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Estimation of Keeping Freshness Period and Practical Storage Life of Mackerel Muscle during Storage at Low Temperatures

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Abstract

The analysis of enzymatic freshness-lowering, bacterial freshness and autoxidation of lipid in mackerel muscle was made for the purposes of investigating the reaction rate, keeping freshness period and practical storage life of muscle during storage at low temperatures.

The reaction rate on freshness-lowering in minced muscle was 1.2 to 1.5 times faster than that on fillets. The fastest of freshness-lowering is by a factor of about 20.0, occurs at temperatures from −10 to 0℃. Keeping freshness period on "sashimi" grade fish with K-value of 20% stored at 10, 5, 0, −3, −10 and −20℃ was found in about 1.5, 2, 3, 12, 52 and 126 days, respectively.

K-value of 50% level after compared with VBN value of 30 mgN/(100 g muscle) and TBA value of 15 mg MA/(1 kg muscle), seems to be useful for limit of acceptability of fish muscle as raw material on certain food processing. 50% level of K-value of muscle stored at 10, 5, 0, −3, 10 and -20℃ was found in about 4, 6, 10, 36 days, 5 and 11 months, respectively.

To keep the good freshness is the main factor for fisheries product before consuming. The changes in freshness is very related with time and temperature during distribution from fishing areas to consuming places. During distribution and processing, different temperatures and different periods are used. Therefore, different periods in distribution and storage and the different temperatures used will effect the different changes of quality.

Mackerel, *Scomber japonicus*, was chosen for the study because at this time very little is published on the freshness assessment related to the temperature dependence of storage life and from viewpoint of freshnesslowering rate.

In the present report we are limited only on some kinds of quality indices such as K-value, volatile bases nitrogen (VBN) and thiobarbituric acid (TBA) value. The reason for using these quality indices are based on what is available and practicable. The storage temperatures used are 10, 5, 0, −3, −10 and −20℃. Temperatures of around 10 and 5℃ are estimated as the temperatures of fish while handling with poor condition of icing. Estimated

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temperature of 0℃ is the temperature of fish while handling with good condition of icing. Temperatures from −10 to −20℃ are the various temperatures of freezing and storing of fish.

Nowadays, storage life studies on frozen food often are on time-temperature tolerance and product-processing-packaging (TTT-PPP) studies, meaning that the storage life is determined at different storage temperatures, and the influence of an alteration in at least one of the PPP-factors is included[1].

In many circles, it has for long been a general conviction that the keeping time of a frozen food depends very much on the storage temperature, and that keeping time were much improved by lowering temperature[2].

The problem of quality deterioration during frozen food distribution is well known and has been dealt with since the beginning of the frozen food trade. The quality losses during storage and distribution are related both to temperature and time[3]. And, the quality lowering rate depends on temperature and species of fish[4].

Materials and Methods

Mackerel, *S. japonicus*, weight 0.6−0.8 kg, was obtained in fresh condition from local fish market. Fillets were sampled on the ordinary muscle of the anterior dorsal region, and then were wrapped individually with polyethylene films, and stored at temperatures of 10, 5, 0, −3, −10 and −20℃, controlled within ±1℃ using the electric thermo sensor. After samples were in constant storage temperature, a certain weight of muscle in duplicate was withdrawn at interval times of storage for chemical analysis. In each sample, two determinations were made.

The K-value was measured by column chromatography[5]. The ionexchanger used was Dowex 1×4, Cl^- type with a mesh of 100 to 200. The VBN value was measured by trichloroacetic acid (TCA) extract, micro diffusion method (CONWAY's method)[5]. The 20 % of TCA solution and CONWAY's cell equipment were used. The TBA number was measured by using the method of SINNHUBER and YU[6]. Fresh and frozen samples were homogenized with the same weight of deionized water. 0.4 g of mixture was put in a test tube for analysis. The TBA number is expressed in mg of malonaldehyde (MA) per 1 kg of sample.

