STUDIES ON TECHNICAL PROBLEMS IN THE PROCESSING OF CANNED CRAB (*PARALITHODES CAMTSCHATICA* TILESIUS)

EIICHI TANIKAWA

Faculty of Fisheries, Hokkaido University, Hakodate, Japan.

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INTRODUCTION

1. Kinds of raw material of the canned crab

Economically important crabs produced in Japan are Alaska king crab (*Paralithodes camtschatica*), and "Ke-gani" (Horse-hair crab, *Erimacrus isenbeckii*). Besides, "Abura-gani" (*P. platypus*,) "Hanasaki-gani" (*P. brevipes*) and "Zuai-gani" (*Chinonectes opilio* (*O. fabricius*)) which are taken in less quantity, are processed for canning.

Alaska king crab is packed by Japanese packers on floating canneries or in land canneries. Other crabs are packed only in the land canneries.

The procedures in all cases are almost the same.

2. Processing of the canned crab

From the bodies of crabs which were captured by tangle nets (bottom gill nets) or by crab pots (for Horse-hair crab) the carapaces are removed.

Thus the legs are separated from the carapace. The carcasses from which the carapace were removed are put into netting bag made of manila twine with about 1.5 inch mesh; they are heated in boiling sea water in an iron tank. The boiling time is about 18~20 minutes for big crab (hard shell crab) when 200 carcasses are put in at one time, and about 17~18 minutes for small carcasses which can be put in at a rate of over 300 carcasses at one time.

After the cooked carcasses are removed from the cooking tank, they are cooled in cold sea water for about 10 minutes before further handling. The separating of the meat from the shell is done by a knife or scissors.

The meat separated from the shell is divided into body meat (shoulder meat), first leg meat (round meat), joint meat (so called scallion-type meat), second leg meat (so called pepper-type meat), claw meat, palm meat (scissor meat). The nomenclature of the body meat of *Paralithodes camtschatica* is shown in Fig. 1. Each type of meat is put into its own separate pan.

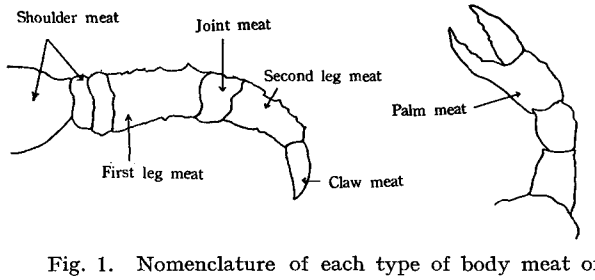

Fig. 1. Nomenclature of each type of body meat of *Paralithodes camtschatica*

After the separation of meat from the shell, the separated meat is transferred into the washing cages and washed in sea water in a tank.

After the washing, the shoulder meat holds its shape. The shoulder meat and leg meat which have gotten out of shape are degraded to "Flake meat".

The first and second leg meats are cut into segments of which the length is within the diameter of the can. The first leg meat holding its shape is used for the ornamental meat of the "First grade" (Fancy-style) canned crab. The second leg meat holding its shape is used for the ornamental meat of the "Third grade"-style canned crab.

The first and the second leg meats which have gotten out of shape are used as "Flake meat". The joint meat, and merus or wrist meats of cheliped are used for the "Flake meat" after deforming the shape. Palm meat (scissor meat) of cheliped is removed from the crust by crushing it.

Prepared crab meats are usually packed in parchment paper lined C-enameled 1/2-pound flat tin cans, of which the net content is 230 *g*. Occasionally a packer will use 1/4- or 1-pound flat can for special market.

The grades of canned crab are "Fancy", "Fair", "Third grade" ("Passed" A and B). In preparation of the "Fancy"-style cans, 2～4 large pieces of the first leg meat are placed in the top and bottom layers in order to show a good appearance; the shaped shoulder meat, and palm meat are placed in the sides. "Flake meat" is placed in the center. The "Fair" grade is the cans which were made as "Fancy-style", but the quality of the contents has not been passed as "Fancy" grade. The "Third grade" style is the cans in which the second leg meat or the broken meat (not flake meat) is placed in the top and bottom layers of the content, and "Flake meat" is placed in the center. When sea water is used for washing and boiling, the addition of salt is not needful. But when fresh water is used, salt must be added to the amount of about one *g* per 1/2-pound can. After the meat is packed in the can, the tops are clinched and then vacuum-sealed.

The sealed cans are placed in a retort where processing takes place for 80 minutes at a temperature of 227°F (108°C)～228.5°F (109°C) (5～5.5 pound pressure). After the processing, as soon as they are removed from the retort, cans must be cooled quickly.

The procedure for the canned horse-hair crab is almost the same as that for the canned king crab.

3. Scientific problems in the processing of canned crab

The crab industry is one of the important canning operations in Japan on the basis of export dollar value, so many studies have been undertaken from many years ago. By those studies, many technical problems or troubles have been solved. All the troubles which have occurred in the past and methods of preventing them are explained in a book by the present author, Eiichi TANIKAWA: "The processing of canned foods, (in Japanese), Kigensha, Tokyo".

The author has studied further the troubles and technical problems which have been called to his attention since the publication of that book.

For example, the author has reported in detail his studies on several problems in the

course of manufacture of canned crab from horse-hair crab (*Erimacrus isenbeckii*[1]). Recently, Kosakabe [2] (1957) has succeeded in preventing the appearance of the blue meat of the canned crab by "low temperature and fractional heating" of the carcasses from which carapace had been removed. In Japan the introduction of Kosakabe's method marks an epoch in the procedure of canning crab meat. However, resulting from the use of Kosakabe's method, derivative problems have occurred.

It is the purpose of this paper to describe the results of studies on those problems in the case of *Paralithodes camtschatica.*

Before going further the aurthor wishes to acknowledge with thanks the assistance rendered in this invesitgation through a grant in aid for the development of scientific research from the Minsitry of Education of Japan.

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I. Characteristics of raw king crab meat

1. *Velocity of bacterial decomposition of king crab meat*

It is well known that the crab meat is decomposable. The author[3] has previously reported the velocity of bacterial decomposition of the meat of *Paralithodes camtschatica* by estimating the amount of volatile basic nitrogen (V.B.-N) produced, and compared it with decomposition velocity of other marine creatures. According to the results obtained, the V.B.-N producing velocity constant (K), temperature constant (A) and temperature coefficient (Q_{10}) of the meat of those marine creatures are shown as in Table 1.

Table 1. V.B.-N producing velocity constant (K), temperature constant (A) and temperature coefficient (Q_{10}) of marine creatures

	King crab	Horse-hair crab	Salmon	Atka-mackerel	Mackerel	Saury	Squid	Sea-cucumber
$K\times10^3$ (30°~37°C)	78	91	63	60	114	49	150	29
$K\times10^3$ (25°~27°C)	—	74	38	36	99	30	103	28
Q_{10}	1.6	1.2	2.0	3.5	3.6	1.3	1.6	1.5
A	7,700	2,900	12,000	21,000	22,000	5,000	9,000	7,000

The values of $K\times10^3$ of king crab and horse-hair crab are larger than those of fish meat except mackerel meat, but they are smaller than the same value of squid meat.

Comparing king crab meat with horse-hair crab, the former shows less value of $K\times10^3$ than the latter, that is to say, the former is less decomposable than the latter. The values of "Q_{10}" and "A" of the fomer are larger than those of the latter. According to the results

previously obtained, when the amount of V.B.-N rises above 20 *mg*% in king crab meat, the meat becomes undesirable as does horse-hair crab meat also. The author has called this amount of V.B.-N that is 20 *mg*%, the limit of freshness of crab meat suitable for use as the raw material for canned food.

2. Why is the raw crab meat more decomposable than fish meat?

The author[4] has previously studied the chemical and physico-chemical properties of *Paralithodes camtschatica* meat.

According to the results obtained, it is remarkable that *Paralithodes camtschatica* meat has larger amount of water-content and less amount of crude fat than that of fish meat, but there is no difference of the protein-content between the two sorts of meat. The greater part of the total amount of nitrogen in *Paralithodes camtschatica* meat was extractive nitrogen in water soluble state. The amount of dissolved nitrogen substances are good media for the bacteria. One of the causes of the fact that the amount of dissolved nitrogen is larger may be the histological characteristics of the crab meat. From the histological observation, in the leg meat, the blocks of muscular fiber bundles are, respectively, surrounded by a thick layer of gelatinous tissue. This is different from the fish meat, in which the muscular fiber bundles are distributed closely and uniformly throughout the gelatinous tissue. Therefore, when the crab flesh is soaked in water, the blocks are deformed.

The soluble nitrogen substances are contained in net-work constructions in gelatinous tissue as body fluid. When bacteria invade into the crab meat, they may utilize the soluble nitrogen and multiply and deform the tissue.

The multiplied bacteria begin to play an imporant rôle in the decomposition of the crab meat.

II. Maximum storing time of PARALITHODES CAMTSCHATICA meat as raw material for canning

If unfresh raw material is empolyed, canned crab of good quality is not obtainable just as in other canned foods; then, what degree of the freshness of the raw material is the limit? And what is the limit number of hours as the maximum permissible storing time of *Paralithodes camtschatica* meat?

This storing time depends on the storing temperature. The author[1)3)5)] has previously determined the amount of V. B.-N produced in raw meat of many kinds of fish meat, and has learned that when that amount of *Erimacrus isenbeckii* meat or *Paralithodes camtschatica* meat rises over about 20 mg%, the meat becomes unfit for canning.

The author[3)], then, has studied the relation between storing temperature and maximum time ("t_{20}") during which *Paralithodes camtschatica* meat can be stored and still remain suitable as raw material for canning.

An equation has been devised showing the relation between the value of "$\log t_{20\theta}$", the length of the time until which the amount of V.B.–N attained 20 *mg*% and the storing tem-

perature, θ.

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

Here, "α" and "β" are constants.

This equation was applied for every sample which was treated by different operations, and the following equation was obtained for the raw meat with the crust.

$$\log t_\theta = 2.02 - 0.03\,\theta$$

From those data, the author has prepared a scale as shown in Fig. 2 in which showing the relation between storing temperature and maximum storing time of *Paralithodes camtschatica* meat as raw material for canned crab.

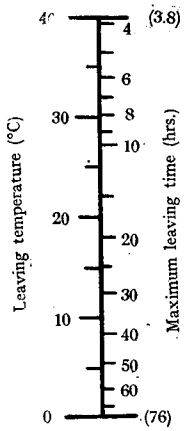


Fig. 2. Relation between storing temperature and maximum storing time of *Paralithodes camtschatica* meat

From Fig. 2, the maximum storing time (hrs.) for the raw fresh material can be learned. For example, at 15°C, the maximum storing time may be learned to be 26 hrs. It is advisable to know the maximum storing time for the raw fresh crab meat from the stand point of rational processing.

III. Maximum storing time of boiled crab meat for canning after heating at "high" or "low temperature"

The carcasses from which the carapace was removed are heated in sea water of high temperature or low temperature. Hitherto, the crab meat in the crust was boiled in boiling sea water, so workers could easily tear off the meat from the crust as a result of the hardening of meat protein.

Recently, in order to prevent the blueing of canned meat or to make canned boneless crab meat, the so called "low temperature boiling method" has been devised by Kosakabe[2]. By that "low temperature boiling method" (60°C for 20 minutes), myosin of the crab meat protein is coagulated, but haemocyanine, a blood protein, is not coagulated. The meat remains in half-boiled state. This meat can be pushed out by pressing of a roller or by water pressure. The pushed meat is soaked to allow flowing out of the blood containing haemocyanine. After having soaked for 10 minutes, the soaked meat is boiled for 3 minutes in sea water to harden it. Then the myogen in the meat protein coagulates in the same manner as that obtained by the usual boiling method. This boiling is called "Yudōshi" (hardening-boiling). The usual boiling method is called the "high temperature boiling method" in contrast to the "low temperature boiling method." When the crab meat boiled by the "high temperature boiling method" or "the low temperature boiling method" is left for a long time, the freshness of the meat becomes unfit for canning. The limit freshness of the crab boiled meat differs properly from that of the raw meat (20 *mg*% of V.B.-N). In fact, the degree

of the freshness of raw meat is scientifically not inspected, but that of the boiled meat is inspected by organoleptic test in canneries. It is rather necessary to know the limit of freshness of the boiled meat and the maximum storing time (hrs.) before the limit is reached.

The maximum storing time depends on the freshness of the meat before the boiling. The freshness of the boiled meat when treated by the "low temperature boiling method" falls depending on the storage temperature and the length of storage before the "hardening-boiling", because this boiled meat treated by "low temperature boiling method" is decomposable by autolytic enzyme. Study was made on the variation of the freshness during the storing after the crab meat was treated by the method of "high temperature" or "low temperature boiling". The limit of freshness of the boiled meat was determined.

1. Variation of freshness of the boiled crab meat treated by the "high temperature" or "low temperature boiling method"

(1) Experimental method

Crab which was captured off Saghalein was classified into two groups: hard shell crab and soft shell crab. The two groups of the material were divided into fresh and unfresh crab. The amount of V.B.-N in fresh hard shell crab meat was 6.3 *mg*%, while that in fresh soft shell crab meat was 6.2 *mg*%, and that in unfresh hard shell crab meats was 16.7, 25, 33.7 *mg*%, respectively (in this case soft shell crab was not employed). A group of samples of those meats having crust which was fresh or unfresh was boiled by the "high temperature boiling method" (100°C, 18 minutes). After the boiling, the meat was left at room temperature (5°~10°C) or in an ice box (3°C), and was estimated for the amounts of V.B.-N and amino-N, pH and bacterial counts. The amount of V.B.-N was estimated by Conway's method, that of amino-N was by Pope-Stevens' method and pH value by a glass electrode apparatus. The bacterial count was done by decimal dilution method employing Burri's tube in order to develop anaerobic thermotolerant bacteria.

Another group of crab carcasses was heated by the "low temperature boiling method" (60°C, 10 minutes); this half-boiled meat was pushed out from the crust and soaked in cold water for 10 minutes; the soaked meat was boiled at 100°C for 3 minutes by "hardening-boiling". The meat was left at room temperature (5°~10°C), or at 3°C and 0°C (in refrigerator).

(2) Experimental results

Results obtained are shown in Tables 2~13 and Figs. 3~6.

As seen in Tables 2~13 and Figs. 3~6, the amounts of V.B.-N and amino-N in fresh crab meats boiled by "low temperature boiling method" increased larger and more rapid than those by "high temperature boiling method".

This may be caused by autolytic action and bacterial action which were remaining even after subjection to "low temperature boiling method", and because of the smaller

Table 2. Variation in the freshness of fresh hard shell crab (V.B.-N, 6.3 mg%) subjected to "high temperature boiling method" and left at 3°~5°C

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Amino-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.6	6.3	—	5×10^2	Good frerhness
(After boiling)					
2	6.7	10.9	68	2.5×10^2	Normal
6	6.7	15.8	113	2.5×10^2	〃
20	6.8	16.3	136	3.5×10^2	Meat was slightly softened
40	6.8	17.2	209	2.4×10^3	Meat was softened, Color was yellowish
52	6.9	20.2	200	3.5×10^4	Ibid., Off flavour
60	6.9	—	—	6.5×10^4	Same as above

Table 3. Variation in the freshness of fresh soft shell crab (V.B.-N, 6.2 *mg*%) subjected to "high temperature boiling method" and left at 3°~5°C

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Amino-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.6	6.2	—	5×10^2	Good freshness
(After boiling)					
2	6.7	10.8	106	1×10^2	Normal
6	6.8	11.2	137	—	〃
20	6.9	12.0	144	3.3×10^2	〃
40	7.0	15.5	—	1.4×10^3	Meat was slightly softened
52	7.0	19.5	—	2.4×10^2	Off flavour
60	7.0	—	—	—	

Table 4. Variation in the freshness of pretty unfresh hard shell crab (V.B.-N, 16.7 *mg*%) subjected to "high temperature boiling method" and left at 0°~5°C

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.2	16.7	2×10^3	Pretty fresh
(After boiling)				
2	6.4	12.0	1×10^3	Normal
24	6.4	15.0	2×10^3	Color was slightly yellowish
48	6.6	16.4	5×10^3	Meat was slightly softened
52	6.7	19.1	6×10^4	Ibid., Slightly stench
72	6.7	23.4	—	Stench
100	6.9	28.5	—	Ibid.

Table. 5. Variation in the freshness of unfresh hard shell crab (V.B.-N, 25 *mg*%) subjected to "high temperature boiling method" and left at 5°~10°C

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.4	25.0	5×10^3	Pretty fresh
(After boiling)				
0	6.4	7.1	2×10^3	Meat was softened. Off flavour
3	6.2	5.4	2×10^3	Ibid. Color was yellowish
48	6.4	7.2	5×10^3	Same as above
56	6.6	12.3	2×10^5	Slightly putrefactive odour
72	7.6	80.5	above 10^6	Remarkably putrefactive odour
96	8.2	106.7	〃	Ibid.

