STUDIES ON THE MANUFACTURE OF CANNED MACKEREL

Part Ⅶ. The Relation between the Freshness Degree of Raw Mackerel Meat and the Quality of Canned Boiled Mackerel

Eiichi TANIKAWA and Tadao YAGI
Faculty of Fisheries, Hokkaido University

It is desirable to know the relation between the freshness of raw mackerel and the quality of the canned product. The authors have recently studied the relation between the freshness of raw saury (*Cololabis saira* (*BREVOORT*))[1] or crab (*Erimacrus isenbeckii* (*BRANDT*))[2] and the quality of the canned products, and made particular scales showing the relationship. The authors have this time studied the relation between the freshness of raw mackerel (*Scomber japonicus HOUTTUYN*) and the quality of canned boiled mackerel.

I. The decomposition velocity constant, temperature constant and temperature coefficient of mackerel meat

1. Sample and experimental method

Several mackerel which were caught off the shore of Kushiro were skinned and boned and then crushed through the chopper and homogenized by the Waring Blendor. The crushed mackerel meat was used as samples.

The amount of volatile base nitrogen of the sample was 9.76 mg%, amino acid nitrogen was 0.159%, total nitrogen was 3.42%, and pH value was 6.0.

The crushed mackerel meat was put in several wide-mouthed bottles, and each bottle was placed aerobically at 15°, 25°, 35° and 45°C (each temperature ± 2°C). After each of several definite periods, the amount of volatile base nitrogen and the pH value of the each sample were determined. The determination of the amount of the volatile base nitrogen was made by Weber-Wilson's method.

From the results obtained, the bacterial decomposition velocity constant (the volatile base producing velocity constant), temperature constant and temperature coefficient were calculated by the same manner used for saury meat[1] and crab meat.[2]

2. Experimental results

Experimental results obtained are shown in Table 1.

From Table 1, the relation between the produced amount of the volatile base nitrogen and storing time (hrs.) is shown in Fig. 1.

Table 1. The variation of the amount of volatile base nitrogen and pH values when the crushed mackerel meat was placed at different temperatures

leaving time (hrs)	at 15°C		at 25°C		at 35°C		at 45°C	
	pH	volatile base-N(mg%)	pH	volatile base-N(mg%)	pH	volatile base-N(mg%)	pH	volatile base-N(mg%)
0	6.0	9.76	6.0	9.76	6.0	9.76	6.0	9.76
5	6.0	11.24	6.1	13.12	6.1	20.41	6.1	25.59
10	6.0	9.47	6.1	24.57	6.1	48.52	6.1	70.41
15	6.0	12.72	6.1	67.52	6.2	131.75	6.2	213.45
20	6.1	12.51	6.4	125.57	6.6	232123	6.6	332.04
25	6.1	13.31	7.0	155.00	6.8	250.87	6.8	340.11
30	6.1	14.02	7.2	187.61	6.8	275.36	6.8	379.47
40	6.2	16.27	6.8	231.43	7.2	308.91	7.4	318.62
45	6.2	18.00	6.7	204.89	6.7	285.22	7.0	376.67
60	6.4	20.18	6.7	233.93	6.7	302.40	7.0	353.29
70	6.6	25.15	6.6	238.21	6.6	343.09	7.0	384.80
80	6.4	55.04	6.8	222.51	6.6	302.43	6.8	390.14
95	6.6	94.67	6.8	218.42	6.8	328.92	6.8	383.11
110	6.8	146.73						
120	6.6	187.56						
130	6.5	235.22						
145	6.6	261.61						
160	6.8	260.59						
170	6.8	257.78						
180	6.6	265.43						