Results and Discussion

The different reaction rate constants of freshness-lowering (k_f) between minced and fillets are shown in table 1.. These differences suggest that the reaction rate on freshness-lowering during storage at 10, 5, 0, −3, −10 and −20℃ on minced muscle were 1.2 to 1.5 times faster than that on fillets. But, Table 1. also shows that by Q_{10} temperature quotient[7], the increase of reaction rate in minced were almost the same as in fillets. The fastest of freshness-lowering is by a factor of about 20.0 occurs at temperatures from −10 to 0℃. The cause of this result may be due to freeze-concentration effect by phase-change of

Table 1. Rate constant (k_f) and temperature quotient Q_{10} of freshness-lowering in minced and fillets mackerel muscle.

Morphological of muscle	Rate Contant k_f and Q_{10}	Temperature of storage			
		+10°C	0°C	−10°C	−20°C
Minced	$k_f(h^{-1}) \times 10^3$	8.182	3.568	0.172	0.069
	Q_{10}	2.293	20.744	2.493	
Fillets	$k_f(h^{-1}) \times 10^3$	7.017	2.450	0.127	0.045
	Q_{10}	2.864	19.291	2.822	

water in fish muscle. This is suggesting that at storage temperatures from 0 to −10℃, the keeping of freshness is more advantages than on using the temperature of storage from −10 to −20℃.

The rate of increases in K-value of mackerel muscle during storage at various temperatures are shown in Fig. 1.. The coefficient correlations (r), of the linear regression

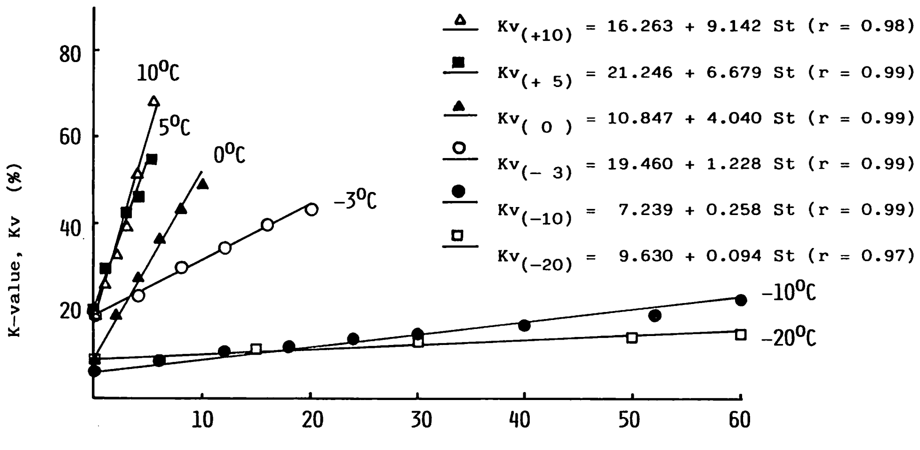

Fig. 1. Rate of increases in K-value of mackerel muscle during storage at various temperatures.

equations in Fig. 1. show that the changes in K-value apparently increased linearly with storage time up to about 60% of K-value. The slopes on these linear regression show that the higher the temperature of storage the faster the deterioration of fish nucleotides, or the faster the lowering of freshness will be.

A level of 30 mg VBN/(100 g muscle) has been found to be a useful indicator of fish and shellfish acceptability [8,9]. In the present report, as shown in Fig. 2., this level of VBN in

