INCREASING SHELF LIFE OF FISH THROUGH HIGH HYDROSTATIC PRESSURE TREATMENT

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Abstract

Fish under high hydrostatic pressure treatment goes through numerous changes. Our experiments served to determine optimal pressure and time parameters which, when applied, result in very small changes in product color, physical and chemical characteristics.

Carp and zander samples were treated at 150, 250, 400, and 600 MPa in the Resato FPU-100-2010 system of Corvinus University’s Department of Refrigeration and Animal Products. Treatment duration were 2 and 5 minutes. To measure color, a MINOLTA CR-400 tristimulus colorimeter was used. For the microbiological analysis, the viable cell count was derived with dilute plate-pouring on Nutrient Agar. We kept vacuum packed samples at 2 - 3 °C for 10 days and tracked the changes.

HHP-treated common carp showed a* values tending toward red after 5 days holding time, while its b* values increased constantly toward yellow. Zander, during 5 days of holding, had reduced a* value in the direction of green, while the b* value moved out of the negative range to positive, that is, toward yellow. Color data for common carp fluctuated throughout the 10-day holding time, whereas color changes in zander equaled those of the 5 day holding time experiment. The HHP treatment resulted in reduced total viable cell count of approximately two orders of magnitude, which is in agreement with the literature. In any case, throughout the holding time, viable cell count remained below the initial count of the control sample.

We have proved with our experiments that high pressure treatment reduces the initial microbe count in comparison to the control. We have made the product safer and lengthened its shelf life by many days. Although fish flesh color became lighter because of the treatment, it did not lose its original appearance, and because the parameters were at optimal levels, the amount of color loss was not significant.

Key words: Fish, HHP, Carp, Bass.

1. Introduction

In Hungary, the annual per capita consumption of fish is 4 kg, which seems very low compared to the European Union annual figure of more than 20 kg per person. Fish is important for its proven positive effect on health. For example, it lowers blood pressure, helps prevent heart attack and thrombosis, and is an antidepressant. The danger of age-related dementia and Alzheimer’s disease is reduced by 30% when fish is consumed once a week. Fish is available for sale all year round. It is, however, one of the quickest foods to go bad, as everyone knows.

Primarily, undesirable microorganisms cause fish to decay, but secondary causes are enzyme activity and auto-oxidation of fatty acids. Therefore, if we want to extend shelf life, it is imperative both to reduce the number of pathogens and microorganisms, and to limit their growth rate.

There are several known and trusted fish preservation treatments (e.g. heat treatment and freezing), but they severely affect taste and color. Our aim is to apply a treatment procedure which achieves better microbiological safety, affords longer preservation time of fish, and does not destroy the food or its sensory characteristics. Such a treatment is high hydrostatic pressure treatment (HHP).
During hydrostatic pressure treatment, food is treated at high pressure, which results in partial or complete inactivation of microorganisms. Only small physical and chemical changes occur in the product, and their extent depends on treatment parameters. The possibilities offered by this technology are apparent in the fact that since 2000, the number of HHP units worldwide has grown exponentially [1].

The technology is applicable to both solid and liquid foodstuffs which have water content and are free of air bubbles. It is an advantage if the food is high in acid content. Foods preserved with HHP are found in the U.S., Japan, and Europe (fruit juices and meat products) [2].

The heart of the HHP system is the high-pressure vessel, which is filled with a pressure-transferring medium, usually water, or any other liquid which is not harmful to health. The product to be treated is usually placed in the vessel in its final packaging, which must sustain the high pressure and subsequent change in volume of the product. After the sample is placed in the vessel, pressure is transmitted in a uniform manner by means of the pressure pump. Pressure is adjustable by means of the control panel. Pressure capacity varies from unit to unit, but generally HHP systems are capable of 100 to 800 MPa. Duration of treatment can also be set, of course, along with monitoring of internal temperature.

A number of experiments were done on fish to discover the possibilities of HHP treatment. Total viable cell count of treated fish was studied, along with investigation of how HHP-treated fish were affected by common microbe groups. Among these are the primarily Gram-negative bacteria which are found in the gills and on the surface of freshly caught fish [3].

It is known from the results of Briones and colleagues [4], that initial microbe count went from 3.16 log to 2.2 log in the salmon treated with high hydrostatic pressure during their experiments. Although the salmon did not achieve longer shelf-life during the experiments, the scientists did achieve better microbiological stability. There are, however, successful experiments in which HHP-treated smoked salmon lasted two weeks longer than the control samples [5].

Pressure treatment of red mullet at 220 MPa for 5 minutes at 25 °C lengthened shelf life by 12 to 14 days, in both microbiological and sensory examinations. On the other hand, samples treated at 330 MPa for 5 minutes at 3 °C increased in preservation time to 15 days [5].

The literature makes it clear that HHP does more than reduce microbe counts. This treatment significantly delays microbial growth as well (p < 0.05), which has been proven, for example with fresh herring and haddock [5].

Beyond microbiological safety, important studies have been done on characteristics that influence organoleptic properties, such as examinations of color, substance, and endurance. Use of HHP may cause undesirable changes in the product, and these must be monitored very carefully. Denaturation, aggregation, and development of gel may occur if the HHP system parameters are not set very precisely, not to mention the increase of fluid seepage [6].

Due to the range of different characteristics in fish, it is advisable to calibrate respective parameters type by type, following results of experiments on each particular fish sort.

