Moisture content							–	–0.527	–0.874*
Fat content								–	0.556

*Correlation coefficient statistically significant ($p \leq 0.05$).

Table 5. The correlation coefficients between texture parameters, pH, moisture content, fat content and mass changes in Atlantic herring fillets packed in vacuum during frozen storage

Parameters	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	pH	Moisture content	Fat content	Weight change
Hardness	–0.619	0.175	0.978*	0.944*	0.580	0.511	0.167	0.398	0
Springiness	–	0.134	–0.529	–0.383	–0.562	–0.990*	–0.377	–0.941*	0
Cohesiveness		–	0.371	0.437	0.691	–0.123	–0.551	–0.416	0
Gumminess			–	0.987*	0.666	0.426	0.022	0.260	0
Chewiness				–	0.625	0.274	–0.047	0.102	0
Resilience					–	0.565	0.050	0.322	0
pH						–	0.376	0.951*	0
Moisture content							–	0.556	0
Fat content								–	0

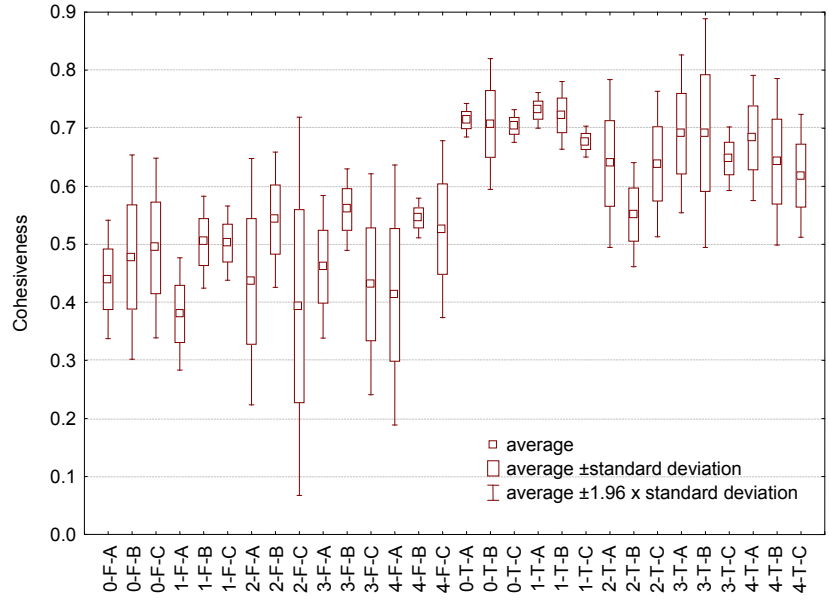
*Correlation coefficient statistically significant ($p \leq 0.05$).

Table 6. The correlation coefficients between texture parameters, pH, moisture content, fat content and weight changes in Atlantic herring carcasses packed in vacuum during frozen storage

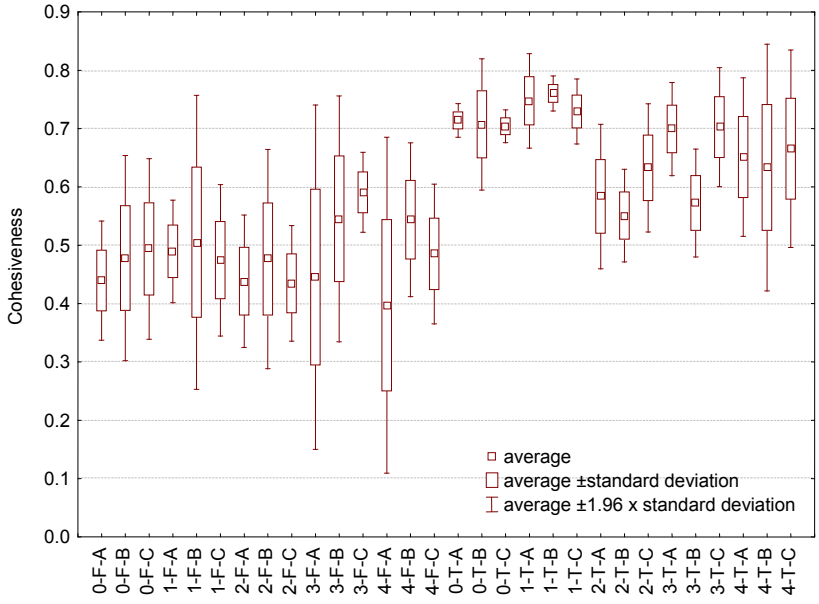
Parameters	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	pH	Moisture content	Fat content	Weight change
Hardness	0.175	–0.110	0.987*	0.960*	–0.081	–0.352	0.245	–0.207	0
Springiness	–	0.909*	0.287	0.192	0.948*	0.337	0.762	0.604	0
Cohesiveness		–	0.034	–0.005	0.942*	0.188	0.573	0.410	0
Gumminess			–	0.981*	0.045	–0.396	0.320	–0.211	0
Chewiness				–	0.020	–0.564	0.258	–0.377	0
Resilience					–	0.317	0.793	0.600	0
pH						–	0.190	0.921*	0
Moisture content							–	0.556	0
Fat content								–	0

