STUDIES ON BOUND WATER IN FISH MEAT MUSCLE (III)

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VI. ESTIMATION BY THE COBALTOUS CHLORIDE AND BY THE ELECTRICAL RESISTANCE METHODS OF THE AMOUNT OF BOUND WATER IN FISH MEAT IN VARIOUS CONDITIONS.

In this experiment, the amounts of Bound Water in raw fresh meat, dried meat, salted meat, fermented meat and decomposed meat of various kinds of fish were estimated by the cobaltous chloride method, and by the electrical resistance method.

1. Experimental methods.

(1) The method of estimating the amount of Bound Water.

The method chosen for estimating the amount of Bound Water was Oyagi's[12c]. The calculation was carried out by the same method as described in the earlier reported Exp. III. 1, (1), (II, B)[38a].

To calculate the amount of Bound Water (R. B.) in the samples (not dyed sample), the total amount of water (R. T.) in the like same sample of each material was determined by the usual drying method.

The calculating formula is as follows:

$$R.\ B. = \frac{(100 - R.\ T.)\ (W_1 - W_2)}{W_2} \quad \text{-----------} \quad (15)$$

where, W_1 is the weight at the point where the colour of the sample changes from pink to pure blue, or the apparent constant value of the weight of the sample during the drying at 30°C, W_2 is the constant weight of the sample during the drying at 110°C. The amount of Free Water (R. F.) in the sample, is calculated as follows:

$$R.\ F. = R.\ T. - R.\ B. \quad \text{---------------} \quad (16)$$

In this calculation, the amount of Bound Water per gm of the dried matter of the sample was supposed to remain unchanged during the steeping of the sample in the cobaltous chloride solution.

(2) The electrical resistance method.

The method for estimating by the electrical resistance was the same as in the previously described Experiment Ⅱ, 1, (1), (Ⅳ). The sample of fish meat filet (4×2×2 cm.) was impaled upon two copper poles (6.7 cm. in length and 0.17 mm. in diameter) fixed on the insulated bakelite plate at definite distance. The electrical resistance was made by Fuji Radio Co., its cycle was 50, and its type was Wheatstone's bridge. The estimating temperature of drying of fish meat was 19°C and 20°~25°C; the sample which was thrust through by the poles was placed in the desiccator before the estimation of electrical resistance. Thus the state of water in the sample was determined by the electrical resistance during the drying.

2. Experimental results and considerations.

(1) Determination of the amount of Bound Water by Oyagi's method.

The results on Sandfish (*Arctoscopus japonicus STEINDACHNER*), Squid (*Ommastrephes sloani pacificus*) and Flat-fish (*Kareius bicoloratus BASILEWSKY*) are shown in Table 24 and Fig. 33.

As stated earlier in Experiment Ⅱ. 1[38a], the sign B. P. in Table 24 and Fig. 33 is the point at which the colour of pieces of dyed fish meat steeped in the cobaltous chloride solution turns to pure blue from pink in the course of drying at 30°C. The amount of water estimated at point B. P. is represented as the amount of Bound Water. But as shown in the experiment there is another point, C. P., which is recognized as the apparent constant weight of water in the sample in the course of drying at 30°C from 1 to 3 hours after the appearance of the point B. P.

Discussing Bound Water from its binding strength, the amount of water determined by the cobaltous chloride method between the points B. P. and C. P. in the course of drying at 30°C, is regareded as the amount of Bound Water. The author calls the amount of water at point B.P. the maximum value of the amount of Bound Water, and the amount of water at point C. P. the minimum value of the amount of Bound Water. The values of the amount of Bound Water at those two points were estimated on the samples of various kinds of fish.

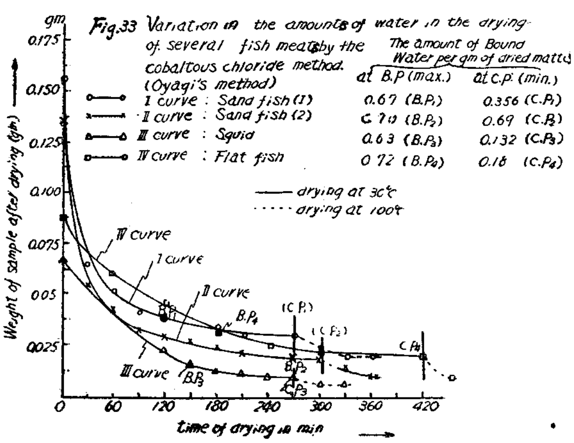


Fig. 33 Variation in the amounts of water in the drying of several fish meats by the cobaltous chloride method. (Oyagi's method)

Table 24. Variation in the amounts of water in the drying of several fish meats by the cobaltous chloride method (Oyagi's method).

Drying time in min.	Sand fish meat			Squid fish meat			Flat fish meat		
	Change of the weight of sample (gm)	g※ (gm)	Drying temp. (°C)	Change of the weight of sample (gm)	g※ (gm)	Drying temp. (°C)	Change of the weight of sample (gm)	g※ (gm)	Drying temp. (°C)
0	0.1352	10.76		0.0641	5.04		0.0883	3.57	
30	0.0534	3.63		—	—		·	—	
60	0.0418	2.63		—			0.0613	2.17	
90	0.0319	1.77		—	—		—	—	
120	0.0282	1.39		0.0242	1.28		0.0476	1.46	
150	0.0265	1.30	25°~30°C	0.0173	0.63 (B.P₃)	25°~30°C	—	—	
180	0.0242	1.10		0.0138	0.30		0.0331	0.72 (B.P₄)	
210	0.0220	0.91 (B.P₂)		0.0130	0.226		—	—	15°~20°C
240	—	—		0.0120	0.132		0.0253	0.31	
270	0.0196	0.70		0.0120	0.132 (C.P₃)		—	—	
300	0.0195	0.69 (C.P₂)		—	—	100° ~ 105°C	0.0231	0.198	
330	0.0157	0.36		0.0106	0.00		—	—	
360	0.0115	0.00	100° ~ 105°C	0.0106	0.00		0.0228	0.180 (C.P₄)	
370	0.0115	0.00					—	—	
420							0.0228	0.180	
480							0.0195	0.010	
540							0.0193	0.00	100° ~ 105°C
600							0.0193	0.00	
Remarks	See II curve in Fig. 33			See III curve in Fig. 33			See IV curve in Fig. 33		

Note : I curve in Fig. 33 is the same curve as shown in Fig. 7, previous Experiment II, 1.
※ Gm of water per gm of bone dried sample.

(I) Determination of the amount of Bound Water by the cobaltous chloride method on the raw fresh meat of various kinds of fish.

The results derived from using Oyagi's method on the raw fresh meat of Squids (*Ommastrephes sloani pacificus* and *Loligo bleekeri KEFERSTEIN*), Flat-fishes (*Microstomus achve JORDAN et STARKE*, *Atheresthes evermanni JORDAN et STARKE*, *Kareius bicoloratus BASILEWSKY*, *Limanda herzensteini JORDAN et SNYDER* and *Paralichthys olivaceus TEMMINCK et SCHLEGEL*), Herring (*Clupea harengus SINNEUS*), Sardine (*Engraulis japonicus TEMMINCK et SCHLEGEL*), Mackerel (*Scomber japonicus HOUTTUYN*), Atka Mackerel (*Pleurogrammus azonus JORDAN et METZ*), Horse Mackerel (*Trachurus japonicus TEMMINCK et SCHLEGEL*), Sand fish (*Arctoscopus japonicus STEINDACHNER*) and Globe-fish (*Sphaeroides rubripes TEMMINCK et SCHLEGEL*) are shown in Tables 25, 26 and 27. Table 25 shows the minimum values of the amount of Bound Water in the samples; Table 26 shows the maximum values of the amount of Bound Water; Table 27 shows the averages of those values of the amount of Bound Water per 100 gm of the dried matter of the samples.