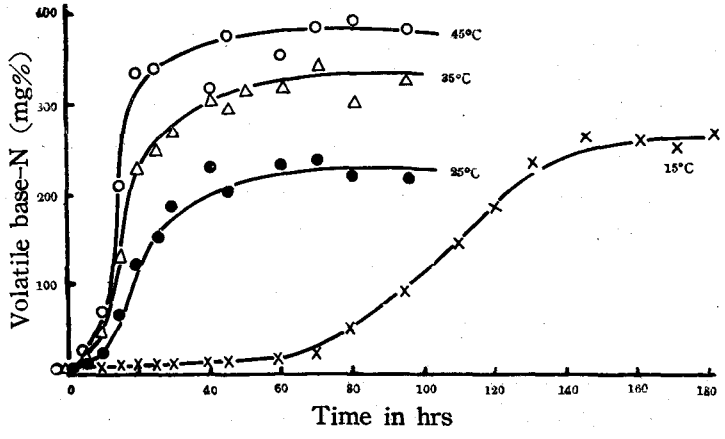

Fig. 1. The variation of the amount of volatile base nitrogen when the crushed mackerel meat was placed at different temperatures

As seen in Table 1 and Fig. 1, the bacterial decomposition velocity of the mackerel meat is rapid with the rising of temperature within the experimental temperatures, therefore the amount of volatile base nitrogen from the samples stored at 45°, 35° and 25°C respectively become larger with the lapse of time until 20

hrs of storing period, and reached equilibrium after 50 hrs or 60 hrs. At 15°C, the time until which the amount of volatile base nitrogen attained equilibrium was about 160 hrs. The amounts of the volatile base nitrogen at equilibrium were considered to be 266 mg% at 15°, 237 mg% at 25°, 336 mg% at 35° and 377 mg% at 45°C respectively.

From Fig. 1, the relation between the storing time (hrs) and the values of "log $\frac{y}{A-y}$" corresponding to the storing time was plotted as shown in Fig. 2. The relation between "t" and the values of "log $\frac{y}{A-y}$" is linear. Of course, the value of the bacterial decomposition velocity constant, K, is shown as the degree of the declination of the straight line.

In the case of the sample stored at 15°C the straight line is one, but in the cases of the samples stored at 25°, 35° and 45°C respectively, the straight lines were broken into two parts as shown in Fig. 2.

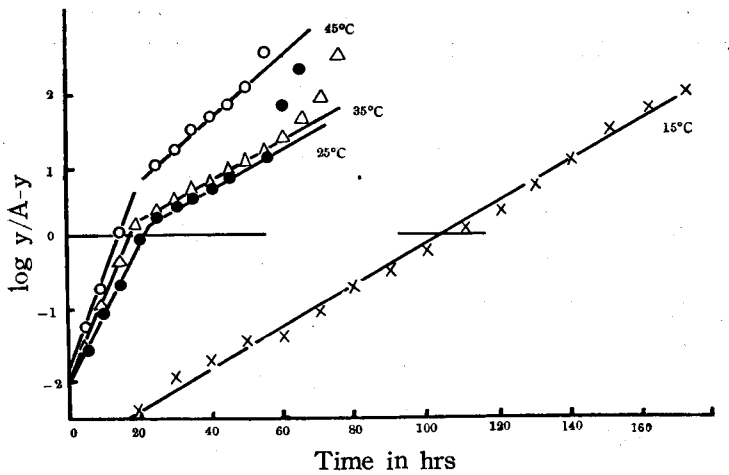

Fig. 2. The relation between the values "log $\frac{y}{A-y}$" and time "t"

Here, if K_1 is the bacterial decomposition velocity constant of the first stage of the broken line, and K_2 is the second stage, respectively, these values are shown in Table 2.

As seen in Fig. 2 and Table 2, in the case of the storing of the sample at 45°C, the value of $K_1 \times 10^4$ shows 1340 until 20 hrs' storing, but it decreases to 450 after 20 hrs. This fact agrees with the case of storing at 35° or 25°C, that is to say, the value of $K_1 \times 10^4$ shows 1140 at 20 hrs, and the value of $K_2 \times 10^4$ shows 310 after 20 hrs. In the case of storing of the sample at 25°C, the value of $K_1 \times 10^4$ shows 22 at the initial storing period, and 990 after 3 hrs, but the value of $K_2 \times 10^4$ shows 320. The value of K_1 is smaller than the value of K_2. However, in the case of storing of the sample at 15°C, the value of $K_1 \times 10^4$ shows 300 within the period

Table 2. The bacterial decomposition velocity constants of crushed mackerel meat at different temperatures

t°C	$K_1 \times 10^4$	$K_2 \times 10^4$
45	1340	450
35	1140	310
25	990	320
15	300	300

from 20 hrs to 170 hrs. At the initial storing period, the bacterial decomposition velocity increases with the rising of temperature, and the higher the temperature, the shorter is time for reaching equilibrium. The time at which the reaction is half completed is 14 hrs at 45°C, 17 hrs at 35°C, 21 hrs at 25°C, 106 hrs at 15°C, that is to say, the higher the temperature, the shorter is the time.