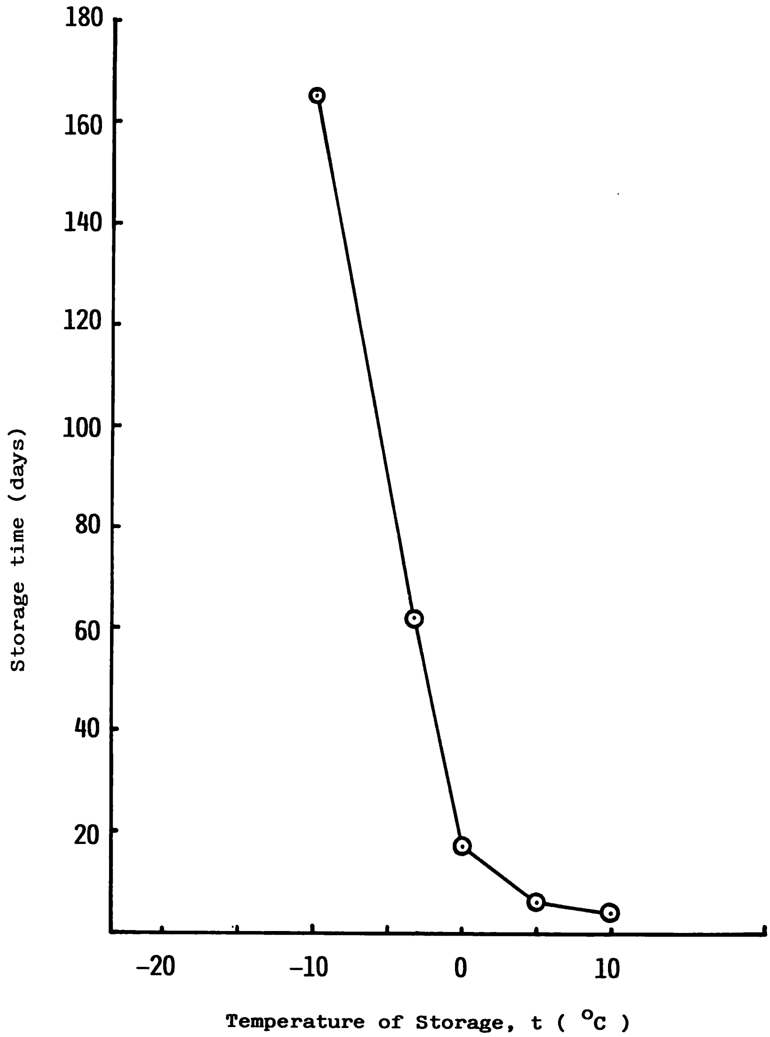

Fig. 2. Storage life for mackerel muscle as a function of temperature, on VBN determination.
Initial value : 12 mg N/100 g muscle
Final value : 30 mg/100 g muscle

mackerel muscle stored at 10, 5, 0, −3 and −10℃ was exceeded in about 3.5, 6, 17, 62 and 165 days, respectively. From the temperature dependence of a storage life in Fig. 2., it is possible to read the storage life at any storage temperatures between +10 and −10℃.

The thiobarbituric acid (TBA) test is most widely used for measuring the extent of oxidative deterioration of lipids. Frozen fish of good quality gave calculated TBA number of less than 3, and products of poorer quality gave TBA number from 4 to 27 [10]. On the present study, we used for the final value on TBA number 15 mg MA/(1 kg muscle), since it is the middle value of 4 and 27.

Fig. 3. shows the relationship between K-values and TBA values in mackerel muscle.

