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Effect of Different Packaging Materials on the Quality of Tuna and Use of Corrugated Cardboard as Suitable Packaging Material for Fisheries Logistics

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Abstract. Foamed styrol is widely used in fisheries logistics. Recently, high-functioning corrugated cardboard has been developed, and it is expected to be widely used in seafood logistics in the future. In this study, we compared the time-dependent changes in fish quality between packaging using foamed styrol and that using corrugated cardboard. According to our results, no differences in the time-dependent change in bacterial count, K-value, pH, color, and odor of tuna flesh were observed between packaging using foamed syrol and that using corrugated cardboard. The CO_2 output during manufacture and recycle of corrugated cardboard is higher than that of foamed styrol, but the transportation efficiency of corrugated cardboard logistics is high, and the manufacturing cost of corrugated cardboard is low. Therefore, considering all parameters, it can be concluded that corrugated cardboard is more desirable for use in fisheries logistics.

Keywords: Packaging material, corrugated cardboard, foamed styrol, tuna, fisheries logistics, quality.

1. Introduction

Currently, foamed styrol is widely used in seafood logistics [1]. As foamed styrol has high strength and adiabaticity, foamed styrol is suitable for the preservation of seafood, which is perishable and can be affected by temperature easily. Moreover, as foamed styrol is water-resistant, it can be efficiently used in fisheries. However, as the manufacturing and transportation cost of foamed styrol is high, the end value of commodities is affected when foamed styrol is used [2]. Another drawback of foamed styrol is that it requires large amounts of space.

In contrast, corrugated cardboard is a packaging material that requires lesser space, and its manufacturing and transportation cost is low. Corrugated cardboard is made using one thick paper, and it has high strength; it does not break, and only bends when fixed pressure is applied. In addition, although the adiabaticity of corrugated cardboard is not as high as that of foamed styrol, and it is not originally water-resistant, corrugated cardboard with high cold insulation and water-repellant properties has recently been developed and used [3]. Therefore, corrugated cardboard is expected to be widely used as packaging material along with foamed styrol in fisheries logistics in the future. Because the quality of seafood deteriorates rapidly, maintaining the quality is important. Therefore, it is important to investigate the effect of different packaging methods on the quality of seafood.

Generally, although determining the bacterial count is of critical importance when evaluating food quality, the freshness of seafood is also an important parameter to be considered in evaluation of seafood quality. The freshness of seafood is evaluated based on the K-value, which represents the amount of ATP-related compounds. In addition, physicochemical tests and evaluation of sensory parameters such as color, pH, and odor are also important in quality evaluation. All these parameters are known to affect one

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another; bacteria have been reported to affect the degradation of ATP-related compounds [4]-[7], and K-value is related to pH [8]. Therefore, it is imperative that several parameters be investigated comprehensively when evaluating seafood quality. In this study, we focused on young tuna (*Thunnus orientalis*), which has not been extensively studied with respect to quality; we investigated the time-dependent changes in bacterial count, freshness (K-value), color, pH, and odor of the tuna fish, and compared the differences observed in these parameters when two different packing materials, corrugated cardboard and foamed styrol, were used.

2. Material and Methods

2.1. Material

Two young tuna (each ~50 cm in length, natural fish) were caught wild in Nagasaki, Japan. As tuna are often transported by freezing, they were filleted and stored at -20 ℃ for 24 h. Next, one fish was packed in corrugated cardboard and the other fish was packed in foamed styrol, and both fish were transported to our laboratory under cold conditions. Fillets were then thawed at room temperature and preserved at 4 ℃ for further analysis.

2.2. Methods

2.2.1. Bacterial count and marine bacterial count measurement

Young tuna dorsal flesh (10 g) and 90 mL of sterilized water were blended in a sterilized bag (PYXON-30, made by ELMEX Ltd.) using a stomacher (EXNIZER-400, ORGANO Co., Ltd.) (30 sec, 260 rpm). After blending, the supernatant was diluted 10 times using 0.9% NaCl in sterile water. The diluted supernatant (100 µL) was then smeared on a standard plate count agar and stored at 35 ℃ for 48 h to obtain a bacterial count. To obtain a count of marine bacteria, the supernatant was smeared onto a standard plate count agar with 1% NaCl and stored at 20 ℃ for 168 h. The bacterial count was measured on both plates every other day for 8 days, starting from day 0.

2.3. Measurement of ATP-related Compounds and K-values

ATP-related compounds were extracted from 2 g of dorsal flesh in 5 mL of 10% perchloric acid by shaking [9]. Briefly, flesh were removed by centrifugation (11,509 × *g*, 10 min, 5 ℃), and the supernatant was transferred to a 50-mL centrifuge tube and 10 % perchloric acid was added to obtain a volume of 25 mL. The mixture was neutralized using KOH and the precipitate was removed by centrifugation (13,697 × *g*, 5 min, 5 ℃). The supernatant was then transferred to a 15 mL centrifuge tube and diluted using sterilized water to obtain a volume of 10 mL. This was filtered (Millex-LG 0.20 µm) and ATP-related compounds were measured by HPLC (high-performance liquid chromatography) (Hitachi L2130, column: Shodex GS-320 HQ, moving phase: 200 mM $NaH_2PO_4 \cdot 2H_2O$, flow rate: 0.6 mL/min, temperature: 30 ℃, detector: Hitachi L7420, wavelength: 260 nm). The amount of ATP-related compounds and K-values were measured every day for 7 days. The K-value was calculated as follows:

K-value (%) = HxR + Hx/ATP + ADP + AMP + IMP + HxR + Hx × 100, where

ATP = adenosine triphosphate, ADP = adenosine diphosphate, AMP = adenosine monophosphate, IMP = inosinic acid, HxR = inosine, Hx = hypoxanthine.

