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INFLUENCE OF COLD AND FROZEN STORAGE ON CARP (*CYPRINUS CARPIO*) FLESH QUALITY

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Carp is becoming a raw material for processing with increasing frequency. At the same time, knowledge regarding processes occurring in the meat of this species of fish during storage is limited. The work presents changes in the quality parameters of carp fillets during seven–day storage on ice as well as long–term freezing at a temperature of –30°C. The results of measurements showed a significant fall in the pH value over the first 24–h period following slaughter (6.58 to 6.41). After seven days, the average reaction of the tested fillets amounted to 6.47. What has been observed is a linear (r^2=0.99) growth in the K–value freshness index from 3.8% immediately following slaughter to 52.6% after seven days of storage on ice, which is mainly the result of the systematic fall in the IMP concentration and an increase in inosine. No significant changes were noted in total fat content (1.41% to 1.77%) nor in saturated (0.37% to 0.41%) and monounsaturated fatty acids (0.77% to 1.00%) during the course of storage on ice and frozen. Only the content of polyunsaturated fatty acids was significantly lower following a period of freezing (from 0.13% to 0.02%; $p<0.001$).

INTRODUCTION

Pond production of carp is the main source of supplies of fresh water fish for the domestic fish product market. For several centuries now, the production and consumption of carp in Poland has been linked with the Christmas holiday tradition. The primary form of distribution was the sale of live carp during the period directly preceding the holidays. Due to the character of distribution and sales to date, testing of the qualities of carp meat was not conducted with any intensity, while available information in this field was minimal. Changes taking place in the fish product market over the past few years as well as current consumer preferences and expectations have resulted in changes in current forms of distribution of this species. As a result of these changes, carp has become a raw material for processing. This situation has resulted in the appearance of a demand for information regarding the quality and technological parameters of carp meat.

The purpose behind the presented work was to define changes taking place in carp meat during its storage subject to refrigeration and freezing.

MATERIALS AND METHODS

Test material consisted of fillets derived from three––year–old commercial carps from a single source providing uniform material in terms of origin. The fish were caught in August in advance of the main sales season. The slaughter of the fish was conducted traditionally by way of mechanical damage to the brain. The fillets were received by way of hand processing. The setup of the experiment was adapted to the practice most frequently used in fish processing plants and stores providing for the slaughter and cleaning of the carcasses, where following slaughter the carp is offered as fresh and stored on ice; should it not be sold within a few days it is frozen and sold in that form. The fillets from the right side of the body were stored on ice for a period of seven days. The pH of the meat was measured over this period and samples were taken for identifying ATP content and the products of its breakdown. The pH measurements were taken at three points of the fillet using a CP315 pH meter (Elmetron, Poland) as well as TipTrode electrodes (Hamilton, U.S.A.). Tests were conducted immediately following partitioning of the fish, after 12 and 24 h and then every 24 h for seven successive days. The meat samples designated for analysis of ATP breakdown product content were taken from the fillets immediately following partitioning and after one, three, five, and seven days. The samples were frozen in liquid nitrogen and subsequently stored at a temperature of –80°C up to the moment of the determination. The ATP and respective derivative content, following PCA extraction, was determined using a liquid chromatograph with UV detection at 254 nm (Perkin Elmer, U.S.A.) [Veciana–Nouges *et al.*, 1997]. The K–value freshness index was calculated as [100*(Hx+Ino)/ /(ATP+ADP+AMP+IMP+Hx+Inp)] [Saito *et al.*, 1959].

The fillets from the left side of the body were ground and divided into three parts. The first was subjected to analy-

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sis on the day of the slaughter. The second and third were stored for seven days on ice after which one was subjected to analysis while the second was not analyzed until after a fifteen-week period of storage at –30 °C. What was determined from the samples was the fat content as well as specific fractions of fatty acids using a Büchi B–820 chromatograph (Büchi, Switzerland) in line with the Büchi–Caviezel method [AOAC PVM 4:1997].