Table 6. Variation in the freshness of very unfresh hard shell crab (V.B.-N, 33.7 *mg*%) subjected to "high temperature boiling method" and left at 5°~10°C

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.8	33.7	1×10^4	Unfresh
(After bolling) 0	6.8	9.3	8×10^3	Meat was softened. Color was yellowish. Slightly putrefactive odour
24	7.1	17.3	2×10^4	Same as above
48	7.2	22.2	3×10^4	〃
72	7.2	24.6	3×10^5	Remarkably putrefactive odour
96	7.4	25.8	10^6	Same as above

Table 7. Variation in the freshness of very unfresh hard shell crab (V.B.-N, 33.7 *mg*%) subjected to "high temperature boiling method" and left at 0°C

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.8	33.7	1×10^4	Unfresh
(After boiling) 0	6.8	9.3	8×10^3	Putrefactive odour. Meat was softened
24	7.2	13.4	1×10^4	Same as above
48	7.2	12.6	1×10^4	〃
72	7.4	12.3	1×10^4	〃
96	7.2	13.7	2×10^4	〃
120	7.2	12.3	2×10^4	〃
144	7.2	18.1	5×10^4	〃

Table 8. Variation in the freshness of pretty unfresh hard crab (V.B.-N, 16.7 *mg*%) subjected to "low temperature boiling method" and left at 0°~5°C for various lengths of time

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.2	16.7	2×10^3	Pretty unfresh
(After boiling) 2	6.2	10.4	1×10^3	Normal
24	6.4	10.8	3×10^3	〃
48	6.5	14.3	2.5×10^3	Meat color was yellowish
52	6.6	19.4	5×10^4	Meat was softened. Off odour
72	6.7	21.6	—	Same as above
100	6.8	27.9	—	Putrefactive odour

Table 9. Variation in the freshness of unfresh hard crab (V.B.-N, 25 *mg*%) subjected to "low temperature boiling method" and left at 5°~10°C for various lengths of time

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.4	25.0	5×10^3	Unfresh
(After boiling) 0	6.4	8.2	2×10^3	Meat was softened. Off odour
3	6.0	6.0	2×10^3	Ibid. Color was yellowish
48	6.4	8.2	8×10^3	〃
56	6.7	14.9	5×10^5	Same as above
72	7.2	73.7	above 10^6	Putrefaction
96	8.4	131.0	〃	〃

Table 10. Variation in the freshness of fresh hard crab (V.B.-N, 6.3 *mg*%) subjected to "low temperature boiling method" and left for various times at 3°~5°C before and after hardening boiling

By low-temp. boiling method at 60°C for 10 mins.						Hardening boiling at 100°C for 3 mins.	Leaving time after the hardening boillng								
							4 hrs.			20 hrs.			54 hrs.		
Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Amino-N (*mg*%)	Bacterial counts (per *g*)	Appearance		pH	V.B-N (*mg*%)	Bacterial counts	pH	V.B.-N (*mg*%)	Bacteril counts	pH	V.B.-N (*mg*%)	Bacterial counts
Before boiling	6.6	6.3	—	5×10^2	Fresh										
(After boiling) 2	6.3	10.1	136	3.3×10^2	Normal										
6	6.7	16.4	189	5.0×10^2	〃	——→	6.5	10.5	1×10^2	6.6	10.8	2×10^2	6.7	14.0	1×10^4
20	6.8	17.7	212	8.6×10^3	Meat was softened	——→	6.6	11.0	1×10^2	6.6	11.0	1×10^3	6.8	15.9	3×10^4
40	6.8	22.0	240	4.5×10^3	〃	——→	6.6	11.0	1×10^3	6.6	11.2	—	6.8	18.8	5×10^4
60	7.2	50.8	—	3.5×10^5	Putrefactive odour										

Table. 11. Variation in the freshness of fresh soft shell crab (V.B.-N, 6.2 *mg*%) subjected to "low temperature boiling method" and left for various times at 3°~5°C before and after hardening boiling

By low-temp. boiling method at 60°C for 10 mins.						Hardening boiling at 100°C for 3 mins.	Leaving time after the hardening doiling								
							4 hrs.			20 hrs.			54 hrs.		
Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Amino-N (*mg*%)	Bacterial counts (per *g*)	Appearance		pH	V.B.-N (*mg*%)	Bacterial counts	pH	V.B.-N (mg%)	Bacterial counts	pH	V.B.-N (*mg*%)	Bacterial counts
Before boiling	6.6	6.2	—	5×10^2	Fresh										
(After boiling) 2	6.2	7.9	159	5.3×10^2	Normal										
6	6.5	10.4	170	6.3×10^2	〃	——→	6.4	7.4	5×10^2	6.5	10.3	2×10^3	6.6	11.9	3×10^3
20	6.6	13.5	190	3.5×10^3	Meat was softened. Off flavor	——→	—	—	—	6.6	12.3	3×10^3	6.7	16.5	1×10^4
40	6.9	22.4	257	4.5×10^3	Slightly putre-factive odour	——→	—	—	—	6.6	12.9	3×10^3	6.8	19.0	1×10^4
60	7.0	43.7	325	4.0×10^5	Putrefaction										

Table 12. Variation in the freshness of very unfresh hard crab (V.B.-N, 33.7 *mg*%) subjected to "low temperature boiling method" and left at 5°~10°C for various lengths of time

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.8	33.7	1×10^4	Unfresh
(After boiling)				
0	6.8	14.2	8×10^3	Meat was softened. Putrefactive odour
24	7.0	10.3	1×10^4	〃
48	7.2	21.1	2×10^4	〃
72	7.4	25.4	8×10^4	〃
96	33.6	33.6	1×10^6	〃

Table 13. Variation in the freshness of very unfresh hard crab (V.B.-N, 33.7 *mg*%) subjected to "low temperature boiling method" and left at 0°C for various lengths of time

Leaving time (hrs.)	pH	V.B.-N (*mg*%)	Bacterial counts (per *g*)	Organoleptic observation
Before boiling	6.8	33.7	1×10^4	Unfresh
(After boiling)				
0	6.8	14.2	1×10^4	Meat was softened, Off odour
24	7.2	14.7	1×10^4	Slightly putrefactive odour
48	7.4	17.8	3×10^4	Putrefactive odour
72	7.4	17.2	3×10^4	〃
96	7.7	23.5	8×10^4	〃
120	7.5	23.2	1×10^5	〃
144	7.6	24.6	1×10^5	〃

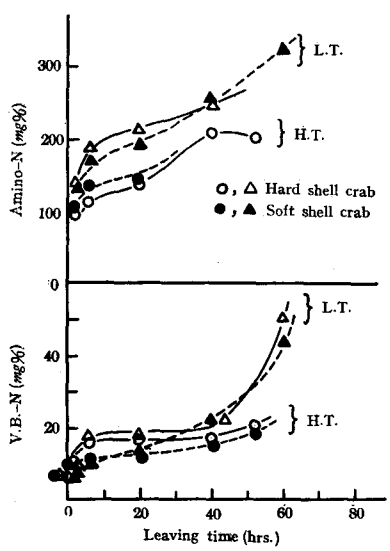


Fig. 3. Variation of the amount of V.B.-N and amino-N in the hard or soft shell crab meats subjected to "high" or "low temperature boiling method" respectively and left at 5°C

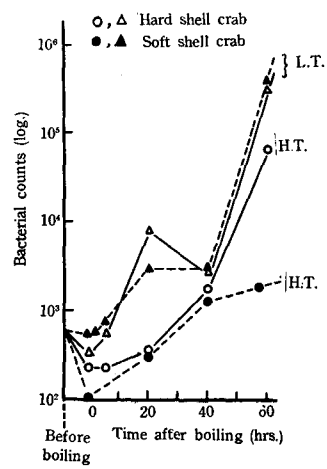


Fig. 4. Variation of the bacterial number in hard or soft shell crab meats subjected to "high" or "low temperature boiling method" respectively and left at 5°C

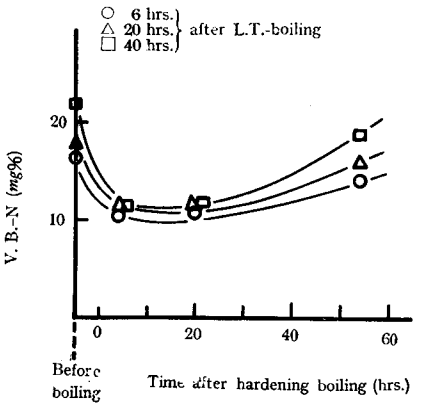


Fig. 5. Variation of the amount of V.B.-N in frsh hard crab meat (V.B.-N, 6.3 *mg*%) subjected to "low temperature boiling method" and then treated by "hardening boiling" after various tmies and left

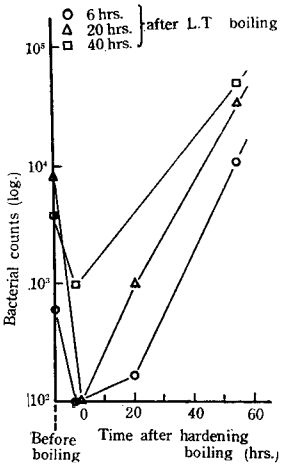


Fig. 6. Variation of the bacterial counts in fresh hard crab meat (V.B.-N, 6.3 *mg*%) subjected to "low temperature boiling method" and then treated by "hardening boiling" after various times and left

amount of dehydration; consequently the nutrient components for bacteria remain in the meat.

Therefore the boiled crab meat prepared by "low temperature boiling method" must be more rapidly transferred to the next procedure than that subject to "high temperature boiling method". It is remarkable that on V.B.-N producing curves of the boiled crab meat, the increaseing velocity of the produced amount of V.B.-N is gradual (lag period of the production curve is comparatively long) and it increases rapidly after the amount of V.B.-N reached to about 20 *mg*%.

But the amount of amino-N increases rapidly from the initial storing period. The amount of V.B.-N and the bacterial counts increase in boiled crab meat treated by "low temperature boiling method" after long storing time, but they decrease after the "hardening-boiling". However, the once decreased amount of V.B.-N and bacterial counts increase with prolongation of the storing time.

Even if the boiled meat prepared by "low temperature boiling method" which was left for a long time, shows less than 20 *mg*% of V.B.-N, the meat becomes soft and emits decomposed odour. If the boiled crab meat prepared by "low temperature boiling method" is left for a long time, the amount of V.B.-N and the bacterial counts after the "hardening boiling" are larger than that if left for a short time; the increase after the "hardening boiling" is larger in long storing than in short storing.

2. The limit freshness of boiled crab meats prepared by "high" or "low temperature boiling method", when the raw meat has various degree of freshness before the boiling

In the previously described experiment, the author has compared the decomposing velocities of the boiled crab meats which were treated by "high temperature boiling," and were left for various periods of time. The boiled crab meats having various degrees of freshness were processed for canning. The quality of the canned crab thus processed was inspected, and the limit of the freshness of the boiled crab meat was determined from the view point of suitability as material for canning.

(1) Experimental method

Raw crab meats having various degrees of freshness (the amounts of V.B.-N were 4.8 *mg*%, 17.0 *mg*%, and 36.9 *mg*%, respectively) as shown in Table 14, were subjected to the "high temperature boiling method" (at 100°C, 18 minutes) or to the "low temperature

Table 14. Record of crab meat employed in the experiments

Degrees of freshness of raw meat (V.B.-N, *mg*%)	4.8, 17.0, and 36.9 *mg*%
Boiling method	High temp. boiling method and low temp. boiling method
Leaving temperature after boiling	0°~3°C and 10°~13°C
Leaving time after boiling	0, 24, 48, 72 and 96 hrs.

boiling method" (at 65°C, 10 minutes) and were left at 0°~3°C, 10°~13°C from 0 hour to 96 hours. Those boiled crab meat samples were divided into two groups. One of them was estimated for pH of the meat, amount of V.B-N and organoleptic test as definite intervals of storing time. The other group was processed for canning respectively at the same intervals. In the case of use of the "low temperature boiling method", after respective storing times, the boiled meats were subjected to "hardening boiling" (at 100°C, 3 minutes), and processed for canning as usual (sterilizing temperature was 6 pound-pressure for 95 minutes).

The cans processed thus were stored for a month in the laboratory and then opened. The quality of cans was examined for pH, amounts of V.B.-N, aminoN-, reducing sugar, and color of the meat; odour components test was also applied.

(2) Experimental results

According to the inspection of the quality of the canned crab processed as above described, the cans which were from the raw crab meat having below 20 *mg*% of V.B.N- and were treated by the "high temperature" or "low temperature boiling 'method", and were then processed, all had good quality. But those cans which were processed from the raw material having above 20 *mg*% V.B.-N and subjected to exactly the same method as

above described, were ascertained to be not good in quality : in texture, taste, odour, nor in color of the content meat. Those results were agreed with the results obtained previously by the author[3]. Even if the raw fresh crab meat was employed, with the lengthening of storage time after boiling, the quality of the contens of the cans becomes worse. In this case, the canned crab meat which was processed from the boiled meat treated by "low temperature boiling method" falls in quality more rapidly than that processed by "high temperature boiling method". With rising of the storing temperature afte the boiling, the quality falls more rapidly than in the case of the comparatively lower storing temperature.

As to the odorous components in stored boiled crab meat, the author has found cadaverine, lactic acid, propionic acid, iso-butylaldehyde, formaldehyde, acetaldehyde besides the components found in normal canned crab (methylamine, trace of formic acid and acetic acid).

From the results obtained in the present experiment, the limit of freshness of the boiled crab meat for good quality cans may be shown in terms of the amount of V.B.-N as recorded in Table 15. That is to say, when the freshness of the raw crab meat is below 10 *mg*% V.B.-N, the limit of the freshness of the boiled meat is 15 *mg*%; and when the

Table 15. Relation between the degrees of freshness of raw crab meat and the limit of freshness of boiled crab suitable for the material of canning.

Degrees of freshness of raw material (V.B.-N, *mg*%)	Limit of freshness of the boiled material
Below 10 *mg* %	Below 15 *mg* %
10~20 *mg* %	10~13 *mg* %

freshness of the raw crab meat is 10~20 *mg*%, the limit of the freshness of the boiled meat should be 10~13 mg%.

When the freshness of the raw crab meat is above 20 *mg*%, even if the raw meat is boiled and processed for canning without delay, good quality of canned crab is not obtainable. This accords with previous results.

3. Relation between storing temperature of the boild crab meat and maximum storing time

The maximum storing time before the limit of the freshness of the boiled crab meat is reached, depends on the storing temperature. It is also advisable to know the maximum storing time for the boiled crab meat at each storing temperature from the standpoint of rational processing.

Under this heating, the author will discuss the relation between the maximum storing time before the limit of the freshness of the boiled crab meat is reached and the storing temperature of basis on the experimental results reported in the previous articles : eight

sets of results are shown in Table 16.

Table 16. Experimental program for study on the relation between storing temperature of the boiled crab meat and maximum storing time

Experiments	Freshness of raw material (V.B.-N, *mg*%)	Boiling method	Leaving temp. after boiling
A	6.3	(1) H.T. (2) L.T.	3°C
B	6.3	(1) H.T. (2) L.T.	13°C
C	16.7	(1) H.T. (2) L.T.	3°C
D	17.1	(1) H.T. (2) L.T.	13°C

From the variations in the amount of increase of V.B.-N in the boiled crab meats which are shown in Table 16, the velocity constant of the V.B.-N production curve were calculated from equation (2) of monomolecular reaction after Kimata[6].

$$\log y/A - y = Kt + C \quad \cdots\cdots\cdots (2)$$

Here, "y" is the increased amount of V.B.-N after "t" hours. "A" is the maximum amount of V.B.-N produced. "C" is a constant, and "K" is the velocity coefficient. Then, temperature coefficient "Q''_{10} is represented by equation (3).

$$\frac{K_{\theta+10}}{K_{\theta}} = Q_{10} \quad \cdots\cdots\cdots\cdots (3)$$

Here, "K_{θ}" and "$K_{\theta+10}$" are velocity constants at the temperatures θ°C and $(\theta+10)$°C, respectively. From equation (3), the temperature coefficient "Q_{10}" was calculated. The results calculated are shown in Table 17

Table 17. Relation between the values of "K" and "Q_{10}" when boiled crab meats treated by both "high" and "low temperature boiling methods" were stored at various temperatures

Freshness of raw material (V.B.-N, *mg*%)	Boiling method	Leaving temp.	$K \times 10^3$	Q_{10}
6.3	H.T.	3°C 13°C	4 10	2.5
6.3	L.T.	3°C 13°C	13 30	2.3
16.9	H.T.	3°C 13°C	26 60	2.3
16.9	L.T.	3°C 13°C	29 63	2.2

As seen in Table 17, the V.B.-N production velocity constant, "K", of the boiled crab meat is larger at higher storing temperature than at lower storing temperature. It is also larger in the boiled crab meat prepared by "low temperature boiling method" than that prepared by "high temperature boiling method". It is also larger in the boiled crab meat which was unfresh raw material than in that which was fresh.

That is to say, it was learned that the boiled crab prepared meat by "low temperature boiling method" is more decomposable than that prepared by "high temperature boiling method", and that the boiled meat made from unfresh raw crab meat is more decomposable than that made from fresh.

There was no difference between the values of the temperature coefficient, "Q_{10}", of the boiled crab meat subjected to "high temperature boiling method" and that by "low temperature boiling method". The mean value of "Q_{10}" was 2.3. Considering on the basis of the inspection standard previously proposed, that the limit freshness of the boiled crab meat is about 15 *mg*% of V.B.-N, when the raw crab was below 10 *mg*% of V.B.-N, and about 12 *mg*% when 10~20 *mg*%, the time required to reach the limit freshness, "t_{15}" or "t_{12}" can be obtained for the boiled crab meats treated by "high" or "low" boiling methods which have had various degrees of freshness of raw meat and which were left at 3°C.

The results obtained are shown in Table 18.

Table 18. The values of "t_{15}" and "t_{12}" of boiled crab meats which were subjected to "high" and "low temperature boiling methods" and stored at 3°C

Freshness of raw material (V.B.-N *mg* %)	Boiling method	t_{15} of t_{12}
6.3	H.T.	$t_{15} = 6.5$
	L.T.	$t_{15} = 5$
16.9	H.T.	$t_{12} = 4$
	L.T.	$t_{12} = 3.5$

From Table 18, the value of "t_{15}" or "t_{12}" will be seen to be smaller in the boiled crab meat perpared by "low temperature boiling method" than in that by "high temperature boiling method," and also smaller in the bolied crab meat made from unfresh raw meat than in that from fresh raw meat. That is to say, the samller the value of "t_{15}" or "t_{12}", the shorter the time required to reach to the freshness limit.

The case in which the boiled meat was left at 13°C was examined, but it was difficult to determine accurately the values of "t_{15}" or "t_{12}", owing to the fact that the temperature was higher than 3°C.

According to the results obtained by the present author[1,3] or Kaneko[7] who have practical experience in the processing of the canned crab, there is an equation (4) between the storing temperature, "θ", and the time required to reach the decomposition, "t_θ".

$$\log t_\theta = \alpha - \beta\theta \quad \cdots\cdots\cdots (4)$$

Here, α and β are constants.

Relation between the storing temperature, "θ", and the time, "log t_θ", shows linear. Also there is the following equation between two storing temperatures, θ_1 and θ_2.

$$\log \frac{t_{\theta_2}}{t_{\theta_1}} = \frac{\theta_2 - \theta_1}{10} \log Q_{10} \quad \cdots\cdots\cdots (5)$$

Here, "t_{θ_1}" and "t_{θ_2}" are the times required to reach the decomposition stage at the temperatures θ_1 and θ_2 respectively. "Q_{10}" is temperature coefficient. Therefore, if θ_1=3°C and θ_2=13°C, $\theta_2-\theta_1$=10°C, then equation (5) becomes briefly $\frac{t_{\theta_2}}{t_{\theta_1}} = Q_{10} \cdots\cdots\cdots (6)$

The values of "Q_{10}" are obtained being 2.3 (mean value) from Table 17.