The values of temperature constant (B) and temperature coefficient (Q_{10}) of mackerel meat were calculated as to K_1 and K_2. The results obtained are shown as Tables 3 and 4 or Figs. 3 and 4. That is to say, the relation between "log K" of the

Table 3. The relation between the values "1/T" and "log K_1"

t°C	$K_1 \times 10^4$	T	1/T	logK_1
45	1340	318	0.003145	3.1271
35	1140	308	0.003247	3.0569
25	990	298	0.003356	2.9956
15	300	288	0.003472	2.4771

Table 4. The relation between the values "1/T" and "log K_2"

t°C	$K_2 \times 10^4$	T	1/T	logK_2
45	450	318	0.003145	2.6532
35	310	308	0.003247	2.4914
25	320	298	0.003356	2.5051
15	300	288	0.003472	2.4771

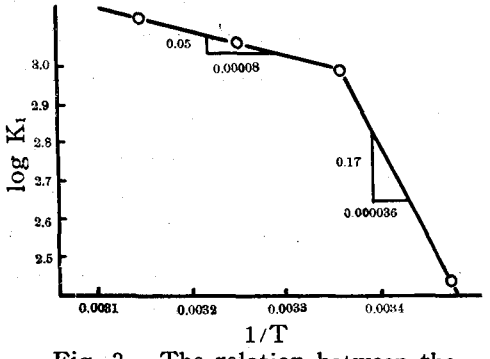

Fig. 3. The relation between the values "1/T" and "log K_1"

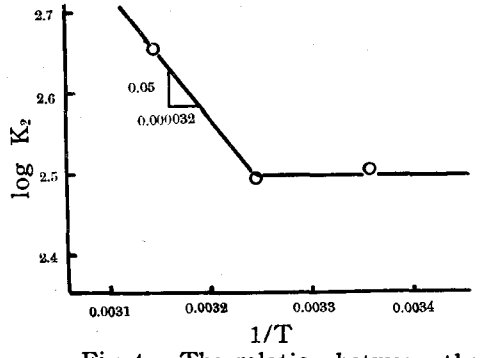

Fig 4. The relation between the values "1/T" and "log K_2"

values of $K_1 \times 10^4$ and $K_2 \times 10^4$ and reciprocal of absolute temperature of the storing temperature shows as a line, and from the degree of the dencliation of the straight line, the values of temperature constant (B) and temperature coefficient (Q_{10}) were calculated. The lines of "$K_1 \times 10^4$" and "$K_2 \times 10^4$" are divided into two stages as a boundary of 25° and 30°C respectively. Therefore, in the case of "$K_1 \times 10^4$," the value of (B) is 2856 and of "Q_{10}" is 1.17 above 25°C, and (B) is 21583, "Q_{10}" is 3.55 below 25°C. From those results, the bacterial decomposition velocity of mackerel meat becomes 1.17 times with each rising of 10°C of the storing temperature above 25°C, and the velocity becomes 3.55 times with each rising of 10°C of the temperature below 25°C.

II. A particular scale showing the relation between the storing temperature and maximum storing time

1. The lowest limit of freshness degree of mackerel meat as suitable raw material for canned boiled mackerel

After catching of mackerel, the freshness of the meat falls with the lapse of time at comparatively high room temperatures. Even if the unfresh meat is skilfully packed and processed, the quality of the canned products is not good. There must be the lowest limit of freshness of the meat. The senior author, Tanikawa,[3] has formerly suggested 30 mg% of the volatile base nitrogen in the fish meat as the index of the incipient putrefaction. But the lowest limit of freshness of the fish meat as suitable raw material for the canned products must be more fresh than the point of incipient putrefaction.

