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SHORT COMMUNICATION

Impact of varying sodium bicarbonate concentrations on carp skin structure and carcass pH

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Abstract. This preliminary study investigated the effects of washing common carp (*Cyprinus carpio*) carcasses with different concentrations of sodium bicarbonate solution (0%, 2%, 5%, and 7%) on skin morphology and carcass pH levels, which could potentially affect shelf life for consumers. Skin biopsies were analyzed histologically using AB/PAS staining, and pH was measured during a seven-day storage period under refrigerated conditions. Results showed that increasing sodium bicarbonate concentrations led to progressive skin degeneration, with the 5% and 7% groups showing the most superficial loss of the epithelial layer. However, no statistically significant differences were observed among the groups. Washing fish carcasses with sodium bicarbonate solution is a promising way to reduce the amount of mucus on the surface and in the fish skin, which could potentially extend the storage life of carp meat. However, further microbiological studies are needed to confirm these preliminary findings and to investigate the optimal concentration and duration of washing with sodium bicarbonate for different fish species, as well as its impact on the product's sensory qualities and nutritional value.

Keywords: carp fillets, fish meat freshness, natural preservative, shelf life, skin morphology, sodium bicarbonate

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Introduction

Common carp (*Cyprinus carpio*) farming in ponds is one of the oldest known forms of European aquaculture (Biermann and Geist 2019). Currently, pond aquaculture is simplified using common carp, especially in central European inland countries (Roy et al. 2020). Poland and the Czech Republic are among the leading European Union producers, accounting for around 52% of EU production (Eurostat 2024). The adaptability of carp allows successful production in tanks near markets (Soltani et al. 2010, Manjappa et al. 2011, Rahman 2015). Since trade in the EU mainly involves live or preprocessed fish, it is crucial to develop effective pre- and post-slaughter techniques (Karnai and Szűcs 2018).

Fish meat is prone to spoilage and pathogen development (Sterniša et al. 2019). This makes fish products challenging to manage in terms of ensuring their quality and safety. The skin and mucus are the primary barrier, protecting fish from harmful external factors (Sanahuja et al. 2023). This surface is one of the most rapidly deteriorating tissues because of the increased proliferation of bacteria following the death of fish (Sterniša et al. 2019). When fish are subjected to stress before or during slaughter, their energy reserves become depleted, and the onset and course of post-mortem changes are shortened. Accelerating

post-mortem processes also hastens microbiological changes in fish meat and shortens its shelf life (Mraz et al. 2022). In the first stage of fish processing, it is essential to focus on mitigating microflora. A reduction in the microbiota certainly influences the more extended period of suitability of fillets for consumption (Shaheenuzzaman et al. 2011).

Traditionally, preservation methods (fermenting, smoking, salting) extended the shelf life of fish products. Due to undesirable changes such as reduced nutritional value or deterioration of sensory characteristics, new solutions are being sought. Innovative methods such as non-thermal atmospheric plasma, pulsed electric fields, pulsed light or ultrasound can extend the freshness of fish meat with minimal impact on its organoleptic properties (Speranza et al. 2021). Given the growing interest in natural substitutes for synthetic antimicrobials in food products (Van Haute et al. 2016), natural methods for increasing the freshness of fish meat are still needed.

One such natural option is sodium bicarbonate ($NaHCO_3$), a white powder that easily dissolves in water and releases carbon dioxide and is commonly used as an anaesthetic for fish (Akinjogunla et al. 2023). In addition, it is widely used in nutrition and industrial processes mainly related to poultry and pork products. Its advantages include affordable price, easy availability, and safety for humans and the environment (Hasimuna et al. 2020). The study aimed to evaluate the effect of sodium bicarbonate solution on the skin morphology and pH level of common carp meat in the context of extending its shelf life.