From Tabler 25, 26 and 27 it is clear that the minimum amount of Bound Water is 10~48 gm (25.2 gm on the average) per 100 gm of the dried matter of the fresh meat, and the maximum amount of Bound Water is 55~82 gm (63.2 gm on the average). Supposing that Free Water has evaporated first when the raw fresh fish meat is dried, the total amount of water remaining in the fish meat is considered to be Bound Water at the time when the water-content of the meat shows about 20% (the minimum water-content) or 40% (the maximum water-content).

Table 25. Minimum values of the amount of Bound Water in the raw fresh meat of various kinds of fish.

Samples \ Water Contents	Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.F.}{R.T.}\times 100$ (%)	$\frac{R.B.}{R.T.}\times 100$ (%)	g. (gm of Bound Water per gm of dried matter)	$\frac{g}{g+D.M}\times 100$ (%) (D.M = Dried matter)
Squid (*Ommastrephes sloani pacificus*)	(1) 83.51 (2) 81.64	81.43 80.64	2.18 3.48	97.50 95.85	2.50 4.15	0.132 0.220	11.6 18 0
Squid (*Loligo bleekeri KEFERSTEIN*)	79.89	70.26	9.60	88.00	12.00	0.477	32.3
Flat fish (*Microstomus achve JORDAN et STARKE*)	76.18	72.50	3.68	95.16	4.84	0.154	13.3
Flat fish (*Atheresthes evermanni JORDAN et STARKE*)	80.99	79.28	1.71	97.87	2.13	0.09	8.25
Flat fish (*Kareius bicoloratus BASILEWSKY*)	(1) 79.19 (2) 78.64	74.51 74.39	4.66 4.25	94.11 94.59	5.89 5.41	0.224 0.199	18.3 16.6
Flat fish (*Paralichthys olivaceus TEMMINCK et SCHLEGEL*)	78.02	73.30	4.72	93.90	6.10	0.215	17.7
Herring (*Clupea herengus SINNEUS*)	(1) 81.64 (2) 80.62	78.84 76.70	2.80 3.92	96.50 95.13	3.44 4.87	0.152 0.202	13.1 16.6
Sardine (*Engraulis japonicus TEMMINCK et SCHLEGEL*)	(1) 76.55 (2) 79.34	71.80 74.54	4.37 4.80	93.80 94.00	6.20 6.00	0.202 0.232	16.6 18.8
Sand fish (*Arctoscopus japonicus STEINDACHNER*)	80.30	73.30	7.00	91.28	8.72	0.356	26.2
Atka Mackerel (*Pleurogrammus azonas JORDAN et METZ*)	(1) 80.00 (2) 83.95 (3) 80.99	71.26 80.47 79.28	8.74 3.48 1.71	89.09 95.85 97.87	10.93 4.15 2.13	0.437 0.216 0.09	30.4 17.8 8.25

Table 26. Maximum values of the amount ot Bound Water in the raw fresh meat of various kinds of fish.

Samples \ Water Contents	Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.F.}{R.T.}\times 100$ (%)	$\frac{R.B.}{R.T.}\times 100$ (%)	g. (gm of Bound Water per gm of dried matter)	$\frac{g}{g+D.M}\times 100$ (%) (D.M = Dried matter)
Squid (*Loligo bleekeri KEFERSTEIN*)	(1) 76.27	59.03	17.24	77.3	22.7	0.726	42.0
	(2) 78.19	60.85	17.34	77.8	22.2	0.778	43.8
	(3) 78.73	59.56	19.17	75.6	24.4	0.896	47.2
	(4) 78.45	60.21	18.24	76.7	23.3	0.845	45.8
Squid (*Ommastrephes sloani pacificus*)	76.62	63.58	13.04	82.9	17.1	0.557	35.8
Sardine (*Engraulis japonicus TEMMINCK et SCHLEGEL*)	(1) 76.70	65.66	11.04	85.6	14.4	0.474	32.1
	(2) 76.70	59.50	17.20	77.5	22.5	0.738	42.5
Sand fish (*Arctoscopus japonicus STEINDACHNER*)	(1) 80.51	67.40	13.11	83.7	16.3	0.673	40.2
	(2) 80.51	66.79	13.72	82.9	17.1	0.704	41.3
Horse Mackerel (*Trachurus japonicus TEMMINCK et SCHLEGEL*)	(1) 76.14	57.60	18.54	75.7	24.3	0.777	43.7
	(2) 73.20	54.28	18.92	74.1	25.9	0.706	41.4
Globe fish (*Sphaeroides rubripes TEMMINCK et SCHLEGEL*)	(1) 80.07	68.97	11.10	86.1	13.9	0.557	35.8
	(2) 80.10	65.40	14.67	81.0	19.0	0.736	42.4
Flat fish (*Limanda herzensteini JORDAN et SNYDFR*)	(1) 78.88	52.96	25.92	67.1	32.9	1.230	55.2
	(2) 78.74	54.99	23.75	69.8	30.2	1.117	52.8
Mackerel (*Scomber japonicus HOUTTUYN*)	76.62	63.58	13.04	82.9	17.1	0.557	35.8

Table 27. Amount of Bound Water in the raw fresh meat of various kinds of fish.

Samples \ Amount of Bound Water	Minimum amount of Bound Water	Maximum amount of Bound Water	Samples \ Amount of Bound Water	Minimum amount of Bound Water	Maximum amount of Bound Water
Squid (*Ommastrephes sloani pacificus*)	17.5	55.7	Flat fish (*Paralichthys olivaceus TEMMINCK et SCHLEGEL*)	21.5	—
Squid (*Loligo bleekeri KEFERSTEIN*)	47.7	81.1	Flat fish (*Limanda herzensteini JORDAN et SNYDER*)	—	54
Sardine (*Engraulis japonicus TEMMINCK et SCHLEGEL*)	21.7	60.6	Atka Mackerel (*Pleurogrammus azonas JORDAN et METZ*)	37.1	—
Sand fish (*Arctoscopus japonicus STEINDACHNER*)	35.6	68.8	Mackerel (*Scomber japonicus HOUTTUYN*)	—	55.7
Flat fish (*Kareius bicoloratus BASILEWSKY*)	21.1	—	Horse Mackerel (*Trachurus japonicus TEMMINCK et SCHLEGEL*)	—	64.8
Flat fish (*Microstomus achve JORDAN et STARKE*)	15.4	—	Globe-fish (*Sphaaroides rubripes TEMMINCK et SCHLEGEL*)	—	64.6
Flat fish (*Atheresthes evermanni JORDAN et STARKE*)	9.0	—	Range (Average)	10～48 (25.2)	55～80 (63.2)

However, at the time of the evaporation of water from the meat, the mechanism of water evaporation varies practically somewhat with the differences in conditions between the inner and surface parts of the meat. That is to say, at the surface because of excess drying, the amount of Bound Water decreases and some amount of Free Water rests in the meat.

Here, it is noteworthy that the amount of Bound Water in the fish meat is not necessarily always the same, because the amount of Bound Water varies apparently with the kind of fish. Even in the same kind of fish, the amount of Bound Water is recognized to vary with each body. Beside those factors, the amount of Bound Water is supposed to vary with catching season in keeping with the chemical components and properties of the fish meat, such as the water-content and protein and fat.

Higuchi[23] has estimated the amount of Bound Water in Squid and Flat-fish meat by a method concerning the depression of the freezing point and calorimetric method. The present author has calculated Higuchi's results as follows: the amount of Bound Water in Squid is 13.4 gm per 100 gm of the dried matter of the sample, and 18.7 gm for Flat fish meat. These values are in correspondence with the minimum values estimated by the cobaltous chloride method. As described in Experiment II, 1, (2), (I), B, the minimum value of the amount of Bound Water is recognized to be the Colloidal Bound Water, and the maximum amount of Bound Water is considered to be the Biological Bound Water.*

(II) The amount of Bound Water estimated in the dried meat of several kinds of fish by the cobaltous chloride method.

