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Original Scientific Paper

Quality attributes of chilled common carp (*Cyprinus carpio*) cuts packaged in vacuum and modified atmosphere

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ABSTRACT

The objective of this study was to investigate the impact of vacuum and modified atmosphere packaging (MAP1: 60%CO_2 + 40%N_2 and MAP2: 40%CO_2 + 60%N_2) on selected microbiological and sensory attributes of common carp (*Cyprinus carpio*) cuts stored at 3±0.5˚C, and to establish the shelf life of the products. Samples were assessed on days 1, 4, 7, 9, 12, and 15. An increase in the APC during the storage period was observed in all types of packaging, with the most exceptional changes occurring in the vacuum packaged fish. Carp cuts stored in a CO_2-enriched atmosphere exhibited lower APC number throughout the entire storage period. Panellists rejected VP fish on day 9, MAP2 fish on day 12, while MAP1 fish was evaluated as unacceptable from a sensory point of view on day 15. The shelf-life of carp cuts was extended from 7 days in VP to 9 days in MAP2 (40% CO_2 + 60% N_2) and to 12 days in MAP1 (60% CO_2 + 40 % N_2).

1. Introduction

Modern consumers demand fresh fish for consumption rather than frozen or processed fish. This requirement is largely met by packaging the products in vacuum or modified atmosphere. Vacuum packaging (VP) and modified atmosphere packaging (MAP) are considered established technologies for food preservation, and they work by changing the gas proportions in a food environment, respectively, by withdrawing O_2 or by replacing the atmosphere inside the package by a mixture of gases, such as carbon dioxide (CO_2) and nitrogen (N_2) gas (*De Witt et al*., 2016). MAP with high levels of CO_2 generally promote fresh fish storage stability (*Olatunde & Benjakul*, 2018). Evaluation of different quality parameters, such as microbial, chemical, physical, and sensory attributes, have been used to determined the shelf-life of fish (*Lerfall et al.*, 2018). The shelf-life of fresh, chilled fish is relatively short, and at refrigeration temperatures of 2 ± 2 °C, it is about 2 to 3 days. MAP can be applied as a preservation method to extend the shelf-life of fresh chilled fish (*Masniyom*, 2011).

In Serbia, fish are traditionally marketed for human consumption as whole fish, freshly slaughtered on flaked ice, or as live fish. For slaughtered fish, the preferred type of fish packaging is VP. There are generally very few studies on freshwater fish produced in Serbia and packaged under modified atmospheres. Therefore, the aims of this research were to monitor changes of selected microbial and sensory parameters of common carp (*Cyprinus carpio*) cuts

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packaged in vacuum and modified atmosphere during storage at 3±0.5°C, and to determine the shelf-life of the packaged fish.

2. Materials and methods

Two-year-old marketable carp (*Cyprinus carpio*) of average body weight of 2.5 kg were used in the experiment. Carp originated from a fishpond located in the lowland region of Serbia, where semi-intensive farming is used. Fish were transported live to the fish slaughtering and processing facility, where they were stunned, slaughtered, scaled, and each carcass was cut into steaks 2 cm thick. Three sample groups of carp cuts were formed. Firstly, two groups were packaged in a modified atmosphere with different respective gas ratios: 60%CO_2+40%N_2 (MAP1) and 40%CO_2+60%N_2 (MAP2), whereas the third group was vacuum packaged. The packing machine was a Variovac (Variovac Primus, Zarrentin, Germany), and the packaging foil was OPA/EVOH/PE (oriented polyamide/ethylene vinyl alcohol/polyethylene, Dynopack, Polimoon, Kristiansand, Norway) with low gas permeability (degree of permeability for O_2 – 3.2 cm^3/m^2/day at 23°C, for N_2 – 1 cm^3/m^2/day at 23°C, for CO_2 – 14 cm^3/m^2/day at 23°C, and for steam – 15 g/m^2/day at 38°C). The gas:fish ratio in MAP packages was 2:1. All packaged fish were stored in the same conditions at 3±0.5°C, and on days 1, 4, 7, 9, 12, and 15 of storage, microbiological and sensory testing was performed. The last examination for each group was conducted on the day when sensory changes were revealed.

