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Original article

The effect of initial freshness on the quality change of tuna meat during frozen storage

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Introduction

Tuna is one of the most valuable fish for the production of sashimi and sushi in Japan. Fish frozen soon after death, especially before the onset of rigor mortis, has high commercial value as a food product in the Japanese market because of its color and texture. In the fish market in Japan, the price of frozen tuna meat is determined based on empirical indicators such as muscle contraction after rapid thawing, which shows the progression of rigor mortis before freezing [1]. One of the most important quality factors for tuna meat is the redness of the color, which deteriorates because of the formation of metmyoglobin (metMb) caused by autoxidation during frozen storage [2]. Additionally, the texture of the meat deteriorates because of the denaturation of myofibrillar protein (Mf) during frozen storage [3]. Therefore, frozen tuna is distributed at temperatures of -50°C or lower in Japan in order to maintain quality for longer periods [1].

After death, postmortem changes in tuna meat cause a decrease in the pH to below 6 and substantial decreases in adenosine 5′-triphosphate (ATP) levels [4]. MetMb formation and frozen denaturation of Mf are suppressed by high pH [5,6]. Moreover, ATP has recently been shown to suppress the formation of metMb [7] and frozen denaturation of Mf [8]. ATP levels, or the pH of frozen tuna meat, can differ considerably depending on whether the fish is alive or dead when the catch is landed [1,7]. Therefore, it has been suggested that the initial freshness of tuna meat affects quality changes during frozen storage; however, previous results have not been conclusive.

Accordingly, in this study, we aimed to elucidate the relationships between the initial freshness of frozen tuna meat, the quality during frozen storage, and frozen storage temperature.

Materials and methods

Sample preparation

Ten bigeye tuna (*Thunnus obesus*) were sacrificed instantly, gutted, and frozen quickly on a board; thereafter, the samples were stored in a -50°C freezer for 1 year on the ship. After landing, the frozen meat was cut into 2-cm slices without thawing. The sliced meat samples were deaerated, packed individually into plastic bags, and stored in a freezer at the National Fisheries University for 1 week until experimentation.

The samples were stored at -20, -35, -40, -45, or -60°C (Chest freezer OF-140, Kanou Reiki Co., Ltd) for a maximum of 14 months. After storage, dark meat was cut off the frozen meat using a saw; only dorsal meat was used. The meat was thawed at 3°C for 24 h. The method of experimental treatments is shown in Fig. 1.

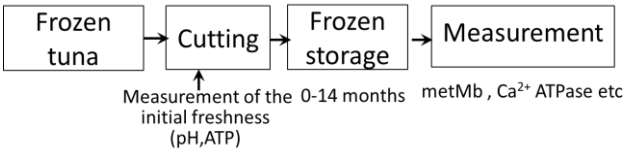

Fig.1. Schematic of experimental treatments for measurement.

pH measurement of the frozen meat

The pH was determined using the method described by Bito [9]. Twenty-five ml of ice-cooled 20 mM sodium iodoacetate was added to 5 g of the samples, immediately homogenized with a homogenizer, and the pH was measured using the glass electrode method.

ATP content measurement of the frozen meat

ATP content was determined using the method described by Ehira et al. [10]. Fifteen ml of ice-cooled 10% $HClO_4$ was added to 5 g of frozen meat, immediately homogenized, and centrifuged at 2,000 × *g* for 3 min at 4°C; the supernatant was adjusted to pH 6.4 with KOH, filtered to a volume of 50 ml, and quantitatively analyzed by high-performance liquid chromatography (HPLC). HPLC analyses were performed using the method described by Maeda [11].

MetMb ratio measurement of the frozen tuna meat

MetMb ratios were primarily determined using the method described by Bito [12]. Five g of chopped frozen meat was ground with 25 ml of cold deionized water on ice and centrifuged at 10,000 × *g* for 10 min. The supernatant was filtered through a 0.2-μm pore filter, and the ratio of the absorbance at 503 nm to the absorbance at 540 nm of the filtrate was used to calculate the metMb conversion ratio.

Ca^{2+} ATPase activity measurement of Mf

The Ca^{2+} ATPase activity of Mf was determined using the method described by Katoh et al. [13]. Myofibrils were prepared by adding buffer solution (pH 7.5, 0.16 M KCl, 40 mM Tris-maleate) to the tuna meat , and then suspending the myofibrils in the buffer. The Mf suspension was added to a reaction mixture containing 0.5 M KCl, 5 mM $CaCl_2$, 25 mM Tris-maleate buffer (pH 7.0), and 1 mM ATP at 25°C. Specific activity was calculated by colorimetric determination of the concentration of inorganic phosphoric acid produced, and was expressed as relative activity.

Results and discussion

Initial pH, ATP contents of frozen tuna meat

Figure 1 presents the initial pH and ATP content of the frozen meat samples. The initial pH of frozen meat was between 6.0 and 7.0, and the ATP content of frozen meat samples was 0–14 μmol/g. Frozen meat with high pH (6.8–7.0) and high ATP content (6–14 μmol/g) was considered high-freshness meat, and meat with low pH (6.1–6.2) and low ATP content (0.3–4 μmol/g) was considered low-freshness meat.

The increase in the ratio of metMb in the high-freshness meat was less than that in the low-freshness meat at temperatures between -40 and -20°C. Decreases in Ca^{2+} ATPase activity were observed at -20°C regardless of freshness, however at -40°C, the activity decline was observed only in low-freshness meat; no changes were observed lower than -45°C, regardless of freshness.

We propose that the initial freshness of tuna meat affects quality changes during frozen storage, and that these changes can be suppressed at temperatures lower than -45°C.

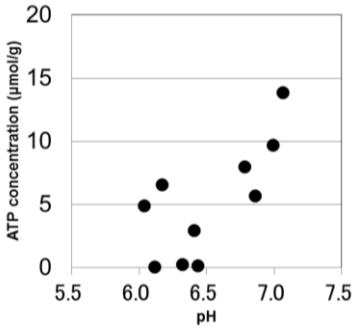

Fig. 2. pH and ATP contents in frozen tuna meat.

Conclusions

We determined that the initial freshness before freezing, frozen storage temperature, and quality changes during frozen storage are closely related. Our findings will be useful for the fish-processing and food distribution industry, as well as for the sustainable use of fish.

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