2.4. Measurement of Color, pH, and Odor

L*a*b* values of the dorsal flesh were measured using a colorimeter (CR-13; KONICA MINOLTA, Inc.). pH values were measured using a pH meter (D-74; HORIBA, Ltd.) in the dorsal flesh of young tuna. Odor in the dorsal flesh was determined by sensory evaluation. Color, pH, and odor were monitored for 7 days from day 0 every day.

2.4.1. Comparative evaluation of life cycle assessment (LCA) and its cost in foamed styrol and corrugated cardboard logistics

We investigated the effects of environmental loads on the manufacture, transport, and recycling of foamed styrol and corrugated cardboard. When these foamed styrol and corrugated cardboard were used as food storage containers, we evaluated the cost by considering the price of each material and the transport efficiency, and decreasing the price of tuna with a decrease in its quality.

2.5. Statistical Analysis

Data were subjected to one-way ANOVA using the least significant difference method and Student's *t*-test. $p < 0.05$ was considered statistically significant.

3. Results

3.1. Time-dependent Changes in the Counts of Bacteria and Marine Bacteria

The counts of bacteria and marine bacteria in young tuna are shown in Fig. 1(A) and Fig. 1(B), respectively. The bacterial count was $<10^2$ CFU/g, and it was negligible in both types of packaging, i.e., corrugated cardboard and foamed styrol, for 8 days. The count of marine bacteria was 10^2–10^3 CFU/g in foamed styrol and 10^1–10^2 CFU/g in corrugated cardboard on day 0. However, it was $<10^2$ CFU/g in foamed styrol, and no marine bacteria were detected in corrugated cardboard after 2 days. The bacterial counts were higher in foamed styrol logistics than in corrugated cardboard logistics at day 0. However, after 2 days, no difference was observed in the count of bacteria between corrugated cardboard and foamed styrol logistics. The amount of marine bacteria in foamed styrol logistics was higher than that in corrugated card logistics for 8 days.

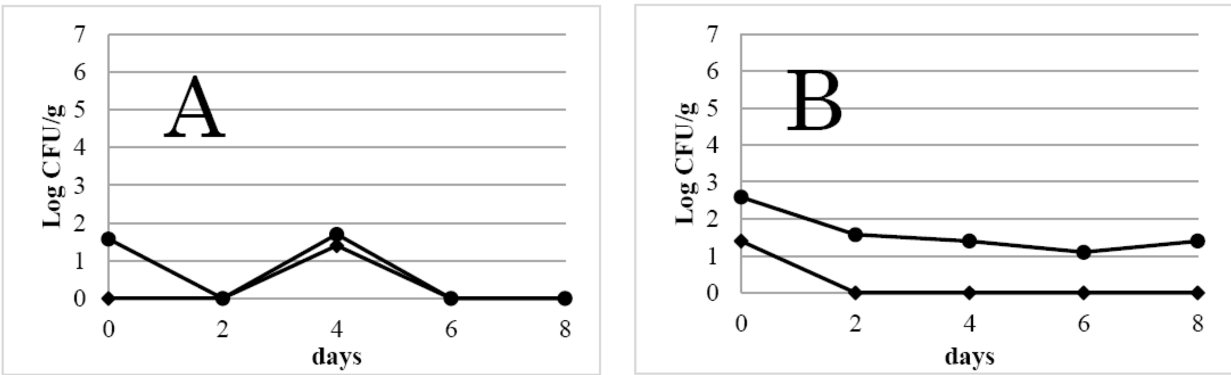

Fig. 1. Bacterial count in young tuna flesh

A: Time-dependent change in the bacterial count, B: Time-dependent change in the count of marine bacteria.

●: packaged using foamed styrol, ◆: packaged using corrugated cardboard

3.2. Time-dependent Changes in ATP-related Compounds and K-value

Time-dependent changes in ATP-related compounds in young tuna in corrugated cardboard and foamed styrol logistics are shown in Fig. 2(A) and Fig. 2(B), respectively. ATP, ADP, and AMP were hardly detected in both corrugated cardboard and foamed styrol logistics at day 0. In corrugated cardboard, the amount of IMP was 16 µmol/g at day 0 and increased to 17 µmol/g on day 2, but decreased to 11 µmol/g on day 7 ($p < 0.05$). In foamed styrol logistics, the amount of IMP was 14 µmol/g at day 0 and increased to 17 µmol/g on day 2, but decreased to 10 µmol/g on day 7 ($p < 0.05$). In corrugated cardboard logistics, the amount of HxR was 1.2 µmol/g at day 0 and increased to 3.2 µmol/g on day 7 ($p < 0.05$). In foamed styrol logistics, the amount of HxR was 2.0 µmol/g at day 0 and increased to 4.7 µmol/g on day 7 ($p < 0.05$). The difference in corrugated cardboard and foamed styrol logistics with regard to the amount of HxR was confirmed for each day ($p < 0.05$), and HxR accumulated significantly faster in foamed styrol logistics than in corrugated cardboard logistics ($p < 0.05$). In corrugated cardboard logistics, the Hx amount was 0.15 µmol/g at day 0 and increased to 1.8 µmol/g on day 7 ($p < 0.05$). In foamed styrol logistics, the Hx amount was 0.18 µmol/g and increased to 1.4 µmol/g on day 7 ($p < 0.05$). No difference in Hx amount was observed between corrugated cardboard and foamed styrol logistics at day 0 ($p > 0.05$), but a significant difference was observed at day 7 ($p < 0.05$). Hx accumulated significantly faster in corrugated cardboard logistics than in foamed styrol logistics ($p < 0.05$).

