CHANGES IN SIZE OF FISH DURING BRINING

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Changes in Size of Fish During Brining

By C.B. Weld, M.A.

During the course of an investigation by Dr. J.C. Forbes of the factors concerned in the production of a sheen on the surface of Finnan Haddies, the impression was gained that those fish brined in 50 per cent. saturated brine for about an hour, actually increased in volume.

This is an interesting observation, and was thought worthy of checking up. Consequently the following measurements were made, not so much with the idea of determining underlying fundamental causes, but rather to record the changes if any as facts instead of merely impressions.

Experiment I

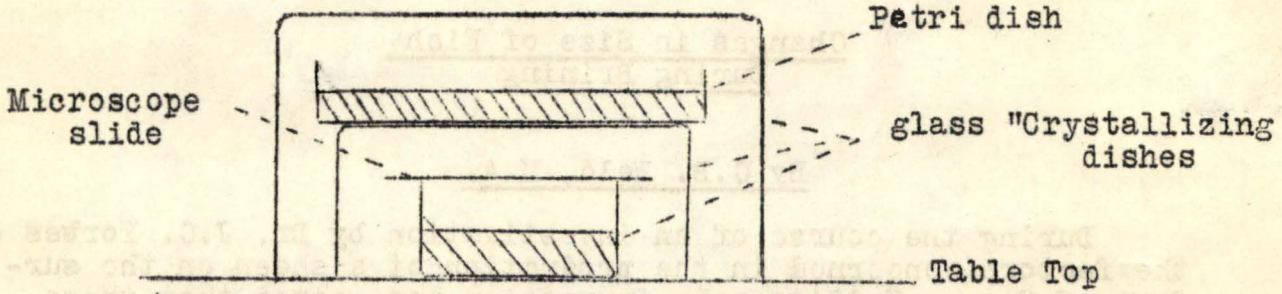
It was thought that a good way of determining the changes of size of the muscle fibres themselves would be to use single fibres and note the changes in size by microscopic observation.

Fibres were teased out under a dissecting microscope, placed singly on a microscopic slide, and kept moist with 3 per cent. sodium chloride solution (by weight). The whole length of the fibre (cell) could not be obtained undamaged, but suitable portions of single fibres were easily obtained. The width or diameter of these fibres was then measured in several places (8 or 10) and the average diameter determined. An ocular scale in the microscope, calibrated in terms of microns was used for this purpose.

After the width of the fibre had been determined the 3 per cent. NaCl was washed off and replaced by the solution whose effect was to be determined. Then the average diameter of the fibre was again measured as above at various intervals.

As will be seen later it was found necessary to vary the temperature (cold, room, or hot) of the solution bathing the fibres.

Close control of the temperature was not possible as no warm stage mechanism was at hand. Some reasonable control was possible however by the following arrangement



(warm water or crushed ice in Petri dish and smallest crystallizing dish)

of dishes, the slides only being removed when measurement of the fibre was necessary.

The solutions themselves whose effects on the size of the fibres was being determined consist of (1) Tap water, (2) 50 per cent. saturated Sodium Chloride solution and (3) saturated Sodium Chloride solution. It was found advisable to alter the acidity (pH) of these solutions and this was done by adding a pinch of some buffer salt to the saline solution. The effect of this trace of buffer was considered negligible as affecting salinity, but both the pH changes and the specific effect of the ion added might have their bearing on the degree and velocity of change of size of the fibre. To dissociate these two effects the buffer salts added were of two series, namely, Phosphates and Carbonates. The pH given to the saline on adding the buffer salts was expected to be:

$NaHCO_3$ -- pH 8.0 - 8.3

Na_2HPO_4 -- pH 8.0 - 8.5

Na_2CO_3 -- pH about 10

This was shown to be true by colorimetric determinations (see 5,6, and 7, Exp. 1). Later on however it was found that these pH's were not being kept constant (see 24, and 27). Hence in later work slightly more buffer salts were added and the PH shown to remain constant by actual determination (28 - 31).