If the value of "t_{θ_1}" at 3°C (t_{15} or t_{12} at 3°C) is known from Table 17, then the value of "t_{θ_2}" at 13°C ("t_{15}" or "t_{12}" at 13°C) will be obtained.

From each value of "t_θ" obtained, the relation between "log t_θ" and "θ" is shown being linear as in Fig. 7.

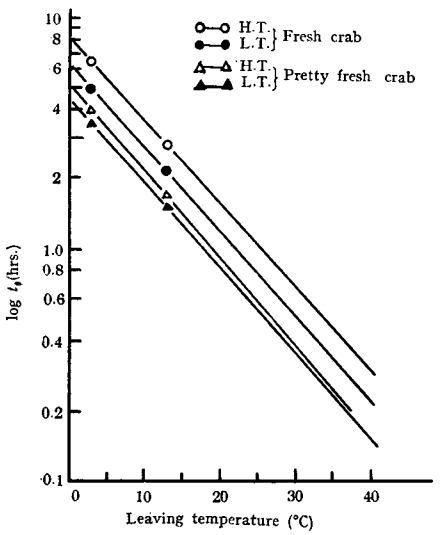


Fig. 7. Relation between the storing temperature "θ" and the time "log t_θ"

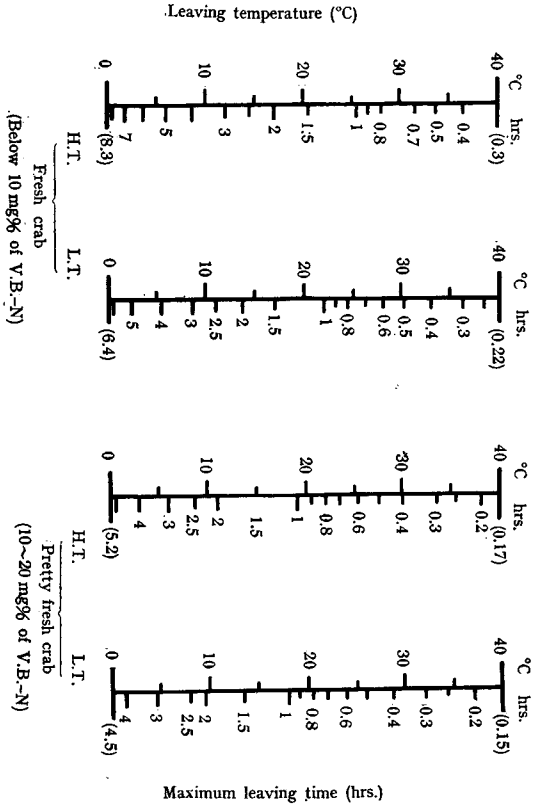


Fig. 8. A scale showing the relation between storing temperature and the limit of freshness in the boiled crab meat

(Fig. 8.)

From Fig. 7, the relation between storing temperature and the limit freshness in the boiled crab meat prepared by each boiling method from the raw crab meat having various freshness is shown as a scale in Fig. 8.

According to Fig. 8, for example, if fresh raw crab meat with the crust (V.B.-N of the raw meat is below 10 *mg*%) is boiled according to "high temperature boiling method" and left at 15°C, the time required to reach the limit freshness will be 2.4 hours. If pretty unfresh raw crab meat with the crust, (V.B.-N of the raw meat is 10~20 *mg*%) is boiled according to "high temperature boiling method" and left at the same temperature, the time will be 1.4 hours. If the pretty unfresh carb meat is boiled according to "low temperature boiling method" and left at the same temperature, the time will be 1.3 hours. That is to say, it is easily known within what storing time the respective lots of crab meat should be processed.

The maximum storing times obtained by the present author are seen to be pretty too severs; but in the actual procedures, the freshness of each raw crab body is different, so some safety factor should be added. For example, the raw crab bodies in the lower layer of a shipment fall rapidly in freshness.

IV. Calculation of processing time at different temperature for various degrees of freshness of raw or boiled crab meat

It is clear that the degree of freshness of raw crab influences the quality of the canned crab as above described. That degree has some influences not only upon the quality, but also upon the effects of the processing. The determination of the processing time for canned foods according to the freshness of the raw material or boiled meat is very important. The author has studied the calculation of the processing time of canned crab using the same formula as that for canned salmon.[8)]

The important difference of canned crab from canned salmon is the boiling of the raw crab meat with the crust before the filling into cans, in order to remove the meat easily from the crust.

It was described as above that there are two methods for the boiling of the raw crab carcasses. By the high temperature boiling procedures, the actions of enzymes and bacteria are prevented, but the freshness will fall with the elongation of the storing period of the meat boiled at higher temperatures. Therefore the number of bacteria in the meat filled into cans before the processing, varies according to the storing time and temperature. The bacteria are considered to have attached to the raw meat and to have survived in the boiled meat even after the boiling and then to have multiplied. Therefore, those bacteria are considered to be thermotolerant. The kind and the number of the bacteria which survived are different according to the boiling methods, and the storing conditions.

Therefore, the processing time should be controlled in connection with the boiling methods and the storing conditions (temperature and time).

Determination was first made of the upper and lower limits of the processing

temperature, then the processing time was calculated on the basis of the number of bacteria attached to the raw and boiled crab meats between the two limits.

1. The highest processing temperature for the canned crab

The highest processing temperature varies by the freshness of the raw material. For example, when the unfresh raw crab meat is processed at the same highest temperature as fresh raw crab meat, the color and odour of the canned product will become worse and have smell of burning. Here, the author has determined the highest processing temperature for the boiled crab meat treated by "high temperature boiling method", which was left for various storing times at different temperatures, and then processed to the canned crab.

(1) Experimental method

From *Paralithodes camtschatica* bodies captured off Nemuro, Hokkaido, and was landed, the carapace was removed immediately after the landing.

The carcases were boiled at 100°C in sea water, and were left with the crust as follows: (1) left in cool place (2°~10°C) over one night (this is called fresh raw meat; V.B.-N was 6~10 *mg*%), (2) left at the same temperature over two nights (this is called pretty unfresh raw meat; V.B.-N, 15~20 *mg*%), (3) left at the same temperature over three nights (this is called unfresh raw meat: V.B.-N 25~30 *mg*%). Those samples having various degrees of freshness were packed in 1/2 pound flat cans, and were processed at different temperatures (100°~115°C) for different processing times (50, 70, 90 minutes, repectively). The finished sample cans were brought to the laboratory, and then opened. The qualities of the cans were examined both organoleptically and chemically (pH, V.B.-N), and the relation between the freshness of the raw material and processing conditions (temperature and time) was determined and the highest processing temperature for the canned crab was decided.

(2) Experimental results

Results obtained are shown in Tables 19~21.

The quality of the canned crab in Table 21, which was processed from the unfresh raw material (V.B.-N 25~30 *mg*%) was inferior in taste, color and odour. This raw matarial was over the limit of freshness of raw material for canning. The quality of the canned crab in Table 20, processed from pretty unfresh raw material (V.B.-N, 15~20 *mg*%) showed that it is merchantable. The quality of the canned crab in Table 19 processed from the fresh raw material (V.B.-N, 6~10 *mg*%) was good. Commercial canned crab is generally processed from such fresh raw crab.

The influences of the processing factors (temperature-time) upon the quality of the canned crab having different degrees of freshness of the raw material are observed also in Tables 19~21. In the canned crab processed from fresh raw material shown in Table 19, with the rising of the processing temperature, the amount of V.B.-N increased proportionally from the initial amount of V.B.-N in the raw meat. But above 112.7°C (8 pound pressure), the amount of V.B.-N in the canned crab meat showed converse tendency, rather decreased.

Table 19. Quality of the canned crab processed from the fresh raw material (V.B.-N, 6~10 *mg*%)

Processing temp. (°C) (or pressure)	Processing time (mins.)	Quality of canned product							
		V. B. -N in meat (*mg*%)	pH of meat	Color of juice	Colour of meat		Elasticity of meat	Flavour	Isolation of bacteria
					Red meat of surface part	White meat of inner part			
105.3°C (3 *lbs*-press.)	50	19.0	6.8	Slightly bluishbrown	Light pinkish	White opaque	Good	Good	+
	70	24.1	6.7	〃	〃	〃	〃	〃	+
	90	26.4	6.7	〃	〃	〃	〃	〃	−
106.9°C (4 *lbs*-press.)	50	21.3	6.7	〃	〃	〃	〃	〃	+
	70	26.7	7.1	Bluishbrown	〃	〃	〃	〃	−
	90	29.9	6.9	Slightly bluishbrown	〃	〃	〃	〃	−
108.4°C (5 *lbs*-press.)	50	20.6	6.8	〃	〃	〃	〃	〃	−
	70	23.9	6.9	〃	〃	〃	〃	〃	−
	90	30.5	6.9	〃	〃	〃	〃	〃	−
109.9°C (6 *lbs*-press.)	50	21.8	6.7	〃	〃	〃	〃	〃	−
	70	26.2	6.9	Slightly violetish and turbid	〃	〃	〃	〃	−
	90	32.3	7.0	Slightly bluishbrown	〃	〃	〃	〃	−
111.3°C (7 *lbs*-press.)	30	20.6	6.8	〃	〃	〃	〃	〃	−
	50	26.7	6.8	Sligitly violetish	〃	〃	〃	〃	−
	70	22.3	6.8	〃	〃	〃	〃	〃	−
112.7°C (8 *lbs*-press.)	30	19.5	6.7	〃	〃	〃	〃	〃	−
	50	25.1	6.8	Strongly violet	Slightly discolor	Slightly browned	Slightly softened	Slightly burned smell	−
	70	26.5	7.1	〃	〃	〃	Softened	〃	−
115.2°C (10 *lbs*-press.)	30	23.6	6.7	Slightly violetish	Faded noticeably	〃	〃	Remarkably burned smell	−
	50	25.6	6.7	Violetish	〃	〃	〃	〃	−
	70	38.0	7.2	〃	〃	〃	〃	〃	−

Table 20. Quality of the canned crab processed from the pretty unfresh material (V.B.-N, 15~20 *mg*%)

Processing temp. (°C) (or pressure)	Processing time (mins.)	Quality of canned product							
		V. B. -N in meat (*mg*%)	pH of meat	Color of juice	Color of meat		Elasticity of meat	Flavour	Isolation of bacteria
					Red meat of surface part	White meat of inner part			
105.5°C (3 *lbs*-press.)	50	25.1	6.6	Slightly bluishbrown	Light pinkish	White opaque	Good	Good	+
	70	25.1	6.7	〃	〃	〃	〃	〃	+
	90	25.9	6.7	Slightly violetish	〃	〃	〃	〃	−
106.9°C (4 *lbs*-press.)	50	26.8	7.0	Slightly bluishbrown	〃	〃	〃	〃	+
	70	25.9	6.7	〃	〃	〃	〃	〃	+
	90	27.1	6.7	Slightly violetish	〃	〃	〃	〃	−
108.4°C (5 *lbs*-press.)	50	30.1	6.7	〃	〃	〃	〃	〃	+
	70	25.3	6.8	Violetish	〃	〃	〃	〃	−
	90	32.1	6.9	〃	〃	〃	〃	〃	−
109.9°C (6 *lbs*-press.)	50	25.6	6.9	Slightly violetish	〃	〃	Slightly softened	〃	−
	70	29.3	7.0	〃	〃	〃	〃	〃	−
	90	32.1	6.9	Violetish	〃	〃	〃	〃	−
111.3°C (7 *lbs*-press.)	30	29.7	6.9	Slightly bluishbrown	〃	〃	Good	〃	−
	50	27.0	6.7	Slightly violetish	Discolor slightly	Slightly brown	Softened	〃	−
	70	37.0	7.0	Violetish	Discolor noticeably	〃	〃	Slightly burned smell	−
112.7°C (8 *lbs*-press.)	30	18.5	6.7	Slightly bluishbrown	Discolor slightly	〃	〃	〃	−
	50	26.2	6.7	Slightly violetish	Discolour noticeably	〃	〃	〃	−
	70	28.4	7.1	Violetish	〃	〃	〃	Remarkably burned smell	−
115.2°C (10 *lbs*-press.)	30	25.2	6.7	Slightly bluishbrown	〃	〃	〃	〃	−
	50	26.9	6.8	Slightly violetish	〃	〃	〃	〃	−
	70	33.4	7.2	Violetish	〃	〃	〃	〃	−

Table 21. Quality of the canned crab processed from the unfresh raw material (V.B.-N, 25～30 *mg*%)

Processing temp. (°C) (or pressure)	Processing time (mins.)	Quality of canned product							
		V. B.-N in meat (*mg*%)	pH of meat	Color of juice	Color of meat		Elasticity of meat	Flavour	Isolation of bacteria
					Red meat of surface part	White meat of inner part			
105.3°C (3 *lbs*-press.)	50	28.2	6.8	Slightly pinkish	Light pinkish	White opaque	Good	Slightly NH_3-smell	+
	70	31.5	6.8	〃	〃	〃	〃	〃	+
	90	31.8	6.9	〃	〃	〃	〃	〃	+
106.9°C (4 *lbs*-press.)	50	31.5	6.9	Dark bluish-brown	〃	〃	〃	〃	+
	70	32.3	6.8	Slightly Violetish	〃	〃	〃	〃	+
	90	32.8	6.9	〃	〃	〃	〃	〃	−
108.4°C (5 *lbs*-press.)	50	27.7	7.0	〃	〃	〃	〃	〃	+
	70	30.5	6.9	〃	Dark pinkish	〃	〃	〃	−
	90	35.6	7.1	〃	〃	〃	〃	〃	−
109.9°C (6 *lbs*-peess.)	50	28.4	7.0	〃	〃	Slightly brown	Slightly softened	〃	−
	70	35.2	7.1	〃	〃	〃	〃	〃	−
	90	30.1	7.1	〃	〃	〃	〃	Slightly burned smell	−
111.3°C (7 *lbs*-press.)	30	30.8	6.8	Slightly pinkish	Discolored slightly	〃	Softened	〃	−
	50	33.5	6.7	〃	〃	〃	〃	〃	−
	70	30.1	7.0	〃	〃	〃	〃	〃	−
112.7°C (8 *lbs*-press.)	30	30.9	6.8	〃	Discolored noticeably	〃	〃	〃	−
	50	32.5	6.8	〃	〃	〃	〃	Remarkably burned smell	−
	70	34.9	7.2	〃	〃	〃	〃	〃	−
115.2°C (10 *lbs*-press.)	30	24.9	6.9	〃	〃	〃	〃	〃	−
	50	35.3	7.0	Slightly dark reddish	〃	〃	〃	〃	−
	70	31.6	7.2	〃	〃	〃	〃	〃	−

The pH value also showed movement to alkaline side with the rising of the processing temperature. In organoleptic tests, when the processing temperature was 112.7°C (8 pound pressure), the color and taste of the canned crab were normal when treated by the processing of 30 minutes. But in case of over 50 minutes' processing at the same temperature, the color of the meat became not good, and had some burned smell. The meat softened. The merchantable quality was inferior.

When the processing time was over 70 minutes, the quality was inferior to that treated for 50 minutes. When the processing temperature was 115.2°C (10 pound pressure), the quality of the canned crab was inferior in both color and taste even treated for 30 minutes. The qualities of the cans treated for 50 and 70 minutes both were inferior.

From those results, the upper limit of the processing temperature is considered to be 112.7°C (8 pound pressure), when the raw material is fresh and when the processing time is short (30 minutes). But when the time is over 50 minutes, the processing temperature should be lower.

From the results obtained as above, when the raw meat is fresh, the upper limit of the processing temperature should be 112.7°C (8 pound pressure).

When the pretty unfresh raw crab meat (V.B.-N, 15~20 *mg*%) was processed, the amount of V.B.-N in the meat heated up to 112.7°C (8 pound pressure) increased with the rising of the processing temperature, but at 115.2°C (10 pound pressure) the amount of V.B.-N reversely decreased. The meat heated at 112.7°C showed discoloring and inferior taste and had some burned smell. The meat heated at 115.2°C (10 pound pressure) showed browning of the white meat of the crab, and smelled burned.

From those results, when the raw meat is pretty unfresh, the processing temperature should be below 112.7°C (8 pound pressure).

In the case of the unfresh raw crab meat (V.B.-N 25~30 *mg*%), the increasing amount of V.B.-N was observed as well as in the case of summarized Tables 19 and 20. The unfresh meat heated at 110°C (6 pound pressure) showed already decrease of the amount of V.B.-N. And the red color of the epidermis of crab meat heated over 110°C (6 pound pressure) became dark, while the white meat became brown. When the processing temperature was over 112.7°C (8 pound pressure), the meat acquired a burned smell. This is because that the hydrating ability of the meat became weak with the falling of the freshness during the storage period, consequently the meat was dehydrated. When such dehydrated meat was heated at higher temperature, the meat began to smell burned. From those results, the highest processing temperature of the unfresh raw material should be lower than that of fresh raw material.

According to the bacteriological consideration, the unfresh meat should be processed at higher temperature in order to sterilize the bacteria attached to the content of the cans. But when the unfresh raw material is processed at comparatively higher temperature for longer period, the quality of the canned crab becomes reversely worse as above described. Thus the upper limit of the processing temperature should be varied according to the

different degrees of the freshness of the raw material.

2. The lowest processing temperature of the canned crab

The lowest permissible processing temperature of the canned crab should be the temperature necessary to sterilize the content in the can. Canned crab has no bone to soften, differing from canned salmon. So, the lower the processing temperature, the better the taste and the color of the canned crab. But when the processing temperature is low, the processing time may be too long for economic procedure. From actual technical experience, the lowest temperature is 107°C (4 pound pressure). When the processing temperature is so lower as pressure is 4 pound, the time for maintenance of the temperature of the center of the can will be too long properly to sterilize the content in the can.

Recently in canned crab processed from crab captured by a trawler net, the thermotolerant bacteria which survived after the processing at 110°C were isolated[9]. If such thermotolerant bacteria are often found, the lowest processing temperature should be raised.

3. Calculation of processing time of canned crab having different degrees of freshness

If the highest and the lowest processing temperatures are determined, then for the sake of economical operation, determination must be made of the time required to sterilize the bacteria in the canned crab at the minimum reasonable processing temperature. If the number of bacteria attached to the boiled crab meat increases with the elongation of the storing time, then the processing time should be prolonged, when processing is being done at the same temperature at which the fresh boiled meat is being processed.

It is conveninent for the technologists in canneries that considering those factors which influence the processing, the adequate processing temperature be determined, then that the processing time corresponding to the temperature be determined, and that those relations be showed in simple scales or tables. The author has tried to draw up such scales by studying the relation among the number of bacteria attached to the raw or boiled crab meat, the freshness, and the processing time similar to that has been done in the case of canned salmon[8].