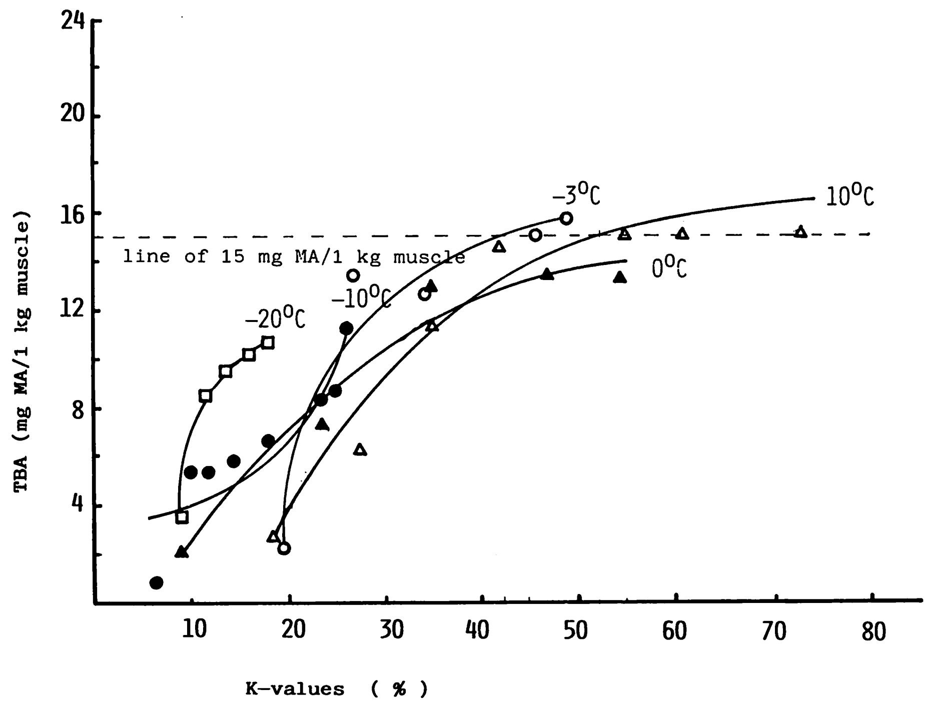

Fig. 3. The relationship between the K-values (%) and the TBA values (mg MA/1 kg muscle) of mackerel muscle during storage at different temperatures.

As shown in Fig. 3., on TBA No. 15 mg MA/(1 kg muscle) during storage at temperatures between −3 and +10℃, the K-values were around 45 and 55 %.

The relationship between 55 % level of K-value and 30 mg N/(100 g muscle) level of VBN shows that the storage life of muscle at 0, −3 and −10℃ on K-value determination was lower than that on VBN determination, and during storage at 10 and 5℃ gave almost the same storage life.

These results suggest that K-value of 50 % level seems to be useful for limit of acceptability of fish muscle as raw material on certain food processing. Many researchers proposed that K-value of 20 % level as a criterion for freshness limit of sashimi-grade fish [11,12,13]. UCHIYAMA *et al.* [11] and EHIRA *et al.* [12] reported that K-value of about 20% is good for raw material of "sashimi" and fish "sushi", and K-value of about 40 and 60% still used for raw material of "kamaboko" and "surimi". These conclusion were reached through statistical calculations based on the data obtained from many samples as the result of surveys on freshness of fish landed at fishing ports in Japan and the freshness of fish in commercial circulation.

EHIRA [13] reported that instantly killed of pacific mackerel have an initial K-value of around 5%. Using this initial value, Fig. 1. could be interpolated into Fig. 4.. As

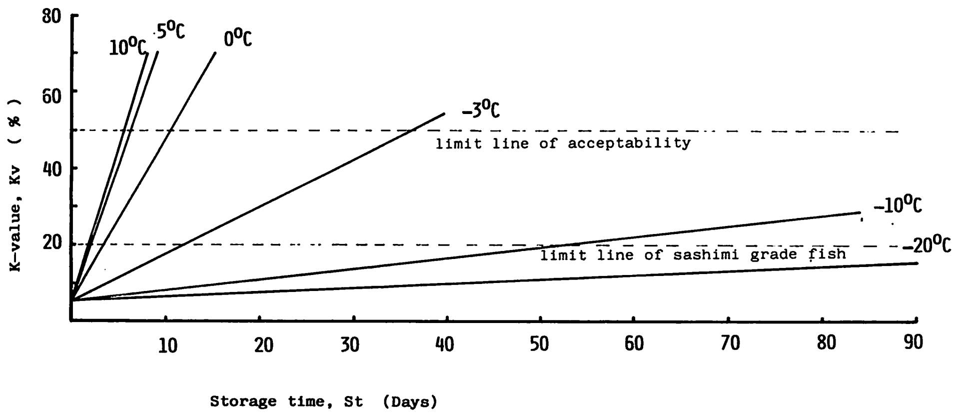

Fig. 4. The keeping freshness period and practical storage life of mackerel muscle during storage at various temperatures.

presented in Fig. 4., the 20 % level of K-value in mackerel muscle stored at 10, 5, 0, −3, −10 and −20℃ was exceeded in about 1.5, 2, 3, 12, 52 and 126 days, respectively ; and 50% level of K-value was exceeded in about 4, 6, 10, 36, 153 and 324 days, respectively.