Variations in the pH of the Phosphate buffered salines were obtained by adding concentrated HCl drop by drop until the desired pH was reached, as shown by colorimetric determinations. This procedure seems to be satisfactory. NaH_2PO_4 would be formed as the acid was added and the extra NaCl formed would be negligible.

Tables I and II contain all the data obtained in this experiment and are fairly self explanatory. Each group of figures (i.e. 1 -3, 4 - 7, 8 - 11, 12 - 15, 16 - 19, 20 - 21, 22 - 23, 24-27, 28 - 31, and 32 - 33) consist a single series of manipulations whose salines are the same and whose measurements were done together. Hence the figures of any one series are probably more closely comparable one with another than with the figures of another series. In one or two instances only however has this influenced the selection of examples when grouping the curves as to show certain points (e.g. the effect of temperature on the action of the solutions).

The figures of Tables I and II have been used in preparing the graphs shown in Charts (I - VIII). These curves have been arranged so as to bring out clearly the different factors involved; but it is to be noted that in each chart, every comparable example is individually included. All of the 33 individual experiments have been included in these charts and there are no examples which, because of some poor correlation with the others, have been omitted.

A word or two in explanation of the figures of Tables I and II may be desirable. In Table I the figures are the actual diameters (average) of the fibres in microns obtained as described above. Each division on the ocular scale of the microscope however represented 20 microns, so that the chances of error are great. In Table II, in order to bring all these measurements to a common basis of comparison, the percentage change in diameter has been calculated. That is, the difference between the diameter of the fibre at the time of examination and its original diameter is found, and the percentage that this is of the original diameter, calculated. This of course magnifies any errors that may be present in the measurements and the wonder is that the different curves compare so well rather than that duplicates show slight variations. It is indeed impossible to say in some cases whether the minor irregularities of the curves are due to errors of measurements or to slight variations in the temperature or composition of the bathing fluids.

It has been assumed, possibly without foundation, that changes in the diameter of the fibre represent changes in volume. The length of the fragments of the fibres was not measured.

Table I

Number	Treatment — The fibre was kept in the solutions noted below, under conditions noted, and measured at the times noted on the right	Original diam. of fibre - micron	Diameter of fibres (microns), after x minutes of treatment — Minutes: 1	2	5	10	15	30	45	60	90	150
1	50% saturated Sodium Chloride in Water Soln. at room temperature	180			172		160	150	140	140		
2	" " NaCl, N/30 NaOH, pH>9.5 at room temp.	174	178	180	176	174			150			
3	Saturated " " " "	172			120		115	110	110	108		
4	Tap water " " "	260	262	262	294		280	278	240	210	206	
5	" " with a trace of $NaHCO_3$ " " " (original estimated, pH 8.0-8.3)	318		320	320	320	320	320	320	320	320	
6	" " with a trace of Na_2HPO_4 " " " (pH 8.0-8.5)	272	280		284	284	296	296	296	296		
7	" " with a trace of Na_2CO_3 " " " (pH>9.4 (about 10)[2])	190	220		220	220		220	220			
8	50% sat. NaCl " " "	264	252	252	252	252	252	238	238	218		
9	" " " with trace of $NaHCO_3$ " " "	344	340	340	340	330	324	280	280	290		
10	" " " " " " " Na_2HPO_4 " " "	204	204	200	200	200	202	208	208	214		
11	" " " " " " " Na_2CO_3 " " "	230	224	224	224	222	222	222	218	210		
12	Saturated NaCl " " "	250	190	180	170	170	168	160	160	152		152
13	" " with a trace of $NaHCO_3$ " " "	318	246	236	228	220	220	210	208	208		206
14	" " with a trace of Na_2HPO_4 " " "	276	212	200	188	182	182	178	178	176		176
15	" " with a trace of Na_2CO_3 " " "	306	230	222	216	212	208	202	292			196
16	50% sat. NaCl " " "	236	222	216	216	216	216	216	208	216	216	