*Correlation coefficient statistically significant ($p \leq 0.05$).

Cohesiveness of herring meat fluctuated during the 4-month storage, regardless of the packing method. Comparison of products packed with the same method revealed that cohesiveness of carcasses was markedly higher than cohesiveness of fillets (Fig. 5, 6). Cohesiveness correlated significantly with resilience, sublimation-derived weight loss and moisture content. The lower moisture content and sublimation-derived weight loss were detected, the higher cohesiveness was measured.



Storage time in air [0 – control, 1, 2, 3 and 4 months], fillet [F] and carcass [T], section [A, B, C]



Storage time in vacuum [0 – control, 1, 2, 3 and 4 months], fillet [F] and carcass [T], section [A, B, C]

Fig. 5, 6. The results of TPA cohesiveness test (fish storage in air and vacuum)

Tironi et al. [2003] examined the effect of malonaldehyde on gelation properties of mofibrillar proteins, and reported that formation of protein network in gel changed textural properties of fish meat, markedly increasing resilience and cohesiveness. In our study, we also observed increase, and next stabilization of resilience. Similarly as in case of cohesiveness, resilience was higher for carcasses than for fillets packed with the same method (Fig. 7, 8).

Gumminess and chewiness of Atlantic herring fluctuated throughout the whole period of frozen storage. Worth noticing is, that for both packing methods, the highest values of the studied parameters were detected in section A, while the lowest – in section C.

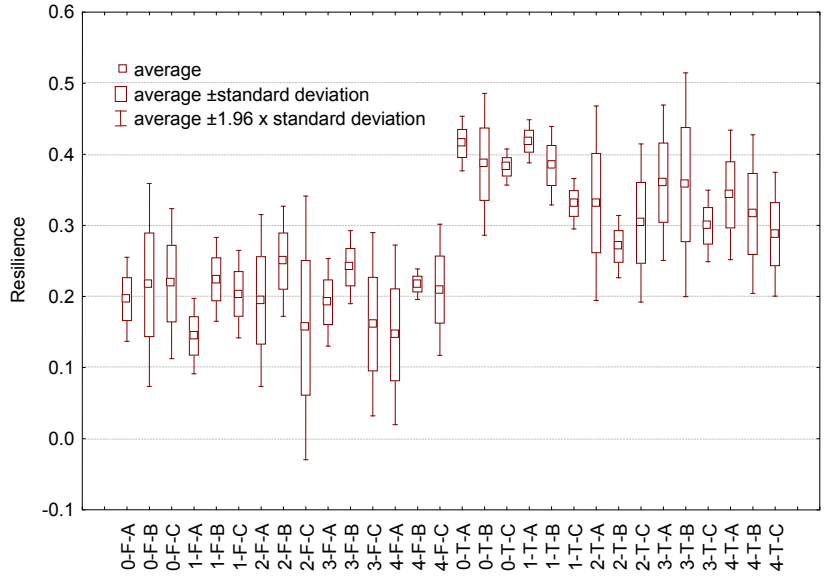
Springiness of the vacuum-packed herring meat increased only slightly during storage, while markedly increased in the fillets and carcasses from the air-packed fish (Fig. 9). For both packing methods, the carcasses had higher springiness compared with the fillets. Godiksen et al. [2009] observed that actin degradation resulted in structural changes and softening of fish flesh, while Koy et al. [2008] proved significance of storage duration and packaging method on the final quality and textural parameters of herring meat.

Our study revealed that, throughout the whole frozen storage period, changes of all the examined textural parameters were the highest in section A, medium in section B, and the smallest in section C, regardless to the packaging method (Fig. 10). Fat, pigments and collagen are distributed unevenly along fish fillets. Therefore fat content may range from 9.6% to 38%, being an important factor during textural measurements [Sigurgisladottir et al. 1999].