These keeping freshness period (KFP) and practical storage life (PSL) results could be explained by using the temperature dependence of a storage life curve, as shown in Fig. 5.. On this curve, it is possible to read the KFP and PSL at any storage temperatures between 10℃ and −20℃. But the assessment of quality was estimated only with K-value. In the frozen state (the broken line in Fig. 5.), the water of muscle convert to the ice. Therefore, we have to consider the change of physical state (texture change) by protein denaturation.

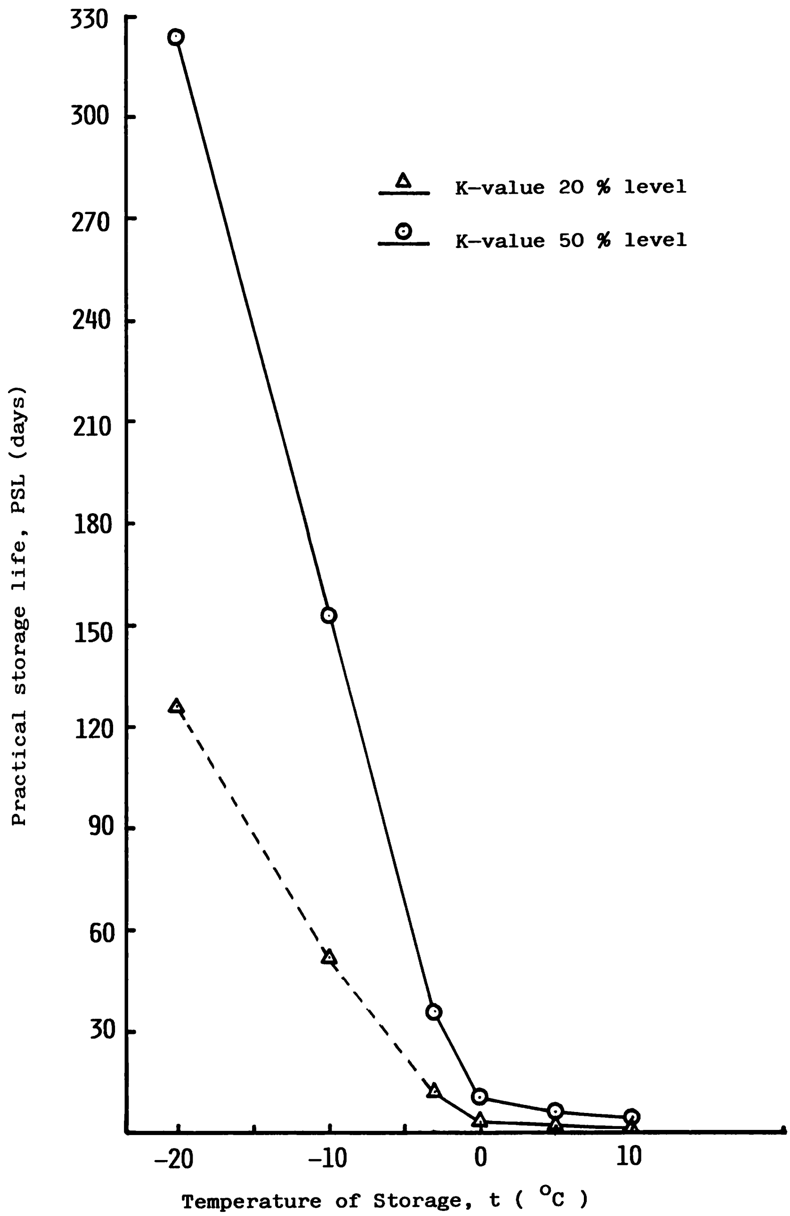

Fig. 5. Storage life for mackerel muscle as a function of temperatures, with initial value of 5.0 % and final value of 20 % as a limit of Sashimi grade fish, and 50 % as a limit of acceptability.

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