The maximum and minimum values of the amount of Bound Water of Squid (*Ommastrephes sloani pacificus* and *Loligo bleekeri KEFERSTEIN*), Mackerel (*Scomber japonicus HOUTTUYN*), Atka Mackerel (*Pleurogrammus azonus JORDAN et METZ*), Sand-fish (*Arctoscopus japonicus STEINDACHNER*), Globe-fish (*Sphaeroides rubripes TEMMINCK et SCHLEGEL*), Sardine (*Engraulis japonicus TEMMINCK et SCHLEGEL*) and Flat fish (*Limanda herzensteini JORDAN et SNYDER*) by the cobaltous chloride method are shown in Tables 28 and 29.

Fig. 34 shows the relation between the total amount of water of each sample of various kinds of fish meat and the amount of Free Water, or the relation between the maximum and the minimum values of Bound Water of each sample. Fig. 35 shows the amount of Bound Water per gm of the dried matter of each sample in relation to the total amount of water in each sample. The curves in

*The Biological Bound Water will be discussed in detail in further experiments.

Table 28. Minimum values of the amount of Bound Water in the dried meat of various kinds of fish.

Samples and Treatments \ Water Contents	Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.F.}{R.T.}\times 100$ (%)	$\frac{R.B.}{R.T.}\times 100$ (%)	g. (gm of Bound Water per gm of dried matter)	$\frac{g}{g+D.M}\times 100$ (%) (D.M = Dried matter)
Squid (*Ommastrephes sloani pacificus*) (Sun-drying)	(1) 77.33	73.33	4.00	94.80	5.20	0.176	15.0
	(2) 74.64	69.11	5.53	92.59	7.41	0.218	17.9
	(3) 62.87	57.83	5.04	91.98	8.02	0.136	12.0
	(4) 38.53	26.48	12.05	68.72	31.28	0.196	16.4
	(5) 31.80	21.28	10.52	66.91	33.09	0.154	13.3
	(6) 31.74	18.10	13.64	57.02	42.98	0.199	16.6
	(7) 31.44	26.10	5.34	83.01	16.99	0.078	7.25
	(8) 14.58	8.38	6.20	57.47	42.53	0.073	6.82
Atka Mackerel (*Pleurogrammus azonas JORDAN et METZ*) (Half-dried)	(1) 79.17	74.51	4.66	94.11	5.89	0.224	18.3
	(2) 78.64	74.39	4.25	94.59	5.41	0.199	16.6
	(3) 77.51	69.50	5.01	86.67	10.33	0.356	27.0
	(4) 77.33	73.33	4.00	94.82	5.18	0.176	15.0
	(5) 76.18	72.50	3.68	95.16	4.84	0.154	13.3
	(6) 74.64	69.11	5.54	92.59	7.41	0.218	17.9
	(7) 69.00	60.29	8.71	87.37	12.63	0.281	21.9
Ditto (Sun-drying)	(1) 80.00	71.26	8.74	89.09	10.93	0.437	30.4
	(2) 64.90	54.16	10.74	83.45	16.55	0.306	23.4
	(3) 57.90	46.92	10.98	81.03	18.97	0.261	19.9
	(4) 55.90	43.47	12.43	77.76	22.24	0.282	21.9
Ditto (Drying by heating)	(1) 63.20	68.74	14.46	77.12	22.88	0.393	28.2
	(2) 40.50	27.35	13.15	67.53	32.47	0.221	18.1
	(3) 38.30	29.54	8.76	77.12	22.88	0.142	12.4
Ditto (Salting and Drying)	(1) 57.00	42.43	14.44	74.44	25.56	0.339	25.3
	(2) 55.00	41.64	13.33	72.33	27.67	0.269	21.2
	(3) 52.90	40.80	12.10	77.12	22.88	0.257	20.4
	(4) 49.30	35.66	13.64	72.33	27.67	0.269	21.2
	(5) 48.60	37.65	10.95	74.73	25.27	0.213	17.5
	(6) 47.60	32.99	15.51	67.41	32.59	0.296	22.9

Table 29. Maximum values of the amount of Bound Water in the dried meat of various kinds of fish.

Samples and Treatments \ Water Contents	Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.F.}{R.T.}\times 100$ (%)	$\frac{R.B.}{R.T.}\times 100$ (%)	g. (gm of Bound Water per gm of dried matter)	$\frac{g}{g+D.M}\times 100$ (%) (D.M = Dried matter)
Squid (*Loligo bleekeri KEFERSTEIN*) (Sun-drying)	(1) 34.31	7.38	26.93	21.50	78.50	0.410	29.0
	(2) 26.42	1.84	24.58	6.96	93.04	0.334	25.0
	(3) 25.61	0.76	28.85	2.97	97.03	0.334	25.0
Mackerel (*Scomber japonicus HOUTTUYN*) (Half-dried)	(1) 73.27	50.68	22.59	68.20	30.80	0.845	45.7
	(2) 73.38	50.21	23.17	68.40	31.60	0.873	46.6
	(3) 73.49	49.74	23.75	67.70	32.30	0.896	47.2
	(4) 64.95	43.75	21.20	67.30	32.70	0.605	37.8
Sandfish (*Arctoscopus japonicus STEINDACHNER*) (Sun-drying)	(1) 52.71	11.76	40.95	22.30	77.30	0.862	46.2
	(2) 28.57	5.15	23.42	18.02	81.98	0.328	24.7
Globe-fish (*Sphaeroides rubripes TEMMINCK et SCHLEGEL*) (Sun-drying)	(1) 39.47	5.82	33.65	14.70	85.30	0.556	35.7
	(2) 39.47	5.94	33.53	15.00	85.00	0.554	35.6
Squid (*Ommastrephes sloani pacificus*) (Half dried)	(1) 74.10	60.17	13.93	81.20	18.80	0.538	35.0
	(2) 73.50	58.93	14.57	80.10	19.90	0.550	35.4
	(3) 73.80	59.55	14.25	80.70	19.30	0.544	35.2
	(4) 70.10	51.26	18.84	73.10	26.90	0.603	37.6
	(5) 63.26	35.38	27.88	55.90	44.10	0.759	43.1
	(6) 66.68	43.99	22.64	65.90	34.10	0.681	40.5
Flat fish (*Limanda herzensteini JORDAN et SNYDER*) (Half-dried)	(1) 76.61	53.06	23.55	69.20	30.80	1.007	50.3
	(2) 68.55	37.98	30.57	55.40	44.60	0.972	49.3
	(3) 65.21	34.98	30.23	53.64	46.34	0.864	46.3
	(4) 66.88	36.80	30.50	54.39	45.61	0.921	47.9
Sardine (*Engraulis japonicus TEMMINCK et SCHLEGEL*) (Sun-drying)	31.76	1.26	30.50	3.96	96.04	0.447	30.9

Fig. 34. Variation of the amount of Free (F. W.) and Bound Water (B. W.) in the course of drying.

