EVALUATION OF TEXTURE PARAMETERS OF VACUUM AND MODIFIED ATMOSPHERE PACKED FRESH CARP (CYPRINUS CARPIO L.)

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Abstract
Investigations of textural parameters of vacuum, protective gas atmosphere (MAP), and at air ambiance packed fresh carp (Cyprinus carpio L.) farmed in Latvia were carried out. The samples of carp were stored at two different temperatures (0 ± 0.5 and +4 ± 0.5 ºC) applying three different types of packaging – vacuum, MAP, and wrapping at air ambiance. Gas mixture used for MAP consisted of 40% CO₂ and 60% N₂. Samples were analyzed before packaging (day 0) and after 2, 4, 6, 8, 11 and 14 storage days. Textural parameters – hardness and shear force were evaluated by texture analyzer TA.XT.plus (Stable Micro System Ltd.). Two instrumental methods were applied for evaluation of textural properties. One method was based on compression test, using spherical probe, 25.4 mm in diameter (type P/1S), and measuring the hardness of the fillet and other method was based on cutting the fillet with a blade (type HDP/BSK) and measuring the shear force. The instrumental hardness and shear force of fresh carp fillets decreased during storage time. Texture variables significantly correlate with storage time, respectively, r = -0.723 and r = -0.748, the hardness and shear force. The storage time, temperature and packaging type with probability of 95 % substantially influence the textural parameters of carp fillets (P < 0.05).

Key words: carp, packaging, storage, texture, quality.

Introduction
Common carp is the main aquaculture in Latvia. Change in consumer’s attitude to carp may be achieved by application of new carp processing technologies. The perspective method of shelf life extension for fish is packaging in vacuum and modified gas atmosphere (MAP). Modified atmosphere packaging (MAP) extends shelf-life of most fresh fishery products by inhibiting the bacterial growth and oxidative reactions (Sivertsvik et al., 2002).

Texture analysis for fish and fish products are important parameters in the research of quality control and product development in the seafood industry (Jain et al., 2007). Texture is a general quality trait related to fish freshness quality (Olafsdottir et al., 1997). Live fish muscle is relaxed and elastic (Venugopal, 2005). Fish stored for various times post-mortem show a rapid loss of muscle hardness and a slower resolution of rigor stiffness (Taylor et al., 2002) indicating that these are separate events.

Texture of raw fish fillets is commonly tested in the industry by the ‘finger method’. A finger is pressed on the skin or the fillet and firmness is evaluated as a combination of the hardness when pressed on the fillet and mark or hole left in the fillet after pressing. This method depends to a large extend upon subjective evaluation of the person who is performing the measurements (Sigurgisladottir et al., 1997).

In raw fish, the texture softens during chilled storage because proteolytic enzymes break down the muscle structure (Sveinsdottir et al., 2002). The fat content of fish flesh appears to influence the texture. When the fat content is high, the flesh is softer and juiciness is increased. The total lipid content of common carp’s fillet was reported by Lengyel et al. (2001) and Hancz et al. (2003) in natural waters (3.1 ± 3.3%) and farmed (10.0 ± 4.5%) in Hungary. Schrenkenbach et al. (2001) determined the total body composition of a large number of fish originating from lakes and ponds in Germany and found that common carp (Cyprinus Carpio L.) had very high variance of fat (8.5 ± 4.4%).
Reproducibility of texture measurements is affected by sampling technique because of the heterogeneity of the fillets (Sigurgisladottir et al., 1999). Therefore, it is difficult to find a representative average sample, and measurement of textural properties may depend on the location within the fillet. However, raw fish should be tested in the form of a fillet or a part of a fillet. Texture of fish fillet is also related to the diameter of the muscle fibres. The strength is higher with smaller diameter and, therefore, higher numbers of fibres, than with larger diameter and lower numbers of fibres (Hatae et al., 1990). Thus, sampling is an important factor in the evaluation of fish fillet texture, because hardness and shear force increased from fish head to tail (Sigurgisladottir et al., 1999).