Table I

Number	Treatment The fibre was kept in the solutions noted below, under conditions noted, and measured at the times noted on the right	Original diam. of fibre-micron	Diameter of fibres (microns), after x minutes of treatment								
			1	2	5	10	15	30	45	60	90	150
17	50% sat. NaCl with a trace of Na HCO$_3$ at room temp.	154	154	154	152	150	150	146	146	146	142	
18	" " " " " " " Na$_2$HPO$_4$ " " "	328		308	308	314	312	320	324	316	308	
19	" " " " " " " Na$_2$CO$_3$ " " "	182	178	178	178	176	176	176	176	176	176	
20	Tap water with a trace of Na$_2$HPO$_4$ original pH 7.0	280	278	278	274	274	274	274	278	282		
21	" " " " trace of Na$_2$HPO$_4$, with HCl, original pH 6.0 " "	262		234	270	266	222	222	224	224		
22	50% sat. NaCl with a trace of Na$_2$HPO$_4$ original pH 7.0 " "	222		210	210	210	202	200	196	190		
23	" " " " a trace of Na$_2$HPO$_4$ with HCl, original pH 6.0 " "	242		196	190	184	184	182	178	178		
24	50% sat. NaCl+ trace phosphate, pH 8.5, all manipulations iced. After 45 mins. pH 6.6	276		262	262	260	258	258	254	258	252	
25	" " NaCl+ trace Phosphate, pH 8.5, at room temp.	180		174	174	174	172	168	168	168	162	
26	" " " + " " , pH 6.0, all manipulation iced.	262		222	212	204	202	196	190	188	188	
27	" " " + " " , pH 6.0, at room temp. After 45 mins., pH 5.6	250		202	192	184	184	180	176	176	178	
28	repeat of 24. The pH remained constant (more phosphates added)	222		220	218	216	216	218	218	220	220	
29	" " 25 The Ph remained constant (more phosphates added)	244		238	238	238	238	238	238	238		
30	" " 26 The pH remained constant (more Phosphates added)	200		178	176	174	170	166	164	164		
31	" " 27 The pH remained constant (more Phosphates added)	182		156	148	144	142	140	140	140		
32	50% sat NaCl trace phosphate, pH 6.0, at 35° C	164		134	126	120	118	112	106	102		
33	" " " " " " at room temp.	112		92	92	94	92	86	84	86		

Table II

The Percentage change in diameter of the fibres after x minutes treatment. (original - final size x 100) / original

