The results obtained may be summarized as follows;

(1) The changes of the amount of amino acid nitrogen and water soluble matter nitrogen showed irregular increase and decrease. There was no remarkable value in such estimations for detecting the freshness of crab meat particularly in the stage of incipient spoilage.

(2) The change of the value of pH showed gradual increase, and reached to equilibrium with the lapse of time of decomposition. Therefore, it was difficult to detect the freshness of crab meat in the stage of incipient decomposition.

(3) The bacterial number in the raw crab meat increased logarithmically and reached equilibrium in the later period of spoilage; therefore it is difficult to detect the freshness of crab meat by the bacterial count in a short time.

(4) W-reaction was positive which indicates unfreshness even though the crab meat was known to be fresh. Therefore it is also unsuitable to detect the freshness of crab meat.

(5) The comment on Eber's reaction is as same as for W-reaction.

(6) The determination of turbidity was not very clear for detecting of freshness of crab meat.

(7) As a method for detecting freshness of crab meat, the estimation of the amount of volatile base nitrogen is the best. When the freshness of crab meat drops to incipient spoilage, the amount of volatile base nitrogen becomes 20 mg%, differing from the 30 mg% in the case of fish meat. This amount of volatile base nitrogen agrees with the result by organoleptic test, that is to say, when 20～25 mg% of the amount of volatile base nitrogen produced in crab meat, abnormal smell is noticeable, and when 30 mg% of the amount of volatile base nitrogen was estimated, the tainted smell was strong, the viscosity increased, and the color of the meat became dark brown.

（水産科学研究所業績　第156号）

IV. STUDIES ON THE INFLUENCES OF THE FRESHNESS OF RAW CRAB MEAT AND DURATION OF STORAGE AFTER BOILING UPON THE QUALITY OF CANNED CRAB MEAT

Eiichi TANIKAWA, Yasunosuke INOUE and Minoru AKIBA

The freshness of raw crab meat varies by fishing methods, such as catching by gill net, catching by basket, catching by a type of dredge net. Even if the carapace was removed from the crab body, and the crab leg and shoulder meat were immediately boiled, it sometimes happens that the boiled meat cannot be taken off from the crust and packed in cans because of the faulty management of the factory. In such cases, storing time and temperature after boiling influence the reduction in the freshness of meat. It is very important to know the limit of freshness of raw meat and boiled meat as raw material of canned crab meat. KANEKO[1] has detected organoleptically the smell of shoulder and joint meat as a means to learn a standard of limit of freshness; he considered the time from boiling to the incipient spoilage which is in inverse proportion to the bacterial decomposition velocity constant; then he devised a scale by which it is possible to calculate the maximum storing time at various temperatures after the boiling.

The present authors have stored raw crab meat which was caught and boiled after removing of carapace, and estimated the freshness by the determination of the amount of volatile base nitrogen, amino acid nitrogen, the value of pH. Then they packed those crab meat samples having various degrees of freshness in can, and estimated the quality of the canned.product.

1. Method of Experiment

Erimacrus isenbeckii which was caught off the shore of Oshamambe on August 28, 1952 was brought to the laboratory within 6 hours after catching. The bodies of crab were divided into two groups. From one of groups the meat was stored as it was at 35° ± 1°C. From the other group the leg and shoulder meat was boiled with crust after removal of carapace and then stored at 35° ± 1°C.

Crab meat loses freshness to a certain degree after the passage of a certain definite time. The freshness of the crab meat was detected by the estimation of volatile base nitrogen of the shoulder meat and leg meat. Thus the samples of crab meat showed 6 degrees of freshness, viz., the samples showing 5～10 mg% of volatile base nitrogen, 10～20 mg%, 30～40 mg%, 40～50 mg%, 50～60 mg% and 60～80 mg%. Each of 4 bodies of different degrees of freshness were respectively packed in cans as usual and stored about 3 weeks at 22°C (room temperature) and then open. The relation between the freshness of raw material or boiled material and the quality of canned crab meat was determined. The item of estimation were the amount of volatile base nitrogen, amino acid nitrogen and value of pH for raw or boiled meat and organoleptic estimation such as the appearance, color, smell, blue meat, blackened meat and further, the amount of volatile base nitrogen, amino acid nitrogen and value of pH of the juice of the canned crab.

2. Results of Experiments.

By previous experimental methods, the freshness of raw meat (shoulder and leg meat were estimated after leaving of crab body with carapace as it was) or boiled meat (shoulder and leg meat were estimated after leaving them with crust after removing carapace) was estimated. And estimated items are shown in Tables 1 and 2.