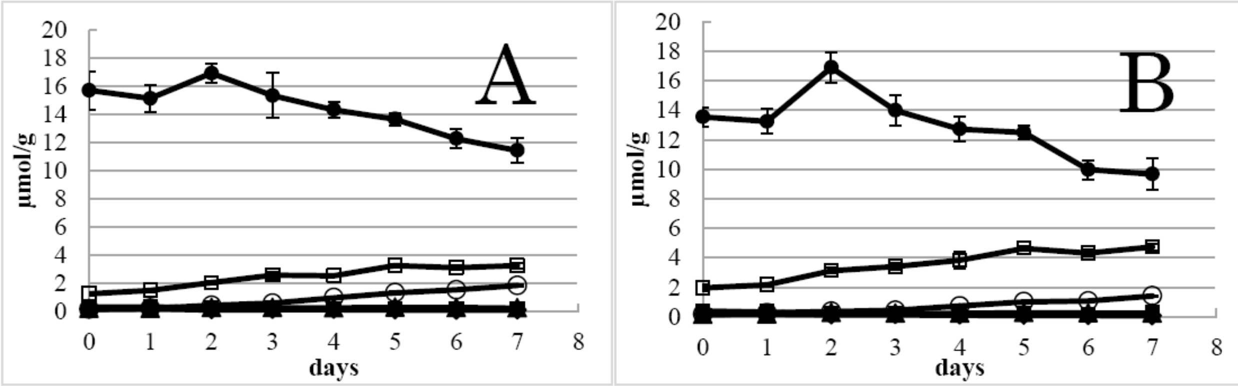

Fig. 2. Time-dependent change in the amount of ATP-related compounds in young tuna flesh.
Error bars denote standard deviations of the mean (n = 9).
A: packaged using corrugated cardboard, B: packaged using foamed styrol
◆ ATP, ■ ADP, ▲ AMP, ● IMP, □ HxR, ○ Hx

Time-dependent changes in the K-value in young tuna in corrugated cardboard and foamed styrol logistics are shown in Fig. 3. In foamed styrol logistics, the K-value was 13% at day 0 and increased to 37% on day 7 ($p < 0.05$). In corrugated cardboard logistics, the K-value was 7.9% at day 0 and increased to 30% on day 7 ($p < 0.05$). A difference in the K-value was observed between corrugated cardboard and foamed styrol logistics on all days from day 0 to day 7 ($p < 0.05$); however, no difference in the rate of increase in the K-value was observed between corrugated cardboard and foamed styrol logistics ($p > 0.05$).

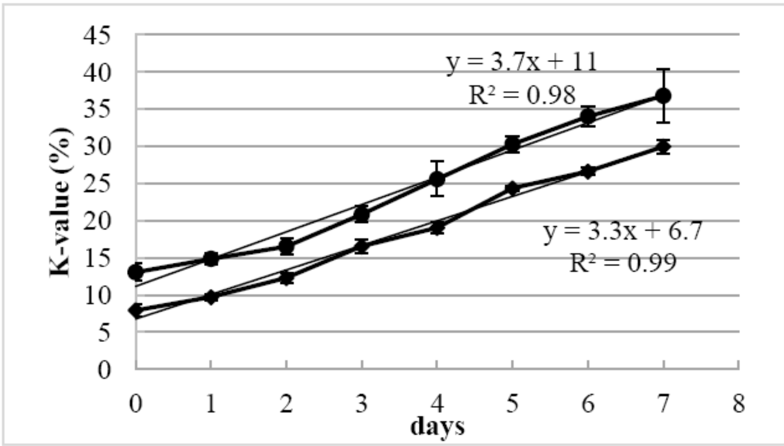

Fig. 3. Time-dependent change in K-values in young tuna flesh
Error bars denote standard deviations of the mean (n = 9).
●: packaged using foamed styrol
◆: packaged using corrugated cardbord