RESULTS AND DISCUSSION

A quality of meat, including the meat of fish, is its perishability. Irreversible biochemical changes begin occurring in the meat immediately following slaughter; they result in a loss of nutritional value, sensory qualities, and technological utility. These processes are relatively well studied in the case of the meat of higher vertebrates as well as certain species of sea fish. Due to limited application to date in the processing of carp meat, information relating to changes taking place in it during storage and its impact on the meat quality is sparse.

pH determination

A characteristic phenomenon involves changes in meat reaction. They are linked with the breakdown of glycogen as well as phosphorous compounds. Glycogen contained in the meat of fish is the basic energy material enabling the work of muscles. Following the death of the fish, the glycogen plays a major role in post–slaughter changes. The breakdown of carbohydrates starts the earliest and serves as the starting point for changes in other components, especially proteins [Kączkowski, 1999]. Changes in carbohydrates may be influenced by species–specific qualities as well as external factors such as conditions of the catch as well as treatment of the fish during slaughter [Vis van de, 2003; Esaiassen *et al.*, 2004]. Following slaughter and partial exsanguination, the process of breakdown of the glycogen takes place subject to anaerobic conditions. This is a one–way process through anaerobic glycolysis resulting in lactic acid. Subject to such conditions, only a small portion of the compound is broken down to glucose with the assistant of the α–amalysis enzyme. The main process of change continues until a sufficient quantity of lactic acid is accumulated to inactivate the glycolytic enzymes. As a result, the lowest pH value is maintained at a steady level up to the autolysis of the muscle proteins. Alkaline products of protein autolysis so created result in an increase in the pH of the meat [Kączkowski, 1999].

Results of pH content measurements over the course of the storage of carp fillets on ice demonstrated significant fluctuations. The greatest fall, the result of the anaerobic transformation of glycogen into lactic acid, was observed over the initial 24–h period following slaughter (6.58 to 6.41) (Figure 1). The second and third days saw an increase in reaction to 6.48, followed by a successive fall to a value of 6.44. The following days witnessed a slow growth tendency of the pH value towards a neutral reaction. After seven days of observations, the pH value of the tested fillets amounted to 6.47. No similar phenomenon has been described in other fish species in accessible scientific papers, although it was observed during a different study of the carp [Białowąs *et al.*, 2004]. The slow increase in the observed pH value is caused by the presence of nitrogen compounds created as a result of the breakdown of protein [Sikorski *et al.*, 1990].

The range of change in the pH value of the tested fillets is in agreement with values noted by other authors in the case of both freshwater fish such as the rainbow rout [Chytiri *et al.*, 2004; Rodriguez *et al.*, 1999] and seawater ones such as the gilthead bream [Grigorakis *et al.*, 2003], sea bass [Grigorakis *et al.*, 2004], and other species [Sikorski, 2004; Simeonidou *et al.*, 1998].

ATP breakdown products

The K–value freshness index was determined on the basis of the results of the content in muscle tissue of ATP as well as the products of its breakdown (ADP, AMP, IMP, inosine, and hypoxanthine) [Saito *et al.*, 1959]. The K–value index is a good indicator of meat freshness although it is specific to the species [Grigorakis *et al.*, 2004; Lougovoisa, 2003]. The K–value of carp meat stored on ice rose from 3.8% to 52.6% (Figure 2). The linear (r^2=0.99) course of changes in its value bears witness to a steady rate of changes in ATP derived substances. The course and value after seven days are similar to the results of tests on the turbot [Aubourg *et al.*, 2005], but significantly higher than in the case of the gilthead bream [Grigorakis *et al.*, 2003; Lougovoisa *et al*., 2003].

Since the observed changes are linked with other breakdown processes in the meat [Saito *et al.*, 1959], it should be assumed that their rate will be similar in character. The

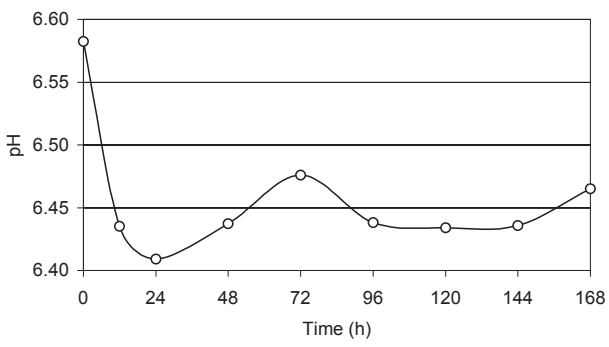

FIGURE 1. Changes of the pH value of the filet (n=60).