number	Treatment	0	1	2	5	10	15	30	45	60	90	min 150
1	50% NaCl, Room Temp.	0	-	-	-4.45	-	-11.1	-16.6	-22.2	-22.2	-	
2	50% NaCl, N/30 NaOH, pH 9.5, Room Temp.	0	+2.30	+3.45	+1.15	0	-	-	-13.8	-	-	
3	Saturated NaCl " "	0	-	-	-30.2	-	-33.2	-36.0	-36.0	-37.1	-	
4	Tap Water " "	0	+0.77	+0.77	+13.1	-	+7.70	+6.92	-7.70	-19.2	-20.8	
5	" " + $NaHCO_3$, (pH 8.0-8.3) " "	0	-	+0.63	+0.63	+0.63	+0.63	+0.63	+0.63	+0.63	+0.63	
6	" " + Na_2HPO_4 (pH 8.0-8.5) " "	0	+2.94	-	+4.40	+4.40	+8.80	+8.80	+8.80	+8.80	-	
7	" " + Na_2CO_3 (pH about 10) " "	0	+15.8	-	+15.8	+15.8	-	+15.8	+15.8	-		
8	50% NaCl " "	0	-4.54	-4.54	-4.54	-4.54	-4.54	-9.84	-9.84	-17.4		
9	" " + $NaHCO_3$ " "	0	-1.16	-1.16	-1.16	-4.06	-5.80	-18.6	-18.6	-15.7		
10	" " + Na_2HPO_4 " "	0	0	-1.96	-1.96	-1.96	-0.98	+1.96	+1.96	+4.90		
11	" " + Na_2CO_3 " "	0	-2.60	-2.60	-2.60	-3.49	-3.49	-3.49	-5.21	-8.70		
12	Saturated NaCl " "	0	-24.0	-28.0	-32.0	-32.0	-32.8	-36.0	-36.0	-39.2		-39.2
13	" " + $NaHCO_3$ " "	0	-22.0	-25.8	-28.3	-30.8	-30.8	-34.0	-34.6	-34.6		-35.1
14	" " + Na_2HPO_4 " "	0	-23.1	-27.5	-31.8	-34.0	-34.0	-35.4	-35.4	-36.2		-36.2
15	" " Na_2CO_3 " "	0	-24.8	-27.4	-29.4	-30.7	-32.0	-34.0	-34.0	-		-35.9
16	50% NaCl " "	0	-5.93	-8.47	-8.47	-8.47	-8.47	-8.47	-	-8.47	-8.47	
17	" " + $NaHCO_3$ " "	0	0	0	-1.30	-2.60	-2.60	-5.20	-5.20	-5.20	-7.80	
18	" " + Na_2HPO_4 " "	0	-	-6.10	-6.10	-4.26	-4.88	-2.44	-1.22	-3.66	-6.10	
19	" " + Na_2CO_3 " "	0	-2.20	-2.20	-2.20	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30	
20	Tap Water + Na_2HPO_4, orig. pH 7.0 "	0	-0.71	-0.71	-2.14	-2.14	-2.14	-1.43	-0.71	+0.71		
21	" " + " + HCl " " 6.0 "	0	-	-3.30	+11.5	+9.9	5.80	-8.25	-7.44	-7.44		
22	50% NaCl + Na_2HPO_4 " " 7.0 "	0	-	-5.40	-5.40	-5.40	-9.00	-9.90	-11.7	-14.4		
23	" " + " + HCl " " 6.0 "	0	-	-19.0	-21.5	-24.0	-24.0	-24.8	-26.4	-26.4		
24	50% NaCl + Phosphate, pH 8.5, iced. pH became 6.6	0	-	-5.06	-5.06	-5.80	-6.52	-6.52	-7.97	-6.52	-8.97	
25	" " + " , pH 8.5, room temp.	0	-	-3.33	-3.33	-3.33	-4.45	-6.67	-6.67	-6.67	-10.0	
26	" " + " , pH 6.0, iced	0	-	-15.3	-19.1	-22.1	-22.9	-25.2	-27.4	-28.2	-28.2	
27	" " + " , pH 6.0, room temp. pH became 5.6	0	-	-19.2	-23.2	-26.4	-26.4	-28.0	-29.6	-29.6	-28.8	
28	repeat of 24, pH constant at 8.5	0	-	-0.90	-1.80	-2.70	-2.70	-1.80	-1.80	-0.90	-0.90	
29	" " 25 " " " "	0	-	-2.45	-2.45	-2.45	-2.45	-2.45	-2.45	-2.45	-2.45	
30	" " 26 " " " 6.0	0	-	-11.0	-12.0	-13.0	-15.0	-17.0	-18.0	-18.0	-	
31	" " 27 " " " "	0	-	-14.3	-18.7	-20.9	-22.0	-23.1	-23.1	-23.1	-	
32	50% NaCl + phosphate, pH 6.0, at 35°C	0	-	-18.3	-23.2	-26.8	-28.0	-31.7	-35.4	-37.8	-	
33	" " + " " at room temp.	0	-	-17.8	-17.8	-16.1	-17.8	-23.2	-25.0	-23.2	-	