The goal of this study was to evaluate the texture of fresh carp fillets at the storage time applying different packaging technologies.

Materials and methods
Sample preparation and packaging
The experimental work was performed at the Faculty of Food Technology, Latvia University of Agriculture. The common carp (Cyprinus Carpio L.), weight 1.5 to 2.5 kg, farmed in one of the large-scale carp breeding companies in Latvia, “Skrunda” Ltd, were used in the studies during February-March 2008.

The carp after slaughtering and preconditioning (scale removal, cleaning, washing, filleting, and portioning with weight of 150 to 180 g) were placed on the thermoformed ready-made polypropylene (PP) trays (size 210 × 148 × 35 mm), sealed on a chamber type machine TECNOVAC Pratica with laminated film BIALON PP (thickness 65 μm). Gas mixture used for MAP packaging consisted of 40% CO₂ and 60% N₂.

The vacuum packed samples of carp were placed on the expanded polystyrene (EPS) trays (size 185 × 140 × 25 mm), inserted in PA/PE polymer pouches (size 300 × 200 mm, thickness 20/45 μm) and sealed by chamber type machine MULTIVAC C 300. Vacuum level was 99 %.

Control samples in air ambiance were also placed on the expanded polystyrene (EPS) trays (size 185 × 140 × 25 mm), just wrapped in polypropylene (PP) film (thickness 15 μm).

All samples, vacuum and MAP packed as well as control were stored in a commercial freezer/Cooler ELCOLD at two different temperatures, 0 ± 0.5 and +4 ± 0.5 ºC (controlled by MINILog, Gresinger electronic), for 14 days under fluorescent lighting (OSRAM Lumilux De Luxe) with radiant fix at 100–800 lux (measured by Light meter LX-107). Throughout the storage period the samples were randomly interchanged to minimize unequal temperature fluctuations and light conditions.

Instrumental texture measurements
The textural properties of samples were determined before packaging (on 0 day) and after 2, 4, 6, 8, 11 and 14 storage days. Each textural measurement of three identical packages was carried out by Texture Analyzer TA.XT.plus (Stable Micro System Ltd., Surrey, England) using a compression and cutting test. Two different attachments were applied: a) spherical probe (Figure 1-a) and b) blade attachment (Figure 1-b). The results were reported as means of five determinations, based on application of the TA.XT.plus texture analyzer with a load cell of 50 kg. This instrument provides a rigid framework for tension compression cycling and texture test to generate true 3-dimensional product analysis of force, distance, and time. The results were expressed as maximum force in newtons (N). During analysis, the core temperature was +4 ± 1 ºC.
**Spherical probe.** A sphere was selected as the second probe to simulate further the human finger method. The sphere affected the fillet without breaking the muscle fibres and a 5 mm distance was chosen. The spherical probe was 25.4 mm in diameter (type P/15). Pre-test speed, test speed and post-test speed were 1 mm sec\(^{-1}\), and trigger force was 0.2 N. The typical compression curve, using the sphere, is shown in Figure 3-a. The location below the dorsal fin is the reliable for textural measurements (Figure 2).

**Blade set with a knife.** The blade (knife edge, 60º) had a thickness of 3.0 mm and width of 70 mm (type HDP/BSK) which cut through the sample at a speed of 1.0 mm sec\(^{-1}\) to 30 mm distance. The post-test speed was 10 mm sec\(^{-1}\) and trigger force was 0.2 N. The typical cutting curve, using the blade, is shown in Figure 3-b. The blade approach was applied by pressing the blade through the muscle vertical to the muscle fibres. Thickness of carp fillets varies from head to tail but is approximately 20 mm thick above the lateral line. The samples were prepared from fillet dorsal part, cut into pieces (size 70 x 65 mm, thickness 20 mm) without skin.