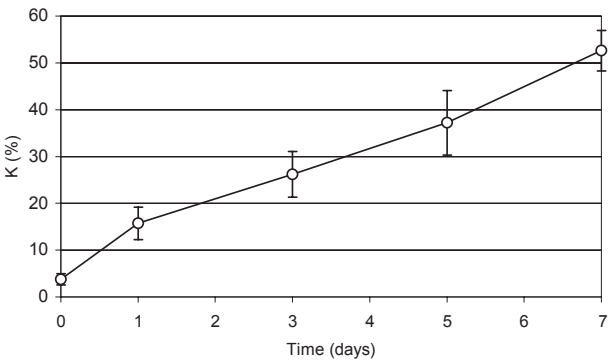

FIGURE 2. Changes of the K value of the fillet (n=10).

relatively low concentrations of ATP and ADP in meat samples taken immediately following slaughter bear witness to the utilization of these substances by the fish during catching and related manipulation as well as the treatment of the fish prior to slaughter (Figure 3). No significant changes in IMP concentration were noted during the first 24 h following slaughter, although there was a simultaneous fall in the quantity of ATP and ADP whose dephosphorylation supplemented the IMP breakdown. IMP is considered a substance with qualities improving flavor [Lougovoisa *et al.*, 2003]. Thus, the observed linear (r^2=0.99) fall in IMP concentration from a value of 3.38 immediately following slaughter to 0.85 μmol/g should have a negative impact on flavor qualities. At the same time, an increase in inosine concentration was noted from 0.17 to 1.32 μmol/g. During the course of the experiment, no growth in hypoxanthine - the substance responsible for the bitter aftertaste in meat stored under refrigeration conditions - was noted (Figure 3) [Lindsay, 1994]. The phenomenon of inosine accumulation, as opposed to hypoxanthine accumulation, is characteristic of certain fish species [Karube *et al.*, 1984]. To confirm whether this phenomenon occurs in the case of carp, longer term storage of the meat on ice is necessary.

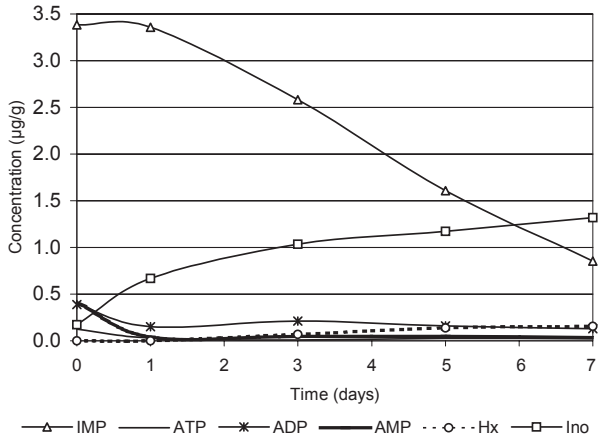

FIGURE 3. Changes of ATP and its breakdown products during cold storage (n=10).

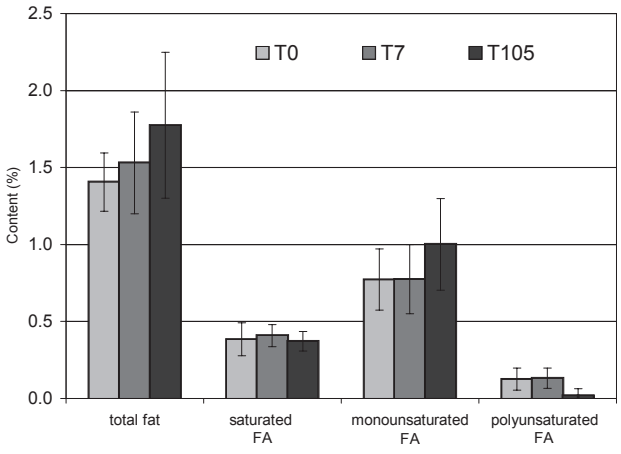

FIGURE 4. Total fat, saturated and unsaturated fatty acids (FA) content in carp flesh immediately following partitioning of the fish (T0), after 7-day of cold storage (T7) and 15-week frozen storage (T105).