Table 1 shows the relation between the storing time and the freshness of samples (expressed by the amount of volatile base nitrogen). Table 2 shows the estimates of meat from sample cans.

3. Discussion.

As seen in Table 1 and Fig. 1, the velocity of increasing of the amount of volatile base in the boiled meat (after removing of carapace) is slower than that of raw sample. Therefore raw material must be boiled as soon as possible after the catching, and stored in a cool place until the processing. However, it may be impossible to treat raw material immediately after the catching according to circumstances. In such cases raw material must be stored in such low temperature (−3° ～ 0°C) that does not freeze the crab meat,

Table 1. The relation between the storing time and the freshness of samples (Changes of the amount of volatile base nitrogen, amino acid nitrogen and value of pH).

Sample No.		Time elapsed (hrs.)	Volatile base-N (mg%)	Amino acid-N (mg%)	pH	Remarks
Raw crab meat, which stored with carapace.	R0	8	5.8	255	6.8	Normal
	R1	10	9	364	6.8	〃
	R2	12	20	220	6.9	Rather abnormal smell Softening of meat
	R3	13.5	29	201	7.0	Putrefactive odour
	R4	14.5	55	178	7.2	Strong putrefactive odour
	R5	17	18	196	7.1	〃
	R6	25	90	160	7.2	〃
Boiled meat, which stored with crust after removing carapace.	B0	0	3	147	6.8	Normal
	B1	2	6	189	6.8	〃
	B2	9	9	168	6.9	〃
	B3	18	20	——	7.0	Rathern abnormal odour Softening of meat
	B4	24	34	——	7.1	Putrefactive odour
	B5	26	40	125	7.0	Strong putrefactive odour
	B6	28	50	112	7.2	〃
	B7	41	120	——	7.5	〃
	B8	50	130	——	7.5	〃

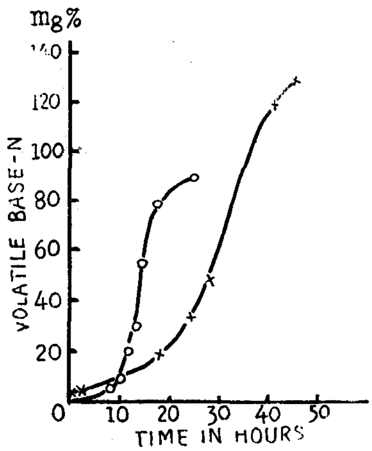

Fig. 1 Changes of the amount of volatile base nitrogen of raw sample and boiled sample at 35°±1°C.
○——○ Raw sample, which with crust and without removal of carapace.
×——× Boiled sample, after removing of carapace.

and crab meat for treatment must be taken out of the cold storage room. As seen in Table 1 in the case of storing of raw material, when the amount of volatile base nitrogen attained to 20 mg%, the crab meat became soft and generated a somewhat abnormal smell. This was observed in the sample R-2. When such deteriorated meat was boiled and cooled, the appearance of the meat became normal. But when such deteriorated meat was packed in can, the quality of the canned product was worse than the normal quality of the canned crab, as indicated in Table 2.

As to the boiled meat with crust after

Table 2. Estimations of samples of canned crab packed as raw or boiled meat having different degrees of freshness.

Samples	Mark of Can.	Out look	Vacuum (inch)	Liquid pH	Volatile base-N (mg%)	Amino acid-N (mg%)	Colour, taste, odour, etc.	Blue meat	Blackening (No. of spot)	Result
Raw crab meat, which stored with carapace.	R0	Normal	13.0	6.8	13	32	Normal, good	+	Can body 3 Cover 1	+++
	R1	〃	15.2	6.8	17	83	〃	++	Can body 2	+++
	R2	〃	16.1	6.8	25	62	〃	++	Can body 4 Cover 1	++
	R3	〃	16.2	7.1	43	122	Liquid turbid, putrefactive odor, softening of meat.	+++	Can body 3	Bad
	R4	Swell	•	7.1	223	384	Putrefactive odor.	++ ++	Can body 1 Numbers of small blackening spot.	Bad
Boiled crab meat, which stored with carapace.	B0	Normal	12.5	6.8	11	67	Normal, good.	+	Can body 1 Cover and bottom 4	+++
	B1	〃	17.5	6.9		49	〃	++	Can body 9 Small blackening spot	+++
	B2	〃	16.0	6.9	14	70	〃	+	Can body 1 Lap 2 Cover 3	+++
	B3	〃	17.0	6.8	23	57	Lack of liquid, black spot over paper.	++	Can body 6 Other parts 6	++
	B4	Swell	—	7.1	55	224	Liquid turbid, putrefactive odour, deformation of meat.	++	Can body 3 Seaming part 1 Cover and bottom 1	Bad
	B5	Normal	0	6.9	140	274	H_2S odour, liquid turbid.	++	Can body 3 Other parts 9	Bad
	B6	Swell	—	7.1	276	437	Liquid turbid, putrefactive odour, deformation of meat.	++	Can body 5 Cover and bottom 8	Bad

