K value of cultured southern bluefin tuna (*Thunnus maccoyii*) imported in chilled state, and its difference among parts of fish body

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Cultured tuna is becoming one of important fish sources in Japan, which is used to be imported by airplane without freezing from abroad. It gives a better economical profit and taste, and also promises a constant supply through out a year. However, there are few data available for the freshness of tuna undergoing such kind of transportation. This study was conducted to evaluate the initial freshness indicated as Kvalue of chilled-southern bluefin tuna (*Thunnus maccoyii*), imported by airplane from Australia, considering the difference of K value among parts of this fish body. The total amount of ATP and its related compounds was 11.82, 9.74, 7.83 and 5.88 μ moles/g for dorsal (red), dorsal (white), tail and abdomen muscles, respecively. Tail muscle was showing the highest K value followed by dorsal (white), abdomen and dorsal (red) muscles, respectively. As tail muscle was more active among parts of fish body before fish was being caught, so that degradation of ATP was thought to occur faster in tail. It was confirmed that the quality of the sample fish imported by airplane was fairly good, which has K value ranged between 8.8~14.7%. The tail muscle could be regarded as a suitable part for analyzing K value.

(Received Oct. 18, 2000 ; Accepted Dec. 4, 2000)

The species of tuna consumed in Japan are bluefin tuna, big-eyed tuna, albacore, and yellowfin tuna. Especially bluefin tuna has lang been a favorite food for sashimi and sushi use in Japan. At dawn, six days of one week, an average of 250 t of bluefin tuna are sold at auction in Tokyo alone to be eaten raw[1]. Despite of such importance, there are not so many studies concerning the freshness quality for tuna species comparing to those for other fishes. If there was, the researches have been carried out more than 30 years ago. TAKEDA[2] and TANAKA[3]pointed out that many factors such as, season and fishing method of tuna affect on its K value and discoloration. Up to now, there was nothing but two reports have been conducted by BITO[4] and AGUSTINI[5], which deal with storage temperature dependence of discoloration and K value for tuna meat. The reason why the study on the quality of tuna did not progress was mainly due to the difficulty of getting sample. This also resulted in confusing on price judgment on its trading at market. However, present day such situation is changing as described in the following. Recently, cultured tuna from Australia or Spain etc. become one of important sources of fish demand. The cultured tuna gives a better economical profit than that of fishing tuna because it promises a constant supply through out a year, and even gives a better taste. More or less a half of the production of cultured tuna is said to be preserved in the form of frozen state and the rest is transported to Japan by air in chilled state using ice after killing. The chilled tuna is believed to be fresh and especially high grade since they did not undergo freezing. However, there are no scientific reports regarding to the quality of such kind of imported tuna.

Therefore, we planned to investigate the initial freshness of chilled bluefin tuna imported from Australia by air, using K value index. At first stage of this study, we focused on a following fundamental question. Which part of the body is suitable for measuring the freshness in the case of large fish such as tuna? Generally, dorsal meat is used for quality evaluation of fish, however, is it adequate for this object. It is thought that K value is different among the parts of a fish body, but there is no authentic data available as for tuna on this line. Only one study was conducted on tuna for distribution of lipid in different muscle types[6]. For other species, there are some reports on the changes in ATP-related compound among different parts of fish and shellfish tissues, such as oyster[7], swordfish[8] and carp[9]. In this study we attempted to investigate the initial K value of bluefin tuna that imported in the chilled state considering the difference of K value among parts of fish body.

MATERIALS AND METHODS

1. Fish sample

Fish used for this experiment was southern bluefin tuna (*Thunnus maccoyii,* Castelnus), which was cultured by Australian Tuna Fisheries Pty. Ltd. at Port Lincoln, South Australia. The sample fish has been passed through the sequences as shown in Fig. 1 before arriving at our laboratory. The weight and age of the fish were approximately 13.9kg and 3 years, respectively. The samples were taken from different part of fish body, which were dorsal (just below first dorsal fin, which consist of two different fish portion: red portion, *upper layer* and white portion, *lower layer*), abdomen, between pelvic fin and anal fin and tail, just close to caudal fin (see Fig. 2).