4. The relationship among storing temperature of raw crab meat with the crust, freshness (the amount of V.B.-N produced) and variation of number of bacteria attached

(1) The velocity of decomposition of raw crab meat in the initial stage of storage

In order to exaplain the decomposition velocity of raw crab meat in the initial stage (in V.B.-N production curve), the author has used the same equation as in the case of raw salmon meat[8].

$$V = pt^2 + V_0 \quad \cdots\cdots\cdots\cdots (7)$$

Here, "V" is the amount of V.B.-N in raw meat after "t" hours, and "V_o" is the initial amount of V.B.-N in the raw crab meat when it is carried into a cannery, "p" is the coefficient of the decomposing velocity in the initial stage. Data of V.B.-N produced which were obtained by leaving raw crab meat (with crust) at various temperatures in another experiments were substituted in equation (7), and values of "p" at various temperatures were calculated. The relation between "p" and storing temperatures "t" is shown in Table 22 and Fig. 9.

Table 22. Relation between the storing temperature and velocity of decomposition of raw crab meat with crust in the initial stage of storage

Leaving temp. (°C)	12	17	27	37	47
"p"	0.0039	0.0143	0.0435	0.0983	0.1182

Next, the value of "V_o" (the amount of V.B.-N at "t"=0) and values of "p" were substituted in equation (1); and then the values of "V" (the amount of V.B.-N produced at various temperatures for various periods of time) were calculated. The values obtained here are called $V_{calc.}$ The obtained values of "V" by practical estimation of acutal materials are called $V_{interp.}$ The values of both $V_{calc.}$ and $V_{interp.}$ were compared as in Table 23.

As seen in Table 23, the formation of V.B.-N up to the amount of 30 mg%, was found to follow equation (7), because the values of $V_{calc.}$ were almost the same as values of $V_{interp.}$

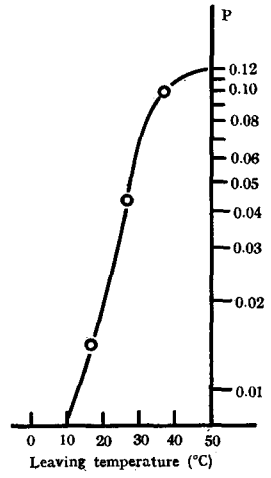


Fig. 9. Relation between the coefficient of the decomposing velocity in the initial stage "p" and storing temperature "t" of raw crab with crust

Table 23. Relation between the values of "$V_{calc.}$" and "$V_{interp.}$"

Leaving temp (°C) / V. B.-N (mg%) / Leaving tmie (hrs.)	12		17		27		37		47	
	$V_{calc.}$	$V_{interp.}$	$V_{cal.}$	$V_{interp.}$	$V_{calc.}$	$V_{interp.}$	$V_{calc.}$	$V_{interp.}$	$V_{calc.}$	$V_{interp.}$
0	12.9	12.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
5	—	—	12.3	12.2	14.1	14.2	14.4	16.5	14.8	15.8
10	—	—	13.3	14.1	16.3	16.1	21.7	18.3	23.7	20.3
20	—	—	13.7	14.9	17.3	20.0	24.2	23.9	26.8	29.4
25		—	17.6	16.5	29.3	20.2	31.1	31.4	59.5	48.9
27	16.8	18.4	20.8	18.9	38.1	25.3	—	—	—	—
30	—	—	24.8	24.0	—	—	—	—	—	—
35	—	—	29.5	31.7	—	—	—	—	—	—
40	—	—	—	—	—	—	—	—	—	—
52	23.5	21.9	—	—	—	—	—	—	—	—

(2) Relation between the velocity of decomposition of raw crab meat in the initial stage and the storing temperature-time

In order to show the relation between the velocity of decomposition of raw crab meat in the initial stage and the storing temperature-time, the author has reformed equation (7) as he also did in the case of raw salmon meat[8].

$$pt^2 = V - V_o \quad \cdots\cdots(8)$$

$$\log p + 2 \log t = \log (V - V_o) \quad \cdots\cdots(9)$$

$$P_{(p)} + T_{(t)} = V_{(v)} \quad \cdots\cdots(10)$$

Here, the value of $(V-V_o)$ is restricted $0 \leqq V-V_o \leqq 30$, because the value of "V" has-bee restricted up to the value 30 $mg\%$ was reached. From the experimental results obtained previously, "t", the time required to reach 30 $mg\%$ of the amount of V.B.-N, was 50~60 hours, therefore the range of "t" is $1 \leqq t \leqq 60$. The value of "p" was below 0.12 at 47°C of the leaving temperature (see Table 22), because the leaving temperature of raw crab meat is not considered to be 47°C. Therefore the range of the value of "p" is considered to be $0.01 \leqq p \leqq 0.12$.

(3) Making of scale showing the relation between the freshness of the raw crab meat and the storing temperature-time

In order to make a scale showing the relation between the leaving temperature-time and the freshness of raw crab meat, ratios of scales of "p", "t" and "$V-V_o$" of 10 cm length were calculated. As the range of "p" is $0.01 \leqq p \leqq 0.12$ $(1 \leqq 100p \leqq 12)$ and the range of "t" is $1 \leqq t \leqq 60$, ratios of scales of "p" and "t" must be obtained from equation (9).

As "p"-sclae is log 12−log 1=1.2079, "t"-scale is 2 log 60−2 log 1 $= 1.7782 \times 2 =$ 3.5564. In order to make the length of "p" and "t" scale, each 10 cm, scale cofficients, m and n will be obtained as follows:

$$m = \frac{10}{1.2072} = 8.29, \quad n = \frac{10}{3.5564} = 2.82$$

The scale coefficients of "V" are obtained as follows.

$$l = \frac{mn}{m+n} = \frac{8.29 \times 2.82}{8.29 + 2.82} = \frac{23.4}{11.11} = 2.1$$

Here, scales of "p", "t" and "$V-V_o$" are drawn as follows:

For sacle of "p", $x = 8.29 \{\log 100p\}$ $\cdots\cdots(11)$

provided that $0.01 \leqq p \leqq 0.12$

For scale of "t", $y = 2.82 \{2 \log t\}$ $\cdots\cdots(12)$

provided that $1 \leqq t \leqq 60$

For sclae of "$V-V_0$", $z = 2.10 \{\log 100 (V-V_0)\}$ $\cdots\cdots(13)$

provided that $1 \leqq V-V_o \leqq 30$

[The distance between the scale of "p" and the scale of "$V-V_o$"]: [The distance between the scale of "$V-V_o$" and the scale of "t"] $=m:n=8.29:2.82=3:1$.

Here, if any values in the ranges of "p", "t" and "$V-V_o$" respectively are substituted in equations (11) (12) (13), the values of "x", "y" and "z" are shown in Table 24 and Fig. 10.

Table 24. Readings "x", "z" and "y" which are correlated with the values of "p", "v" and "t" on scales "p", "$V-V_0$" and "t"

P-scale		$(V-V_o)$-scale		t-scale	
p	x (cm)	v (mg%)	z (cm)	t (hrs.)	y (cm)
0.01	0	1.0	2.10	1	0
0.02	2.49	2.5	2.94	5	3.94
0.03	3.95	5.0	3.55	10	5.64
0.04	4.98	7.5	3.94	15	6.64
0.05	5.80	10.0	4.20	20	7.33
0.06	6.45	12.5	5.04	25	7.88
0.07	7.00	15.0	5.67	30	8.34
0.08	7.50	17.5	6.82	35	8.71
0.09	7.91	20.0	6.94	40	9.05
0.10	8.92	25.2	7.12	45	9.32
0.11	8.63	30.0	7.31	50	9.58
0.12	8.95	—	—	55	9.82
—	—	—	—	60	10.00

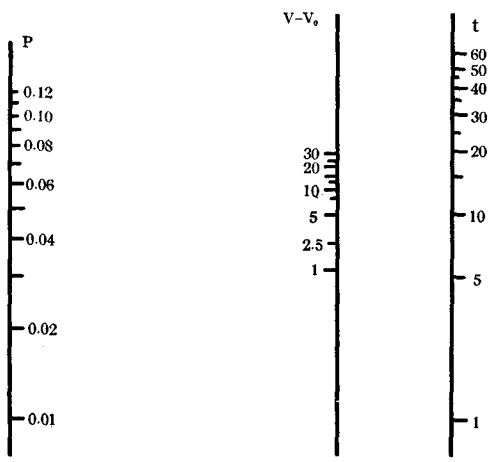


Fig. 10. Scales showing "p", "$V-V_o$" and "t"

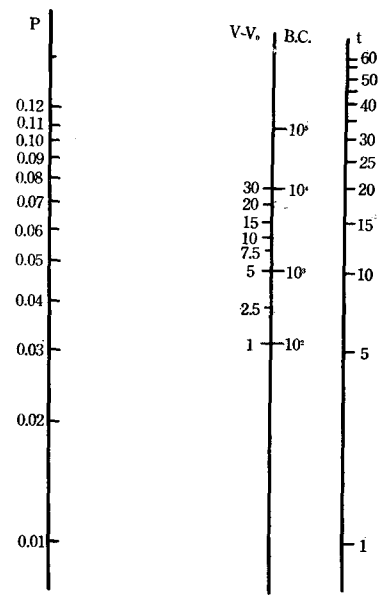


Fig. 11. Scales showing "p", "$V-V_o$," "t" and "$B.C.$" (bacterial counts)

(4) Relation between the increase of the amount of V.B.-N and increase of the bacterial counts with the falling of freshness

From the following Table 25 (p. 123), the bacterial counts (*B.C.*) are drawn to the right side of the scale "$V-V_o$" in Fig. 11.

(5) Relation between the leaving temperature-time and the bacterial counts

Here, Figs. 9, 10 and 11 are together drawn as shown in Fig. 12.

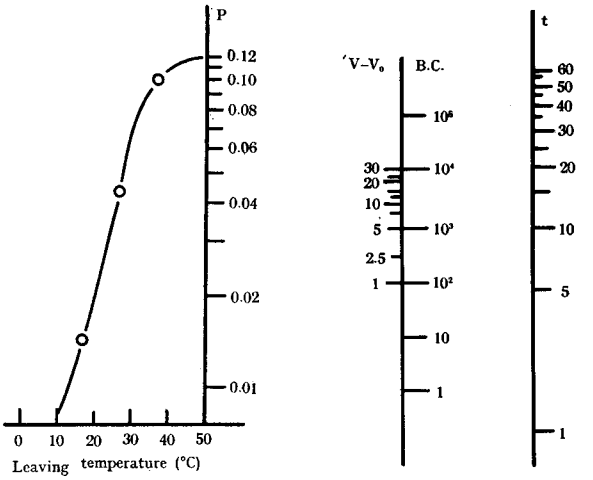


Fig. 12. Diagrams showing the relation among the leaving temperature-time and the bacterial counts and V.B.-N

If the leaving temperature of the raw crab meat in a cannery is known, crose the perpendicular line corresponding to the given temperature and the hyperbolic line showing the relation between the coefficient of the decomposing velocity in the initial stage and the leaving temperature. From the point of the crossing, a horizontal line is drawn and is crossed with "*p*"-scale. The crossed point is combined with any leaving time on "*t*"-scale by a straight line. The point at which the straight line and "$V-V_o$"-scale cross, shows the increase of the amount of V.B.-N on the left side and the bacterial counts on the right side of "*B.C.*"-scale.

5. The variation of the amounts of V.B.-N and bacterial counts during the storage of the boiled crab meat

(1) Varations of the amounts of V.B.-N and bacterial counts during the procedure of the boiling of the carcasses of crab

In the procedure of crab canning, the carcasses from which the carapaces were removed

are boiled with the crust by "high-" or "low temperature boiling method". After the boiling at high temperature, the carcasses are cooled in water, and then the crusts are split off by a knife in order to take out the meat.

The bolied crab meat treated by "low temperature boiling method" is pushed out by a pressing-roll or by water pressure. The quality of the canned crab, *e.g.*, color, or hardness of the meat, is influenced largely by the conditions of the boiling of the carcasses. Therefore the boiling is an important procedure.

During the boiling, the meat in the crust is dehydrated, the chemical components flow out with the water, and the amount of V.B.-N and number of bacteria in the meat vary. Those variations are influenced by the conditions of the boiling (*e.g.*, boiling methods, temperature and time).

The variations of the amount of V.B.-N and the number of bacteria in the boiled crab meat treated by "high temperature boiling method" (100°C at 18 minutes), or treated by "low temperature boiling method" (60°C at 10 minutes) are shown in Table 25.

Table 25. Variations in the amounts of V.B.-N and the bacterial counts of crab before and after boiled by the "high" and "low temperature boiling methods"

Items / Boiling method	Raw meat			Boiled meat		
	pH	V.B.-N (*mg*%)	Bacterial counts per *g*	pH	V.B.-N (*mg*%)	Bacterial counts per *g*
High temp. boiling method	6.6	6.3	5×10^2	6.7	10.9	2.5×10^2
	6.2	16.7	2×10^3	6.4	12.0	1×10^3
	6.4	25.0	5×10^3	6.4	7.1	2×10^3
	6.8	33.7	1×10^4	6.8	9.3	8×10^3
Low temp. boiling method	6.6	6.3	5×10^2	6.3	10.1	3.3×10^2
	6.2	16.7	2×10^3	6.4	10.4	1.5×10^3
	6.4	25.0	5×10^3	6.4	8.2	3×10^3
	6.8	33.7	1×10^4	6.8	14.2	1×10^4

As seen in Table 25, the amount of V.B.-N and the number of bacteria decrease in the crab meat during the boiling procedure. The degree of the decrease is influenced by boiling methods or by the degrees of freshness of the raw crab meat. The decrease of the amount of V.B.-N and the number of the bacteria in the boiled crab meat treated by the "high temperature boiling method" was remarkably more than those by the "low temperature boiling method".

As to the decrease of number of bacteria in the boiled crab meat, according to freshness of raw crab meat, the ratio of the decrease of the boiled meat prepared from the raw meat of which the amount of V.B.-N is below 20 *mg*% (the limit of the freshness) is about 50 % when it is treated by the "high temperature boiling method" and about 30% when treated by "low temperature boiling method". But the ratio of the decrease in the boiled meat prepared from the raw meat of which the amount of V.B.-N is above 20 *mg*% is slight.

This may be due to the fact that with the falling of the freshness, the number of bacteria increases, and the bacteria make the spores, and the thermotolerance increase.

(2) Increase of the amount of V.B.-N and the number of bacteria during the storage of the boiled crab meat

The once decreased amount of V.B.-N and number of bacteria by the boiling procedure both increase gradually again during the storage of the boiled crab meat. The rates of the increase are different in accordance with the boiling methods.

The rate of the increase in the boiled meat treated by "low temperature boiling method" is more remarkable than in that treated by "high temperature boiling method."

The rate of increase in the amount of V.B.-N and the number of bacteria at the higher leaving temperatures are more remarkable. With the elongation of the storage period, that increase maintained.

The relation between the velocity of decomposition (the variation of the amount of V.B.-N and the number of bacteria) of the boiled crab meat treated by "high-" or "low temperature boiling method" and the leaving temperature-time are shown in Table 26 and Figs. 13 and 14.

As seen in Table 26 and Figs. 13 and 14, the increases in the amount of V.B.-N and the number of bacteria in the boiled crab meat were slow in the initial storage period, but after a certain point, the increases were rapid. The increase in the boiled crab meat samples from raw unfresh meat were larger than that from raw fresh meat. Differing from the canned salmon which is processed directly from the raw meat, the processing condition of the canned crab which is processed after the boiling of the raw meat (carcass) may be influenced by the degrees of freshness of the boiled meat as well as the degrees of freshness of the raw

Tables 26. The relation between the variation of the amounts of V.B.-N and the bacterial counts of the boiled crab meat treated by "high" or "low temperature boiling methods" and the leaving temperature-time

Boiling method / Temp. (°C)		High temp. boiling method				Low temp. boiling method			
		5		10		5		10	
Time (min.) / Sample	Freshness	V. B.-N (*mg*%)	Bacterial counts per *g*.	V. B.-N (*mg*%)	Bacterial counts per *g*.	V. B.-N (*mg*%)	Bacterial counts per *g*.	V. B.-N (*mg*%)	Bacterial counts per *g*.
Fresh material	2	10.9	2.5×10^2	7.9	1×10^2	10.1	3.3×10^2	10.4	7×10^2
	6	15.8	2.5×10^2	18.2	5×10^2	16.4	5.0×10^2	19.0	2×10^3
	20	16.3	3.5×10^2	19.5	3×10^3	17.7	8.6×10^2	22.6	2×10^4
	40	17.2	2.4×10^3	22.0	3×10^4	22.0	4.5×10^3	27.8	1×10^5
	52	20.2	3.5×10^4	24.6	1×10^5	—	—	30.4	8×10^5
	60	—	6.5×10^4	29.0	5×10^5	50.8	3.5×10^5	—	10^6
Unfresh material	0	9.3	8×10^3	9.3	8×10^3	14.2	1×10^4	14.2	8×10^3
	24	13.4	1×10^4	17.3	2×10^4	14.7	1×10^4	10.3	1×10^4
	48	12.6	1×10^4	19.2	3×10^4	17.8	3×10^4	21.1	2×10^4
	72	12.3	2×10^4	24.6	3×10^5	17.2	8×10^4	25.4	8×10^5
	96	13.7	2×10^4	25.8	1×10^6	23.5	1×10^5	33.6	1×10^6

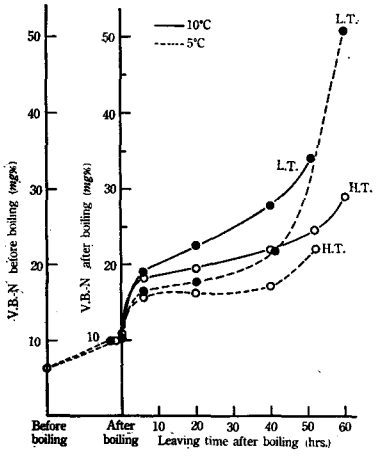


Fig. 13. Variations in the amounts of V.B.-N of the boiled crab meat treated by "high" or "low temperature boiling method" and left at various temperatures and times

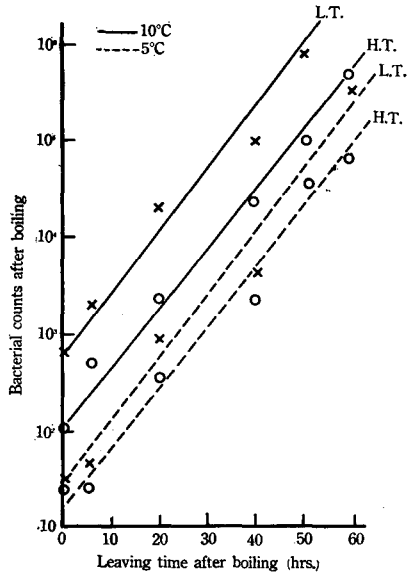


Fig. 14. Variations in the bacterial counts of the boiled crab meat treated by "high" or "low temperature boiling method" and left at various temperatures and times

material.