removal of carapace which was stored at 35° ± 1°C, when the amount of volatile base nitrogen reached 19.6 mg%, the meat was found to have become soft and viscous by finger touching, and it generated a tainted smell.

When such deteriorated meat was packed in can, this canned meat was edible, but its quality is worse than the normal quality of the canned crab, as indicated in Table 2.

In conclusion, when the amount of volatile base nitrogen produced in raw meat or boiled crab meat attains to about 20 mg%, the meat becomes unfit material for canning. When such decomposed meat was packed, the quality of the canned crab meat became so bad that swelled can, or softening of canned meat, and blue meat were observed to occur.

Here, the authors call the time until which the amount of volatile base nitrogen rcached to 20 mg% in the crab meat the "maximum time of storing the crab meat". The authors have discussed the relationship between this maximum time of storing the crab meat and the storing temperatures.

Citing from Table 2 of article II of Report I, which summarized a discussion of the bacterial decomposition velocity of *Erimacrus isenbeckii*, the values of time, t_{20}, at which the amount of volatile base nitrogen produced in the crab meat reached to 20 mg%, are collated in Table 3 for various treatments of the crab meat as follows.

Table 3.Comparison of the values of "t_{20}" of the different samples.

No.	Sample \ Temp.	4°C	23°C	24°C	35°C	Remarks.
I	Raw crab	30 hrs.	——	12	5.5	(4-35°C) Q_{10}=1.2
II	Boiled crab	70	——	20	9	(4-23°C) Q_{10}=1.4
III	Raw crab, with crust without removal of carapace.	(70)	Average 16, 27 } 21.5	——	11.5	Q_{10}=1.8
IV	Boiled meat, with crust, which were removed from carapace.	(140)	——	(35)	17.5	Q_{10}=2

(I) Samples of raw leg and shoulder meat removed from the crust, and stored aerobically at 4°, 24° and 35°C.

(II) Samples of boiled leg and shoulder meat removed from the crust, stored aerobically at 4°, 24° and 35°C.

(III) Samples of raw leg and shoulder meat with crust without removal of the carapace, stored aerobically at 35°C.

(IV) Samples of boiled leg and shoulder meat with crust which were removed from the carapace, stored aerobically at 35°C.

In Table 3, the value of "t_{20}" found for sample (III) at 23°C is the average value of 16 and 27 which were the values of shoulder meat and leg meat respectively, the values given in parentheses were calculated from the following equation (7).

$$\log \frac{t\theta_1}{t\theta_2} = \frac{\theta_2 - \theta_1}{10} \log Q_{10} \quad \cdots\cdots\cdots\cdots\cdots\cdots (7)$$

The value of "t_{20}" of sample (III) at 4°C was calculated from Q_{10} as 1.8, and for sample (IV) at 4°C or 24°C, Q_{10} was 2. The values of Q_{10} for samples (I), (II) and (III) are shown in the remarks column in Table 3. Those values were calculated from the values of volatile

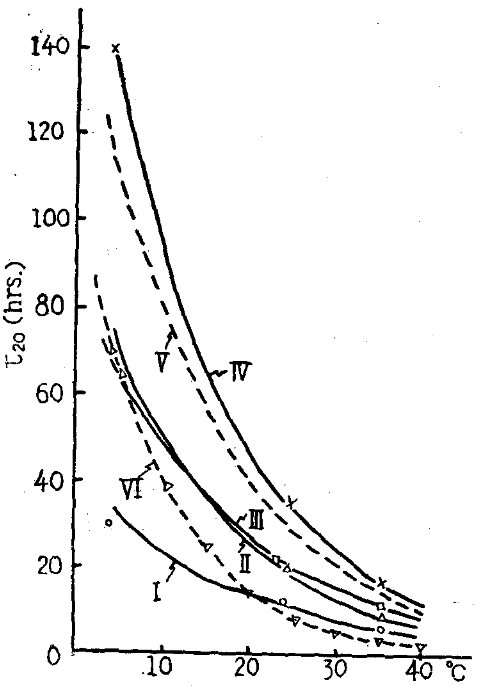

Fig. 2 Relation between the value of "t_{20}" and storing temperature.