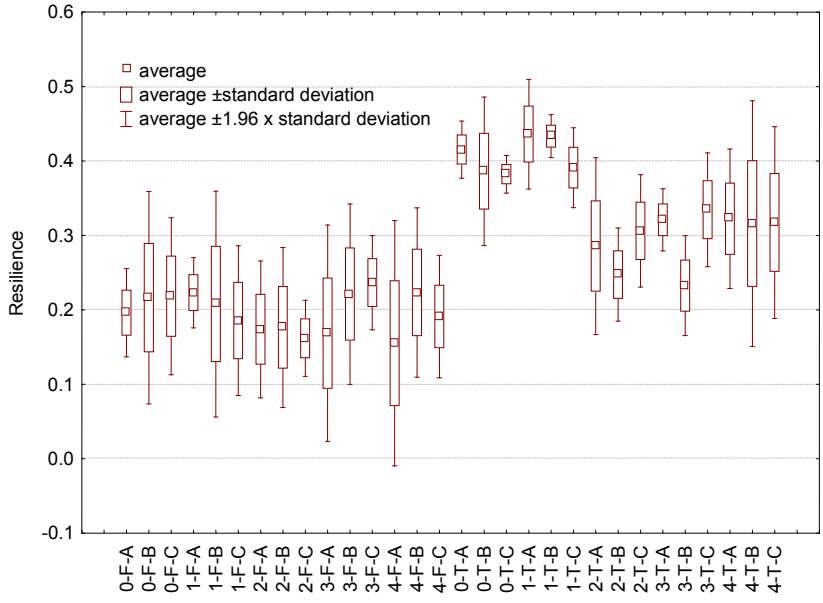
Textural changes may be imperceptible during prolonged frozen storage and shortly after thawing [Zhou and Li-Chan 2009], but post-mortem softening of fish tissue often results in low yield and decreased product quality [Godiksen et al. 2009]. Błoński [2006] indicated the influence on rheological parameters of such factors as temperature, freezing and storage duration, or packaging method, and postulated the necessity for technological control of post-slaughter changes.

CONCLUSIONS

Four-month frozen storage of Atlantic herring packed in air resulted in sublimation-derived weight losses. On the contrary, weight losses did not occur in case of vacuum packing. The value of meat pH decreased along with frozen storage duration of both vacuum- and air-packed herring, the change being the most distinct after the first month of storage. Frozen storage of air-packed material resulted in fluctuations of lipid content, while vacuum packing reduced lipid extractability from fish muscle along with storage time. In the vacuum-packed fish, textural parameters of fillets changed less, and of carcasses changed more compared with the air-packed fish. In both: fillets and carcasses, textural parameters changed most in section A, next in section B, and the less in section C.



Storage time in air [0 – control, 1, 2, 3 and 4 months], fillet [F] and carcass [T], section [A, B, C]



Storage time in vacuum [0 – control, 1, 2, 3 and 4 months], fillet [F] and carcass [T], section [A, B, C]

Fig. 7, 8. The results of TPA resilience test (fish storage in air and vacuum)

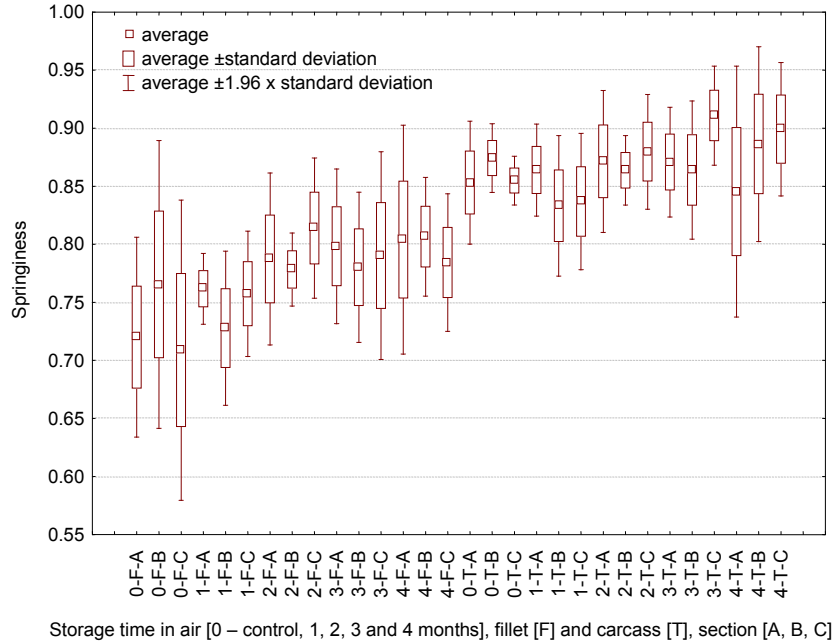


Fig. 9. The results of TPA springiness test (fish storage in air)