Here, samples of mackerel meat of different stages of freshness were obtained by placing them at room temperature and the degree of freshness was determined by the estimation of the amount of the volatile base nitrogen according to Weber and Wilson' s method. Those samples of different stages of freshness were packed and processed and the cans were opened after 4 weeks' incubation at 37°C.

The processing of the canned mackerel was as follows: Mackerel meat was immersed in NaCl solution of Bé 15° for 30 minutes. After immersion the meat was packed in cans. Can type used was flat No. 2 can (a half pound). Net weight was 240 g. Exhausting time was 10 minutes at 100°C. The sterilizing time was 1.5 hrs at 235°F.

The results of the estimations after opening of the cans are shown in Table 5.

Table 5. The qualities of canned mackerel made from raw material which were of various degrees of freshness

Raw material			Results of canned mackerel after opening									Grade of quality
leaving time (hrs)	volatile base-N (mg%) (freshness)	pH	volatile base-N (mg%)	pH	vacuum (inch)	odor	color	taste	juice	curd	hardness	
0	9.76	5.9	23.12	meat 6.1 juice 6.3	7	good	good	good	trans-parent	++	+++	splendid
14	15.32	6.0	30.39	6.1 6.2	8	〃	〃	〃	trans.	+	++	good
18	18.71	6.1	32.68	6.2 6.2	8	fair	〃	〃	trans.	±	++	〃
21	21.45	6.1	32.51	6.2 6.2	10	〃	slight pink	fair	slight pale	±	++	fair
23	23.47	6.1	36.09	6.2 6.2	9	slight smell	slight pale	slight poor	slight turbid	±	+	poor
25	24.08	6.1	38.84	6.2 6.2	6	stale	poor	poor	turbid	±	+	〃

As seen in Table 5, the amount of volatile base nitrogen of the mackerel meat

was about 20 mg% at the lowest limit of the freshness as raw material for the canned product. This conclusion agreed with the results which were obtained from the experiments using for saury meat[1] and crab meat.[2]

2. The maximum storing time of mackerel meat as raw material for the canned product

It was known that mackerel meat must be handled and processed below about 20 mg% of volatile base nitrogen as the index of the freshness, for the sake of making of good quality of canned mackerel.

Here, the maximum time until which the amount of volatile base nitrogen of the sample reaches to about 20 mg% at different temperatures is obtained from Fig. 1 and shown in Table 6.

Table 6. The time until which the amount of volatile base nitrogen reaches to 20 mg% in the crushed mackerel meat at different temperatures

leaving temp.	15°C	25°C	35°C	45°C
t_{20} (hrs)	53.5	8.5	5.0	3.5

The results shown in Table 6 were data concerning the crushed mackerel meat stored aerobically at different temperatures. Those data may be different from actual conditions in commercial canning process. Here, the fresh mackerel bodies (volatile base nitrogen was 9.58 mg%, amino acid nitrogen 0.108 %, pH 6.1) were placed aerobically at 10°, 25°, 35° and 45°C (± 1°C), and the time, "t_{20}", until which the amount of volatile base nitrogen reaches to about 20 mg% was determined by using back meat of fish bodies as shown in Fig. 5. The values of "t_{20}" obtained were shown in Table 7.

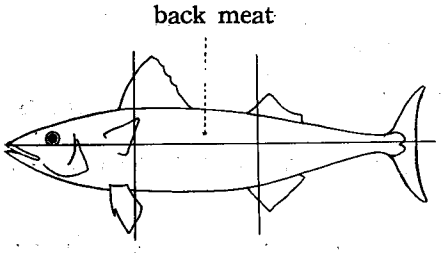

Fig. 5.

Table 7. The time until which the amount of volatile base nitrogen reaches to 20 mg% in meat of mackerel bodies at different tempeatures

leaving temp.	10°C	25°C	35°C	45°C
t_{20} (hrs)	65.5	11.0	7.0	5.5

The relation between the value of "t_{20}" and the corresponding storing temperature is shown in Fig. 6. The relation between the values of "log t_{20}" and the corresponding storing temperature is shown in Fig. 7.

As seen in Fig. 7, the straight line showing the relation between the values of "log t_{20}" and the corresponding storing temperatures is broken into two parts at the point of 25°C. The reason for this is the fact that the values of "Q_{10}" are divided into 1.17 and 3.55 at the point of 25°C.