3.3. Color, pH, and Odor

Time-dependent changes in the L*a*b* value in young tuna in corrugated cardboard and foamed styrol logistics are shown in Fig. 4(A) and Fig. 4(B), respectively. In corrugated cardboard logistics, the L* value was 30 at day 0 and decreased to 27 on day 2, and then increased after day 4 ($p < 0.05$). In foamed styrol logistics, no change was observed in L* value from day 0 to day 5; the L* value increased after day 5, and was 36 on day 7 ($p < 0.05$). In addition, no difference in L* value was observed between corrugated cardboard and foamed styrol logistics from day 0 to day 5, but the L* value was higher in foamed styrol than in corrugated card logistics after day 5. No significant difference in L* value was observed between corrugated cardboard and foamed styrol logistics, except for at day 6 ($p > 0.05$). The a* value in corrugated card and foamed styrol logistics decreased from 12 to 2.8 and from 8.3 to 1.6 respectively from day 0 to day 7 ($p < 0.05$). The a* value was higher in corrugated cardboard than in foamed styrol logistics during the 7 days, and it decreased from day 0 to day 7 in both corrugated cardboard and foamed styrol logistics. In corrugated cardboard logistics, the b* value was 9.2 at day 0 and decreased to 6.6 on day 1, and then increased to 12 on day 7 ($p < 0.05$). In foamed styrol logistics, the b* value was 7.6 at day 0, decreased to 5.1 on day 1, and then increased to 9.8 on day 7 ($p < 0.05$). The b* value was higher in corrugated cardboard than in foamed styrol logistics during the 7 days, and the a* value and b* value in both corrugated cardboard and foamed styrol logistics showed the same behavior. The difference in both the a* and b* values for both corrugated card and foamed styrol logistics was confirmed on each day ($p < 0.05$).

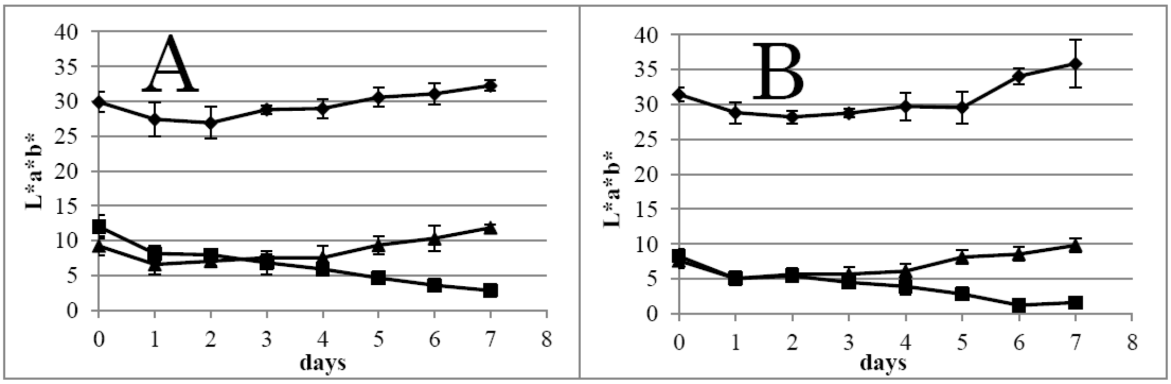

Fig. 4. Time-dependent change in the color of young tuna flesh. Error bars denote standard deviations of the mean (n = 3). A: packaged using corrugated cardboard, B: packaged using foamed styrol.

◆: L* value, ■: a* value, ▲: b* value

Time-dependent changes in pH in young tuna in corrugated cardboard and foamed styrol logistics are shown in Fig. 5. The pH in corrugated cardboard logistics was 5.9–6.0 and that in foamed styrol logistics was 6.1–6.2. No change in pH was observed in either logistic modality during the 7 days ($p > 0.05$), but the pH was significantly higher for foamed styrol than for corrugated cardboard during the 7 days ($p < 0.05$). In addition, no putrid odor was detected during the 7 days.

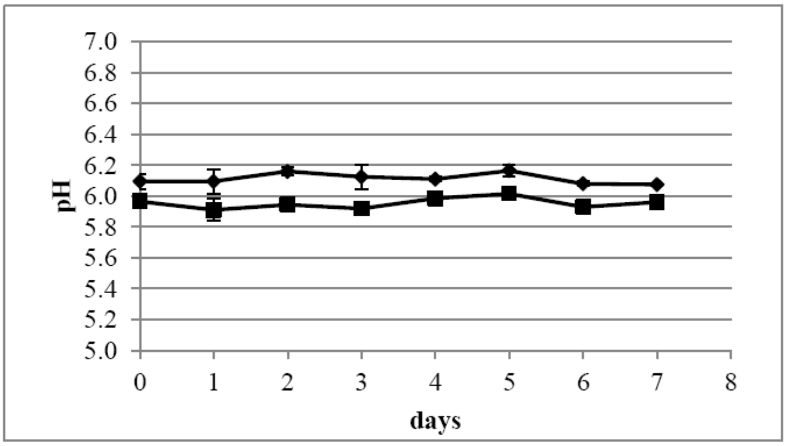

Fig. 5. Time-dependent change in the pH values of young tuna flesh. Error bars denote standard deviations of the mean (n = 3).

◆: packaged using foamed styrol

■: packaged using corrugated cardboard

4. Discussion

4.1. Time-dependent Changes in the Amount of Bacteria and Marine Bacteria

According to Fig. 1(A) and 1(B), the bacterial and marine bacterial count in young tuna was <10^3 CFU/g for 8 days, and this count was lower than that observed for raw tuna in a previous study [10]. Although the bacterial and marine bacterial count is reduced by freezing, no difference in bacterial and marine bacterial count was previously observed between frozen and raw flesh of Atlantic cod (*Gadus morhua*) [11]. Bacteria generally do not exist in fish muscle, and bacteria that are detected in fish muscle are from the external surface of the body or organs after death. The bacterial count in Atlantic cod fillet processed before rigor was previously found to be less than that in fillets processed after rigor [12]; therefore, to prevent invasion of fish muscle by bacteria, fish organs must be removed, and the fish body surface must be washed as soon after death as possible. In this study, as young tuna was processed to fillet immediately after death, the bacterial count in the frozen young tuna was very low.