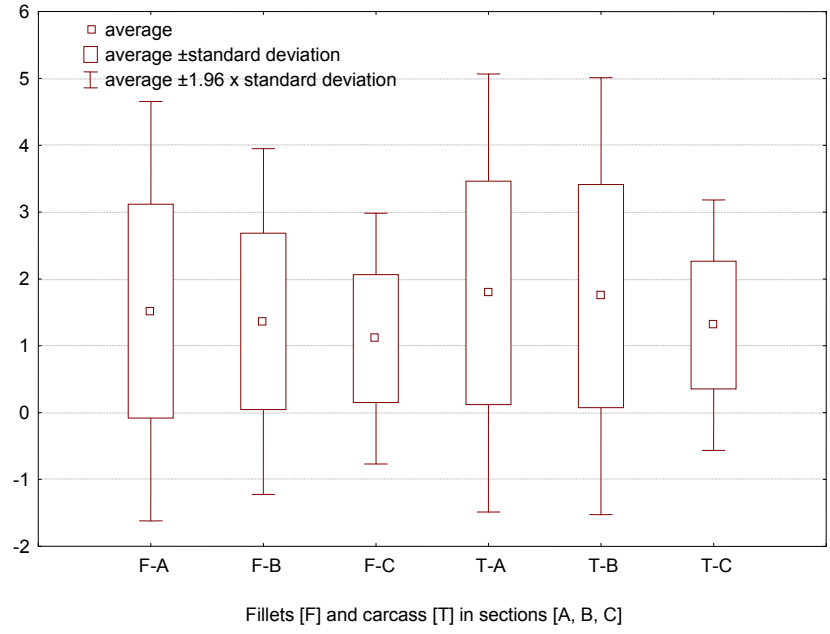


Fig. 10. The results of all TPA tests during all frozen storage

REFERENCES

Błoński Z., 2006. Freezing and storage of pork and beef carcasses. Przem. Spoż. 9, 30-32.
Godiksen H., Morzel M., Hyldig G., Jessen F., 2009. Contribution of cathepsins B, L and D to muscle protein profiles correlated with texture in rainbow trout (*Oncorhynchus mykiss*). Food Chem. 113, 889-896.
Goussault B., Leveau B., 2006. Guide to packaging technology for seafood value-addition. Eurofish. Copenhagen – Gdynia, 1-20.
Gruda Z., Postolski J., 1999. Fish and other seafood. Food freezing. WN-T, 370-389.
Herrero A.M., Heia K., Careche M., 2004. Stress relaxation test for monitoring post mortem textural changes of ice – Stored Cod (*Gadus morhua* L.). J. Food Sci. 69 (4), 178-182.
Koy J., Bilska A., Krysztofiak K., Uchman W., 2008. The influence of packaging method on quality storage changes of salted herrings. Nauka Przyr. Technol. 2, 1 (7), 1-10.
Linko R.R., 1967. Fatty acid and other components of Baltic herring flesh lipids. Ann. Univ. Turk. Ser. A, 101, 7-121.
Marzec A., 2007. Food texture. Przem. Spoż. 5, 5-10.
Morkore T., Einen O., 2003. Relating sensory and instrumental texture analyses of Atlantic salmon. J. Food Sci. 68 (4), 1492-1497.
Morkore T., Pablo I., Mazo T., Tahirovic V., Einen O., 2008. Impact of starvation and handling stress on rigor development and quality of Atlantic salmon (*Salmon salar* L.). Aquaculture 277, 231-238.
Rywotycki R., 2005 a. Quantitative and qualitative factors in food-processing and cold storage and their impact on consumer value of fishery products. Chłodnictwo 60 (5), 45-48.
Rywotycki R., 2005 b. Impact of freezing and salting on micro-flora and quality of fishery products for prolongation of their shelf-life. Chłodnictwo 60 (3), 45-48.
Sigurgisladottir S., Hafsteinsson H., Jonsson A., Lie O., Nortredt R., Thomassen M., Torrissen O., 1999. Textural properties of raw salmon fillets as related to sampling method. J. Food Sci. 64 (1), 99-104.
Stodolnik L., Kryża K., Kowalski A., 2007. Oxidative and hydratative changes in the muscle tissue of striped catfish (*Pangasius hypophthalmus*) and escolar (*Lepidocybium flavobrunneum*) during frozen storage. Chłodnictwo 62 (12), 46-49.
Stodolnik L., Rosiński P., Grzegrzółka A., 2004. Cryoprotective properties of pectin and lecithin in chicken meat tissue during frozen storage. Chłodnictwo 39 (8), 74-77.
Tironi V.A., Tomas M.C., Anon M.C., 2003. Effect of malonaldehyde on the gelation properties of myofibrillar proteins of sea salmon. J. Food Sci. 68 (1), 42-47.
Zhou L.S., Li-Chan E.C.Y., 2009. Effects of *Kudoa* spores endogenous protease activity and frozen storage on cooked texture of minced Pacific hake (*Merluccius productus*). Food Chem. 113, 1076-1082.