Materials and Methods

The study was conducted in the winter on 40 adult common carp (with a weight range of 1.28–2.07 kg) that were reared at the Experimental Fish Farm of the Warsaw University of Life Sciences in Łąki Jaktorowskie. The fish were slaughtered and then placed in a sodium bicarbonate solution at concentrations of 0%, 2%, 5%, and 7% with five individuals per group for a period of 15 minutes. Fillets and skin biopsies were obtained for pH and histological analyses. The biopsies were fixed in Bouin's solution, subjected to standard histological procedures, and stained with the AB/PAS (Alcian blue-Schiff's reagent with periodic acid) techniques. A Nikon Eclipse NI-E microscope with a Nikon DS-Fi3 camera and NIS Elements AR software (Nikon, Tokyo, Japan) were used for microscopic analysis. The changing pH of the carcass was analyzed under refrigerated conditions (4°C). For five days, pH measurements were taken with a pHmeter Testo 205 (Testo SE & Co KGaA). The results were analyzed statistically with the student's t-test in Statistica software. Differences were considered statistically significant at $P < 0.05$

Results

The study found differences in skin degeneration that correlated directly with increasing concentrations of sodium bicarbonate (Fig. 1). While washing the carcass in water did not result in any histological changes (Fig. 1A), the group exposed to 2% sodium bicarbonate localized damage to the outermost layer of the skin (Fig. 1B) was detected, and this effect became more pronounced in the 5% and 7% groups (Fig. 1C, D). The histological pH level of the skin assessed by the AB/PAS reaction suggests a neutral pH level close to 7 (PAS-positive). Although no damage to the mucous cells was noted, there was a gradual reduction in the amount of surface mucus on the skin, which decreased inversely with the increasing sodium bicarbonate concentration (see Fig. 1A-D). The most superficial epithelial layer loss was observed in the 5% (Fig. 1 C) and 7% (Fig. 1D) groups, with the surface mucus layer absent in fish treated with 7% sodium bicarbonate.

During storage, the carp carcass showed a systematic decline in pH (Table 1). Although no statistically significant differences were observed among the groups, the fish meat washed in 7% sodium bicarbonate had the lowest pH (Fig. 2) on the fifth day of storage.