4.2. Time-dependent Changes in ATP Degradation and K-value

The K-value in young tuna in corrugated cardboard and foamed styrol logistics was 8–13 % at day 0, 16–20 % on day 3, and 30–37 % on day 7 (Fig. 3). This result is consistent with the changes in K-value observed in Japanese jack mackerel (*Trachurus japonicas*) [13], Japanese sardine (*Sardinops melanostictus*) [14], spotted club mackerel (*Scomber australasicus*) [15], bastard halibut (*Paralichthys olivaceus*) [16], and greater amberjack (*Seriola dumerili*) [17]. In addition, the K-value in adult northern bluefin tuna (*Thunnus orientalis*) was approximately 6% at day 0, 20% on day 3, and 27 % on day 7 at 5 ℃, [18], and it was approximately 8% at day 0, 15% on day 3, and 25 % on day 7 at 3 ℃ [19]. No significant difference was found between young tuna and northern bluefin tuna with regard to K-value.

In contrast, it was previously reported that the K-value in complete aquacultured northern bluefin tuna at 4 ℃ was approximately 10% on day 2 [20]. This value was lower than the K-value found in the present study. However, it is considered that the start day was different from that in the present study because the complete aquacultured northern bluefin tuna was preserved immediately after it was killed.

IMP accumulated more at day 0, and constituted approximately 70% of ATP-related compounds over 7 days (Fig. 2(A), (B)). The amount of IMP was previously found to be the highest among all ATP-related compounds in both northern bluefin tuna and Atlantic Bluefin tuna immediately after fishing, and remained at ~70% of the IMP at day 7 [15], [18], [19]. Our results are consistent with these results. Therefore, the change in K-value in young tuna follows the same increase observed generally in fish, and it can be suggested that no difference exists between adult fish and young fish with respect to the increase in K-value and accumulation of IMP.

The K-value was higher for foamed styrol than for corrugated cardboard logistics during the 7 days (Fig. 3). In addition, the amount of IMP was higher in corrugated cardboard than in foamed styrol logistics (Fig. 2(A), (B)). However, no difference in the rate of increase in K-value was observed between foamed styrol and corrugated cardboard logistics. In contrast, the K-value in foamed styrol logistics was different from that in corrugated cardboard logistics, largely at day 0. It was previously reported that the time-dependent change in the K-value and the content of ATP-related compounds depends on the habitat (aquacultured or wild) [21], temperature used in aquaculture [22], [23], and mode of death (agonized death or mercy killing) [24]-[26]. In addition, the K-value in Pacific bluefin tuna has been reported to vary by approximately 13% at maximum over different years and by approximately 10% at maximum in the same year [18]. Therefore, it can be stated that the K-value in fish is strongly influenced by the external environment and inter-individual differences. The 7% difference in K-values between corrugated cardboard logistics and foamed styrol logistics at day 6 and differences in the rate of increase of Hx may thus be attributed to individual differences.

4.3. Color, pH, and Odor

The L* value increased, a* value decreased, and b* value increased with time in young tuna in foamed styrol and corrugated cardboard logistics after decreasing initially (Fig. 4(A), (B)). This result is consistent with the trend of the L*a*b* value previously reported in Atlantic bluefin tuna (*Thunnus thynnus*) [27]. The L* value represents index of whiteness, and it is evaluated as transparency. Okamoto [28] evaluated the range of cloudiness in oval squid using the L* value; therefore, the L* value is correlated with transparency and cloudiness, and the increase in the L* value after day 3 shows that the transparency decreased and cloudiness increased. As no difference in L* value was observed between foamed styrol and corrugated cardboard logistics, we consider that the logistic method does not influence L* value. The a* value represents the index of redness, and the b* value represents the index of yellowness, and these parameters are correlated with the metmyoglobin ratio. It was previously reported that a*/b* = 1 shows a color degradation reference value, and that the color is acceptable when a*/b* < 1 in bluefin tuna and yellowfin tuna (*Thunnus* *albacares*) [29]. The relationship between the a* value and b* value in foamed styrol and corrugated cardboard logistics is shown in Fig. 6(A) and (B). The a*/b* value in foamed styrol logistics was below 1 from days 0 to 2, but was above 1 after day 3. The a*/b* value in corrugated cardboard logistics was below 1 from days 0 to 3, but was above 1 after day 4. Therefore, the color of young tuna flesh deteriorated after day 3 in foamed styrol and after day 4 in corrugated cardboard logistics. It was previously reported that color deterioration in freeze-thawed tuna flesh is faster than that in raw tuna flesh [29]. In this study, tuna flesh was frozen and thawed in in both foamed styrol and corrugated cardboard logistics. It is possible that the tuna flesh in foamed styrol logistics thawed faster and that the color of tuna flesh in foamed styrol logistics deteriorated faster because the size of tuna flesh in foamed styrol logistics was smaller than that used in corrugated card logistics. However, Kodani et al. [30] previously reported that the rate of decrease in the a* value of three freezing tuna varied approximately twice as much as the variation in each individual tuna. Thus, it was found that inter-individual differences in tuna greatly influenced the a* value.