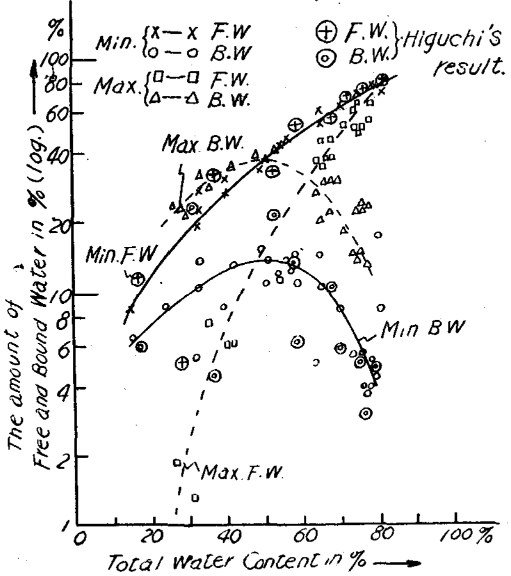


Fig. 35. Distribution of the absolute amount of Bound water in the course of drying

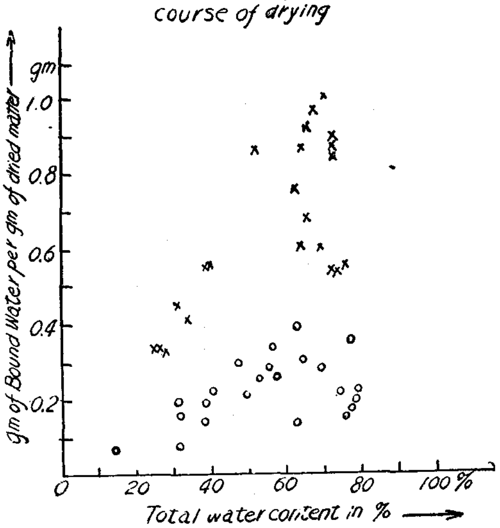


Fig. 34 are formed by joining the massed points for the amounts of Free Water and Bound Water (the maximum and the minimum values) of all the samples. These curves are considered to show the variation of the amounts of Free and Bound Water during the drying of fish meat.

From Fig. 34 it is clear that with the drying, the percentage of the amount of Free Water decreases and the percentage of the amount of Bound Water increases relatively; the relative amount of Bound Water for total amount of Water shows the maximum value at about 40～50% of the total amount of water in the fish meat. With further dehydration, the percentage of the amount of Bound Water decreases. When the maximum value of the amount of Bound Water is determined, the percentage of the amount of Bount Water for the total amount of Water in the fish meat is from about 25% (minimum) to 75% (maximum) as seen in Table 28 and 29.

Higuchi's results for Squid and Flat fish meat during the drying which were together shown in Fig. 34 agreed generally with the minimum value of the amount of Bound Water (Colloidal Bound Water) obtained by the present author. It is interesting that the values of the amount of Bound Water obtained by the thermodynamic methods such as the one concerning the depression of the freezing point and the calorimetric method by Higuchi agreed almost with the results obtained by the chemical methods such as the cobaltous chloride which is different from the thermodynamic methods in the idea of the determination. This agreement encourages the present author to believe that the minimum value of the amount of Bound Water obtained by the cobaltous chloride method (the amount of water at the point of C. P. in the course of drying of the sample) should be considered as the Colloidal Bound Water. This conclusion has also been substantiated by the previously reported Experiment Ⅲ, 1.

From Fig. 35 the absolute value of the amount of Bound Water per gm of the dried matter of the fish meat apparently decreases generally with the drying of the sample.

(Ⅲ) Results obtained by the cobaltous chloride method on the salted fish meat.

Tables 30 and 31 show the amounts of Bound Water in the salted fish meat —Atka Mackerel (*Pleurogrammus azonus JORDAN et METZ*), Squid (*Loligo bleekeri KEFERSTEIN*) and Mackerel (*Scomber japonicus HOUTTUYN*).

Salted Atka Mackerel meat was prepared by the dry-salting and brine-salting processes. Salted Mackerel and Squid were made by dry-salting process. The amount of salt used was 2)% by weight of the raw material in the dry-salting process.

The brine was saturated salt solution. The amounts of Bound Water in these salted fishes were determined by the cobaltous chloride method (Oyagi's).

Fig. 36 shows the variation of the amount of Bound Water in the salted Atka Mackerel, Squid and Mackerel meat at certain intervals after the salting.

Fig. 36. Variation of the amount of Bound Water in the course of salting.

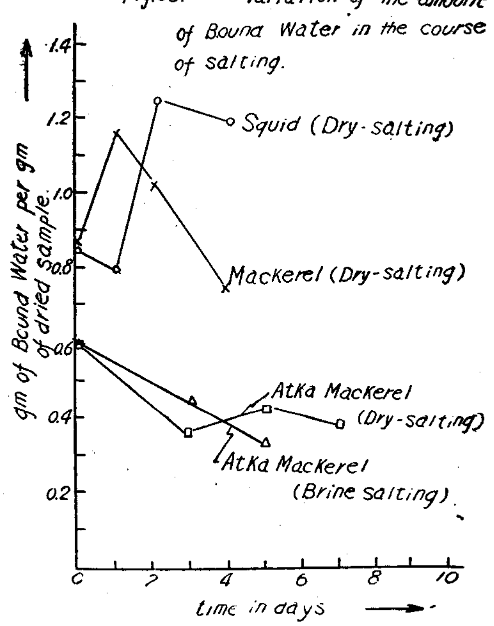


Table 30 shows the variation of the amount of Colloidal Bound Water (the minimum value of the amount of Bound Water at C. P.) in Atka Mackerel meat at certain intervals after the salting process. Table 31 shows the variation of the amount of Biological Bound Water (the maximum values at B. P.) in Mackerel and Squid meat at intervals after the salting process.

From Tables 30 and 31, it is observed that the total amount of water decreases with the lapse of hours after the salting process because of the osmotic dehydration

Table 30. Variation in the amount of Colloidal Bound Water in Atka Mackerel meat at certain intervals after salting.

Samples, Treatments and Days		Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.B.}{R.T.}\times 100$ (%)	$\frac{R.F.}{R.T.}\times 100$ (%)	g (gm of Bound Water per gm of dried matter)
Atka Mackerel (*Arctoscopus japonicus* *STEINDACHNER*) (Brine-salting)	Raw fish meat	80.5	68.92	11.58	14.39	85.61	0.594
	3 days after	61.7	44.73	16.97	27.53	72.47	0.443
	5 〃 〃	62 8	50.52	12.28	19.56	80.44	0.330
	7 〃 〃	63.1	—	—	—	—	—
Ditto (Dry-salting)	Raw fish meat	80.5	68.92	11.58	14.39	85.61	0.594
	3 days after	61.1	47.18	13.92	22.88	77.12	0.358
	5 〃 〃	59.7	42.62	17.08	28.60	71.40	0.425
	7 〃 〃	42.4	20.80	21.60	59.95	49.50	0.375

Table 31. Variation in the amount of Biological Bound Water in Squid and Mackerel meat at certain intervals after salting.

Samples, Treatments and Days		Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.B.}{R.T.}\times 100$ (%)	$\frac{R.F.}{R.T.}\times 100$ (%)	g (gm of Bound Water per gm of dried matter)
Squid (*Loligo bleekeri* *KEFERSTEIN*) (Dry-salting)	Raw fish meat	78.45	60.21	18.24	23.26	76 74	0.845
	1 day after	62.52	33.73	29.79	46.05	53.95	0.795
	2 days 〃	61.94	14.41	47.53	76.74	23.26	1.249
	4 〃 〃	60.44	13.24	47.20	78.10	21.90	1.193
Mackerel (*Scomber japonicus TEMMINCK et SCHLEGEL*) (Dry-salting)	Raw fish meat	73.38	50.21	23.17	31.58	68.42	0.873
	1 day after	58.04	9.62	48.42	83.43	16.57	1.154
	2 days 〃	55.65	10.32	45.33	81.46	18.54	1.022
	4 〃 〃	57.94	26.68	31.30	53.99	46.01	0.745

by salt. The dehydrating action of the dry-salting process is greater than that of the brine-salting process. This fact agrees with the previous results of many investigators.[46]

In salted fish meat, the amount of Free Water decreases and the amount of Bound Water increases relatively. This fact agrees with the case of the dried fish meat.