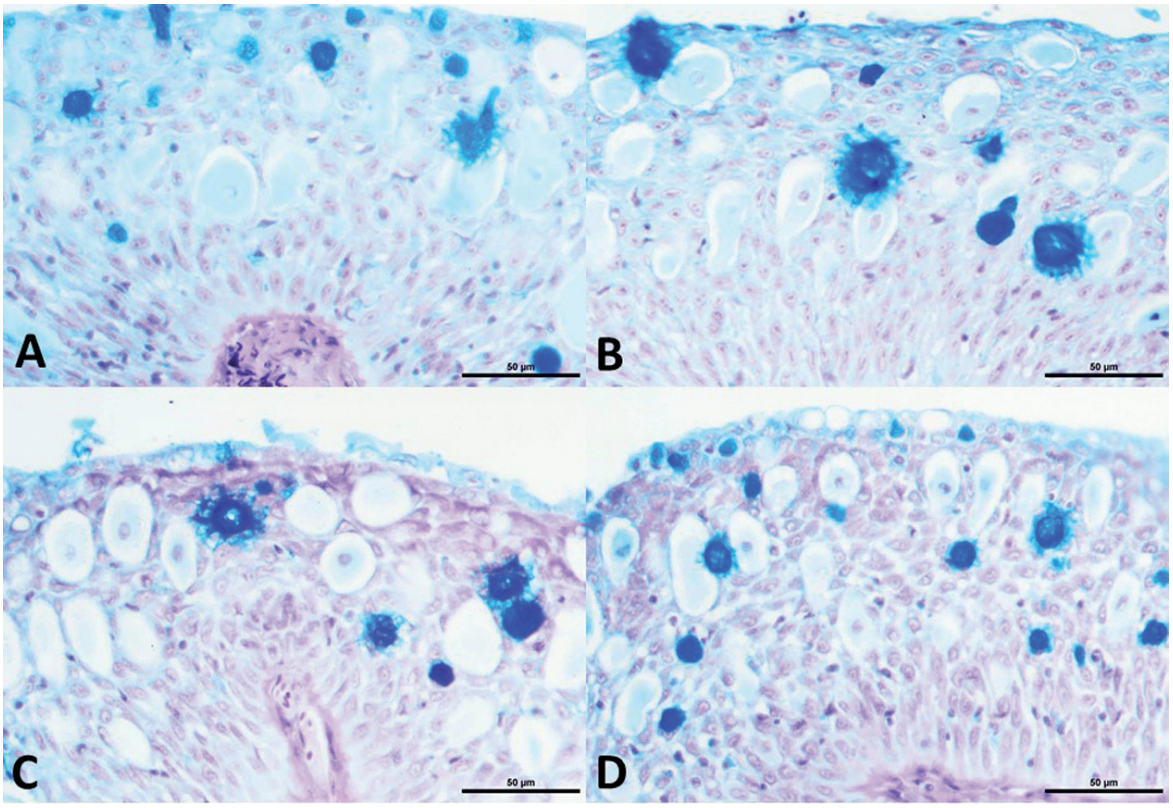

Figure 1. Common carp skin morphology with visible mucus cells (arrows): A – control group, B – 2% group, C – 5% group, D – 7% group; AB/PAS, scale 50 µm.

Table 1
pH level of carcass during the week of the storage trial (mean and SD)

	Groups							
	Control		2%		5%		7%	
Days	mean	SD	mean	SD	mean	SD	mean	SD
0	6.96	0.05	6.99	0.01	6.95	0.06	6.93	0.10
1	6.82	0.03	6.83	0.09	6.90	0.05	6.80	0.01
2	6.75	0.08	6.70	0.08	6.73	0.03	6.70	0.05
5	6.66	0.04	6.61	0.04	6.57	0.06	6.50	0.04
7	6.53	0.10	6.56	0.04	6.55	0.13	6.44	0.01

Discussion

Sodium bicarbonate is commonly used in oriental cuisine as a marinade component to improve quality in pale soft exudative meat (Zou et al. 2022), as it tenderizes and minimizes the intensity of meat odor. Using soda in contact with meat raises its pH due to its ability to retain water in the meat (Xiong et al. 2020). Furthermore, it has been observed that the injection of sodium bicarbonate in trout carcasses may affect meat softening after pH decreases during storage (Korkmaz 2023). Thus, there are indications that this substance can significantly affect not only the physicochemical properties of fish meat, but also its freshness during storage.