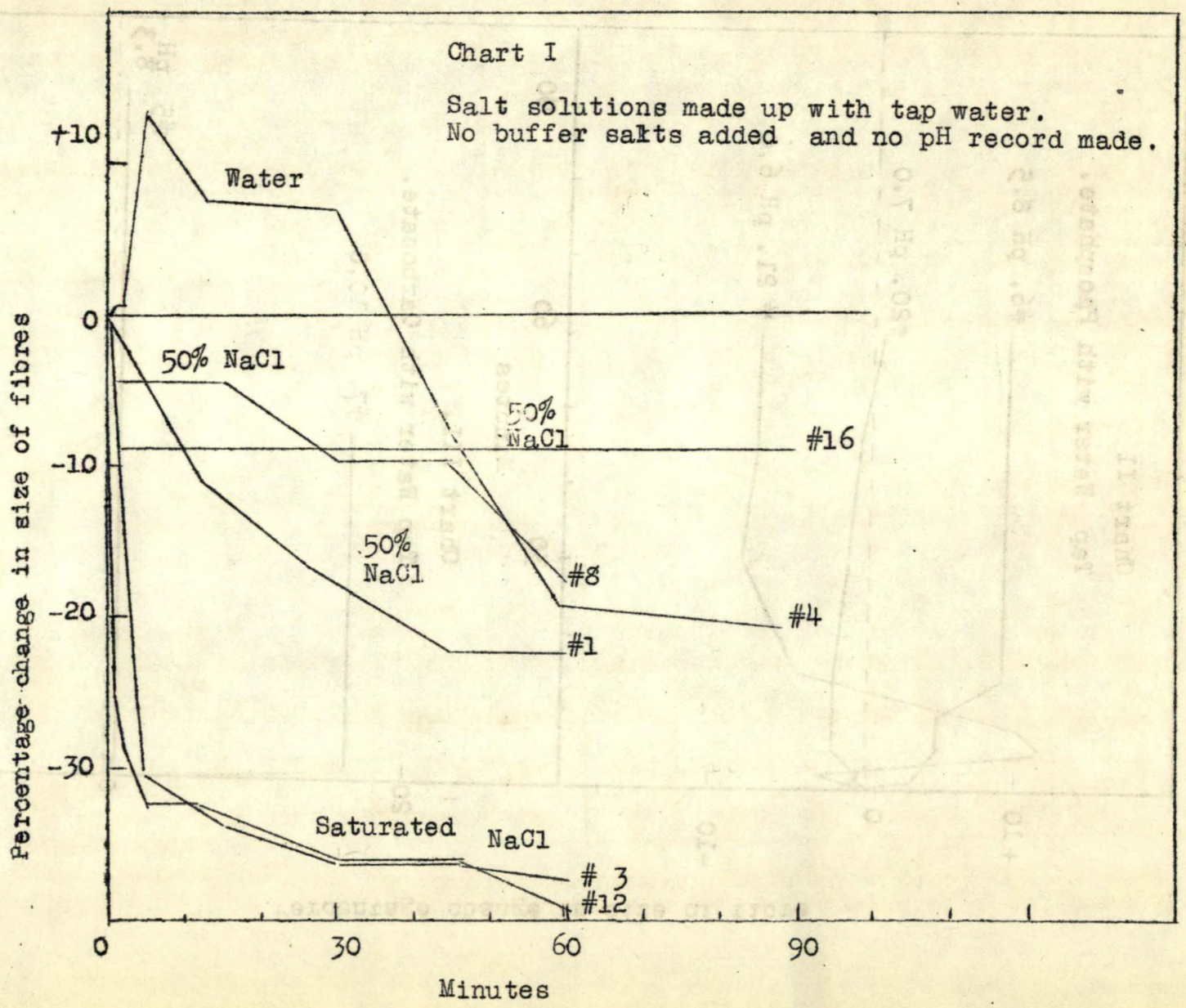


Chart I
Salt solutions made up with tap water.
No buffer salts added and no pH record made.
+10
0
-10
-20
-30
Percentage change in size of fibres
Water
50% NaCl
50% NaCl
#16
50% NaCl
#8
#4
#1
Saturated NaCl
3
#12
0
30
60
90
Minutes