Texture parameters recorded from the force-time graphs included: force of compression and area (Figure 3).
The $F_{\text{max}}$ represents the force recorded at maximum compression and the force at complete cutting. Hardness = $H_1$, resilience = $A_2/A_1$ equals the area under the curve from beginning of measurement until maximum force is reached, and $A_2$ equals the area under the curve from maximum force until the force has reached zero again.

**Statistical evaluation**

The results were processed by mathematical and statistical methods. Data were subjected using one-way analysis of variance (ANOVA) using the statistical analysis software SPSS 13.0 for Windows, significance was defined at $P < 0.05$. Fitting of curves and charts was done by using spread-sheets MS Excel.

**Results and discussion**

Accordingly to the explanation of Stroud (2001), rigor or, to give it its full name, rigor mortis means the stiffening of the muscles of an animal shortly after death. The word “rigor” is used throughout this paper because it is shorter and easier to use than either death stiffening or rigor mortis.

Post mortem can to distribute three stages: 1) pre-rigor condition immediately after death the muscles of an animal are soft and limp, and can easily be flexed; 2) in rigor the muscles begin to stiffen and harden; 3) post-rigor condition after some hours or days the muscles gradually begin to soften and become limp again.

The fish remains rigid for a period which can vary from an hour or so to three days, then the muscles soften again. The time a fish takes to go into, and pass through, rigor because the temperature at which the fish is kept can be controlled.

The instrumental hardness of fresh carp fillets decreased with storage time, indicating softening of the carp flesh.

The variation in textural parameters in vacuum, MAP and at air ambiance packaged fresh carp fillets during a 14 days storage period at temperature (0 ± 0.5 and +4 ± 0.5 °C) is shown in Figures 4 to 7.

The optimum defined shelf life of fresh carp fillets is as follows: at 0 ± 0.5 °C – 6 days at air ambiance, 8 days in vacuum, 14 days in MAP; at +4 ± 0.5 °C – 3 days at air ambiance, 6 days in vacuum, 14 days in MAP packaging (Kamolina and Dukalska, 2007).

Statistical analysis (ANOVA) of the data showed that all texture parameters – hardness and shear force – were found to be significantly decreased during the storage period ($P < 0.05$). The storage time and storage temperature has significant influence on the shear force, which was measured by cutting test with a blade, whereas storage condition (vacuum, MAP and air ambiance) and storage time was significant for hardness, detected by compression test with a sphere ($P < 0.05$).

All texture variables determined with the 25.4 mm diameter spherical probe correlate significantly with storage time (days). The correlation was on a 0.01% significance level ($r = -0.723$). The texture parameters recorded the blade showed highest correlation with storage time ($r = -0.748$). Between the methods of instrumental texture measurements and texture values (force in newtons) a hard correlation exists ($r = 0.872$).

The experimental data expressed in Figure 4 clearly indicate that the values of hardness decreased at the storage time. The hardness value of the fresh carp samples was 26.84 N. The hardness of carp fillet’s flesh decreased drastically 2-3 times already at the storage time from day 0 till day 2. The decrease in values at the first days of storage can be explained by ‘post mortem’ changes.
Figure 4. Hardness of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of 0 ± 0.5 °C, measured by compression with a spherical probe.

After 6 storage days (0 ± 0.5 °C) in air ambience, the hardness value of wrapped carp samples decreased from 26.84 N to 10.88 N, of vacuum packed – only to 12.5 N, while in MAP packed – even to 8.39 N; however, following 8 storage days – to 7.32 N. After 14 storage days in the MAP, the hardness diminished nearly 5 times – to 5.25 N. Whereas the hardness of fresh vacuum packed carp samples after 2 storage days (11.75 N) even slightly increased up to 14.2 N at day 8.