The limit of the freshness of the boiled crab meat is influenced by the degrees of freshness of the raw material. When the amount of V.B.-N in the raw meat was below 10 *mg*%, the limit of the freshness of the boiled crab meat should be 15 *mg*% of V.B.-N; when the amount of V.B.-N in the raw crab meat was 10~20 *mg*%, the limit of the freshness of the boiled meat should be 10~20 *mg*% of V.B.-N.

If the limit of the freshness of the boiled crab meat is considered on the basis of the number of bacteria in the boiled meat, good quality canned crab is not obtainable unless the number of bacteria is less than 10^2~10^3 per *g* in the boiled material. From the experimental results, if various conditions, *e.g.*, the number of bacteria in the raw crab meat before boiling, the boiling methods, the storage temperature-time after the boiling, are known, the number of bacteria in the boiled crab meat can be presumed. Next, if the number of bacteria in the boiled crab meat is known, the conditions of the processing of the canned crab can be calculated.

Here, the consolidated scale shown in Fig. 15, indicates the number of bacteria in the boiled meat, resulting from the number of bacteria in the raw crab meat, the boiling methods, and the storage temperature-time after the boiling.

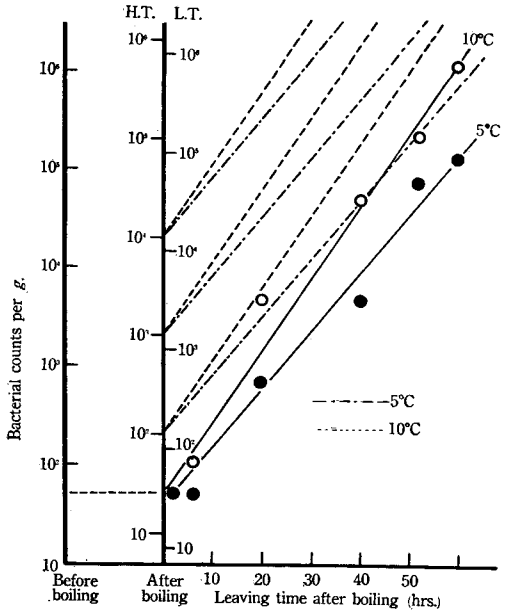


Fig. 15. Diagram showing the number of bacteria in the boiled crab meat, resulting from the number of bacteria in the raw crab meat, the boiling method, and the storage temperature after the boiling

6. Calculation of processing time, when the boiled crab meat having various degrees of freshness is processed

(1) Thermotolerance of bacteria attached to the boiled crab meat

The processing conditions depend upon the thermotolerance of bacteria attached to the boiled crab meat.

The author has previously isolated thermotolerant bacteria from the boiled crab meat. The bacteria were identified to be *Bac. subtilis var.* of which the thermotolerance is shown in Table 27.

This *Bac. subtilis var.* has been often isolated from the swelled canned crab with *Bac. megatherium* by the present author[10]. The thermotolerance of *Bac. megatherium* which was also studied by the present author, is shown in Tables 28 and 29.

Table 27. Thermal death time of *Bac. subtilis var.* isolated from boiled crab meat

Heating temp.	Thermal death time (min.)
100°C (212°F)	140
108°C (228°F)	60
110°C (230°F)	30
111°C (232°F)	20
115°C (239°F)	8

Table 28. Thermal death time of *Bac. megatherium* isolated from swelled canned crab

Heating temp.	Thermal death time (min.)
100°C (212°F)	140
105°C (221°F)	60
110°C (230°F)	28
115°C (239°F)	8

Table 29. Number of *Bac. megatherium* survived after the heating at 105°C (221°F)

Heating time (min.)	Number of survived bacteria
0	10,000
10	3,000
20	500
30	130
40	20
50	5

Comparing Table 27 with Tables 28 and 29, no remarkable difference between *Bac. subtilis var.* and *Bac. megatherium* in respect to thermotolerance is observable. Here, as an example of the kind of bacteria in the canned crab, use was made of *Bac. megatherium*, which is a spore-forming bacerium and has been frequently isolated from the swelled canned crab.

(2) Heat-penetrating curve in the processing of canned crab

It is important to know the temperature of the center of the can content during the processing of the canned crab in order properly to calculate the processing time.

Estimations were made of the heat-penetration into the canned crab of 1/2-pound flat can which was processed from the boiled crab meat treated by "high-" or "low temperature boiling method". The heat-penetration was estimated by a thermocouple during the processing at 108.4°C (5 pound pressure), 109.9°C (6 pound pressure), 111.3°C (7 pound pressure) and 112.7°C (8 pound pressure). The heat-penetrating curves (by "high-" or "low temperature boiling method") at 109.9°C (6 pound pressure) are representatively shown in Fig. 16.

From Fig. 16, calculation is made of the value of f_h, that is the time required to reduce the difference between the retort temperature and the temperature at the center of the can content to reach 1/10 value of that original difference. The value of f_h was 47 for the canned crab subjected to the "high temperature boiling method"; the value was 35 for that subjected to the "low temperature boiling method."

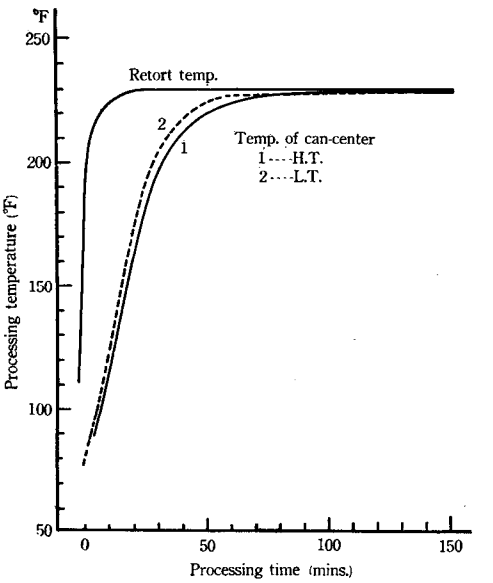


Fig. 16. Heat penetration curves of canned crabs which were prepared by "high" or "low temperature boiling method" at 109.9°C (6 pound pressure)

The heat-penetrating curves are different according to boiling methods of raw crab meat as seen in Fig. 16. The heat-penetration obtained from the canned crab subjected to the "high temperature boiling method" is worse than that subjected to the "low temperature boiling method.". This may be due to the reason that the boiled crab meat treated by the former method has less water-content than that treated by the latter method, because the dehydrating ratio of the former material is larger than that of the latter.

(3) Calculation of the processing time

The processing time was calculated after Stumbo[11] who is considering the number of bacteria before the processing and surviving bacteria. Procedure was the same as in the paper dealing with canned salmon[8].

Stumbo's equations are as follows:

$$U = Z\ (log\ a - \log b) \quad \cdots\cdots\cdots\cdots (14)$$

or $$U = Z\ (log\ a + P) \quad \cdots\cdots\cdots\cdots (15)$$

Here, "U" is the time required to reduce the number of bacteria attached to the content of the canned foods to a definite aimed number of surviving bacteria, "Z" is the inclination of the thermal death rate curve at a definite processing temperature, "a" is initial number of bacteria per unit of the raw material of a canned food, "b" is the number of bacteria in the canned food after the processing. "P" is logarithm of reciprocal of the number of the bacteria after "U" minutes. Here, it is assumed Z=0.5, and z=20.5 ("z" represents the degree of slope of the thermal death time curve.).

Then the processing time was calculated at various processing temperatures (5, 6, 7 and 8 pound pressures) using materials with different degrees of freshness of the boiled crab meat treated by two boiling methods respectively. Here, as an object of the kind of bacteria in the canned crab, use was made of *Bac. megatherium* as above described. The number of bacteria attached to the boiled crab meat was employed from 10^2 to 10^5 per 1 *g*. The value of "b" was taken to be 0.01 of survival number of bacteria in the canned crab.

The results calculated are shown in Table 30 and Fig. 17.

Table 30. Relation between the degrees of freshness of raw crab meat and the processing temperature-time

Bacterial counts / Boiling method / Processing temp.	10^2		10^3		10^4		10^5	
	High-temp.	Low-temp.	High-temp.	Low-temp.	High-temp.	Low-temp.	High-temp.	Low-temp.
	min.							
108.4°C (227.2°F) (5 *lbs*-press.)	90.8 (108.0)	85.6 (102.8)	98.6 (118.2)	92.6 (111.2)	105.4 (126.7)	99.5 (116.3)	112.5 (135.0)	106.1 (127.4)
109.9°C (229.8°F) (6 *lbs*-press.)	74.4 (89.3)	70.1 (84.2)	79.7 (95.6)	75.2 (90.3)	85.4 (102.3)	80.5 (96.6)	91.9 (110.2)	86.2 (103.3)
111.3°C (232.4°F) (7 *lbs*-press.)	64.6 (77.5)	60.9 (73.0)	68.5 (82.2)	64.6 (77.5)	72.3 (86.8)	68.1 (81.7)	77.8 (93.4)	73.4 (88.1)
112.7°C (234.8°F) (8 *lbs*-press.)	63.2 (75.8)	59.6 (71.5)	65.5 (78.6)	61.7 (74.0)	67.0 (80.5)	63.2 (75.8)	72.6 (87.1)	68.5 (82.2)

In Table 30, parentheses show the processing time to which was added 20% of safety factor[7,8], considering various factors, *e.g.*, velocity of rise in temperature of cans, or the kinds of bacteria attached to the raw material assuming the bacteria to be *Bac. megatherium*.

As seen in Fig 17, the processing time at any definite processing temperature must be increased according to the increase of the number of bacteria in the boiled crab meat. If the number of bacteria attached to the boiled crab meat prepared by both boiling methods is the same, the processing time for the boiled meat treated by the "high temperature boiling method" should be somewhat longer than that treated by the "low temperature boiling method".

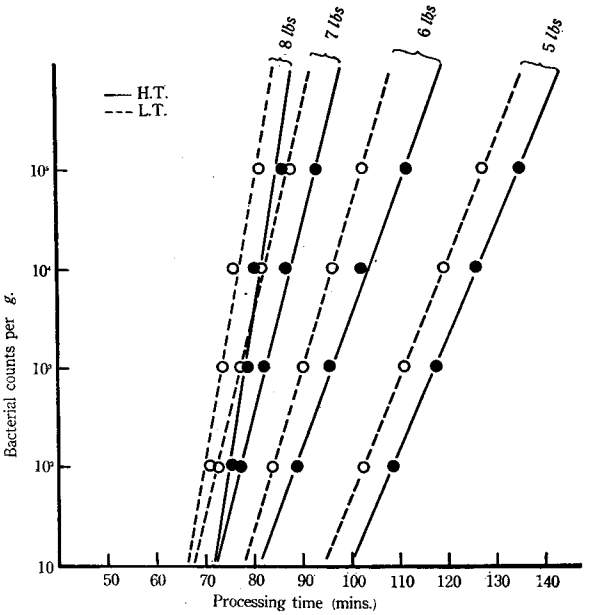


Fig. 17. Relation between the degrees of freshness of raw crab meat and the processing temperature-time

7. *Consolidated scale showing the relations among the storage temperature of the raw or boiled crab meat, boiling methods, falling of freshness and the processing temperature-time of canned crab*

Fig 12, Fig. 15 and Fig. 17 are put together in a consolidated scale as shown in Fig. 18.

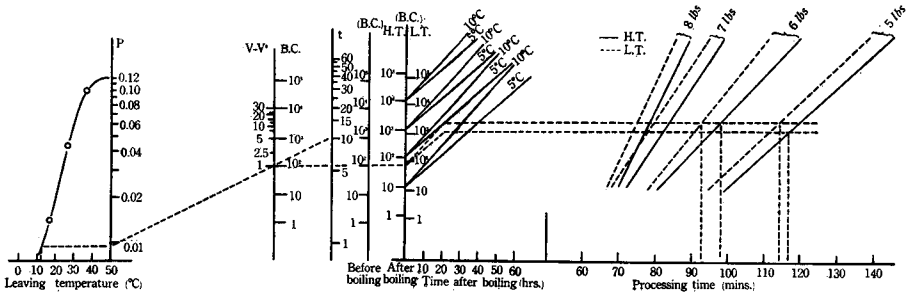


Fig. 18. Consolidated scale showing the relations in canned crab among the storage temperature of the raw or boiled crab meat, boiling methods, falling of freshness and the processing temperature-time

In Fig. 18, if the room temperature in a cannery is 12°C, the coefficient ("p") of the decomposing velocity of raw crab meat in the initial stage is known to be 0.009.

Then, if the leaving time of the fresh raw material (V.B.-N, 10 mg%) is 10 hours after

unloading into a cannery, the amount of V.B.-N in raw meat shows 11 *mg*% resulting with the increase of 1 *mg*% of V.B.-N, and at that time the number of bacteria is 10^2. Here the raw meat with the crust is boiled by "high-" or "low temperature boiling method. By the boiling procedure, the number of bacteria is descreased to about 7×10^1 or 9×10^1 in the case of "high-" or "low temperature boiling method" respectively. If the boiled crab meat is left at 10°C for 20 hours, the number of bacteria becomes about 1.3×10^3 or 2×10^3 in "high-" or "low temperature boiling method.

Then, the safety processing time is found to be 98 minutes at 6 pound pressure for the boiled meat treated by "high temperature boiling method", and 92 minutes for the boiled meat treated by "low temperature boiling method".

In this paper, a plan of making up consolidated scales for crab canning by which the adequate processing time may be found from the leaving temperature-time of raw and boiled crab meat, was described. The scale may be convenient for the technologists of canneries.

V. Some problems concerned with canned crab processed subjecting to the "low temperature boiling method"

1. Topics and the explanation

The "low temperature boiling method" which has been invented by Kosakabe[8] in order to prevent the blueing of the canned crab meat, is being actively employed in the making of canned boneless crab. However, the "low temperature boiling method" involves many problems to be solved by scientific studies, therefore this method is now in a test period. Here, comparing the canned crab subjected to "low temperature boiling method" with that subjected to the "high temperature boiling method", the scientific problems arising from the use of the "low temperature boiling method" will be summarized in a list as shown in Table 31.

As seen in Table 31, in the canned crab which has been processed by the usual method ("high temperature boiling method"), blue meat was often seen, as a result of which the packers have suffered damages, and also the uneatable bone (tendon) is left in the product.

On the other hand, in the canned crab processed by subjecting to the "low temperature boiling method", there are many problems: (1) browning, (2) black spots, (3) decrease of the yield of canned crab meat, (4) inferior taste, and (5) occurrence of crystals, etc.

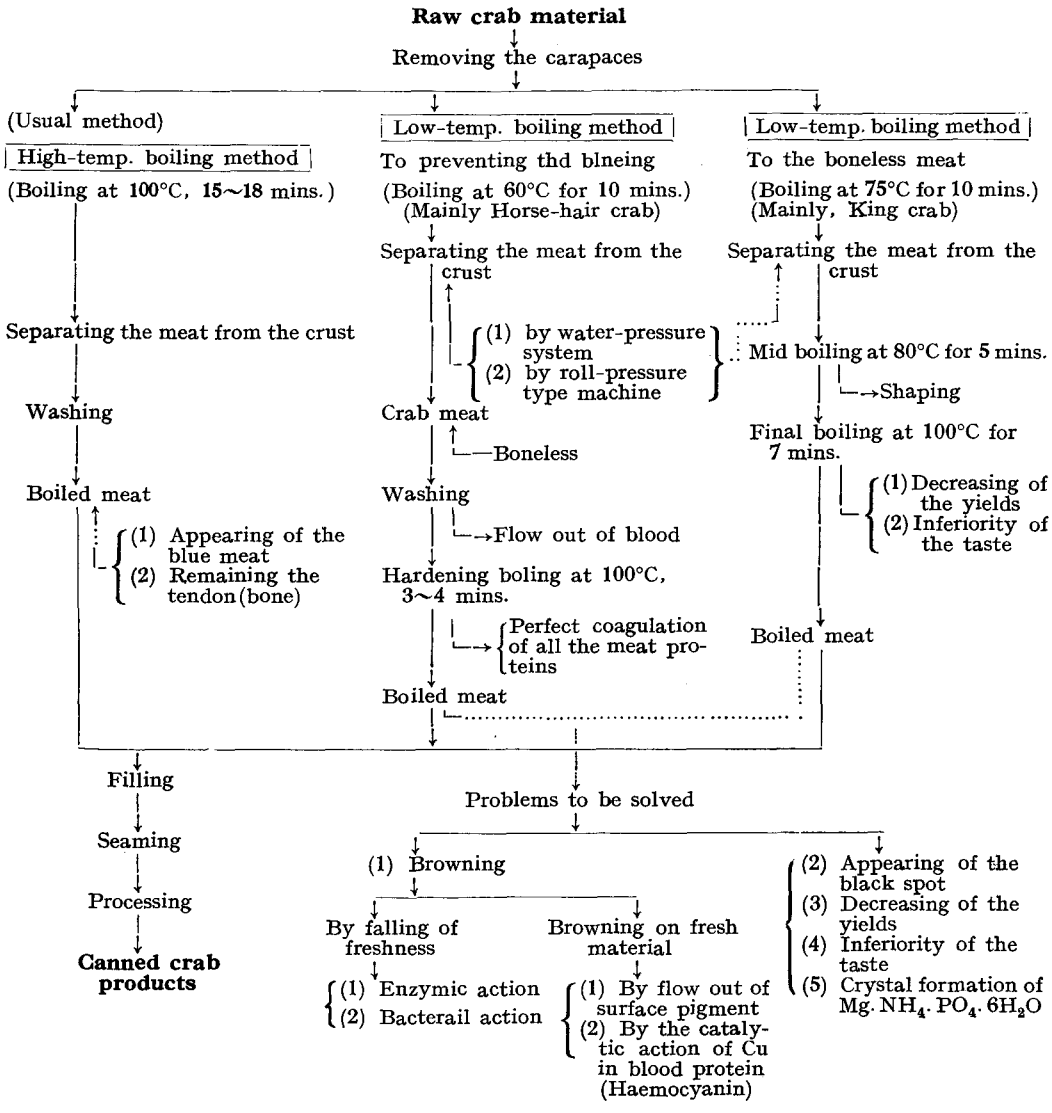
Here, those problems will be discussed on the basis of the authors previous studies.