2.1. Microbiological analysis

For each test group, fish from three packages was analyzed each sampling day. For the analyses, from each package, 20 g of fish muscle was removed aseptically with a sterile scalpel and tweezers, transferred into a stomacher bag, diluted with 180 mL of 0.9% NaCl solution, and homogenized for 2 min (Steward Stomacher 400 Lab Blender, London, UK). For microbial enumerations, ten-fold serial dilutions were prepared and 1 mL from each dilution was used.

Aerobic plate count (APC) was determined in plate count agar (PCA, Merck) using the pour plate technique with agar tempered to 44°C. Plates were incubated at 30°C for 72 h. All plates were prepared in duplicate and examined visually for typical colony types and morphological characteristics, and counts were expressed as logarithms of the number of colony-forming units per gram (log cfu/g).

2.2. Sensory assessment

Sensory analysis was conducted by six experienced judged from laboratory staff, in the laboratory for sensory evaluation, at room temperature (20 °C) and adequate lighting. Fish was removed from the packaging 10 min before trial and presented on the tray. These trays were coded by randomly chosen 3-digit numbers. Each panellist analyzed the samples individually for overall acceptability, with regard to odour, flesh colour and texture using 1-7 intensity scale, with 7 corresponding to the most liked sample and 1 corresponding to least liked sample. The product was defined as unacceptable when it achieved a score less than 3 points recorded by at least of 50% of the judges. Fish from each test group was evaluated throughout the storage period on each sampling day.

2.3. Statistics

The mean values and standard deviations were calculated by using column statistics with the processing of six values for each analyzed group. Significant differences between groups were calculated using one-way ANOVA. When a significant F was found, additional post-hoc tests with Tukey's adjustment were performed. Statistical significance was set at the ($p<0.05$) level of confidence. All analyses were performed using the program Microsoft Office Excel (2016).

3. Results and discussion

The APCs of common carp cuts, expressed as log cfu/g (mean ± SD), are presented in Figure 1. The initial low numbers of mesophilic bacteria imply good microbial quality of the fish. Good hygiene practices during growing and handling of the fish could also help limit bacterial contamination as inferred by these findings. An increase in the APC during the storage period was observed in all types of packaging, with the most exceptional changes occurring in VP fish, with a significantly higher ($p<0.05$) APC from day 4 of storage compared to MAP fish. From day 4, the APC was significantly lower ($p<0.05$) in the group with the highest percentage of CO_2 in the packaging, and this trend was observed until the end of storage. Our results indicated a strong bacteriostatic effect of

CO_2 and a consequent reduction in the growth of mesophilic bacteria during the entire storage period. This effect depended on the applied CO_2 concentration and is in agreement with numerous results from the literature. The results of *Provincial et al*. (2010) indicated that there was significant reduction in the APC of fresh sea bass fillets packaged in a gas mixture with high CO_2 content compared to control fillets. Similar results were published by *Rodrigues et al.* (2016), who investigated the shelf-life of trout fillets packaged in MAP and in MAP with applied UV-C radiation, as well as *Esteves et al.* (2021), who examined grey triggerfish fillets packaged in vacuum and MAP.