An important decrease in the hardness of carp samples was observed to those stored at +4 ± 0.5 °C (Figure 5): after 6 storage days in MAP, the hardness was 6.24 N. Similarly it was observed in samples stored at air ambiance – 6.65 N, whereas hardness of the vacuum packed carp sample at the same storage time was 12.32 N. Subsequently, at the next storage days the hardness values were invariable. During 14 storage days, the hardness of samples packed in MAP and stored at 0 ± 0.5 °C decreased from 26.84 N (day 0) to 5.25 N (day 14); when stored at +4.0 ± 0.5 °C, respectively, to 6.75 N. During storage time in MAP at low temperature the solubility of carbon dioxide (CO₂) on the filet surface of the product increased; therefore the flesh texture properties in hardness as well as in the cutting forces considerably changed.

Figure 5. Hardness of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of +4 ± 0.5 °C, measured by compression with a spherical probe.
In all investigated samples stored at 0 ± 0.5 °C, a sharp shear force decrease was observed during first 2–4 storage days. The decrease in shear force value of fillets packed in air ambiance was slower (Figure 6) – from 193.44 N to 108.65 N (day 6); whereas in MAP packed, the shear force values decreased more notably – to 96.73 N (day 6) and 84.24 N (day 14), respectively. Similar changes in hardness were observed in vacuum packed carp fillets stored for 8 days.

![Figure 6. Shear force of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of 0 ±0.5 °C, measured by cutting with a blade.](image)

The shear force value of wrapped carp fillets stored at temperature of +4 °C in air ambiance diminished very sharply – from 193.44 N (day 0) to 65.40 N (day 6); compared to the same time in vacuum – to 98.56 N, and in MAP – to 87.29 N (Figure 7). The shear force value of MAP packed carp fillets within the storage time of 14 days decreased more than 2 times.

![Figure 7. Shear force of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of +4 ±0.5 °C, measured by cutting with a blade.](image)

The texture variation can be explained due to rigor mortis, describing the stiffness in muscle tissue after fish death. For all textural parameters, there was decrease in their values after first five storage days.

Rigor mortis of fish has technological significance since the process influences the quality of fillets. Ideally, fish should be filleted post-rigor (Venugopal, 2005).

Rigor results from a series of complicated chemical changes in the muscle of a fish after death; the process is not yet fully understood, and research is still going on, but it is known that factors like the physical condition of the fish at death, and...
the temperature at which it is kept after death, can markedly affect the time a fish takes to go into, and pass through, rigor (Stroud, 2001).

In the literature (Jain et al., 2007) it is reported that the course of completion of rigor mortis for fish requires 5–24 h. The fish is considered as fresh and good for human consumption during rigor mortis. After rigor mortis stage, the decomposition of fish tissue occurs rapidly.

Carbon dioxide (CO\textsubscript{2}) can be seen as most effective gas in reducing the growth of aerobic and gram-negative psychotropic bacteria, whereas negative affect of CO\textsubscript{2} has been observed on the color changes of fish tissues as well as on the texture and drip loss of fresh fish (Sivertsvik et al., 2002).

Significant differences ($P < 0.05$) were found between the data of textural measurements of different packed samples during 14 days of storage. Primarily, the storage time (days) has a significant influence ($P < 0.05$) on the textural parameters of vacuum and modified atmosphere packed fresh carp tissues. Also the packaging type and storage temperature had a significant effect ($P < 0.05$) on the textural parameters of carp.

The sampling technique is an important factor that can affect the final results of texture analysis. The difference in textural properties within one fillet can be higher in some instances than between fillets of different individuals. Mixing samples from different locations of a fillet may, therefore, be questionable. This can lead to difficulties in some cases in studying effects of processing or storage of fillets on texture (Sigurgisladottir et al., 1999).

**Conclusion**

Studies on the textural properties of common carp (Cyprinus Carpio L.) during storage in vacuum, MAP and at air ambiance indicated considerable changes in the compression characterising the hardness and cutting share forces, which could be influenced by post mortem textural changes. The highest changes in texture were found after rigor condition for first two days of storage. Primarily, the storage time with probability of 95% substantially influences the textural parameters of vacuum and modified atmosphere packed carp fillets ($P < 0.05$). Also temperature and packaging type has a significant effect on the textural parameters.

**References**