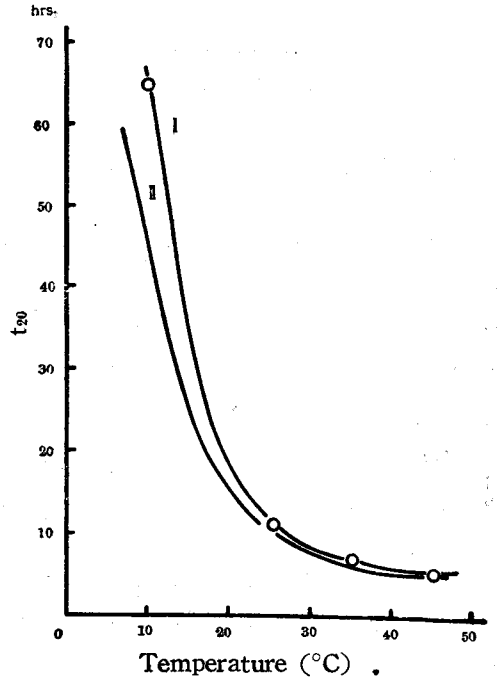

Fig. 6. The relation between the values "t_{20}" and storing temperature

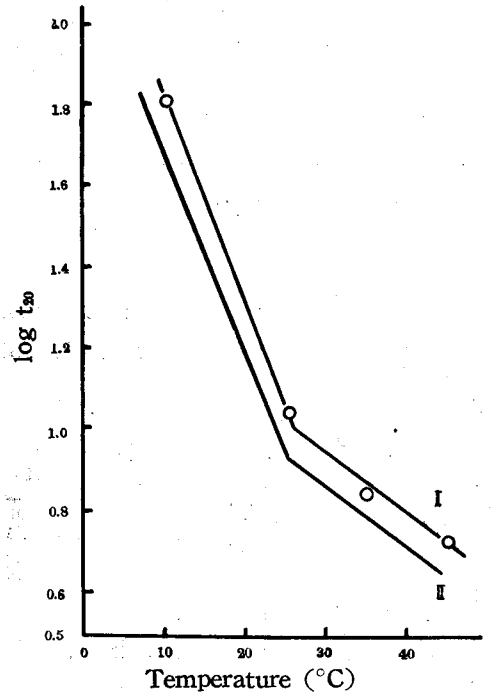

Fig. 7. The relation between the values "log t_{20}" and storing temperature

The lines shown in Fig. 7 are expressed by equation (1).

$$\log t_0 = \alpha - \beta\theta \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Here, α and β are constants.

In the actual process of making canned mackerel, large quantities of fish bodies are handled, therefore the contamination or damage of fish bodies happens sometimes, and the processing time is sometimes prolonged. Also fish bodies which are different in the freshness of the meat are sometimes carried into the cannery. Those factors concerning the freshness of fish bodies must be considered in determining the maximum safe storing time.

The authors suggest period of 10 hrs at 15°C as a safe time as shown by curve II in Fig. 6 and the straight line II in Fig. 7.

3. Making of a particular scale showing the relation between the storing temperatures and the corresponding maximum storing time

By using equation (1) the constant values of α and β of the straight line II in Fig. 7 are obtained and shown in Table 8.

Table 8. Values of α and β

temp.	α	β
below 25°C	2.14	0.048
above 25°C	1.39	0.017

When the values of α and β are replaced

into equation (1), the following equations are obtained.

below 25°C: $\log t_{20} = 2.14 - 0.048\theta$ ..... (2)

above 25°C: $\log t_{20} = 1.39 - 0.017\theta$ ..... (3)

From Fig. 7 and equations (2) and (3), a particular scale showing the relation between the storing tempratures and corresponding maximum storing time can be set up as shown in Fig. 8.