However, the absolute amount of Bound Water in the Atka Mackerel meat per gm of the dried matter decreased somewhat with the lapse of days after the salting, as shown in Fig 36.

This fact is clearly due to the decomposition of fish meat protein, that is, to the denaturation of the protein by the salting.

In the case of Squid and Mackerel meat the increase in the absolute amount of Bound Water is not so clear as in Atka Mackerel as shown in Fig. 36.

(VI) The results of estimations of the amount of Bound Water in fermented fish meat and decomposed fish meat by the cobaltous chloride method.

(A) The variation of the amount of Bound Water in Soused Squid meat ("Shiokara" in Japanese) during its ripening.

The variation of the amount of Bound Water in Soused Squid meat was observed as follows:

Soused Squid meat ("Shiokara") is a Japanese special product which is made from cut Squid meat, its liver, and salt (sodium chloride). The author has prepared it by the following process. The body of fresh Squid (average weight of a Squid is 284 gm) was cut in small rectangular pieces (0 5 × 3 cm), and was mixed with NaCl and Squid liver, then was stirred every day for 4 weeks. The percentage of added NaCl was 15% of the weight of the cut Squid meat. The percentage of Squid liver added was 3% (A), and 6% (B), respectively by weight, of the cut Squid meat.

The amount of Bound Water in the Soused Squid meat was estimated by the cobaltous chloride method (Oyagi's method) after washing the surface of the cut Squid meat and adsorbed water attached to the surface of the meat.

Table 32. Variation in the minimum amount of Bound Water during the ripening of Soused Squid ("Shiokara")

Days of processing	Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.F.}{T.R.} \times 100(\%)$	$\frac{R.B.}{R.T.} \times 100(\%)$	g. (gm of Bound Water per gm of dried matter)
(A) Squid liver added in 3%						
0	82.63	79.38	3.25	96.06	3.94	0.187
4	85.66	82.95	2.71	96.83	3.14	0.189
7	89.00	87.38	1.62	98.17	1.83	0.147
'0	82.44	82.01	0.43	99.47	0.53	0.024
21	87.46	87.22	0.24	99.72	0.28	0.019
(B) Squid liver added in 6%						
0	82.63	79.38	3.25	96.06	3.94	0.187
4	88.54	85.84	2.70	96.95	3.05	0.232
7	89.03	86.63	2.40	97.30	2.70	0.219
10	81.15	80.09	1.06	98.69	1.31	0.056
21	82.17	82.20	0.97	98.81	1.19	0.054

The variation of the amount of Bound Water during the ripening of Soused Squid ("Shiokara") is shown as (A) and (B) in Table 32. The values there tabulated are the minimum amounts of Bound Water (the values of the amount of Bound Water at C. P.)

From Table 32 (A), (B), it is observed that the total amount of water increased gradually with the decomposition of fish meat protein by enzymatic action for the first 10 days, and then the total amount of water decreased as a manifestation of the effect of dehydrating action. In the total amount of water, the amount of Free Water increased gradually and the amount of Bound Water decreased. This fact is contrary to the results obtained with the dried fish meat or the salted fish meat. The amount of Bound Water per gm of the dried matter of the fermented fish meat decreased during the ripening. But the amount of Bound Water was observed to increase contrarily during the incipient ripening of fish meat. This fact will be understood that the dried matter of fish meat decreases owing to the decomposition of fish meat protein, but the amount of Bound Water is hardly influenced. However, this conclusion is somewhat doubtful because of the supposition that the amount of Bound Water did not vary during the steeping of the sample in cobaltous chloride solution. It is certain that the variation of the amount of Bound Water in the fermented Squid meat is different from that in either the dried fish meat or the salted fish meat.

(B) The variation of the amount of Bound Water in the decomposed Atka Mackerel meat.

The variation of the amount of Bound Water in half dried Atka Mackerel meat (water-content 69%) which was left to the time of detecting tainted odour in the Petri dish at 30°C, was observed. The experimental results are shown in Table 33.

Table 33. Variation in the minimum amount of Bound Water in putrefied Atka Mackerel meat.

Days of processing	Total Water (R. T. %)	Free Water (R. F. %)	Bound Water (R. B. %)	$\frac{R.F.}{R.T.} \times 100(\%)$	$\frac{R.B.}{R.T.} \times 100(\%)$	g. (gm of Bound Water per gm of dried matter)
0	69.0	60.29	8.71	87.37	12.63	0.281
2	69.4	62.24	7.16	89.68	10.32	0.237
6	74.2	67.39	6.81	90.82	9.18	0.264

As shown in Table 33, the muscle tissue of fish meat decomposed with the putrefaction, the total amount of water increased gradually, and the tainted odour was notable already a day after the handling. It was observed that the amount of Free Water increased and the amount of Bound Water decreased with the putrefaction of fish meat. That is to say, the variation of the amount of Bound Water in the putrefied fish meat is similar to that in the fermented Squid meat. However, the variation of the absolute amount of Bound Water per gm of the dried matter of the sample is not clear.

In this experiment employing the cobaltous chloride method, the estimation was very difficult owing to the softening of fish meat; estimation was made again by the electrical resistance measurement. The vapour tension method was also tried for estimating the amount of Bound Water in the putrefied fish meat, but this method was not satisfactory, because the volatile basic matters grew from the meat.

(2) Results of estimations by the electrical resistance of some fish meat.

Ueda, Ito and Nishi[47a] and Tamura[47b] have observed the variation of the electrical resistance in the carp meat fresh after the death. They stated that the electrical resistance decreased rapidly after a definite time after the death, and the lower the temperature is, the longer the time needed to decrese electrical resistance. The cause of the decreasing of electrical resistance is perhaps the change of the muscle tissue of fish meat by autolysis and bacterial action. Yamamura[47c] has observed that the specific electrical resistance of the direct current is 2,400～3,000 Ohms and of the alternating current of 1,000 cycles is 80～90 Ohms for the raw fresh meat of Horse Mackerel (*Trachurus japonicus TEMMINCK et SCHLEGEL*), Mackerel (*Scomber japonicus HOUTTUYN*) or Flat fish (*Limanda herzensteini JORDAN et SNYDER*). Tamura, Miyazaki and Kajiyama[47d] have studied the relation between the amount of penetrated NaCl in fish meat and the electrical resistance in the salted fish meat. Callow[47e] has also studied the distribution of the electrical resistance of the muscular tissue of farm-killed pigs and of pigs killed in factory or abattoir. Recently Yamada and Kitano[47f] have studied the variation of the electrical resistance and of pH value of the denatured myosin added with NaCl. Ito, Kyozuka and Sugizaki[47g] have also studied the electrical resistance of raw fresh fish meat, heated fish meat and chilled fish meat.

The present author has studied in his Experiment Ⅲ, 1, the variation of the electrical resistance of 50 cycles in samples of gelatine and fish meat having various water-contents, and has obtained the following results: the electrical resistance decreased somowhat with the decreasing of water-content at first, but it decreased gradually at points above a definite concentration or dryness, and thereafter it increased rapidly. The gradual increasing of the electrical resistance in the first stage was considered to be due to the increasing of the amount of Bound Water in inverse proportion to the decreasing of the Free Water. The rapid increasing in the next stage was considered to be due to the remaining of Bound Water which has strong force at the time when the amount of Bound Water which has weak binding force, decreased.

The amount of water estimated at the point of rapid increasing of the electrical resistance was considered to be Colloidal Bound Water as compared with the results obtained by the cobaltous chloride and vapour tension methods.

Here, the author reports the results obtained by estimating the electrical resistance for some fish meat.