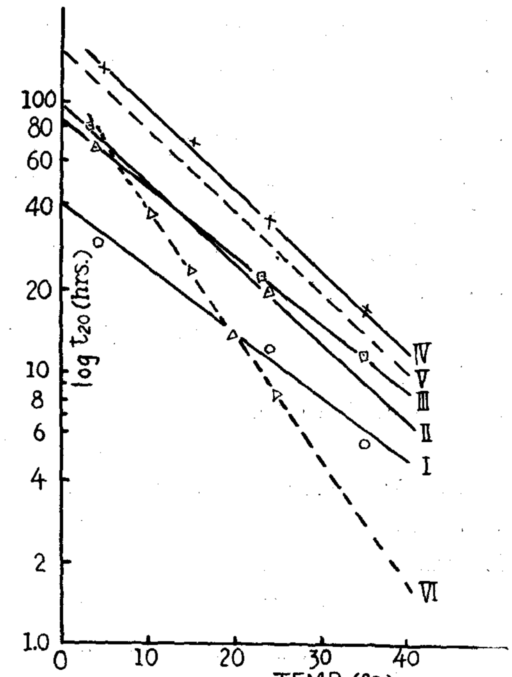

Fig. 3 Relation between the value of "log t_{20}" and temperature.

base producing velocity and have been already reported in a previous Report in detail.

From Table 3, the relation between the values of "t_{20}" and various storing temperatures is shown as curves I, II, III and IV in Fig. 2. The relation between the values of "log t_{20}" and various storing temperatures is linear; the maximum time of leaving the crab meat "t," is given by the following equation (8).

$$\log t_{\theta} = A - B\theta \quad \cdots\cdots (8)$$

In equation (8) A and B are constant for each sample. Curve IV in Figs. 2 and 3 shows the relation between the value of "t_{20}" and the storing temperatures after boiling of leg and shoulder meat which were removed from carapace.

In the processing of canned crab, the operations of removal of crust of leg, washing, selecting of meat, and packing give the occasion to contamination of bacteria because of contact with the air; there are also differences of speed until the completion of processing for various reasons. When the raw material is carried into the factory, material of various degrees of freshness are mixed indiscriminately, e.g. living crabs and crabs which were already dead when removed from the nets, whose death time is not exactly known.

When the sum of such differences of time as a safety time is added to the commercial operation time (strictly speaking the time of difference between the minimum and maximum time to complete processing of canned crab after the death of crab), the supposing that this time is 10 hours at 15° storage temperture as KANEKO[1] says, then the curve of supposition in shown as IV-straight line which runs parallel with V-straight line in Fig. 3. This V-straight line in Fig. 3 is rewritten as V-curve in Fig. 2. VI-curve in Fig. 2 or VI-straight line in Fig. 3 was offered by KANEKO, which showed the relation between various storage temperatures and the maximum limit time of storing of boiled crab meat (*Paralithodes camtschatica*) with crust after removal of carapace, as indicated by organoleptic test. KANEKO has drawn out VI-curve as follows: In the case the raw material was meat of *Paralithodes camtschatica*, the relation between the maximum limit time of storing, $t_{\theta r}$ and room temperature, θr, is shown as equation (9).

$$\log t_{\theta r} = 2.20 - 0.045\,\theta r \quad \cdots\cdots\cdots\cdots (9)$$

Here, if safety time as above stated is 10 hours at 15°C, the equation (9) is substituted by the equation (10).

$$\log t_{\theta r} = 2.04 - 0.045\,\theta r \quad \cdots\cdots\cdots\cdots (10)$$

The equation (10) is shown as VI-line. in Figs. 2 and 3. In the case of the raw material was *Erimacrus isenbeckii* which has been used by the authors, each straight line in Fig. 3 is expressed by the following equation.

I-straight line ········ $\log t_{\theta r} = 1.62 - 0.024\theta r$

II-straight line ········ $\log t_{\theta r} = 1.99 - 0.029\theta r$

III-straight line ········ $\log t_{\theta r} = 1.75 - 0.018\theta r$

IV-straight line ········ $\log t_{\theta r} = 2.27 - 0.03\,\theta r$

V-straight line ········ $\log t_{\theta r} = 2.19 - 0.03\,\theta r$

From equation (7) the values of Q_{10} of each straight line in Fig. 3 are calculated as follows.