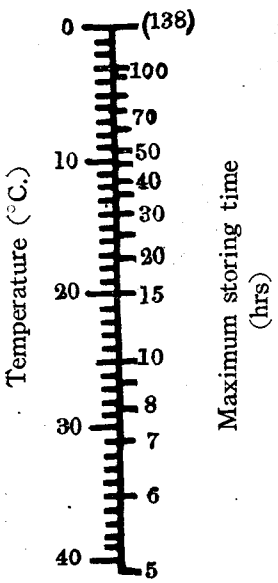

Fig. 8. The relation between the storing temperature and the maximum storing time

For example, it may be seen from Fig. 8 that if the room temperature of the cannery is 20°C, the mackerel must be handled and packed in cans and the sterilization started within 15 hrs.

4. Detection of reliability of the particular scale

In order to ascertain the reliability of this particular scale, experiments in the practical canning course were made. Fresh mackerel (volatile base nitrogen 10.06 mg%, amino acid nitrogen 0.085 %, pH 5.9) were stored at 8°, 20°, 30° and 37°C (± 1°C) to cause different stages of freshness, and then the stored mackerel bodies were handled and packed in cans and sterilized respectively after the different known storing times.

The processing of canned mackerel was the same as the above described method.

When those cans were opened, the results obtained are as shown in Table 9 to Table 12.

Table 9. The quality of canned mackerel made from raw material which was left at 37°C (± 1°C)

Raw material			Results of canned mackerel after opening									Grade of quality
leaving time (hrs)	volatile base-N (mg%) (freshness)	pH	volatile base-N (mg%)	pH	vacuum (inch)	odor	color	taste	juice	curd	hardness	
0	10.06	5.9	22.48	meat 6.1 juice 6.2	7	good	good	good	trans-parent	++	+++	splendid
4.0	16.12	6.0	30.56	6.2 6.2	10	fair	fair	〃	〃	++	++	good
5.0	17.87	6.0	32.40	6.1 6.2	8	〃	〃	fair	〃	++	++	〃
6.0	19.61	6.2	36.24	6.1 6.2	6	〃	〃	〃	〃	+++	+	〃
7.0	21.01	6.0	35.10	6.1 6.2	8	slight smell	〃	〃	slight turbid	++	+	fair
8.0	23.87	6.0	39.96	6.2 6.2	6	slight smell	slight pink	slight poor	turbid	++	+ skin out	poor
9.0	27.33	6.1	43.56	6.2 6.3	10	stale	pale	slight poor	〃	++	+ skin out	〃

Table 10. The quality of canned mackerel made from raw material which was left at 30°C (± 1°C)

Raw material			Results of canned mackerel after opening									Grade of quality
leaving time (hrs)	volatile base-N (mg%) (freshness)	pH	volatile base-N (mg%)	pH	vacuum (inch)	odor	color	taste	juice	curd	hardness	
0	10.06	5.9	22.48	meat 6.1 juice 6.2	7	good	good	good	trans-parent	++	+++	splendid
5	16.21	5.9	32.76	6.1 6.2	5	fair	fair	〃	〃	++	++	good
6	18.22	6.0	28.15	6.2 6.2	7	〃	〃	〃	〃	+	++	〃
7	18.92	6.0	33.02	6.1 6.2	7	〃	〃	〃	〃	++	++	〃
8	19.56	6.1	30,33	6.2 6.3	5	〃	slight poor	fair	〃	±	++	fair
9	21.15	6.1	28.67	6.3 6.4	12	〃	〃	〃	slight turbid	±	++ slight skimmed	poor
10	22.63	6.1	29.86	6.2 6.3	8	slight smell	〃	slight pale	〃	++	++	〃
11	24.11	6.1	36.47	6.1 6.3	10	slight smell	poor	〃	〃	+	+	〃
12	23.99	6.1	39.79	6.2 6.3	10	stale	〃	〃	turbid	±	+ skimmed	〃
13	25.14	6.1	41.91	6.2 6.3	10	〃	〃	〃	〃	+	+	〃

Table 11. The quality of canned mackerel made from raw material which was left at 20°C (± 1°C)