Fat changes

A significant element among processes taking place in the meat is the breakdown of acids. Carp meat contains from 5% to 25% fat and is considered among the group of fat or semi–fat fish [Sikorski, 2004]. Thus, the breakdown of fats and changes in the fatty acid profile can be used to define sensory, nutritional, and technological qualities of this species of fish. Fish fat is composed of a complex mixture of acids with variable molecule size. They are mainly unsaturated fatty acids containing two or more double bonds in a *cis* configuration.

The average fat content amounted from 1.41% to 1.77% (Figure 4). No statistically significant changes in total fat content were noted as a result of storage subject to conditions of refrigeration or freezing. Growth in fat content was caused by meat dehydration during storage [Sikorski, 2004].

No significant changes were noted in the content of saturated fatty acids (the average content ranged from 0.37% to 0.41%) and in monounsaturated ones (0.77% – 1.00%). The samples subjected to freezing noted a significantly lower content of polyunsaturated fatty acids ($p<0.001$). Immediately following slaughter and after seven days of storage on ice, their average content amounted to 0.13%, while after fifteen weeks in a frozen state it amounted to 0.02%. A quality of all unsaturated fatty acids is their shorter shelflife in the case of double bonds. The reason why the meat of fish becomes rancid quickly, especially of fat fish, is the high content of unsaturated fatty acids (easily oxidized) as well as their high level of unsaturation. Hydroperoxide is created as a result of oxidation [Kączkowski, 1999]. Secondary products of the oxidation of hydroperoxide such as hydroxy acids, carbonyl compounds, low molecular fatty acids, alcohols, and esters give a specific taste and smell, as well as deteriorate the appearance, thus disqualifying the meat as a product for consumption.

CONCLUSIONS

1. The storage of carp meat on ice results in significant changes in the pH value taking a course not found in other species of fish.
2. The k–value freshness index increases systematically reaching 52.8%, which should disqualify carp meat from consumption after six or seven days of storage on ice.
3. No hypoxanthine growth phenomenon was noted, but there was an increase in inosine content.
4. No significant changes in the total content of fat were noted, nor in the content of saturated and monounsaturated fatty acids over the course of seven days of refrigeration followed by fifteen weeks of being subjected to freezing. It was only in the case of polyunsaturated fatty acids that long–term freezing caused a significant lowering in their content. Thus, long–term freezing results in significant deprivation of carp meat with respect to the most valuable fractions of fatty acids.

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WPŁYW CHŁODZENIA I ZAMRAŻANIA NA JAKOŚĆ MIĘSA KARPIOWEGO

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Coraz częściej karp jest surowcem dla przetwórstwa a jednocześnie zasób wiedzy o procesach zachodzących w mięsie tego gatunku ryb w trakcie przechowywania jest ograniczony. W prezentowanej pracy przedstawiono zmiany parametrów jakościowych filetów karpia podczas 7-dniowego przechowywania na lodzie oraz długotrwałego mrożenia w temperaturze –30°C. Wyniki pomiarów wykazały znaczny spadek wartości pH w ciągu pierwszej doby po uboju (6,58 do 6,41) (rys. 1). Po 7 dniach obserwacji średnia wartość odczynu badanych filetów wynosiła 6,47. Zaobserwowano liniowy (r^2=0,99) wzrost wartości indeksu świeżości K z wartości 3,8% bezpośrednio po uboju do 52,8% po 7 dniach przechowywani na lodzie (rys. 2) spowodowany głównie systematycznym spadkiem stężenia IMP i wzrostem inozyny (rys. 3). Nie stwierdzono istotnych zmian całkowitej zawartości tłuszczów (1,41% do 1,77%) oraz nasyconych (0,37% do 0,41%) i jednonienasyconych kwasów tłuszczowych (0,77% do 1,00%) w trakcie przechowywania na lodzie i mrożenia (rys. 4). Jedynie zawartość wielonienasyconych kwasów tłuszczowych była istotnie niższa po okresie mrożenia (z 0,13% do 0,02%; $p<0,001$).