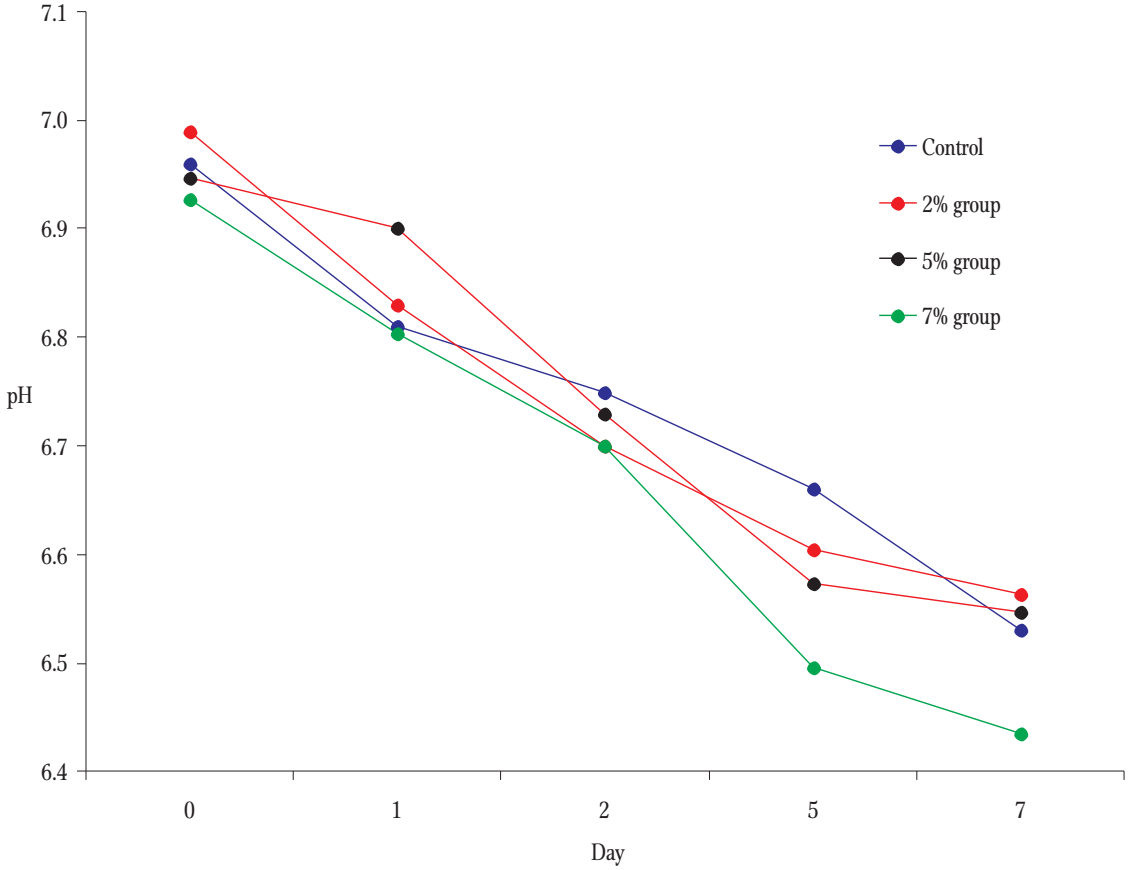

Figure 2. pH level of carp meat treated with r – rhodium changes over time.

Fish meat spoils quickly because of multiple factors, including numerous mucosa cells on the epidermal surface of the skin, which is an optimal medium for microorganism growth. Many microorganisms use elementary elements such as carbon, oxygen, and nitrogen, as well as more complex chemical compounds such as glycosaminoglycans and mucopolysaccharides, which have functional and structural roles (Gupta et al. 2016, Padra et al. 2017). Carcass washing is a crucial step in fish processing that serves multiple purposes. This procedure helps remove surface contaminants, including mucus and bacteria. The application of a sodium bicarbonate washing step as a simple, easy method for reducing the amount of mucus in fish is a promising way to extend the freshness of the meat because it not only removes bacteria and general mucosa from fish skin or whole carcasses, but it also removes the mucous located inside the goblet cells as shown this research. Analyses have shown that applying as little as 5% sodium bicarbonate solution affects the epithelium surface and the morphology of mucous cells. The removal of most or all of the mucus from the skin of the fish is an important step in prolonging the freshness of the final product. A similar effect was observed when washing grass carp fillets in a solution with lysozyme and phytic acid, with extended shelf life due to reduced bacterial counts (Sun et al. 2020).

In this study, no effect of the applied baths on the pH of carp meat was observed. The duration of the washing step (15 minutes) was probably insufficient to observe beneficial changes in the inhibition of the decrease in pH that promotes meat spoilage. Future studies could investigate the optimal concentration and time of sodium bicarbonate washing for different

fish species, as well as its impact on the sensory qualities and nutritional value of products. Additionally, combining sodium bicarbonate washing with other preservation techniques, such as vacuum packaging or modified atmosphere storage, may yield synergistic effects in prolonging the shelf life of fish products.

Author contributions. WC – data collection, analysis, writing – original draft preparation, writing – review and editing; DAU – data collection, analysis, visualization, writing – original draft preparation; JS – data collection, writing – original draft preparation, supervision; MC – conceptualization, methodology, materials.

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