(1) Browning of the canned crab meat

The browning of canned crab meat means the browning of the white part of the meat. This browning has been observed even in the processed canned crab which was treated by the "high temperature boiling method" from unfresh raw material.

According to Nagasawa[12], a member of the staff of the author's laboratory, the cause of the browning may be found in the use of unfresh raw material. In the canned crab which

Table 31. Some problems concerned with canned crab processed by subjecting to the "low temperature boiling method"



was processed by subjection to the "low temperature boiling method," the falling of the freshness which caused by the action of enzymes remaining after the boiling surely plays a part in the browning. In the same processed canned crab, even when fresh raw material is used, browning often occur. The casue, the mechanism and the methods of preventing the browning are discussed in Nagasawa's paper[12].

(2) Black spots on the canned crab meat

This matter is different from the blackening of the canned crab meat which had been observed in the past, caused by the combination of the metals of tinplate of the container and the hydrogen sulfide produced from the meat during the processing. Such black spots appear near the ends of cut leg meat in the canned crab, especially in *Erimacrus isenbeckii*.

This may be explained by the belief that tyrosinase in the blood of crab decomposes tyrosin in the meat and forms melanin. The details of the results of investigation will be described in another paper.

(3) Taste

It is said that the taste of the canned crab processed from the boiled meat treated by "low temperature boiling method" is inferior to that treated by "high temperature boiling method"[13]. This may be due to the reason that when the boiled meat treated by the former method is filled into cans, the boiled meat has abundant water content, and when it is processed, the water flows out abundantly from the meat as juice accompanying with taste components. Therefore the solid of crab meat itself loses the taste.

The details will be presented in another paper.

(4) The decrease in the amount of solid content of canned crab

When the raw carcasses are boiled by the "low temperature boiling method", the ratio of dehydration of the meat is small. The hardening-boiling after the low temperature boilng is done in short time, so the dehydration is small. Therefore large volume and large water-content are obtained in the boiled meat treated by the "low temperature boiling method" before the filling into the cans. So it is difficult to seal the cover being raised by the meat having a large quantity of water.

But when the filled cans are processed in a retort under high temperature, the meat is dehydrated, the solid content becomes small and a larger amount of the juice is obtained in the can.

This may be also explained by the difference in the ratio of dehydration as formerly described[4].

(5) Formation of crystals

The cause of the formation of glass-like crystals ($Mg \cdot NH_4PO_4 \cdot 6H_2O$) in the canned crab has been cleared already by the present author and Nagasawa[14].

It is said that the crystals are found in the canned crab treated by "low temperature boiling method". This may be due to the reason that there is a larger amount of Mg ion in the free state in the canned crab meat treated by "low temperature boiling method". It has been cleared that the formation of the crystals in the canned crab treated by the "low temperature boiling method" can be prevented by boiling in water containing polyphosphate, "Calgon". The details will described in another paper.

2. Autolysis of crab meat after the "low temperature boiling"

Scientific problems arising in the case of canned crab processed from the boiled meat treated by the "low temperature boiling method" are caused not only by the characteristics of the crab meat tissue itself, but also largely by the action of autolytic enzymes after the "low temperature boiling". For example, by autolysis of the crab meat, decomposition is expedited and browning occurs easily. Studies were made on the velocity of the autolysis of the crab meat after the low temperature boiling, also optimum temperature and pH of the autolytic enzyme in the crab meat were determined.

(1) Experimental method

Shoulder and leg meats were taken from fresh raw crab carcasses; each meat was crushed and homogenized. Ten *g* of the homogenized crab meat, 10 cc of distilled water and 5 *cc* of toluene were put into a large sized test tube, shaken and plugged with a rubber stopper. The sample thus made was left at 27°C or 37°C. After a definite duration of the leaving time, the 10 *g* of the meat suspension taken out from the test tube was employed for the estimation of amino acid nitrogen produced.

(2) Experimental result

Results obtained from the use of raw meat are shown in Table 32 and Fig. 19.

Table 32. Variations in the amounts of amino acid nitrogen in raw crab meat during the course of autolysis

Temp. / Parts / Time (hrs.)	27°C		37°C	
	Shoulder meat	Leg meat	Shoulder meat	Leg meat
	mg%	*mg*%	*mg*%	*mg*%
0	224	198	224	224
24	224	205	243	237
48	243	224	378	282
72	326	250	525	352
96	306	358	582	429
144	544	448	646	506
168	621	518	653	570

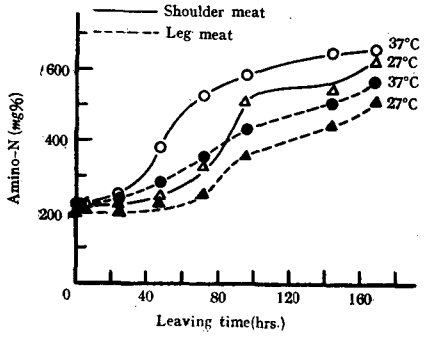


Fig. 19. Variations in the amounts of amino acid nitrogen in raw crab meat during autolysis

After the heating of raw shoulder and leg meats treated by the "low temperature boiling method" at 65°C for 10 minutes, 10 *g* of the boiled meat was treated in the same manner as above described. The results obtained from the use of boiled meat are shown in Table 33 and Fig. 20

Table 33. Variations in the amounts of amino acid nitrogen during autolysis in boiled crab meat treated by "low temperature boiling method"

Temp. / Parts / Time (hrs.)	0°C		27°C		37°C	
	Shoulder meat	Leg meat	Shoulder meat	Leg meat	Shoulder meat	Leg meat
	mg%	*mg*%	*mg*%	*mg*%	*mg*%	*mg*%
0	160	108	163	106	173	96
24	160	108	166	109	186	102
48	166	122	198	109	275	154
72	—	—	—	—	320	154
96	173	123	218	134	429	294
120	—	—	282	250	525	467
144	192	126	390	326	—	—

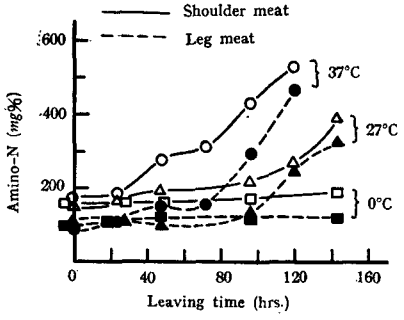


Fig. 20. Variation in the amounts of amino acid nitrogen during the autolysis of boiled crab meat which was treated by "low temperature boiling method"

As seen in Figs. 19 and 20, the autolysis continues to advance even after the "low temperature boiling". With the rising of the leaving temperature, the velocity of the autolysis increases. The velocity of the autolysis of the shoulder meat in raw or boiled state is more rapid than that of leg meat.

Whether the data obtained can be applied to the equation of monomolecular reaction after Oya,[15] or not, has been discussed. After consideration, it was decided that the relation between "t" and "$\log \frac{a}{a-x}$" was apparently linear and that it can be applied to the equation.

$$\log \frac{a}{a-x} = Kt + C \quad \cdots\cdots\cdots (16)$$

Here, "a" is the total amount of amino acid nitrogen in the sample which was hydrolyzated by conc. HCl solution. "x" is the increased amount of amino acid nitrogen at estimating time, "t"; "K" is velocity constant in the autolysis; "C" is a constant.

The temperature coefficient ("Q_{10}") in the autolysis is determined by equation (17).

$$Q_{10} = \frac{K_{\theta+10}}{K_{\theta}} \quad \cdots\cdots\cdots\cdots (17)$$

Here, "θ" is the leaving temperature; "K_{θ}" and "$K_{\theta+10}$" are the values of the velocity constant in the autolysis at "θ°" and "$(\theta+10)$°C". The values of "K" and "Q_{10}" which were calculated from Figs. 19 and 20 are shown in Table 34.

Table 34. Values of "K" and "Q_{10}" in the autolysis of crab meat.

Kinds of meat	Meat parts	Velocity constant ($K \times 10^6$)		Temperature coefficient (Q_{10})
		37°C	27°C	
Raw meat of *Paralithodes camtschatica*	Shoulder meat	980	420	2.34
	Leg meat	490	200	2.45
Same as above. (Low temp. boiling method)	Shoulder meat	475	200	2.38
	Leg meat	200	80	2.50
Erimacrus isenbekii	Mixed meat (Shoulder and Leg)	1,700 (35°C)	590 (25°C)	2.6 (0°~35°C)

In Table 34, the data obtained as to *Erimacrus isenbeckii* meat[1] are also included. According to that table, the following conclusion will derived: (1) The value of "K" (velocity constant of the autolysis) decreased to a half after the "low temperature boiling", but the autolysis did not stop. (2) The velocity of autolysis of leg meat decreased to a half that of the shoulder meat in raw state or the boiled meat treated by the "low temperature boiling method". (3) The values of "Q_{10}" in the raw or the boiled meat showed the same. The mean value of "Q_{10}" for the shoulder or leg meats was about 2.4. (4) The value of "K" of *Erimacrus isenbeckii* meat showed larger than that of *Paralithodes camtschatica* meat. That is to say, the autolytic action of the former is stronger than that of the latter.

From the results as above obtained, when the raw crab carcasses are boiled by the "low temperature boiling method", the autolytic enzymes show activation, especially in shoulder meat, after the boiling. This may be due to the fact that the shoulder meat is incontact with the viscera enzymes.

3. *Optimum temperature for the autolytic enzyme of the crab meat and the enzyme-destroying temperature*

In order to determine the optimum temperature for autolytic enzyme in *Paralithodes camtschatica* meat, the author has estimated the amounts of amino acid nitrogen produced in 10 *g* samples of fresh raw leg meat antiseptized with toluene, which were left at different temperatures for 12 hours.

Results obtained are shown in Table 35 and Fig. 21.

Table 35. Relation between the temperature and the amounts of amino acid nitrogen produced during the autolysis of crab meat

Temperature	Amino-N (*mg*%)	Temperature	Amino-N (*mg*%)
0°C	181	70°C	212
25	214	80	196
37	230	90	181
50	242 (Opt.)		
60	221	Remarks	181 *mg*% in initial sample

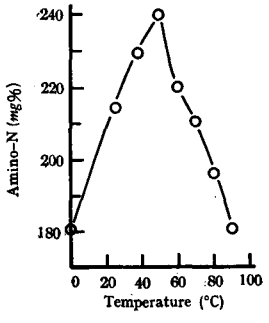


Fig. 21. Relation between the temperature and the amounts of amino acid nitrogen produced during the autolysis of crab meat

As seen in Fig. 21, the autolytic action of the enzyme in the crab meat was maximum at 50°C. If the temperature were over 50°C, the action decreased. Even at a higher temperature, at 80°C, the action was observed slightly.

Next, the raw crab meat was heated at 60°, 70° and 80° for 10 or 15 minutes, or at 90° and 100°C for 5 or 3 minutes respectively. After the heating, toluene was added to each sample and the heated meat was left at 25° for 72 hours. The amount of amino acid nitrogen produced in 10*g* of each heated sample was estimated. The amount of reducing sugar in the sample was also estimated.

Results obtained are shown in Table 36 and Fig. 22.

Table 36. Heat resistance of autolytic enzymes of crab meat

Heating temp. (°C)	Heating time (min.)	Amino-N (*mg*%)	Reducing sugar (*mg*%)
60	10	97	22.0
	15	85	10.0
70	10	80	10.2
	15	80	9.2
80	10	80	9.2
	15	76	9.0
90	5	76	9.0
	10	73	9.0
100	3	73	9.0
	10	73	9.0
Remarks (In initial sample)		73	9.0

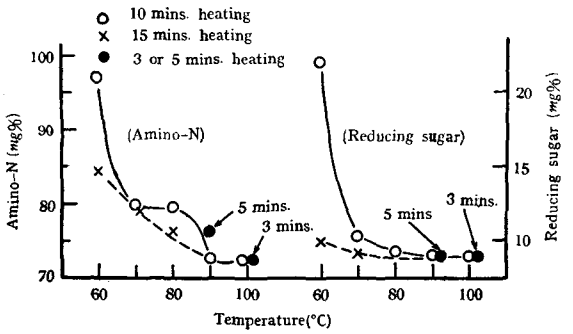


Fig. 22. Heat resistance of autolytic enzymes of crab meat

As seen in Table 36 and Fig. 22, by the heatings of the raw crab meat for 10 or 15 minutes respectively, the amounts of amino acid nitrogen and reducing sugar produced in the meat heated at 60°~90°C decreased, while heating at above 90°C resulted in the amounts of amino acid nitrogen and reducing sugar produced in the heated crab meat before and after the leaving period being almost the same. That is to say, the autolytic action of the crab meat was destroyed by above 90°C heating.

By the "high temperature boiling method" (at 100°C for 15~20 minutes), which has been hitherto employed, the autolytic action in the heated crab meat was completely stopped. Therefore the decomposition of the boiled meat becomes slow.

On the other hand, in case of the "low temperature boiling method", the autolytic action of the boiled meat is maintained until the hardening boiling (100°C, 3~5 minutes), which is done after the "low temperature boiling", as above described. In this case, if the leaving period of the boiled crab meat is comparatively long until the hardening boiling, the decomposition becomes rapid.

VI. Soured smell of canned crab

It has been often observed in canned crab that the meat tastes sour slightly, though the top and bottom of the can are flat. It is called "flat sour" of canned foods, of which the cause is some kinds of thermophiles.

However, studies were made of the "flat sour"-like canned crab, of which the cause was ascertained to be not bacteria. The chemical components of the soured substance have been identified.

1. Chemical components of the soured substance in the soured canned crab meat

Canned crab which was processed in "fancy"-style and was rejected because of "flat sour" upon inspection, was used for the study.

Though the quality of this canned crab was almost the same as that of the normal cans in flesh and juice, it has soured taste. Those canned crab were incubated at 37° or 50°C

for 14 days, but the top and bottom of the cans did not swell.

(1) Experimental method

Three cans (Nos. 1~3) which had been judged to be "flat sour" cans and one normal can (control), were opened in sterile condition, and a part of the content of each can was taken out with a sterilized pipette and inoculated into media by the usual method. Also, 150 *g* of the content of each sample can was subjected to paper chromatography. The rest of the content was used for the estimation of the amount of V.B.-N.

(i) *Detection of chemical components of soured smell*

The soured smell substance can be distilled by steam distillation. When S-benzyl-tiuronium chloride* was added to a part of the distillate, some crystals were formed out, and the distillate showed strong acid reaction. Therefore, this distillate would be considered to be acid substances such as volatile fatty acids.

The sample taken from the content of each can (3 soured cans and one normal can) were crushed in a mortar, respectively; hydroxamate was formed after Fink[17], from which the chemical components were detected by paper chromatography. The method of forming hydroxamate of fatty acids is shown in Scheme 1.

Scheme 1. Method of preparing hydroxamate of volatile acid

Raw crab 150 *g* + dist. water 200 *cc* + conc. H_2SO_4 15 *cc*
↓
Steam distillation
↓
200 *cc* Extract
↓
Extraction with ether (18 hours.)
↓
Evaporation of ether
↓
Brown liquid (1 *cc*)
↓
95 % ethanol 30 *cc* + conc. H_2SO_4 2 *cc*
↓
On oil bath, esterification (140°C)
↓
With sat. Na_2CO_3, neutralize of acid
↓
Heat about 70°C. (With reflux tube)
↓
Volatile acid ethylester
↓
Hydroxylamine hydrochloride 1.2 *g* + 7.5 *cc* alcohol + KOH 1.4 *g*
↓
←Filtrate ← KCl was removed
↓
Potassium hydroxamate
↓
Condensation
↓
Sample material of paper chromatography

* J.D. Leavy (1936) *J.A.C.S.* **58**, 1004.

The hydroxamate obtained was used for paper partition chromatography, use being made of filter paper No. 50 (20×20 *cm*) of Toyo Filter Paper Co.

The sample was developed with water saturated n-butanol for 6 hours, and as spray reagent alcoholic solution of 2 % ferric chloride was used.

Before the detection of spots, the position of spots which appeared by application of pure formic acid, acetic acid, propionic acid, butylic acid and isovaleric acid was determined.

(ii) *Isolation of bacteria*

As "flat sour" cans are considered generally cuased by thermophiles, the contents of sample cans were subjected to bacteriological study. The media used were (1) liver-broth, (2) crab meat-broth (infusion of crab meat with 10 times volume of water, 100 *cc*, pepton 5 *g*, beef extract 5 *g*, NaCl 2 *g*; pH 7.2), (3) crab meat infusion agar, (4) glucose-agar, (5) Dyer & Snow's agar[16] (pepton 2 *g*, beef extract 2 *g*, glucose 1 *g*, NaCl 5 *g*, yeast extract 2 *g*, dipotassium phosphate 1 *g*, agar 1.5 *g* ,water 1000 *cc*; pH 7.2).

The inoculated media were incubated anaerobically (Burri's method, Manteufel method) at 37° and 50°C.

(2) Experimental results

From cultivated media, no bacterium was grown. Therefore, the cause of the soured decomposition was considered not to be bacterial origin.

The chromatograms obtained from each sample are shown in Fig. 23.

The amount of V.B.-N. was 32.4 *mg*% for No. 1 can, 31.7 *mg*% for No. 2 can, 35.2 *mg*% for No. 3 can and 26.9 *mg*% for the normal can.

As seen in Fig. 23, spots corresponding to formic acid, acetic acid, and propionic acid were observed for all samples of "flat sour" cans. In No. 2 can, the map which corresponded to butylic acid was observed, but not distinctly.

In normal can (control,) lower molecular acid such as formic acid was not detected, but propionic acid was detected. Besides this propionic acid, a spot was observed near 0.20 of R_f, but this spot was identified.