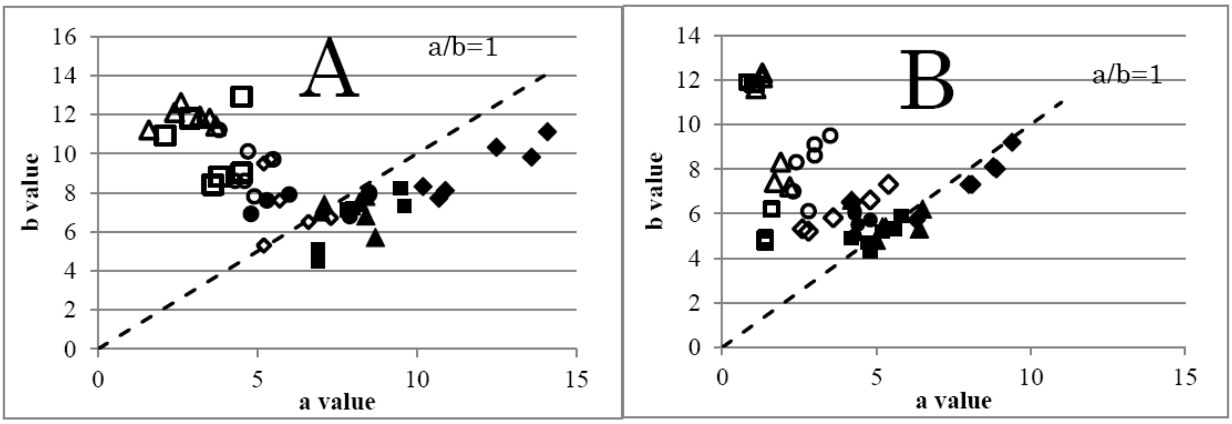

Fig. 6. Relationship between a* and b* values in young tuna flesh
A: packaged using corrugated cardboard, B: packaged using foamed styrol
◆day 0, ■ day 1, ▲ day 2, ● day 3, ◇ day 4, ○ day 5, □ day 6, △ day 7

The pH in foamed styrol logistics and corrugated card logistics was between 5.9 and 6.2 during the 7 days (Fig. 5), and this result is consistent with the pH value previously reported in Pacific bluefin tuna [18]. In addition, the pH value in full-cycle aquacultured Pacific bluefin tuna was reported to decrease with time, and was 5.7–6.0 [20]. This value is similar to the values reported in this study. It was previously reported that the pH value in fish with red flesh is 5.2–5.6 [8]. However, as it was previously reported that the pH in bluefin tuna was 5.4–5.6 [30] and that in bigeye tuna (*Thunnus obesus*) was 6.0–7.0 [31], pH in tuna flesh is considered to depend on the species, and Pacific bluefin tuna has a relatively high pH compared to other species of tuna.

In this study, we did not detect odor in tuna flesh during the 7 days. Tanaka et al. [32] reported that the odor in Pacific bluefin tuna and bigeye tuna became worse after day 3, but the bacterial count increased. Because we did not observe an increase in bacterial count in the present study, we did not detect any odor.

4.4. Comparative Evaluation of Life Cycle Assessment (LCA) and Its Cost in Foamed Styrol and Corrugated Cardboard Logistics

The environmental load in the manufacture of foamed styrol is lower than that of corrugated cardboard with regard to energy consumption, air pollution, water pollution, and global warming [33]-[34]. This is because the manufacture of corrugated cardboard needs a considerable amount of water as compared to that of foamed styrol.

The transport efficiency of corrugated cardboard boxes, which can be easily constructed, is higher than that of foamed styrol boxes. For example, when transporting boxes made of either material, (size: 65 × 40 × 25 cm), the corrugated cardboard boxes are only 2–3 cm high because these can be easily folded. Thus, the transport efficiency of the corrugated cardboard is 8–12 times higher than that of foamed styrol.

With regard to recycling, at present, the recycling rate of foamed styrol is 88.3% [35], whereas that of corrugated card is 99% [36]. Moreover, the recycling rate of corrugated card is higher than that of foamed styrol. With regard to reducing CO_2 output, approximately 50% of recycled foamed styrol can be reproduced as useful materials such as a pen and other goods, whereas 30% is reproduced as a heat source. As foamed styrol is not recycled to foamed styrol again, ~5 kg of CO_2 is reduced by the recycling [37]. In contrast, corrugated cardboard can be recycled to form corrugated cardboard again. Paper recycling does not contribute much to reduction of CO_2 emissions [37].

When determining the transport efficiency of these materials, we found that when identical-sized foamed styrol and corrugated cardboard boxes are used, the foamed styrol box can carry a lower volume than the corrugated cardboard box because the latter's walls are thin (5 mm vs. 30 mm for foamed styrol). Therefore, as the corrugated cardboard shows higher transport efficiency than the foamed styrol box, the environmental load of corrugated cardboard logistics is reduced.

These findings indicate that it is desirable to use foamed styrol boxes based on considerations of the environmental load and corrugated cardboard boxes based on the transport efficiency. However, because foamed styrol will always result in higher CO_2 output, it is desirable to use corrugated cardboard.

In the present study, the foamed styrol box (65 × 40 × 25 cm; 935 yen) was four times more expensive than the corrugated cardboard box (56 × 33 × 34 cm; 219 yen), and the corrugated cardboard had a higher transport efficacy than the foamed styrol box. However, because the foamed styrol box exhibits higher heat reception properties than the corrugated cardboard box, it is desirable to use the foamed styrol box in cases where the quality of the commodity is considerably influenced by the temperature. Moreover, it is desirable to use foamed styrol logistics because the commodity value using corrugated cardboard logistics is one-fourth of that with foamed styrol logistics as a result of the deterioration of quality. The quality of frozen tuna flesh shows relatively little difference between foamed styrol logistics and corrugated card logistics; hence, it is desirable to use corrugated cardboard because it has a relatively high transport efficiency.