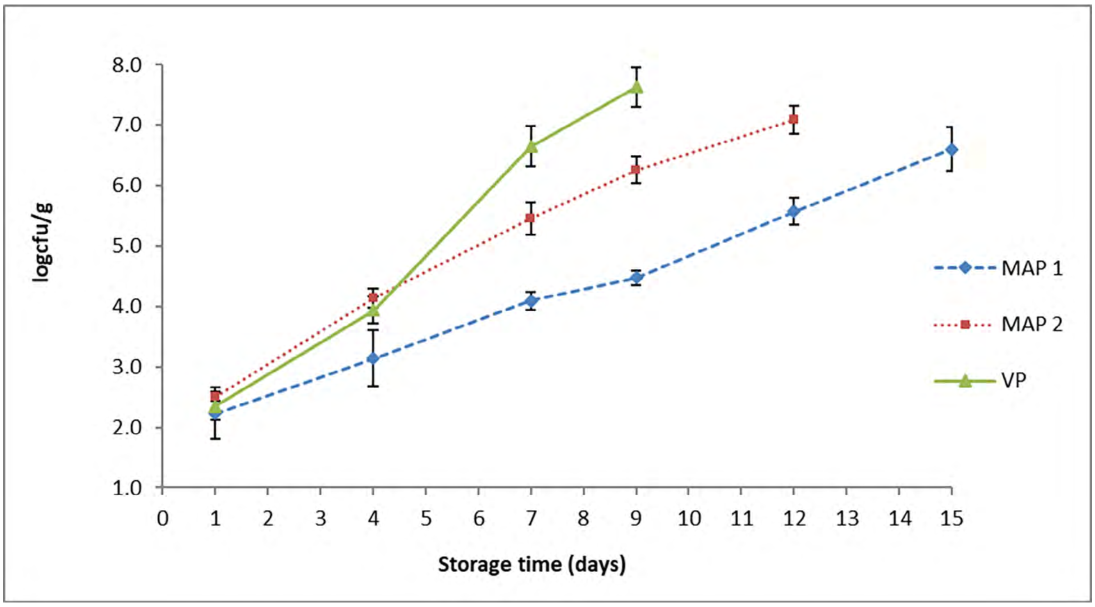

Figure 1. Aerobic plate count of common carp cuts expressed as log cfu/g (mean ± SD) packaged under different conditions during the storage period

According to ICMSF recommendations, the APC in fresh fish should not exceed 7 log cfu/g (*ICMSF*, 1986). This limit was also considered as a microbiological criterion that indicated the shelf-life of fish during the storage. In our study, in VP fish, APC reached numbers above the recommended limit on day 9 and in MAP2 fish on day 12; this corresponded with sensory unacceptability, i.e., spoilage. In MAP1 fish, APCs never exceeded 7 log cfu/g over the 15 days of the study.

Our research showed there was a good correlation between the aerobic plate counts of carp cuts packaged in vacuum and MAP2 and overall sensory acceptability. Similar findings were reported by *Fletcher et al.* (2002) who concluded that the aerobic plate count in salmon fillets packaged in a modified atmosphere (40% CO_2 + 60% N_2) was a good indicator of fish spoilage. In salmon fillets packaged in a modified atmosphere (60% CO_2 + 40% N_2) or vacuum, *Hansen et al.* (2009) also found a high level of correlation between APC and odour, as the main sensory attribute of fish freshness.

On the other hand, our research showed that although higher CO_2 concentration in the MAP1 gas mixture significantly slowed down the growth of APC, fish was not acceptable from the sensory point of view at the end of storage period (see below). *Stamatis & Arkoudelos* (2007) proved that the APC did not exceed 10^7 log cfu/g at the time of the first signs of spoilage of fresh sardine fillets packed in a modified atmosphere, supporting the results of the present study.

Sensory scores decreased over time in all experimental groups. At the beginning of storage (day 1), the quality of the fish was characterized by a uniform rosy colour and elastic texture of flesh and fresh, neutral odour. Sensory scores did not change significantly until day 4, so on days 1 and 4, fish from all groups were assessed as fresh and of very good quality. From day 4 on, as expected, sensory parameters changed differently in the different packaging conditions.

The greatest decrease of all sensory parameters was established in VP fish. A closer analysis showed the attributes that had the greatest impact on overall acceptability in VP fish were odour and flesh colour. At the moment of sensory rejection after 9 days of storage, the odour of VP fish was sour and unpleasant and discolouration of fish flesh was detected.

In the MAP1 and MAP2 fish, the sensory attributes that most influenced the overall acceptability were odour and flesh texture. The odour changed from fresh at the start to neutral and ammoniacal during the extended the storage. At the end of the shelf-life, the odour was unpleasant, sour (MAP2) and rancid (MAP1). Metabolic activities of microorganisms at the end of the storage period could be a reason for the unpleasant odour in MAP2 fish. Since a rancid odour was detected in MAP1 fish when samples were evaluated as unacceptable, chemical changes could be a reason for this. Carbon dioxide-rich packaging effectively inhibited microbial spoilage, but did not prevent chemical changes, especially lipid oxidation. For this reason, some antioxidants would have to be applied in combination with MAP to achieve an extended shelf-life in terms of microbial and chemical changes. On the other hand, dissolution of the CO_2 in the aqueous phase of the fish muscle packaged in MAP1 and MAP2 led to a drop in the pH and consequent loss of meat juice, which negatively affected the texture of the fish flesh. Panellists rejected MAP2 fish on day 12, while MAP1 fish was evaluated as unacceptable from a sensory point of view on day 15.

4. Conclusion

Based on sensory and microbiological parameters, MAP has great potential for preserving fish quality and extending the shelf-life of carp cuts from 7 days in VP to 9 days in MAP2 (40% CO_2 + 60% N_2) and to 12 days in MAP1 (60% CO_2 + 40 % N_2).

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