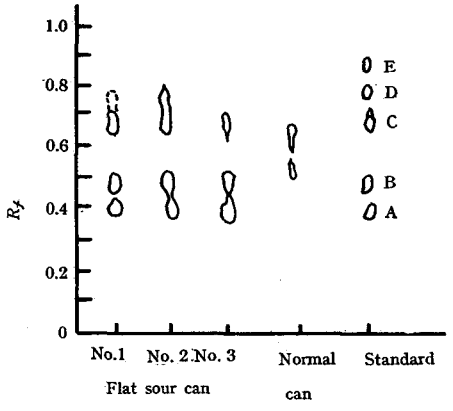


Fig. 23. Chromatograms obtained from the crab meat of "flat sour" cans and a normal can

A : Formic acid (0.40), B : Acetic acid (0.51), C : Propionic acid (0.70), D : Butylic acid (0.79), E : Isovaleric acid (0.84)

This spot may be considered to be some substance which was present in the original sample, or which was formed during the formation of hydroxamate.

The fact that spots revealed by the sample from the normal canned crab (control) were

less distinct than those from the "flat sour" cans, may be due to the presence of less amount of volatile acids in the normal cans.

From the results obtained, it seems that there were more kinds of volatile acids including lower molecular acids, and more amount of the volatile acid in the "flat sour" cans than in the normal can (control). That is to say, those volatile acids give the sour or stimulative taste of the canned material. This distribution of lower molecular fatty acids in the natural substances is limited except the acids having particular physiological functions. Therefore, those lower molecular acids are considered to be originated from the decomposition of amino acid of the protein of crab meat or from the lowering action of higher molecular fatty acids. The mechanisms of the decomposition or the lowering of amino acid of the protein of crab meat have been studied. The fact that the lower molecular volatile acids were found in the crab meat means that the final stage of decomposition has been reached. That is to say, the presence of lower molecular acids is considered to be created from amino acids or higher molecular fatty acids which are present in crab meat.

2. Relation between the degrees of freshness and the production of volatile acids

In the previous article, the author has presumed that the sour or stimulative tastes of the flat sour cans may be due to the presence of lower molecular volatile acids in the meat.

In order to know the reason why those substances were found without having been caused by bacterial decomposition in the canned food, study was made of the change of paper chromatograms of the chemical compounds created from the crab meat which had various degrees of freshness.

(1) Experimental method

The carapaces of *Paralithodes camtschatica* which were caught off Nemuro of Hokkaido were removed from the bodies after the landing. The raw crab meat of legs and shoulder was cut off from the crust.

The raw crab meat was broguht to the laboratory in a thermos container with crushed ice. The raw crab meat was used as soon as possible after it reached the laboratory. The lapsed time was not over 30 hours after the capture. The same quantities of leg and shoulder meats were crushed and homogeneously mixed. An adequate amount of the homogenized meat was used for the determination by the same paper chromatography as described in the previous article. The spots revealed were determined, and compared with those noted in the previous article.

Raw crab meat having various degrees of freshness was made by leaving the raw meat in an ice box (5°C) for various lengths of time. The estimated or observed items were the same as those described in the previous article.

(2) Experimental results

The degree of freshness of raw crab meats which were employed for the estimation are

Table. 37. The amounts of V.B.-N and qualities in raw crab meat of various degrees of freshness

Leaving time (hrs.) (at 5°C)	V. B. -N (*mg*%)	Organoleptic inspection
0	8.6	Fresh, Sweet flavour
24	18.7	Less texture
48	31.1	Off flavour, Slight stimulous odour
72	50.5	Putrefactive odour

Fig. 24. Volatile acids of crab meat of various degrees of freshness

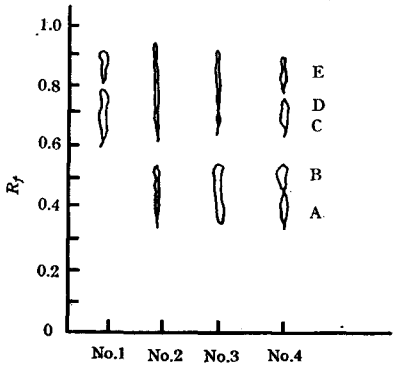
A : Formic acid (0.40), B : Acetic acid (0.51), C : Propionic acid (0.70), D : Butylic acid (0.79), E : Isovaleric acid (0.84)

No. 1……Fresh raw crab (V.B.-N, 8.6 mg%)

No. 2……Pretty unfresh raw crab (V.B.-N, 18.7 mg%)

No. 3……Unfresh raw crab (V.B.-N, 31.1 mg%)

No. 4……Very unfresh raw crab (V.B.-N, 50.5 mg%)



shown in Table 37.

The spots of volatile acids which were detected by paper chromatography are shown in Fig. 24.

As seen in Fig. 24, the spots obtained from fresh raw crab meat (V.B.-N, 8.6 *mg*%) were considered to show the presence of propionic, butylic and isovaleric acids. But slight appearance of the spots made difficult the identification of each substance. The spots obtained from pretty unfresh raw crab meat (V.B.-N 18.7 *mg*%) were identified to be acetic acid, and formic acid in addition to the isovaleric, butylic and propionic acids which were identified from fresh raw crab meat.

The spots obtained from unfresh raw crab meat (V.B.-N, 31.1 *mg*%) were identified to be the same kinds as those from pretty unfresh raw crab meat. In this case, the spots obtained were more clear than those obtained from pretty unfresh raw crab meat. The spots obtained from very unfresh raw crab meat (V.B.-N, 50.5 *mg*%) were identified to be butylic, propionic, acetic and formic acids. In this case, the spot to be identified for valeric acid was very much slighter than that observed from the pretty unfresh or unfresh raw crab meats.

The relation between the various degrees of freshness and the composition of volatile acids created in raw fish meat has been studied by many investigators[18,19,20,21,22]. According to Asakawa[22], the composition of volatile acids created was more or less

different by the kinds of fish,even though the degree of the freshness was almost the same. Therefore, it seems that no proportional relationship exsists between the composition of volatile acids and the degree of freshness of fish meat. However, in the case of crab meat the number of kinds and the amounts of volatile acids increased with the falling of the freshness. That is to say, with the falling of the freshness, volatile acids were found extending to the higher molecular fatty acids, if formic acid is left out of consideration. But that can not be decidedly declared on the basis of these experimental results only. It is rather considered that with the decompsition of raw crab meat, after the higher molecular compounds decomposed to lower molecular compounds or oppositely, composition of higher molecular compounds from the lower molecular compounds had taken place, the wider range of kinds of volatile acids was created.

In the present author's result, propionic acid was found even in fresh raw crab meat, but according to Asakawa, this acid was detected in the decomposed raw fish meat. No exact comparison can be made between the present author's result and Asakawa's result. In this case the factor of microorganisms as concerned with the process of the decomposition of the meat should not be omitted from this discussion. From this consideration, with the variation of the mode of the decomposition, the kinds of produced chemical components became greater.

Comparing the variation of the kind of volatile acids in the raw crab meat having various degrees of freshness with the kinds of volatile acids in flat soured cans of crab meat, one finds that the kinds of volatile acids in the raw fresh crab meat in this experiment were the same as those in the normal cans (control can for soured cans). Considering from the results that in the flat sour cans, formic, acetic and propionic acids were always found and butylic acid was sometimes found in some "flat sour" cans, with the fact that in the unfresh raw crab meat, the same kinds of volatile acids were found, the phenomenon of soured taste in the cans is presumed to be caused by the falling of the freshness of raw crab meat. But it is not safe to conclude that the volatile acids formed in "flat soured" cans are created from the raw crab meat of fallen freshness, because during the processing of canned crab, the raw crab meat is created by the boiling and retorting procedures, therefore changes of chemical components in the meat are considered to have taken place.

3. Relation between volatile acids in canned crab meat and the freshness of the boiled crab meat before the canning

It was ascertained that the amount of V.B.-N produced in the canned crab varies by the freshness of the raw crab meat. It is presumed that the amount or kind of volatile acids also in the canned crab varies by the freshness of the raw meat.

Hitherto, the relation between the volatile acids and the freshness of raw fish meat has been studied by many investigators[20,22]. The present author has also studied the variations in amount and kind of volatile acids in crab meat in connection with the freshness, and in the previous article has expressed the opinion that the soured taste in the "flat sour"

cans may be due to the falling of freshness of the crab meat before processing. Therefore the story of the various factors concerned during the processing of canned crab must be discussed.

In this article, when the boiled crab meat having various degrees of freshness was processed after the meat had been left in an ice box or at room temperature, the amount and the kind of formed volatile acids were studied.

(1) Experimental method

Raw fresh *Paralithodes camtschatica* meat taken from the bodies was boiled with the usual procedures. The boiled meat was left in an ice box or at room temperature, and thus material having various degrees of freshness was obtained. Those boiled meats of various degrees of freshness were processed into canned crab at various temperatures (2~6 pound pressure) for various times (60, 80 minutes) and the finished products were used for the estimation of volatile acids.

(2) Experimental results

The experimental results of analysis of above samples for the amount of V.B.-N and by organoleptic test are shown in Table 38.

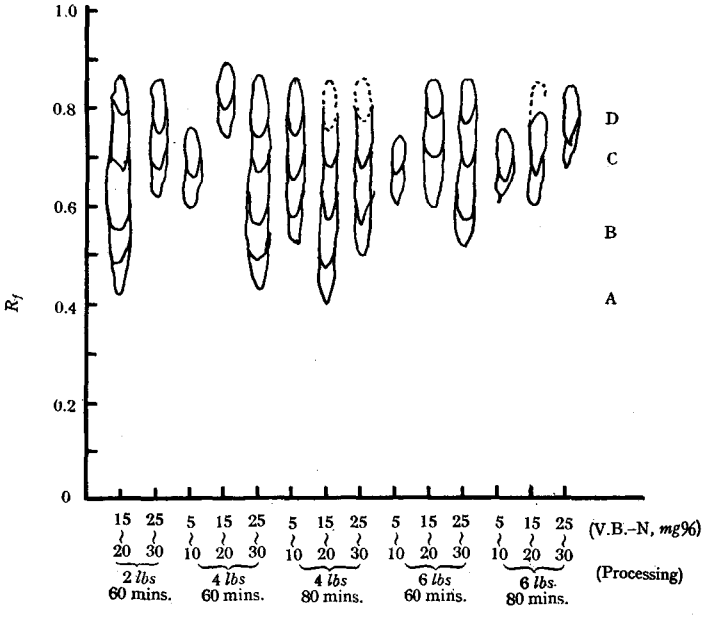


Fig. 25. Volatile acids of canned crab prepared from boiled meat of various degrees of freshness
A : Formic acid (0.40), B : Acetic acid (0.51), C : Propionic acid (0.70), D : Butylic acid (0.79)

Table 38. Opening inspection of canned crab prepared from boiled crab meat of various degrees of freshness

V. B. -N (Raw material) (*mg*%)	Processing time (mins.)	Processing press. (*lbs*) / Estimating items	0	2	4	6
6～15	60	V. B. -N (Canned crab) (*mg*%)	7.8	11.1	13.8	15.8
		pH			6.2	6.0
		Aerobic bacteria	++	+	+	+−
		Anaerobic 〃	++	+	+	−
		Organoleptic inspection		Acid taste	Normal	Normal
	80	V. B. -N (Canned crab) (*mg*%)	7.8	13.7	21.5	20.5
		pH			6.2	6.2
		Aerobic bacteria	+	+	+−	−
		Anaerobic 〃	++	+	+	−
		Organoleptic inspection			Acid taste	Normal
15～20	60	V. B. -N (Canned crab) (*mg*%)	15.5	16.3	23.3	31.1
		pH		6.4	6.2	6.0
		Aerobic bacteria	+	+	+−	−
		Anaerobic 〃	+	+	+	−
		Organoleptic inspection	Acid taste	Acid taste	Acid bitter taste	Normal
	80	V. B. -N (Canned crab) (*mg*%)	18.7	25.0	25.4	33.4
		pH			6.0	6.2
		Aerobic bacteria	+	+	+−	−
		Anaerobic 〃	+	+	+−	−
		Organoleptic inspection	Acid taste, Stimulate odour	Acid taste	Acid taste	Normal
25～30	60	V. B. -N (Canned crab) (*mg*%)	24.7	26.1	31.0	38.9
		pH			6.2	6.6
		Aerobic bacteria	+	+	+	−
		Anaerobic 〃	++	+	+	−
		Organoleptic inspection	Acid taste, Stimulate odour	Acid taste	Acid taste	Normal
	80	V. B. -N (Canned crab) (*mg*%)	20.5	30.7	33.9	38.1
		pH		6.4	6.4	6.4
		Aerobic bacteria	+	+	+	−
		Anaerobic 〃	+	+	+	−
		Organoleptic inspection	Acid taste, Stimulate odour	Acid taste	Acid taste	Normal

Chromatogram of the composition of volatile acids is shown in Fig. 25.

As seen in Fig. 25, it will be observed that with the elongation of the leaving time of the boiled meat, the amount and the kind of volatile acids increased.

As to the processing temperature and time, there are few differences of the amount and the kind of volatile acids in the canned crab meats which were processed for various

periods in the range of this experiment at the same temperature. But when the processing temperature was changed, though there was no remarkable difference between the amount and kind of volatile acids in the canned crab meats which were processed at 103.6°C (2 pound pressure) or at 106.9°C (4 pound pressure), the number of kinds of volatile acids decreased in the canned crab meat processed at 109.9°C (6 pound pressure).

This may be due to the reason that the bacteria attached to the boiled meat which was filled into cans survived the processing at 103.6°C (2 pound pressure) or perhaps survived 106.9°C (4 pound pressure) and then caused decomposition of the crab meat forming volatile acids.

On the other hand, in the crab meat processed at 109.9°C (6 pound pressure), in which the bacteria were destroyed and the bacterial decomposition was prevented, the number of the kinds of volatile acids was small. The composition of volatile acids produced in the boiled meat left for various storing times will be changed by the heating, and the degrees of the change will be varied by the different processing temperatures.

When the processing temperature was 109.9°C (6 pound pressure), the molecular composition of volatile acids produced will become larger than those at other processing temperatures, 103.6°C or 106.9°C.

Those two considerations as above described may be due to the thermotolerance of the isolated bacteria. From the canned crab samples prepared by the experimental method as above described, the bacteria were aerobically and anaerobically isolated, and were tested for their thermotolerance. According to the results obtained, the isolated bacteria were able to survive at 107°C (4 pound pressure) for 20 minutes, but they were destroyed at 110°C (6 pound pressure) for the same time. Therefore, the bacteria present in canned crab could survive 2 or 4 pound pressure of processing, but were destroyed at 6 pound processing pressure.

Therefore, the change of the kinds of volatile acids after the processing may be influenced by bacterial action in the finished product rather than by the heating.

In this experiment, the samples from which formic acid was found, was one of canned crab processed at 103.6°C (2 pound pressure) for 60 minutes from the boiled meat left for two nights, and was processed at 106.9°C (4 pound pressure) for 80 minutes from the same boiled meat, or in canned crab processed at 106.9°C (4 pound pressure) for 60 minutes from the boiled meat left for three nights. In those cans the contents were understerilized. Accordingly it may be said that the canned crab which was processed from boiled meat left for two or three nights is apt to be understerilized, and in those cans, formic acid is possibly produced during storage after processing. However, when the cans were completely sterilized, the source of the production of formic acid must be considered to be from elsewhere.

From canned crab which was processed at 109.9°C (6 pound pressure) for 60 minutes or 80 minutes, no bacterium was isolated. In those cans processed from fresh boiled meat, the same components of volatile acids such as acetic acid and propionic acid were found

amongst components found in normal canned crab.

Against expection, in the canned crab processed from the unfresh raw crab meat, formic acid was not found, but only acetic, propionic and butyric acids were found.

In the canned crab processed at 109.9°C (6 pound pressure) for 80 minutes, propionic and butyric acids were found, but acetic acid was not found. Such differences in canned crab are considered to be caused by bacterial metabolism which will be caused by the multiplication of bacteria in the boiled crab meat during the leaving, or caused by the secondary decomposition of volatile acids which were once produced throughout the heating at the processing.

At any rate, except the case that fresh crab meat is processed, when the boiled crab from fresh raw material is even left and then processed, deterioration of the canned crab is normally differing from that which was processed from raw unfresh crab meat.

4. Composition of volatile acids in canned crab processed from the material having various degrees of freshness

In the previous article report was made on the composition of volatile acids in crab cans which were processed from the boiled meat having various degrees of freshness by leaving the boiled meat for various storage period. According to the results obtained, no difference of the kinds of volatile acids was observed as resultant from the freshness of the boiled meat.

In the next experiment, the raw crab meat was left for various lengths of time before the boiling, so the freshness of the raw meat was varied.

After the boiling the raw crab meat of various degrees of freshness, the meat was processed into canned crab. The composition of volatile acids was detected by paper chromatography.

(1) Experimental method

After the removing of carapace, the raw crab meat was left for some period of storage. Those raw crab meat lots having various degrees of freshness were processed at 109.1°C (5.5 pound pressure) for 85 minutes after the boiling. The samples of canned crab were opened, and a part of the can content was used for bacteriological test; the rest was used for detection of the composition of volatile acids by paper chromatography and for the estimation of the amount of V.B.-N.

(2) Experimental result

Results obtained are shown in Table 39 and Fig. 26.

As seen in Table 39, no bacterium was isolated from the sample cans. Therefore, the sample cans were considered to have been completely sterilized at 109.1°C (5.5 pound pressure) for 85 minutes. As seen also in Table 39 and Fig. 26, the kinds and the amounts of volatile acids increased with the falling of the freshness of the raw crab meat material. In canned crab meat processed from fresh raw crab, acetic and propionic acids were found.

Table 39. Opening inspection of canned crab prepared from raw crab meat of various degrees of freshness

V. B.-N (Raw crab) (*mg*%) / Estimating items of canned crab	6~10	15~20	25~30	35~40
Vacuum (*inch*)	17.5	16.5	14.0	23.0
Odour	Sweet flavour	Sweet flavour	Sweet, slight unpleasant	Unpleasant
Color of meat	Bright red	Bright red	Bright red	Discolorate
Quality of meat	Medium	Medium	Medium, softening	Softening
pH	6.6	6.8	6.6	6.8
Amount of Volatile acid (*mg*%)	16.5	67.4	76.2	93.5
V. B.-N (canned crab) (*mg*%)	23.4	25.5	34.2	49.4
Taste	Sweet	Sweet	Sweet, slight bitter	Acid

The revealed spot corresponding to propionic acid was more remarkable than that acetic acid. In canned crab meat processed from pretty unfressh raw material (V.B.-N, 15~20 *mg*%), propionic acid and butyric acid were found. In canned crab meat processed from unfresh raw crab meat (V.B.-N, 25~30 *mg*%), the kinds of volatile acids increased; formic, acetic, propionic and butyric acids were found. But in this case, the revealed spots became more remarkable with the increase of the molecular weight of each component. That is to say, spots of formic acid and acetic acid were slightly remarkable. In canned crab meat processed from very unfresh raw meat (V.B.-N, 35~40 *mg*%), the kinds of volatile acids were the same as those in canned crab meat processed from unfresh raw meat (V.N.-B, 25~30 *mg*%). In this case, the revealed spots of higher or lower molecular acids were both remarkable.