5. Conclusion

In this study, we compared the quality of young tuna transported in foamed styrol with that transported in corrugated cardboard. The bacterial and marine bacterial count, ATP-related compound content, K-value, color, pH, and odor were evaluated over time as indicators of the quality of the tuna flesh. The bacterial and marine bacterial counts were less than $<10^2$ CFU/g and $<10^3$ CFU/g respectively, the IMP content was 10-18 μmol/g and was the highest among ATP-related compounds, and the K-value increased over time with a value of 30-37% at day 7. Additionally, the L* value increased, a* value decreased, and b* value increased after decreasing initially. The pH was between 5.9 and 6.2 during the 7 days, and we did not detect odor in the tuna flesh during the 7 days in the foamed styrol logistics and corrugated card logistics. Therefore, only minor differences in these parameters were found between foamed styrol and corrugated cardboard for the preservation period. Our results suggest that the quality of young tuna flesh after transportation does not depend on the packaging method. Although the CO_2 output during the manufacture and recycling of corrugated cardboard was found to be higher than that for foamed styrol, corrugated cardboard has a low manufacturing cost in addition to high efficiency and low cost of transportation. In terms of quality and environment evaluation, our findings thus indicate that it is desirable to use corrugated cardboard for seafood logistics.

6. References

[1] L. Yamamoto, K. Yamauchi, H. Hayashi, T. Okano. A consideration on Utilization Possibility of Returnable Containers in Fishery Products. *The Japanese Institute of Fisheries Infrastructure and Communities Research and Study Proceedings*. 2010, **21:** 59-68. (in Japanese)

[2] M. Tokuda, M. Hirose. Improvement of distribution system for w=Welsh onion. *Bulletin of Oita Industrial Research Institute*. 2009, **2008**: 34-37. (in Japanese)

[3] M. Kumabe. Functional Corrugated Cardboard for Farm and Marine Products. *JPI Journal*. 2008, **46** (12): 1001-1006. (in Japanese)

[4] Y. Yokoyama, M. Sakaguchi, Y. Azuma, F. Kawai, M. Kanamori. Postmortem Changes of ATP and Its Related Compounds in Oyster Tissues in the Presence of Antibiotic Chloramphenicol. *Fish Sci.* 1996, **62** (2): 312-316.

[5] M. Matsumoto, H. Yamanaka. Influences of Antibiotics Chloramphenicol on Post-morten Biochemical Changes in the Muscle of Kuruma Prawn during Storage. *Nippon Suisan Gakkaishi*. 1991, **57** (12): 2291-2297. (in Japanese)

[6] M. Hayashi, K. Nakata. Effect of contaminating bacteria on the inosinic acid content of chicken meat. *J. Home Econ.* 2003, **54** (6): 441-448. (in Japanese)

[7] H. Seki, N. Hamada-Sato. Identification of Bacteria that Contribute to IMP Degradation in Horse Mackerel. *J. Food Process. Technol.* 2014, **5** issue 8.

[8] S. Koseki, S. Kitakami, N. Kato, K. Arai. Rigor mortis of fish and shellfish and evaluation of freshness of their muscles as K value. *J. Sch. Mar. Sci. Technol. Tokai Univ.* 2006, **4** (2): 31-46. (in Japanese)

[9] P. Srirangsan, N. Hamada-Sato, K. Kawai, M. Watanabe, T. Suzuki. Improvement of fish freshness determination method by the application of amorphous freeze-dried enzymes. *J. Agric. Food Chem*. 2010, **58**:12456-12461.

[10] Y. Tsukamasa, Y. The quality change and the color tone maintenance of cultured bluefin tuna meat under refrigeration, the 21st-century COE program of Kinki University. *The Supportive-type Research Base of the Fish Culture Industry of Bluefin Tuna and Others Reports*. 2005: 163-166. (in Japanese)

[11] H. Magnusson, E. Martinsdottir. Storage Quality of Fresh and Frozen-Thawed Fish in Ice. *J. Food Sci*. 1995, **60** (2): 273-278.

[12] E. Martinsdottir, H. Magnusson. Keeping Quality of Sea-Frozen Thawed Cod Fillets on Ice. *J. Food Sci.* 2001, **66** (9): 1402-1408.

[13] T. Takagi. A study on freshness maintenance of marine products (Change of freshness in aquacultured or wild horse mackerel). *The Report of Shizuoka Fisheries Research Institute*. 2001, **2000**: 50-51. (in Japanese)

[14] Y. Kodani, K. Akita, M. Noguchi, T. Kageyama. Research on quality improvement of sardine fillet. *Bulletin of the Food Industrial Research Institute, Tottori Prefecture.* 1993, **32**: 33-43. (in Japanese)

[15] T. Shiraita, Y. Kado, H. Matsubara. Maintenance of freshness of Spotted mackerel (Scomber australasicus). *Report of Aomori Prefectural Industrial Technology Research Center Food Research Institute.* 2012, **3**: 9-11. (in Japanese)