I-straight line ········ $Q_{10} = 1.7$, II-straight line ········ $Q_{10} = 1.9$

III-straight line ········ $Q_{10} = 1.8$, IV-straight line ········ $Q_{10} = 2.0$

According to KANEKO, the value of Q_{10} of *Paralithodes camtschatica* calculated from the VI-straight line in Fig. 3 is 2.8. Compared the values of Q_{10} of each straight line (that is to say each sample) calculated by equation (7) with values of Q_{10} which are shown in Table 3, calculated by the producing velocity of volatile base, there seemed to be some difference for samples (I) and (II).

The values of Q_{10} which are given in Table 3 seem to be smaller than 2~3 of the value of Q_{10} of general chemical reaction. This is perhaps due to the reason that the bacterial decomposition velocity constant, K, is influenced by some factors, e.g. the temperature and specific humidity in storing place, water content in the samples, contamination by bacteria, the kind and number of bacteria attached to the sample.

Equation (7) used for the calculation of Q_{10} is expressed by a factor of temperature only, that is to say, supposing the bacterial decomposition velocity constant, K, is K_{θ} at θ°C of storing temperature, $K_{\theta+10}$ at $(\theta+10)$°C, the Q_{10} is $\frac{K_{\theta+10}}{K_{\theta}}$. The other factors are regarded as the same.

The making of an equation in which the other factors are inserted is reserved for further studies.

Compared the VI-curve or VI-straight line respectively in Fig. 2 or Fig. 3 which were obtained by KANEKO for the meat of *Paralithodes camtschatica* with V-curve or V-straight line which were obtained by the present authors for the meat of *Erimacrus isenbeckii*, there is some difference. The meat of *Paralithodes camtschatica* seems more decomposable than the other from Figs. 2 and 3, although both samples were treated as the same, that is to say, both samples were boiled after removing carapace and stored meat with crust. This difference is perhaps due to the difference of experimental methods such as chemical test or organoleptic test, different kind of sample, and storing condition. So it is impossible to reach a strict conclusion.

Furthermore, the authors wish to study *Paralithodes camtschatica* as sample using exactly the methods as they used with sample of *Erimacrus isenbeckii*, and to discuss in detail the results which will be obtained.

Fig. 4 shows scales for the relation of the maximum time limit of storing crab meat

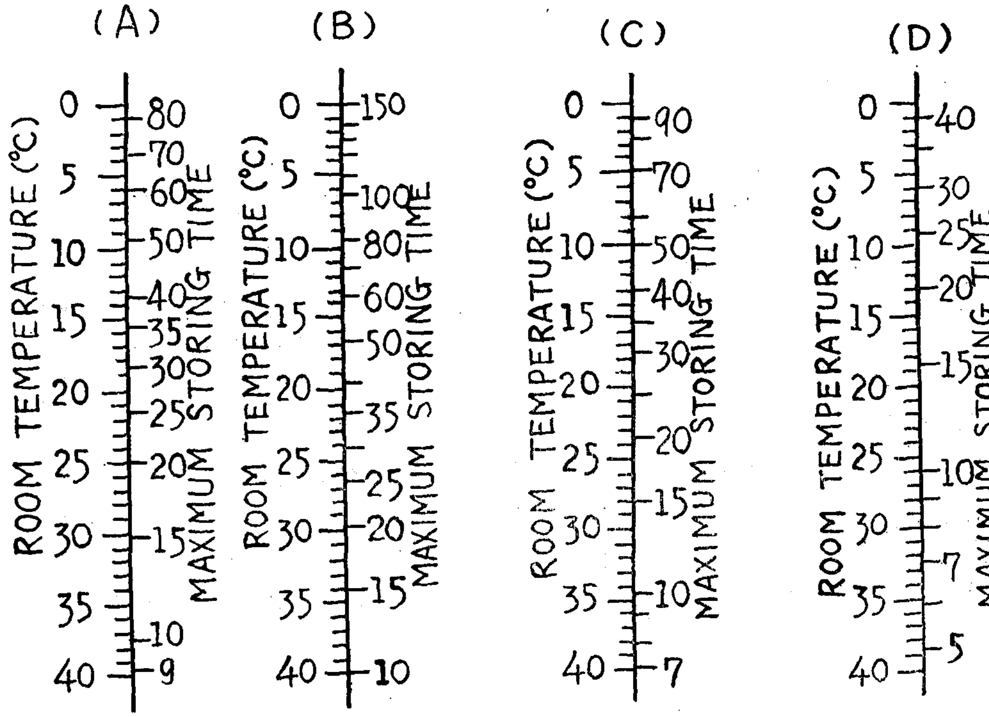

Fig. 4 Relation between storing temperature and maximum storing time for each samples.
(A) is in the case of storing crab body as it is.
(B) is in the case of storing boiled meat with crust after removal of carapace.
(C) is in the case of storing boiled meat without crust.
(D) is in the case of storing raw meat after removal from crust.