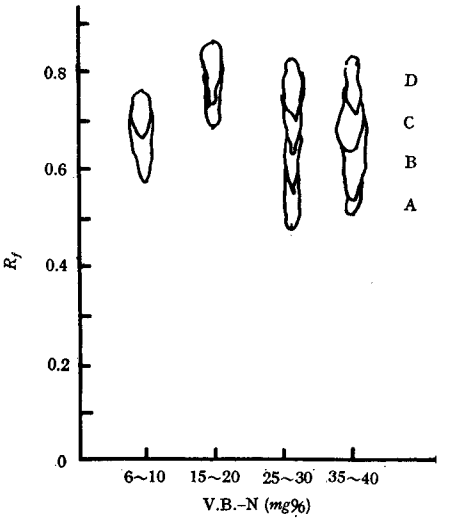


Fig. 26. Volatile acids of canned crab prepared from raw meat of various degrees of freshness

A: Formic acid (0.40), B: Acetic acid (0.51), C: Propionic acid (0.70), D: Butylic acid (0.79)

Comparing those results obtained from canned crab processed from raw crab meat having various degrees of freshness, with those results above obtained on material made from boiled meat having various degrees of freshness, when the raw crab meat was fresh (V.B.-N, 5~10 *mg*%), acetic and propionic acids were found before the boiling, and the same acids

were found after the processing. In the case of pretty unfresh raw crab meat (V.B.-N, 15～20 *mg*%), formic acid, acetic acid, propionic acid, butyric acid and valeric acid were found before the boiling, and after the processing of the same boiled crab propionic acid and butyric acid were detected. In the case of unfresh raw crab meat (V.B.-N, 25～30 *mg*%), the same kinds of acids as above listed were found before the boiling, and also the same kinds of acids except valeric acid were detected after the processing. In the case of very unfresh raw crab meat, the same kinds of acids were detected both before boiling and after processing.

From those results, the kinds of acids in canned crab were ascertained to be the same as with these in raw material. That is to say, if there are many kinds of volatile acids in canned crab, the freshness of the raw material is considered unfresh. On the contrary, if there are few kinds of volatile acids in the canned crab, the freshness is considered to show fresh. The kinds of volatile acids in the canned crab, of which content was deteriorated were the same kinds as in the canned crab which was processed from unfresh raw material (V.B.-N, 25～30 *mg*%). The same kinds of volatile acids were found in canned crab processed from the boiled meat left for some period and of which the freshness fell. In raw crab meat, of which the freshness fell, valeric acid was already found before the boiling. But this acid can not be found in the canned crab processed after boiling from the same raw material. This may be considered due to the reason that some kinds of acids formed in raw meat flow out into juice at the boiling, for example valeric acid formed in unfresh raw meat flowed out into juice, therefore a small quantity of that acid perhaps remained in the canned crab. This matter is under further study in detail.

It was obviously shown that in that canned crab meat which was prepared from boiled meat left over two nights and processed at 103.6°C (2 pound pressure) for 60 minutes or at 106.9°C (4 pound pressure) for 80 minutes, and that which was processed at 106.9°C (4 pound pressure) for 60 minutes from the boiled meat left over three nights, formic acid was detected; the product tasted sourer than that in other cans. When raw unfresh crab meat in which formic acid had formed was packed into tin container, the meat tasted sour. In canned crab, of which the content deteriorated, formic acid and other acids were formed as above described. From those observations, sour taste may be due to the presence of formic acid. However, in a certain range of degree of freshness of crab meat, at which formic acid is detected, other volatile acids are also found remarkably, so the author wishes to interpret that the sour taste may be due to the increase in the total amount of all volatile acids due to the fallen freshness of the material.

From the fact that the series of volatile acids in the canned crab in which the quality of content is deteriorated, is almost similar to those in the fallen freshness of raw crab meat, the deterioration of canned crab is considered to be dependent upon the fallen freshness of the material before the processing.

According to the results obtained by experiments and observations, the series of volatile acids produced in raw crab meat except valeric acid, appear to go with the meat

into the container, but that is not yet quite clear. To the author's opinion, some quantities of volatile acids once produced in crab meat by the boiling, dissolve into boiling water, and the amount of such acids in the crab meat decreases, then the amount of volatile acisd in the crab meat after the processing again increases owing to chemical decomposition of the components of crab meat. Those considerations will be ascertained in future studies.

As the volatile acids responsible for the sour taste of crab meat were presumed to originate from some amino acid in crab meat protein, in order to ascertain the amino acid precursor the author has tried to detect the composition of amino acids in the meat protein of crab.

In two dimensional paper chromatography the HCl-hydrolyzed products were employed. According to the results obtained, aspartic acid and glutamic acid, alanine, valine, phenylalanine, leucine, serine and threonine were found as monoamino acids, while cystine, arginine and lysine were found as diamino acids.

It is known that those amino acids are decomposed anaerobically to the saturated fatty acids. For example, aspartic acid detected in this experiment changes to propionic acid *via* malic acid and succinic acid as seen in the following chemical formula[23].

$$\underset{\text{Aspartic acid}}{COOHCHNH_2CH_2COOH} \rightarrow \underset{\text{Malic acid}}{COOHCHOHCH_2COOH} \rightarrow \underset{\text{Succinic acid}}{COOHCH_2CH_2COOH} \rightarrow \underset{\text{Propionic acid}}{CH_3CH_2COOH}$$

It is easily presumed that aspartic acid which is abunduntly present in raw crab meat changes to propionic acid with the falling of freshness of the crab meat.

Beatty *et al*[24] have studied the glycolysis of fish and shell fish meats, and interpreted the process of the the production of acetic acid from lactic acid. In crab meat, glycogen changes to lactic acid during rigor mortis, the produced lactic acid will decompose reductively in the presence of trimethylamine oxide, to form acetic acid, trimethylamine and CO_2 by the following chemical formula.

$$\underset{\text{Lactic acid}}{CH_3CHOHCOOH} + 2\underset{\text{Trimethylamine oxide}}{(CH_3)_3NO} + H_2O \rightarrow \underset{\text{Acetic acid}}{CH_3COOH} + 2\underset{\text{Trimethylamine}}{(CH_3)_3N} + 2H_2O + CO_2$$

Therefore, the precursors of sour tasting chemical components are considered to be present in the raw crab meat.

5. The influences of boiling procedure upon the composition of volatile acids in crab meat

As described in the previous article, in the raw pretty unfresh crab meat (V.B.-N, 15~20 *mg*%), formic, acetic, propionic, butyric and valeric acids were found before the boiling, but only propionic acid and butyric acid were found after the processing. In the raw unfresh crab meat (V.B.-N, 25~30 *mg*%), formic, acetic, propionic, butyric and valeric acids were found before the boiling, but valeric acid was not found after the processing. On the basis of those results, the author has presumed that volatile acids in raw crab meat dissolve out into the boiling water, though the amount is different for each acid, then the

amount decreases in the meat during the boiling procedure, at which large quantities of some volatile acids in crab were removed into boiling water, and that the remaining portions are retained. The author has also considered that volatile acid may increase again in crab meat on account of chemical change of meat tissue during the processing after the sealing of the cover.

Here, an attempt is made to clear the influences of the heating on the series of volatile acids.

(1) Experimental method

In practical procedures in crab canneries, crab carcasses were boiled in 3~4 *mg*% NaCl solution or in sea water. Those waters are changed after being used for boiling 4 or 5 lots of carcasses. In this experiment, raw crab carcasses having various degrees of freshness were boiled in 3% NaCl solution. A part of the saline solution was taken after 5 times of boiling. The series of volatile acids in raw crab meat were detected by paper chromatography as above described. Employing the crab meat, after the boiling process, the kinds of volatile acids in the boiling water were detected by adding ethyl ether to the water and agitating, leaving at 20°C for 18 hours thereby causing of the volatile acids into the ether layer.

(2) Experimental results

Results obtained are shown in Figs. 27~29.

As seen in Figs. 27~29, acetic acid and propionic acid were always found in raw crab meat. This result agrees with the results obtained as described in the previous article. If the pretty unfresh raw crab meat (V.B.-N, 15~20 *mg*%) was boiled, the series of volatile acids from formic acid to valeric acid were formed in the first time boiling water, but the spots of formic acid and valeric acid in chromatography were more slight than those of other acids. With the falling of freshness of crab meat, the spots became clear. That is to say, with the falling of freshness, larger amounts of volatile acids dissolved out into the boiling water.

In respect to the number of times of boiling, if the crab carcasses having the same degrees of freshness were boiled at different number of times, the kinds of volatile acids were almost the same without relation to the number of times of the boiling. For example, if the very unfresh raw carcasses were boiled, the kinds of volatile acids in the boiling water were almost the same as in cases of one time boiling or of five times boiling.

If the raw pretty unfresh crab carcasses (V.B.-N, 15~20 mg%) were boiled, the spots revealed of all the kinds of volatile acids in the boiling water after the first boiling were more clear than those after the fifth boiling. On the contrary, if the raw unfresh crab carcasses (V.B.-N, 25~30 *mg*%) were boiled, the spots after first boiling were less clear than those after the fifth boiling. With the increase in number of times of boiling, the number of kinds of volatile acids dissolved out into the boiling water is considered to increase correspondingly. Therefore, the results obtained from the raw unfresh crab carcasses meat can be considered

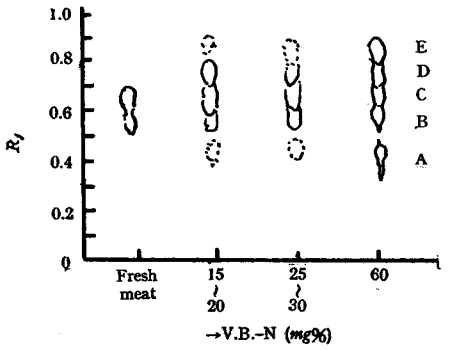


Fig. 27.

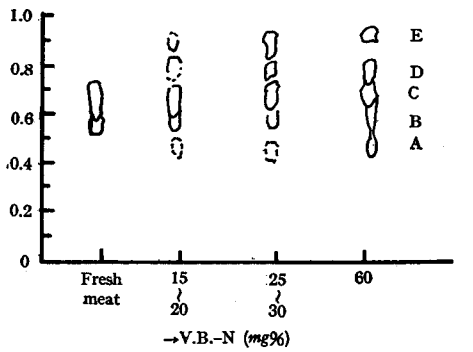


Fig. 28.

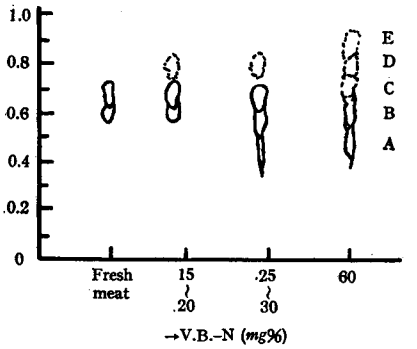


Fig. 29.

Fig. 27. Volatile acids in boiling water after one time of boiling of raw crab of various degrees of freshness

A : Formic acid (0.40), B : Acetic acid (0.51), C : Propionic acid (0.70), D : Butylic acid (0.79), E : Isovaleric acid (0.84)

Fig. 28. Volatile acids in boiling water after five boilings of raw crab of various degrees of freshness

A : Formic acid (0.40), B : Acetic acid (0.51), C : Propionic acid (0.70), D : Butylic acid (0.79), E : Isovaleric acid (0.84)

Fig. 29. Volatile acids in boiled crab meat after boilings of raw material of various degrees of freshness

A : Formic acid (0.40), B : Acetic acid (0.51), C : Propionic acid (0.70), D : Butylic acid (0.79), E : Isovaleric acid (0.84)

trustworthy. But the reason why the results obtained from the raw pretty unfresh carcasses are contrary is not yet clear. At any rate, it is considered that the boiling water can be used in the canneries for five times of boiling without changing.

As described in the previous article, in the fresh raw crab meat after the boiling, acetic acid and propionic acid were found. These sorts of volatile acids were the same as those in the first or in the fifth boiling water in which the raw carcasses were changed. From these

observations, the kinds of volatile acids may remain the same in crab meat even after the boiling.

If the pretty raw unfresh crab carcasses (V.B.-N, 15～20 mg%) are boiled, all the kinds of volatile acid were found in the boiling water, but acetic acid, propionic acid and butyric acid were found in the boiled crab meat itself. Comparing those results with that described in the previous article, when the pretty unfresh raw crab carcass meat (V.B.-N, 15～20 mg%) was processed after boiling, acetic acid, propionic acid and butyric acid were found in the canned crab meat; the kinds of volatile acids were almost the same in the boiled crab meat before the processing.

Therefore, the assumption seems disproven which was made in the previous article that some kinds of volatile acids in the crab meat disappear once as a result of boiling, but the kinds increase secondarily on account of the change of the meat after the processing.

Results obtained as to the unfresh crab meat showed almost the same tendency as the results described as above.

It is insufficient to state from the above assumption that the kinds of volatile acids produced in the crab meat before the boiling were not found in the meat after the boiling. Therefore, the facts that the kinds of volatile acids in fresh crab meat are the same before and after boiling, and that those in the boiling water and the boiled crab meat are different, lead to the following conclusion: the amounts of various kinds of volatile acids are not equal, therefore when those acids flowed out into the boiling water, the larger part of each acid which is present in less amount flowed out into the bioling water, and less amount of volatile acid which is present in larger amount will be left in the boiled crab meat, even if the larger part of those acids flowed out into the boiling water. Under this consideration, almost the total amount of formic acid or valeric acid which are produced in less quantity in comparatively fresh raw crab meat, will flow out in the boiling water, even if those acids are produced in the crab meat, therefore those acids will not remain to be detected in the crab meat. On the other hand, in the unfresh raw crab meat, formic acid, butyric acid and valeric acid will be produced in larger amount, so some part of the amounts of those acids will flow out, and another considerable part will remain in the crab meat.

From those facts, in the case when the pretty unfresh raw crab meat is boiled, if the boiling time and washing time are prolonged, the larger part of the amount of volatile acids will be flowed out. But with the increase of boiling and washing times, larger amounts of meat extractive will also be flowed out, so that taste will become inferior.

As clear in the previous results, when the raw crab meat is pretty unfresh or unfresh, many kinds of volatile acids remain in the crab meat even after the boiling. Those remained volatile acids will transfer into the can with crab meat and taste sour. This is considered to be a cause of "flat sour" of canned crab.

From the discussions offered above, the following conclusions are reached.

(1) Sour taste of the canned crab which is called "flat sour" has relation with volatile

acids. (2) With the falling of the freshness of raw crab meat, the amounts of volatile acids increase. (3) By the boiling of raw crab meat, a part of the amount of volatile acids produced in the raw crab meat is caused to flow out into the boiling water and if the produced amount in crab meat is comparatively large, the acids remain in the crab meat. (4) The kinds of volatile acid in the boiled meat are unchanged even after the processing. (5) The presence of formic acid in the canned crab is considered to take part in causing the sour taste. (6) When the raw crab meat is unfresh (V.B.N, 25~30 mg%) formic acid is found in the boiled crab met. (7) Therefore, in order to prevent "flat sour" of which the cause is without relation to bacteria, the fresh raw crab must be used.

SUMMARY

In this paper, the author has studied the troubles and technical problems attendant upon the processing of canned crab (King crab : *Paralithodes camtschatica*) which have been called to his attention.

In Article I, the decomposability of raw king crab meat was discussed from the viewpoint of the histological characteristics.

Then, the author ascertained that when the amount of volatile basic nitrogen (V.B.-N) in the raw crab meat rises over about 20 *mg*%, the meat becomes unfit for canning. Therefore in Article II, studies were tried on the relationship between the storing temperature and maximum storing time for which the crab meat can be stored and still remain suitable as raw material for canning. From the results obtained, a scale was prepared by which one can learn the maximum storing time at various temperatures of the raw crab meat from the standpoint of rational processing. But, in practice, it is rather necessary to know also the limit of freshness of the boiled crab meat and the maximum storing time before the limit is reached.

For the purpose, the author in Article III has reported on the variation of the freshness of boiled crab meat treated by the "high-" (at 100°C, 15 minutes) or "low temperature boiling method" (at 60°~65,° 10~15 mins), and the limit of the freshness of the boiled crab meat was determined from the view point of suitability as material for canning.

From the results of study, it is concluded that when the freshness of the raw crab meat is below 10 *mg*% of V.B.-N, the limit of the freshness of the boiled meat should be 15 *mg*%, and when the freshness of the raw meat is 10~20 *mg*%, the limit of the freshness of the boiled meat should be 10~13 *mg*%. When the freshness of the raw crab meat is above 20 *mg*%, even if the raw meat is boiled and processed for canning without delay, good quality of canned crab is not obtainable. At this points, the author prepared a scale showing the relation between the storing temperature of the boiled crab meat and maximum storing time for the canning, which it is also advisable to use in the rational processing.

Further, the determination of the processing time for canned foods according to the freshness of the raw or boiled material is very important. In Article IV, it is presented a

discussion on calculation of processing time of canned crab meat having different degrees of freshness; a consolidated diagram is prepared which shows the relation among the storage temperature of the raw or boiled crab meat, boiling methods, falling of freshness and the processing temperature-time of canned crab. The diagram may be convenient for the technologists employed in crab canneries.

In Article V, some problems were discussed concerned with canned crab processed by subjecting to the "low temperature boiling method" which has been invented by Kosakabe[2].

Especially, the author has studied the action of autolytic enzymes after the "low temperature boiling method". From the results, it was observed that the autolytic action of enzymes in the crab meat was maximum at 50°C, and was destroyed by above 90°C boiling.

At last, in Article VI, studies were described of "flat-sour"-like canned crab, of which the cause was ascertained to be not thermophilic bacteria, but to be due to the production of soured chemical substances by the falling of the freshness. The soured substances were identified as volatile acids, especially the presence of formic acid in the canned crab was considered to take a part in causing the sour taste. And, when the raw crab meat is pretty unfresh or unfresh, many kinds of volatile acids remain in the crab meat even after the boiling. Those volatile acids which are left will be transferred into the can with crab meat and taste sour. This is considered to be a cause of the "flat-sour" of this canned crab.

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