(I) Preliminary experiment

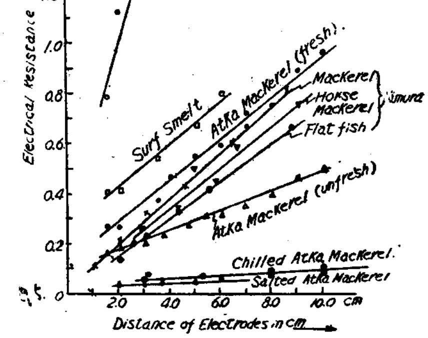
(A) Relation between the electrical resistance (50 cycles) and the distance of electrodes for various kinds of fish meat.

Table 34 and Fig. 37 show the relation between the electrical resistance of

Table 34. Relation between the electrical resistance of 50 cycles and the distance of the electrodes for various kinds of fish meat.

Samples / Distance of Electrodes	Whole body of a species of Surf-smelt	Fresh raw Atka Mackerel meat	Chilled Atka Mackerel meat	Salted Atka Mackerel meat	Unfresh raw Atka Mackerel meat	Freh raw Squid (*Loligo bleekeri*) meat
1.5cm.	0.395KΩ	0.266	—	—	0.162	0.77
2.0	0.400	—	—	0.030	0.178	1.11
2.5	0.530	0.363	—	—	—	1.25
3.0	—	—	0.063	0.040	0.194	—
3.5	—	—	—	0.048	0.228	1.45
4.0	—	0.455		—	—	—
4.7	—	—	—	-	0.268	2.0
5.0	0.655	0.540	—	0.050	—	—
5.4	—	—	0.075	-	0.298	—
6.0	0.780	0.576	—	0.060	0.305	—
6.9	—	0.700	—	—	0.332	—
8.0	—	0.735	0.083	—	0.378	—
9.0	—	0.870	—	—	0.453	—
10.0	—	0.950	0.105	—	0.485	—
Remarks	Water Content 75.8%			Total Water 70.2% NaCl 15.7%		

Fig. 37. Relation between the electrical resistance of 50 cycles and the distance of electrodes for various kinds of fish meat (Temp. 15°~16°C)



50 cycles and the distance of the electrodes for various kinds of fish meat. In Fig. 37, the results obtained by Yamamura[47c] are written togethor. It was observed that the electrical resistance was proportional to the distance of electrodes and showed liner function. This result is the same as in the result obtained by Yamamura.

The electrical resistance of unfresh raw or chilled Atka Mackerel meat is less than that of fresh raw Atka Mackerel meat. This result agrees with the results obtained by Tamura[4b]. In salted Atka Mackerel meat, the electrical resistance decreased with the penetration of the electrolyte (NaCl).

(B) The electrical resistance of fish meat gruel.

According to the method employed by Tamura[47b], the present author ground 100 gm of raw fresh meat of Atka Mackerel and filtered it through gauze. This filtered meat was added with 200 c.c. of distilled water and made into fish meat gruel. It was separated in two parts: (A) Antisepticized gruel by toluene. (B) Non-antisepticized gruel. The electrical resistance of these two samples has estimated in a glass desiccator for several days.

The electrodes were two platinum-black plates 2×2 cm in size. They were fixed keeping them at a distance of 3 cm from each other in fish meat gruel. In this case, the specific electrical resistance was not estimated, but the apparent electrical resistance was estimated. The results are as shown in Table 35.

Table 35. Variation in the electrical resistance of fish meat gruel (Atka Mackerel meat) at certain intervals.

Processing \ Time (hrs)	0 hr.	15	21	63	87	111	135	159	183	231
(A) Antisepticized gruel by toluene	160Ω	160	155	185	180	170	170	175	170	170
(B) Non-antisepticized gruel	160	160	150	160	150	150	150	145	150	150
Remarks	pH {A.6.3, B.6.6	6.3 6.6	— 6.4							pH {A.6.4, B.6.8

The electrical resistance of two samples (A) and (B) almost did not vary with the lapse of time after the handling. This result agrees with the results obtained by Tamura.

It was considered that the depression of the electrical resistance, that is to say, the increasing of electrical conductivity is not due to the increasing of the amount of the soluble matter by the autolysis of meat protein or the decomposition of meat protein by bacteria, but that it is due to the destruction of muscle tissue of the meat.

(C) The relation among the water-content in the putrefied fish meat, the electrical resistance and the distance of the electrodes.

From the previous two experiments, it was observed that the electrical resistance decreased with the destruction of the muscle tissue of fish meat.

Here, the present author has undertaken to study the relation among the water-content in the putrefied fish meat in the incipient drying, the electrical resistance and the distances of the electrodes.

The samples were fresh raw Atka Mackerel meat filet (11×1.5×1.0 cm) and the whole body of a species of Surf-smelt (*Hypomesus japonicus*), (10 gm in weight, 13 cm in length).

The distance between electrodes was 1.5 cm to 10 cm. The electrical resistances were observed for the samples two times in the incipient drying, and were observed thereafter for the putrefied samples which were laid at 30°C in the Petri dishes and began to have tainted smell. The putrefied fish meat was detected by Amano's $HgCl_2$[48] reaction. The electrical resistance of those samples was estimated at various water-content during the air drying. The estimation of the electrical resistance for the whole body of Surf-smelt was carried out as follows: two electrodes were thrust through into the center part of fish body between the surface of the body and back bone at the lateral line, and the electrical resistance was estimated at various distances of electrodes.

The experimental results are shown in Table 36 and 37. The average value of three samples is tabulated. The relation between the electrical resistance and the distance of electrodes is illustrated in Fig. 38, and the relation among

Table 36. Relation among the water contents in the putrefied Atka Mackerel meat, the electrical resistance (50 cycles) and the distance of electrodes.

Water Content (%) \ Distance of Electrodes (cm)	1·5cm	2.0	3.0	3.7	4.7	5.4	6.1	6.9	8.0	9.0	10.0	Remarks
75 %	KΩ 0.163	0·178	0.194	0.228	0.268	0.298	0.305	0.330	0.378	0.453	0.485	Drying
72.6	0.176	0.167	0.218	0.258	0.295	0.331	0.363	0.376	0.416	0.448	0.495	〃
70.0	0.208	0.238	0.256	0.296	0.325	0.371	0.402	0.427	0.498	0.546	0.605	〃
60.4	0.141	0.154	0.234	0.236	0.285	0.344	0.366	0.442	0.507	—	0.757	(Putrefied)
50.3	0.163	0.217	0.345	0.410	0.479	0.563	0.656	0.503	0.979	1.393	1.550	Drying

Table 37. Relation among the water contents in the putrefied meat of a species of Surf-smelt (Whole Body), the electrical resistance (50 cycles) and the distance of electrodes.

Water Content (%) \ Distance of Electrodes (cm)	1.5 cm	2.0	3.5	5.0	6.0	Remarks
75.4 %	0.390KΩ	0.380	0.535	0.663	0.813	Drying
72.5	0.390	0.415	0.550	0.738	0.825	〃
69.4	0.430	0.502	0.728	0.988	1.240	〃
64.7	0.366	0.393	0.638	0.913	1.192	(Putrefied)
55.7	0.421	0·457	0.866	1.373	2.085	Drying
40 3	0.640	0 817	1.618	5.325	30.533	〃
25.0	1.708	2.255	43.25	778	8,000 over	〃

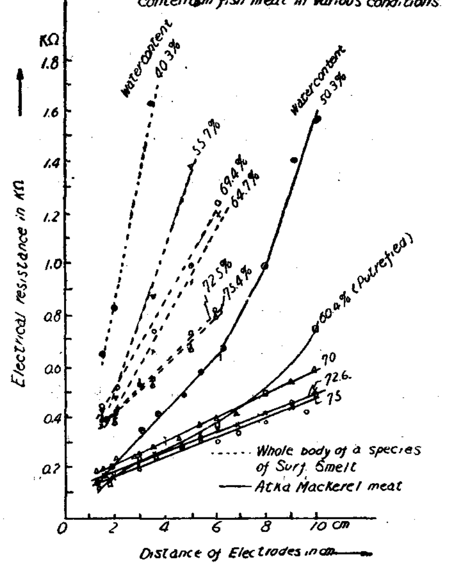


Fig. 38. Relation among the electrical resistance (50 cycles), the distance of the electrodes and the total water content in fish meat in various conditions.