Raw material			Results of canned mackerel after opening									Grade of quality
leaving time (hrs)	volatile base-N (mg%) (freshness)	pH	volatile base-N (mg%)	pH	vacuum (inch)	odor	color	taste	juice	curd	hardness	
0	10.06	5.9	22.48	6.1 6.2	7	good	good	good	trans-parent	++	+++	splendid
13	14.56	6.0	23.76	6.1 6.2	8	fair	〃	〃		++	+++	〃
14	15.32	6.0	30.54	6.1 6.1	5	〃	fair	〃		+	++	good
15	17.11	6.0	28.31	6.2 6.2	8	〃	〃	fair		+	++	〃
16	18.49	6.1	32.70	6.2 6.2	9	〃	〃	〃	slight turbid	±	++	〃
17	20.19	6.1	34.39	6.2 6.2	10	slight smell	slight pink	〃		±	++	fair
18	21.45	6.1	29.85	6.2 6.3	6	〃	〃	〃		±	++	〃
19	22.62	6.1	37.56	6.2 6.3	10	〃	〃	slight poor		±	+	poor
20	23.22	6.1	38.01	6.2 6.2	9	stale	〃	〃		±	+ skimmed	〃
21	23.12	6.1	35.82	6.2 6.2	10	〃	〃	〃		+	+ skimmed	〃
22	24.14	6.1	40.73	6.2 6.3	6	〃	pale	〃		±	+	〃

Table 12. The quality of canned mackerel made from raw material which was left at 8°C (± 1°C)

Raw material			Results of canned mackerel after opening									Grade of quality
leaving time (hrs)	volatile base-N (mg%) (freshness)	pH	volatile base-N (mg%)	pH	vacuum (inch)	odor	color	taste	juice	curd	hardness	
0	10.06	5.9	22.48	6.1 6.3	7	good	good	good	trans-parent	++	+++	splendid
60	13.98	5.9	27.52	6.0 6.1	5	fair	〃	〃	〃	+	+++	〃
65	14.86	5.9	30.11	6.1 6.1	6	〃	fair	〃	〃	±	++	good
70	15.11	6.0	29.83	6.1 6.1	6	〃	〃	〃	slight colored	+	++	〃
75	18.65	6.0	36.77	6.1 6.2	10	〃	〃	fair	slight turbid	±	++	fair
80	21.10	6.0	39.51	6.1 6.2	6	slight smell	slight colored	〃	〃	±	++	poor
83	22073	6.1	38.02	6.1 6.2	6	〃	slight pink	〃	turbid	±	++ skimmed	〃
85	23.24	6.1	35.02	6.1 6.2	7	〃	〃	slight pink	〃	±	+	〃
90	24.47	6.1	41.08	6.2 6.2	9	stale	〃	〃	〃	±	skimmed	〃

As seen in the Tables, the qualities of canned product were good when raw mackerel was used of which the freshness was within the maximum storing time. That is to say, satisfactory results were obtained proving the validity of the proposed scale by actual testing and observing of samples which had been canned and processed as in commercial canneries.

By using this particular scale, when mackerel is handled and processed within the maximum storing time at known temperature of storing place or canning factory, good qualities of the canned mackerel will be obtained.

Summary

The freshness of the meat of mackerel (*Scomber japonicus HOUTTUYN*) was artificially varied by leaving raw mackerel as it was.

The degree of freshness of those samples was detected by the estimation of the amount of volatile base nitrogen, value of pH and by organoleptic test.

Mackerel meat of various degrees of freshness was packed in cans and processed. After a certain period the cans were opened, and the quality of canned meat was determined by the estimation of the amount of volatile base nitrogen and by organoleptic test. According to the those experiments, it is shown that raw mackerel meat of which the amount of voltile base nitrogen is estimated as 20 mg% is no more fit material for canned mackerel.

The relation between the storing temperature and the corresponding maximum limit time of storing of mackerel meat was shown as a particular scale.

By using this scale, when the storing temperature is 20°C, the maximum limit time of storing of mackerel meat will be 15 hours.

The data on the scale were found to agree almost exactly with the practical values from experiment.

Literature cited

1) Tanikawa, E. & Yagi, T. (1954). *Bull. Fac. Fish., Hokkaido Univ.* **5** (2), 209-221. (Japanese).

2) Tanikawa, E. *et al.* (1953). *Bull. Fac. Fish., Hokkaido Univ.* **4** (1), 1~39; **4** (2), 123~131.

3) Tanikawa, E. (1938). *Bull. Soc. Sci. Hyg. Aliment. Paris* **26**, 149.