WPŁYW METOD PAKOWANIA NA ZMIANY FIZYKOCHEMICZNE I TEKSTURALNE ŚLEDZIA ATLANTYCKIEGO W CZASIE PRZECHOWYWANIA ZAMRAŻALNICZEGO

Wstęp. Chłodzenie i zamrażanie są jednymi z istotniejszych oraz powszechnie stosowanych sposobów utrwalania żywności. Należy jednak podkreślić, że podstawowym celem wykorzystania niskich temperatur nie powinno być gromadzenie dużych zapasów, ale usprawnienie organizacyjne produkcji, równoważenie popytu i podaży oraz umożliwienie regularnego zaopatrzenia konsumentów w bogaty asortyment świeżego surowca.

Materiał i metody. Surowiec przeznaczony do badań zapakowano w folię polietylenową (PE): próżniowo oraz z pozostawieniem powietrza w opakowaniu. Następnie materiał zamrożono i przechowywano w temperaturze –25°C. Jakość śledzia atlantyckiego – świeżego, a następnie poddanego obróbce do postaci tusz i filetów – po 1, 2, 3 i 4 miesiącach przechowywania oceniano przez oznaczenie: ubytku masy w wyniku sublimacji, pH, zawartości wody i tłuszczu, twardości, spójności, sprężystości, elastyczności, gumiastości oraz żuwalności.

Wyniki. Wraz z upływem czasu przechowywania zamrażalniczego zwiększał się ubytek masy badanych prób śledzi pakowanych z pozostawieniem powietrza. Surowiec zapakowany próżniowo nie wyróżniał się ubytkiem masy. Zawartość wody była skorelowana ze spójnością tkanki mięśniowej surowców pakowanych w PE bez odpowietrzenia. Zaobserwowano też korelację pomiędzy twardością i gumiastością a żuwalnością bez względu na metodę pakowania oraz sprężystością i pH a zawartością tłuszczu charakteryzującą filety śledzi pakowanych próżniowo, a także sprężystością i spójnością a elastycznością w tuszach śledzi pakowanych próżniowo. Stwierdzono istotną korelację pomiędzy spójnością a elastycznością dla tusz pakowanych bez odpowietrzenia oraz między gumiastością a żuwalnością bez względu na zastosowaną metodę pakowania. Niewątpliwie metoda pakowania, a także sposób obróbki ryb miały istotny wpływ na spójność i sprężystość oraz w tuszach także na elastyczność. Nie stwierdzono istotnych różnic w twardości, gumiastości i żuwalności w badanych odcinkach tusz i filetów. Zanotowano natomiast istotne różnice w teksturze pomiędzy próbami świeżymi i przechowywanymi zamrażalniczo. Jedynie twardość, gumiastość i żuwalność nie wykazywały istotnych zmian w całym okresie składowania surowców.

Podsumowanie. Zamrażalnicze przechowywanie surowca w powietrzu wpłynęło na wahania w zawartości lipidów. Natomiast ekstraktywność lipidów z tkanki mięśniowej śledzia atlantyckiego przechowywanego próżniowo zmniejszyła się wraz z upływem czasu składowania surowca. Sposób pakowania wpływał mniej na zmianę parametrów tekstury w filetach przechowywanych w próżni. W przypadku tusz zaobserwowano tendencję odwrotną. Wykazano, że największe zmiany badanych parametrów tekstury wystąpiły na odcinku A, mniejsze na odcinku B, a najmniejsze na odcinku C. Obserwacje dotyczą całego okresu przechowywania zamrażalniczego, bez względu na zastosowany sposób pakowania ryb, w postaci zarówno filetów, jak i tusz.

Słowa kluczowe: próżnia, ryba, twardość, TPA (analiza profilu tekstury)

Accepted for print – Zaakceptowano do druku: 9.09.2010

For citation – Do cytowania: Szczepanik G., Kryża K., Ostrowska M., 2010. Influence of method of packing on physicochemical and textural changes in Atlantic herring during frozen storage. Acta Sci. Pol., Technol. Aliment. 9(4), 425-441.