[16] [16] M. Kimura, K. Mikami, and M. Sakamoto. Maintenance of high freshness of raw flounder. *The Report of Hokkaido Fisheries Research Institute.* 2009, 79: 15-17. (in Japanese)

[17] K. Nakanishi, M. Nagatomo, T. Minami, H. Murata, K. Yamauchi, and N. Ishida. Development of the freshness judgment index of the cultured fish. *The Report of Miyazaki Fisheries Research Institute*. 2012, 2010: 106-109. (in Japanese)

[18] G. Kimura, M. Takeuchi, H. Matsubara. Effect of "Kaimin" processing on freshness of Pacific Bluefin tuna(Thunnus orientalis) under storage in ice. *Report of Aomori Prefectural Industrial Technology Research Center Food Research Institute.* 2014, **5/6**: 1-6. (in Japanese)

[19] G. Kimura, R. Suzuki, H. Matsubara. Methods to maintain the freshness of Pacific Bluefin tuna(Thunnus orientalis). *Report of Aomori Prefectural Industrial Technology Research Center Food Research Institute*. 2013, **4**: 18-23. (in Japanese)

[20] Y. Nakamura, M. Ando, M. Seoka, K. Kawasaki, Y. Tsukamasa. Changes in Physical/chemical Composition and Histological Properties of Dorsal and Ventral Ordinary Muscles of Full-cycle Cultured Pacific Bluefin Tuna, Thunnus orientalis, During Chilled Storage. *J. Food Sci.* 2006, **71** (2): E45-E51.

[21] M. Iwamoto, H. Yamanaka. Remarkable differences in rigor mortis between wild and cultured specimens of the red sea bream Pagrus major. *Nippon Suisan Gakkaishi.* 1986, **52** (2): 275-279. (in Japanese)

[22] H. Abe, E. Okuma. Rigor-Mortis Progress of Carp Acclimated to Different Water Temperatures. *Nippon Suisan Gakkaishi*. 1991, **57** (11): 2095-2100.

[23] S. Watabe, G. C. Hwang, H. Ushio, K. Hashimoto. Changes in rigor-mortis progress of carp induced by temperature acclimation. *Agric. Biol. Chem.* 1990, **54** (1): 219-221.

[24] S. Mochizuki, A. Sato. Effects of Various Killing Procedures and Storage Temperatures on Post-mortem Changes

in the Muscle of Horse Mackerel. *Nippon Suisan Gakkaishi*. 1994, **60** (1): 125-130. (in Japanese)

[25] S. Mochizuki, A. Sato. Effects of Various Killing Procedures on Post-mortem Changes in the Muscle of Chub Mackerel and Round Scad. *Nippon Suisan Gakkaishi*. 1996, **62** (3): 453-457. (in Japanese)

[26] T. Mitsuhashi, K. Ayabe, R. Suzuki. Postmortem changes in texture and freshness of fish which were killed instantly or dead after struggling. *Report of the College of International Relations Research Institute of Sciences for Living, Nihon University*. 2007, **29**: 57-66. (in Japanese)

[27] C. Y. Pong, T. K. Chiou, M. L. Ho, S. T. Jiang. Effect of polyethylene package on the metmyoglobin reductase activity and color of tuna muscle during low temperature storage. *Fish Sci*. 2000, **66** (2): 384-389.

[28] A. Okamoto. A trial of the high quality maintenance technology development of squid. *Dev. Fish.* 2010, **105**: http://www.marinelabo.nagasaki.nagasaki.jp/news/suisankaihatsu/no105.pdf, accessed on 2015-07-09. (in Japanese)

[29] Y. Ochiai, C. J. Chow, S. Watabe, K. Hashimoto. Evaluation of tuna meat discoloration by Hunter color difference scale. *Nippon Suisan Gakkaishi*. 1988, **54** (4): 649-653.

[30] Y. Kodani, M. Honda, A. Kato, M. Mathumoto, H. Nakano. The studies on the Techniques of Freezing and Storage of Thunnus thynnus (1st Report), Industrial Technology Institute. Tottori Prefecture. *Reports of the Industrial Research Institute of Tottori Prefecture*. 2009, **11**: 18-24. (in Japanese)

[31] K. Hashimoto, S. Watabe. Changes in Color and Water Holding Capacity of Tuna Meat during Frozen Storage. *Nippon Suisan Gakkaishi.* 1983, **49** (2): 203-206. (in Japanese)

[32] M. Tanaka, H. Nishino, K. Satomi, M. Yokoyama, Y. Ishida. Gas-exchanged packaging of Tuna Fillets. *Nippon Suisan Gakkaishi*. 1996, **62** (5): 800-805. (in Japanese)

[33] LCA evaluation in foamed styrol. http://www.asahara-kk.co.jp/recycle04.htm, accessed on 2015-07-15.

[34] LCA of foamed styrol. http://tohoku.sekisuiplastics.co.jp/environment/lca.html, accessed on 2015-07-15.

[35] Japan Expanded Polystyrene Association, recycling achievements. http://www.jepsa.jp/recycle/results.html, accessed on 2015-07-15.

[36] The Japan Corrugated Case Association. The 2013 achievements of the second free agency plan about the corrugated card. http://www.danrikyo.jp/publics/index/104/. accessed on 2015-07-15.

[37] Ministry of the Environment, Government of Japan. Calculation method of 3R output level. https://www.env.go.jp/press/files/jp/19747.pdf, accessed on 2015-07-15.