Mioglobin is what gives fish flesh its color. In the cells, mioglobin helps to bind and store oxygen, which is transported by hemoglobin [7]. During pressure treatment, products change color. For example, with pressure-treated brill, (100 MPa and 200 MPa, 15 and 30 minutes) it was noted that the product gradually lightened in color with increased pressure, and at high pressure settings it took on the appearance of having been cooked [8]. In the interest of maintaining original characteristics, we must search for the values where the fish flesh does not suffer noticeable changes. On the other hand, we must be aware that type of fish, age, and surroundings determine fish quality, therefore, some parameters are beyond our control.

2. Materials and Methods

2.1 Experiment preparation

Our experiments were done in two phases in order to adjust the parameters to optimal settings, with the necessary attention to precision. The fish types involved were common: carp, African sharpooth catfish, bighead carp, and zander. The fish were packaged in polyethylene-polyamide bags and vacuum-packed. They were bought fresh on the day of the experiment. The samples were treated at: 150, 250, 400, and 600 MPa in the Resato FPU-100-2010 system of Corvinus University’s Department of Refrigeration and Animal Products. Duration of treatment was 2 and 5 minutes. We subjected the samples to sensory analysis, and also examined the effects of treatment on seepage and loss of cooking value (this methodology is described in next section).

On the basis of the preparative experiment, we determined that the ideal treatment was 250 MPa for 5 minutes. The 400 and 600 MPa treatments adversely affected color (the product became pale), and both seepage and loss of cooking value increased. In sensory analysis, common carp and zander provided positive results.

2.2 Analysis

Following the preparative experiment, we carried on with common carp and zander for the primary experiment (treatment of bighead carp and African...
sharptooth catfish yielded such negative results in sensory characteristics that we thought they were not worth handling further). The common carp and zander were treated at 250 MPa for 5 minutes.

A shelf-life experiment was done on the treated samples. To replicate the refrigerated case in a shop, samples were kept unpackaged at 2 - 3 °C for 5 days and constantly monitored using the previously obtained parameters. Simultaneously, a second experiment was run, in which we duplicated vacuum-packed product. We kept vacuum-packed samples at 2 - 3 °C for 10 days and tracked the changes.

Following the treatment, we did physical and chemical examinations daily for the 5-day storage experiment and every other day for the 10-day storage experiment. The following parameters were examined: pH, color, seepage, loss of cooking value, sensory characteristics, and aerobic viable cell count. The pH was determined with a Testo 206 digital pH meter, while the fluid was measured by volume. We measured loss of cooking value with vegetable oil such that during frying the internal temperature exceeded 72 °C.

To measure color, a MINOLTA CR-400 tristimulus colorimeter was used. We monitored color changes in the samples with the three types of data from the device: L*, a* and b*. L* is no color (black point L* = 0, white point: L* = 100), a* is characteristic of red-green color, and b* is the blue-yellow color (sign: +a* red, -a* green, +b* yellow, -b* blue).

For the microbiological analysis, the viable cell count was derived with dilute plate-pouring on nutrient agar.

3. Results and Discussion

Based on the results of the preparative experiment, we determined the ideal treatment for common carp and zander to be 5 minutes at 250 MPa. In the case of bighead carp and African sharptooth catfish, even the lightest treatment which could significantly affect viable cell count (5 minutes at 250 MPa) caused serious sensory damage.

At HHP of 5 minutes at 250 MPa, the color change in our samples for L* (dark to light function) ranged between 15% and 40%. For both shelf-life experiments, in the beginning the value rose suddenly, then leveled off, and finally decreased slightly. This is shown in the Figures below (Figures 1 - 4).

HHP- treated common carp showed a* values tending toward red after 5 days holding time, while its b* values increased constantly toward yellow. Zander, during 5 days of holding, had reduced a* value in the direction of green, while the b* value moved out of the negative range to positive, that is, toward yellow.
Color data for common carp fluctuated throughout the 10-day holding time, whereas color changes in zander equaled those of the 5-day holding time experiment.

Loss of fluid increased day by day under HHP treatment and 5 days of holding time for both common carp and zander. This was of course brought about by the conditions in which the fish was kept. Samples which were packaged and held 10 days had less fluid loss than samples held only 5-days without packaging, in spite of double the holding time.

The loss of cooking value became gradually worse during the holding time. Loss of cooking value in zander was twice as bad as that of the common carp, and this can be explained by the higher fat content of the common carp, which prevented the flesh from drying out.

One effect of HHP treatment which applies to every sample is that the pH values increased at the beginning, then gradually fell during storage (i.e. the shelf-life tests).

The HHP treatment resulted in reduced total spore count of approximately two orders of magnitude, which is in agreement with the literature. In any event, throughout the holding time, total spore count remained below the initial count of the control sample. After treatment, the total spore count continued to decrease, presumably due to sublethal damage to the microbes. Figures 5 - 8 illustrate the microbiological changes.

4. Conclusions

- We have proved with our experiments that high pressure treatment reduces the initial microbe count in comparison to the control (5 minutes at 250 MPa yields two orders of magnitude reduction). We have made the product safer and lengthened its shelf life by many days.

- Further, we can say that vacuum packaging reduces loss of fluid, which is an advantage from the sales and marketing standpoint.

- Although fish flesh color became lighter because of the treatment, it did not lose its original appearance, and because the parameters were at optimal levels, the amount of color loss was not significant.

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5. References