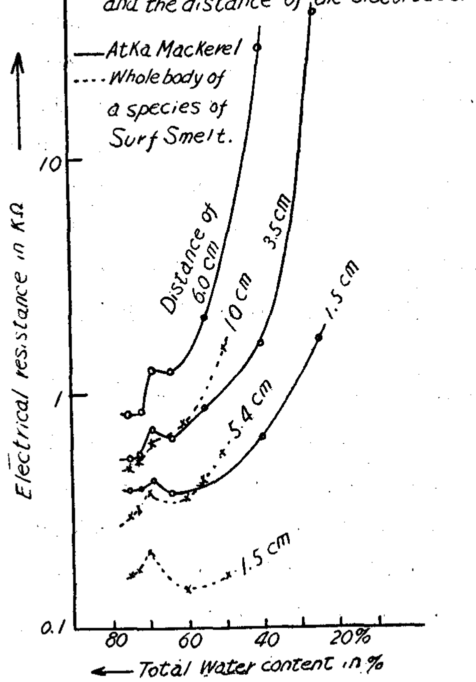


Fig. 39. Relation among the water contents in the putrefied fish meat, the electrical resistance and the distance of the electrodes.

the electrical resistance, the water-content and the distance of electrodes is illustrated in Fig. 39.

From Fig. 38, it was observed that the relation between the electrical resistance of Atka Mackerel meat and the distance of the electrodes was a linear function, and with the drying of meat the straight line slipped off upwards. But the electrical resistance of the completely putrefied Atka Mackerel meat (water-content 60.4%) depressed temporarily with the decreasing of water content and the linear function was not observed in the relation of the electrical resistance and the distance of the electrodes. This fact is perhaps due to the destruction of the muscle tissue of the fish meat. But the electrical resistance increased with the progressive drying of the putrefied fish meat. Then the straight linear showing of the relation between the electrical resistance of electrodes slipped off upwards. At excessive drying, the electrical resistance increased logarithmically as indicated in Fig. 39.

The straight line showing the relation between the electrical resistanc of Surf-smelt and distance of electrodes slipped off upwards at the upper part of the line with the drying. But the electrical resistance of the putrefied fish meat decreased temporarily with the decreasing of the water-content, then it increased logarithmically with the drying.

The electrical resistance of the drying fish meat without becoming putrefied could be estimated. However, supposing from Figs. 38 and 39 showing the comparison of the curves of electrical resistance at the beginning of drying with after the putrefaction, the curve of the electrical resistance of the dried fish which was dried from fresh raw meat without putrefaction, perhaps slips off left from the curve of the electrical resistance of the putrefied meat. As stated in Experimet Ⅲ, 1[38a] of the previous paper, if the rapid ascending of the curve of the electrical resistance in the small water-content of the sample is due to the change of the amount of Bound Water in fish meat, the rapid ascending point of the curve of the electrical resistance of the putrefied fish meat may indicate lower water-content than in the fresh raw fish meat.

These facts are perhaps due to the decreasing of the amount of Bound Water or to the weakening of binding strength of Bound Water included in the same total amount of water in the sample, owing to the destruction of muscle tissue of fish meat. However, that the change of the electrical resistance varies with the change of pH value of the fish meat is also considered as one of the cause in this case. So the conclusion on the cause of these facts must be taken into further consideration.

(Ⅱ) Results of observation of the electrical resistance of 50 cycles in fresh meat, salted meat and putrefied meat of Atka Mackerel at various water-contents.

In this experiment, use was made of fresh raw Atka Mackerel meat (8×1.8 ×1.0 cm), putrefied Atka Mackerel which has a slight putrefied smell in incipient drying and in the same size, and brine-salted Atka Mackerel meat which has been immersed in saturated NaCl solution for 5 hours. The distance between the electrodes was 1.5cm. The observed results of the electrical resistance of 50 cycles at various water-contents are shown in Tables 38 and 39. The results on the amount of Bound Water for the same samples by the cobaltous chloride method are also shown in the same Tables. The results shown in Table 38 were the results in the case of drying at 19°C, and in Table 39 in that of drying at 20°~30°C.

The temperature at which observations were made for all the samples was 17°C. Fig. 40 was derived by plotting the results in Tables 38 and 39.

From Fig. 40 it is observed that the electrical resistance of the raw fresh Atka Mackerel decreased with the incipient decreasing of the total amount of water during the drying of the fish meat at 19°C, and then the electrical resistance increased gradually at the neighbourhood of the water-cotent at the point B.P. which indicated the blue change point by the cobaltous chloride method (Oyagi's method), and the

Table 38. Relation between the electrical resistance (50 cycles) and the water contents in fresh, salted and putrefied Atka Mackerel meat. (Drying temp. 19°C)

Fresh Raw Meat		Salted Meat		Putrefied Meat		Putrefied Meat (Continued)	
Total Water Content (%)	Electrical Resistance (KΩ)	T. W. (%)	E. R. (KΩ)	T. W. (%)	E. R. (KΩ)	T. W. (%)	E. R. (KΩ)
79.6	0.45	70.2	—	79.1	0.455	15.1	50.0
70.3	0.41	64.2	0.035	74.0	0.340	14.5	135.0
48.4	0.45	55.2	0.045	68.6	0.450	14.0	160.0
38.2	0.65	52.0	0.049	60.9	0.400	12.9	279.0
24.5	5.50	45.6	0.060	49.6	0.420	12.4	300
20.2	60	40.0	0.110	37.4	0.500	10.2	7,000
14.8	1,000 over	31.0	0.260	29.4	1.23	—	—
—	—	21.2	65.0	17.0	3.23	—	—

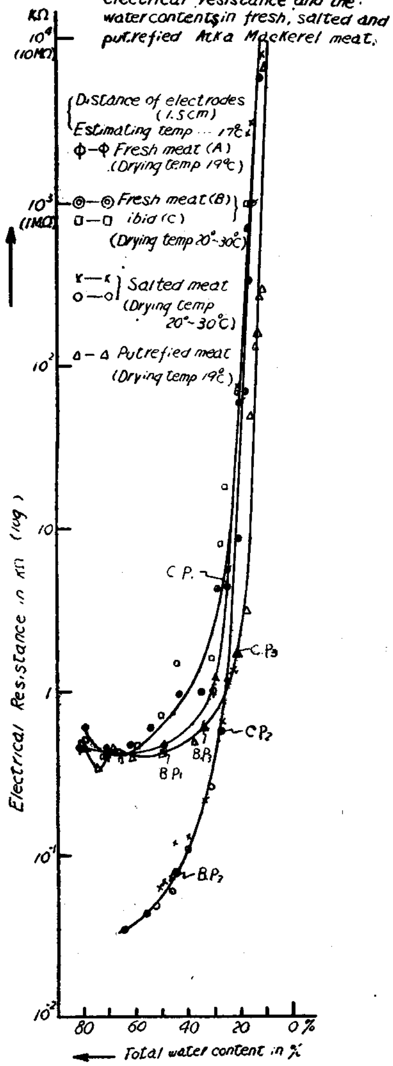
Fresh Raw Meat	Salted Meat	Putrefied Meat
Total Water 79.6%	Total Water 70.2%	Total Water 79.1%
Free Water 60.0%	Free Water 46.3%	Free Water 68.6%
at B. P_1 { Bound Water 19.6%, (g)※ (0.961)	at B. P_2 { Bound Water 23.9%, (g)※ (0.808)	at B. P_3 { Bound Water 10.5%, (g)※ (0.503)
at C. P_1 (g)※ (0.372)	at C. P_2 (g)※ (0.358)	at C. P_3 (g)※ (0.280)
	Ash content 16.6%	
	NaCl 〃 15.7%	

※ g=gm of Bound Water per gm of dried matter.