2. Chemical analysis

K value was measured to evaluate the state of fish quality based on modified method of RYDER[10]. One g of muscle tissue of fish was homogenized with 8 mℓ of chilled 10% and 5% perchloric acid. The homogenate was centrifuged at 2,000×g for 10 min at 5℃ and supernatant immediately neutralized to pH 6.8 with 1 N and 10 N KOH. The neutralized mixture was centrifuged again at 2,000×g for another 10 min and

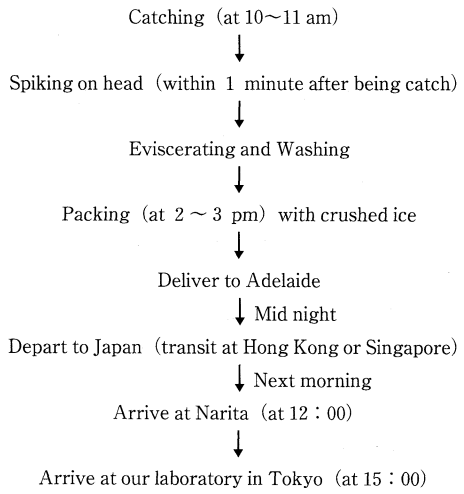

Fig. 1 Schematic flow chart of transportation of cultured bluefin tuna from Australia from catching to arrival

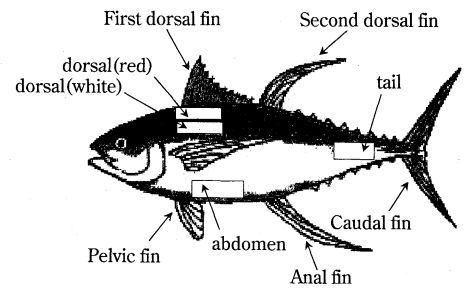

Fig. 2 Part of fish body taken for the samples

the supernatant was diluted to 20mℓ with neutralized perchloric acid and then filtrated prior to storage at −46℃ for subsequent analysis. Separation of ATP related compound was achieved on a reverse-phase column Asahipak GS-320 HQ. The mobile phase of 200 mM sodium dihydrogenphosphate-dehydrate (pH 2.8) was used at a flow rate 1mℓ/min and temperature 30℃. The eluant was monitored at 258 nm for each ATP-related compound. The concentration of each compound was determined based on its peak height, which was obtained from HPLC graph for each ATP and its related compounds. This peak height was then used to calculate the concentration of each compounds using calibration curve constructed before carrying out the analysis on the sample. The analysis of K value was carried out in duplicate.

RESULTS AND DISCUSSION

The results of HPLC analysis for different parts of body are listed on Table 1. The total amounts of ATP and its related *compounds* were 11.82, 9.74, 7.83 and 5.88 μ moles/g for dorsal (red), dorsal (white), tail and abdomen muscles, respectively. The value for dorsal (white) was in fair agreement with values reported for frozen southern bluefin tuna (ranged from 9.1~13.5 μ moles/g)[2] which were caught from the eastern South Indian Ocean, and transported by ship. And also it was near to that of tuna species used for 'sushi' (6.3~13.5 μ moles/g) in general[11]. However, the value of abdomen part was out of the range of reported values. The abdomen part that is used to consume as 'toro', contains higher amount of lipid than muscle fiber. Therefore, low concentration in ATP and its related compounds observed in abdomen are though to be reasonable. The difference in total amount of ATP related compounds among other parts of body would also be due to the difference in composition among the parts. We could not recognize any different in the initial ATP, HxR and Hx contents among different parts of body except for abdomen, however, IMP concentration in tail part was the lowest in those on other parts. This means that degradation of ATP occurred faster in tail compared to that of other body parts and it reflects on the K value.

The ATP related compounds and the K values of different muscles of the southern bluefin tuna sample are shown in Fig. 3. It was found that there was a clear difference of K value taken from different parts of fish body. Tail was showing the highest K value followed by dorsal (white), abdomen and dorsal (red), respectively. The ATP degradation of fish is known to be affected by some factors such as method of killing[12]. Further, there is difference of ATP degradation among fish body parts, depending on activity of its muscle tissue before death. For other fish species, especially high-speed swimming fish, it was thought that the tail part shows the highest K

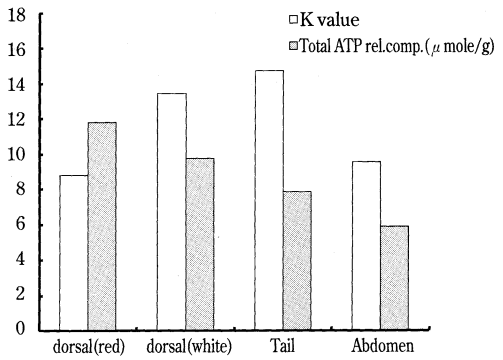

Fig. 3 Concentration of total ATP related compounds and K value of different part of fish body