(*Erimacrus isenbeckii*) and the storing temperatures. In the scale, (A) is in the case of storing crab body as it is. This scale will be used for fresh raw crab meat. (B) is in the case of storing boiled meat with crust after removal of carapace, (C) is in the case of storing boiled meat without crust (In this case, a safety time added is 10 hours). This scale can be used in the cases of selecting meat operation and packing operation. (D) is in the case of storing raw meat after removal from crust; this scale is rarely used for normal canning process.

By those scales it becomes possible to know the maximum time limit of keeping crab meat (*Erimacrus isenbeckii*) at various storage termperatures, e.g. when storing temperature is 22°C, (A) is 24 hours, (B) is 34 hours, (C) is 23 hours and (D) is 13 hours.

If those maximum time limits for storing crab meat are known, the limit time is also known for storing cans packed (not yet sterilized) in front of the retort after the beginning of the operations of removing carapace, boiling, taking off meat, selecting of meat, and packing. Within those time limits, processing must be completed. In order to compare the calculted values from the author's scale with practical values in the canning process, various samples (Samples (II), (III), (IV) as stated above) were stored at 22°C, and the relation between storing time and the quality of canned crab made from samples was studied.

Table 4. The relation between different storing time at 22°C and the quality of canned crab meat.

	Time (hrs.)	Vacuum (inch)	pH	Volatile base-N (mg%)	Amino acid-N (mg%)	Blue meat.	Colour, taste, and odour of meat.	Result.
Raw crab meat, with crust without removal of carapace.	22	16	6.6	8	70	++	Normal	+++
	24	13	6.8	13	32	++	Normal. Loss the colour.	+++
	26	16.2	7.1	43	120	+++	Liguid turbid, abnormal smell.	+
After removal of carapace and boiling (with crust).	32	12.5	6.8	10	49	+	Normal	+++
	34	17.5	6.9	14	70	+	Normal. Loss the taste.	++
	36	Swell	7.1	140	274	++	Odour of H_2S gas. Turbid.	−
Crab meat, which taken off crust, after removeal of carapace and boiling.	20	12	6.8	17	83	++	Normal	+++
	23	15.2	6.9	23	58	++	Abnormal smell.	++
	26	15.2	7.1	43	150	+++	Liguid turbid. Tainted smell.	−

The experimental results were as shown in Table 4.

As seen in Table 4, the calculated value of maximum limit time of storing almost agree with the practical values.

4. Summary

The freshness of the meat of crab (*Erimacrus isenbeckii*) was artificially varied by leaving raw crab body as it was, or by leaving boiled meat with crust after removal of carapace.

The degree of freshness of those sample was determined by chemical test such as the estimation of the amount of volatile base nitrogen, amino acid nitrogen, value of pH, and

organoleptic test.

Crab 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 chemical and organoleptic tests. According to the previous experiments, it is known that raw or boiled meat, of which the amount of volatile base nitrogen is estimated as 20 mg% is no more fit material for canned crab.

The relation between the maximum limit time of storing of crab meat (*Erimacrus isenbeckii*) and the storing temperatures was discussed.

It was admitted that there was relation between storing temperature, θr, and storing time $t_{\theta r}$; the relation can be expressed by the equation $\log t_{\theta r} = A - B_{\theta r}$. This equation was applied for every sample which was treated by different operations. From the results obtained by using the equation, when the storing temperature is 22°C, the maximum limit time of storing the crab meat is found to be 24 hours in the case of boiled meat with crust after removal of carapace, 23 hours in the case of boiled meat without crust and 13 hours in the case of raw meat without crust. Those calculated values from the authors' scale are known to agree almost exactly with the practical values from experiment.

The value of Q_{10} for the crab meat was obtained as 1.7～2.0.

Literature cited

(1) KANEKO (1952) : The Canners Journal (Kanzume jiho) Vol. 31, No. 7, p. 78

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