Table 39. Relation between the electrical resistance (50 cycles) and the total water contents in fresh and salted Atka Mackerel meat. (Drying temp. 20°~30°C)

Fresh Raw Meat (A)		Fresh Raw Meat (B)		Salted Meat	
Total Water (%)	Electrical Resistance (KΩ)	T. W. (%)	E. R. (KΩ)	T. W. (%)	E. R. (KΩ)
78.8	0.60	78.4	0.52	70.7	—
70.2	0.45	71.6	0.40	52.0	0.05
61.7	0.47	64.8	0.38	49.6	0.065
54.1	0.60	68.9	0.46	48.4	0.070
43.1	0.95	50.2	0.72	45.6	0.075
34.6	1.00	43.9	1.50	44.3	0.120
28.2	4.20	30.5	1.60	39.1	0.130
20.9	8.50	27.1	8.00	33.5	0.220
18.0	70.0	25.8	18.0	25.4	0.66
17.4	360	21.9	70	22.1	1.35
16.8	700	17.4	1,000	20.2	76
12.8	6,500	—	—	16.6	270
—	—	—	—	14.7	3,000
—	—	—	—	11.45	8,000

Fig. 40 Relation between the electrical resistance and the watercontents in fresh, salted and putrefied Atka Mackerel meat.



resistance increased rapidly at the point of C. P. which indicates the constant-weight of the sample during the drying at 30°C. The curves showing the electrical resistance of two samples of the raw fresh Atka Mackerel are also almost the same curves during the drying at 20°~30°C.

However, the electrical resistance of the raw fresh meat dried at 20°~30°C was larger than that of the raw fresh meat dried at 19°C at the same water-content in 10~20% of the range of the water-content.

The higher the temperature is at the time of the observation, the smaller the electrical resistance is. The difference of the electrical resistance at the same water-content was considered to be due to the different drying temperatures, because the temperature at time of observation was the same after leaving the samples in the desiccator at 17°C for some time.

There is a factor, pH influencing the value of electrical resistance of the samples. The electrical resistance shows generally the maximum value at the iso-electric point of muscle protein. However, the value of pH of the fish meat is not considered to vary owing to the difference of the drying temperatures (the average difference of temperature is 5°C) which were employed in the experiment above described. The difference of the electrical resistance may better be considered to be due to the difference of the muscle tissue as affected by the drying temperatures. The muscle tissue of the fish meat dried at 19°C is rather homogeneous and closed by the gentle evaporation of water, but the muscle tissue of the fish meat dried at 20°~30°C has some gaps containing no water in the muscle tissue because of the more rapid evaporation. Therefore the electrical conductivity decreases and the electrical resistance increases.

The ascending of the curve of the electrical resistance of the sample dried at 20°~35°C below 20% of the water-content agrees with the sample dried at 19°C, so there is rather little change of the amount of Bound Water in the two samples of fish meat dried at 19°C and at 20°~30°C.

In the putrefied meat, the property of the curve of the electrical resistance of the sample is the same as the curve in the case of raw fresh meat. The electrical resistance began to decrease at the water-cotent of the point of $B.P_3$ by the cobaltous chloride method, and increased rapidly at the point of $C.P_3$. However, the values of electrical resistance of the putrefied fish meat at various water-contents were lower than those of the raw fresh meat. Therefore, the curve of the putrefied fish meat slips wholly away from the curve of the raw fresh fish meat as expected from the preliminary experiment. Furthermore the amount of Bound Water of the putrefied fish meat at the points of $B.P_3$ and $C.P_3$ was less than that of the raw fresh fish meat at $B.P_1$ and $C.P_1$. This fact is perhaps due to the decreasing of Bound Water in the meat owing to the decomposition of the muscle tissue. However, the cause of this fact can not be concluded without clearing the relation between the change of the amount of Bound Water and the change of the value of pH with the putrefaction of fish meat.

In the salted fish meat, there is little difference in the electrical resistance of the samples dried at 19°C or at 20°~30°C. The salted fish meat contains an abundant amount of NaCl as the electrolyte in the fish meat (about 25% of the dried matter of the sample). Its electrical resistance is less than the raw fresh fish meat in the beginning of the estimation, but the electrical resistance increased rapidly with the lapse of the time of drying, and at last the ascending of the curve agreed almost with the curve of the raw fresh fish meat.

Suppoing that fish meat is a colloidal system consisting of water and protein, a part of the water in Bound Water which has weak strength to combine with protein hydrates with the elctrolyte, NaCl, by the addition of NaCl, and there perhaps remains only water which has strong ability to combine with protein. Therefore the electrical resistance was considered to increase rapidly by the remarked influence of combining strength of Bound Water with the decreasing of water in the course of the drying.

3. Conclusion as to the results of estimations of the amount of Bound Water in the various states of meat of various kinds of fish by the cobaltous chloride method and by the measurement of the electrical resistance.

The author has estimated the amount of Bound Water in the meat of various kinds of fish by the cobaltous chloride method (Oyagi's method) and by the measurement of the electrical resistance, and the following results and considerations were obtained.

(1) The amounts of Bound Water in the fresh raw meat of 12 kinds of fish were estimated; they differed with the kind of fish and individual bodies used, but it was recognized that the maximum amount of Bound Water is 55～82 gm, the minimum amount of Bound Water is 10～48 gm per 100 gm of the dried matter of the sample.

(2) From the estimated results of the amount of Bound Water, the absolute value of the amount of Bound Water decreased with the decreasing of the total amount of water during the drying of fish meat. The amount of Free Water in the total amount of water in the fish meat decreases from the beginning with the drying of the meat. But the amount of Bound Water increased relatively to the decreasing of the amount of Free Water at the incipient decreasing of the total amount of water in fish meat. The maximum value of the amount of Bound Water is observed as 40～50% of the total amount of water in fish meat, and then the amount of Bound Water decreased with the decreasing of the total amount of water in fish meat.

(3) The total amount of fish meat decreased by osmotic dehydration during and after salting. In this case, the percentage of the amount of Free Water decreased with decreasing of the percentage of the total amount of water and the percentage of the amount of Bound Water per gm of the dried matter with the decreasing of the weight of the dried matter of fish meat was not recognized during the salting. However, the amount of Bound Water is considered geneally to decrease.

(4) In this case of the decomposition of fish meat, e. g. in the putrefaction or in the fermentation of Squid meat (Soused Squid meat), it was observed that the percentage of the total amount of water increased gradually, the percentage of the amount of Free Water increased also, while the percentage of the amount of Bound Water decreased relatively. These results were observed to be different from the results influenced dehydration during the drying and salting. But in this case, the change of the absolute amount of Bound Water

was not clearly recognized by the cobaltous chloride method.

(5) During the autolysis or the putrefaction of fish meat, the electrical resistance decreased rapidly. This fact is considered to be due to the decomposition of the muscle tissue of the fish meat. And it was also observed that the larger the amount of Bound Water in fish meat was, the higher the electrical resistance was.

(6) Under this consideration, from the relation between the electrical resistance of fresh raw fish meat and putrefied fish meat and the amount of water in fish meat, the amount of Bound Water was considered to decrease with putrefaction.

(7) From the estimated results of the electrical resistance at various water-contents in the fresh raw fish and salted fish meat, it was supposed that when a large amount of NaCl penetrates into the fish meat, a part of the amount of Bound Water, except Bound Water possesing strong combining strength, hydrates with the added electrolytes (e. g. NaCl).

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(水產科學研究所業績 第91號)