Table 1 The ATP and its related compounds (in μ moles/g) and K value (%) of chilled bluefin tuna

Part of body	ATP	ADP	AMP	IMP	HxR	Hx	Total ATP related compounds (T)	K value (Kv)	Average T	Average Kv
Dorsal (red) sample 1	0.09	0.46	0.15	10.36	0.84	0.20	12.10	8.60	11.82	8.80
Dorsal (red) sample 2	0.09	0.46	0.14	9.82	0.80	0.24	11.55	9.00		
Dorsal (white) sample 1	0.09	0.29	0.09	8.03	1.07	0.24	9.80	13.35	9.74	13.42
Dorsal (white) sample 2	0.09	0.29	0.09	7.92	1.11	0.20	9.69	13.49		
Tail sample 1	0.09	0.27	0.08	6.24	0.92	0.20	7.79	14.33	7.83	14.74
Tail sample 2	0.09	0.27	0.08	6.24	1.00	0.20	7.86	15.16		
Abdomen sample 1	0.05	0.25	0.06	4.66	0.42	0.16	5.61	10.32	5.88	9.54
Abdomen sample 2	0.05	0.29	0.06	5.21	0.42	0.12	6.15	8.77		

Abbreviations:
ATP : adenosine 5′-triphosphate
ADP : adenosine 5′-diphosphate
AMP : adenosine 5′-monophosphate
IMP : inosine 5′-monophosphate
HxR : inosine
Hx : hypoxanthine

value since tail is more active before fish being caught. This suggestion could be applied for tuna judging from our result.

With respect to the difference of K value changing rate between red and white muscle of some fishes, especially dark-fleshed fishes, it is generally known that red muscle will be degraded much faster than that of white muscle[13]. However, in this study we found that red muscle was degraded slower than white muscle. The special term of red muscle used by other author is the muscle along the lateral line of fish body, but the red muscle that was used in this study was slightly different because the muscle was taken from the upper part of dorsal muscle, which can be regarded as 'toro'. That is why the result did not follow the general opinion. From this study, it can be said that the initial freshness of chilled bluefin tuna used was fairly good compared to that of frozen one obtained at market (K value ranged from 22.33～44.54%)[2] and close to that of very fresh tuna, just after catching by long line fishing (K value around 2～3 %, personal communication). Moreover, from the point of evaluation of big size fish such as tuna, the use of tail muscle may be a suitable part for analysis of K value for fish to be safely eaten raw, as the tail would give the highest K value among parts of fish body. That means if K value of tail is in the range of eatable raw for fish quality, the other part of fish body is definitely eatable raw.

ACKNOWLEDGMENT The authors wish to thank Mr. Yasuhiro SATO and Mr. Takeo OGAWA of the Nihon Marine Corporation and Australian Tuna Fisheries Pty. Ltd. for providing the fish and Dr. Tomoaki HAGIWARA for helping in preparation of fish sample.

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空輸畜養ミナミマグロのK値とその部位による差異

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海外で畜養され氷蔵状態で空輸される高級マグロが，近年市場に多く出回るようになった。それらは，脂肪分も高く年間を通して安定的に供給可能である等，経済的に優れている。しかしながら，そういった新しい流通形態におけるマグロの品質に関して利用しうるデータは非常に少ない状態にある。本研究では温度，および経過時間等履歴を明確にしつつオーストラリアから空輸した直後のチルドミナミマグロのK値の測定を試みた。また，大型魚であることから魚体部位による差異についても検討を行った。採取肉単位重量当た

りのATP関連物質の総量は，魚体各部で背肉赤身，同白身，尾部，腹部の順で，それぞれ11.8，9.7，7.8，5.9μmol/gで，いわゆる大トロとされる腹部では，脂質が多いためにATP関連物質の総量が著しく低い値を示した。K値に関しては，8.8～14.7%の範囲にあり，マグロの生食可能とされるK値の上限20%と比べて低い値を示すことが確認された。特に，K値は尾部で高い値を示すことも明らかになった。尾部は水揚げ前に最も活動の激しい部位であることから，ATPの分解が早く進むものと考えられているが，それを裏付ける結果となった。マグロのような大型魚では，最も劣化の激しい尾部肉のK値を指標として使うことが，品質および安全性を保証するうえで推奨される。

（平成12年10月18日受付，平成12年12月4日受理）