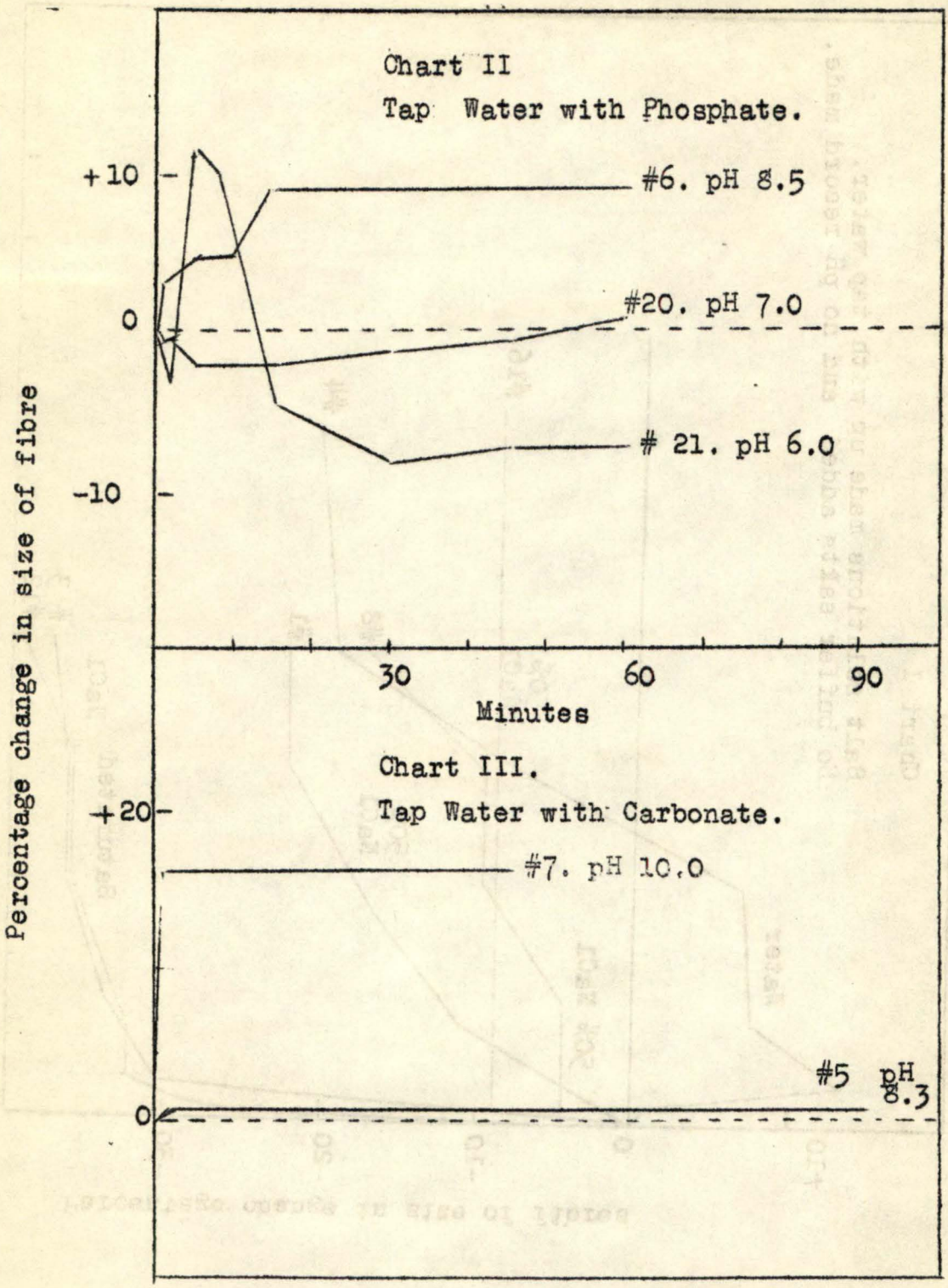


Chart II
Tap Water with Phosphate.
+10
0
-10
#6. pH 8.5
#20. pH 7.0
21. pH 6.0
30
60
90
Minutes
Percentage change in size of fibre
Chart III.
Tap Water with Carbonate.
+20
0
#7. pH 10.0
#5 pH 8.3

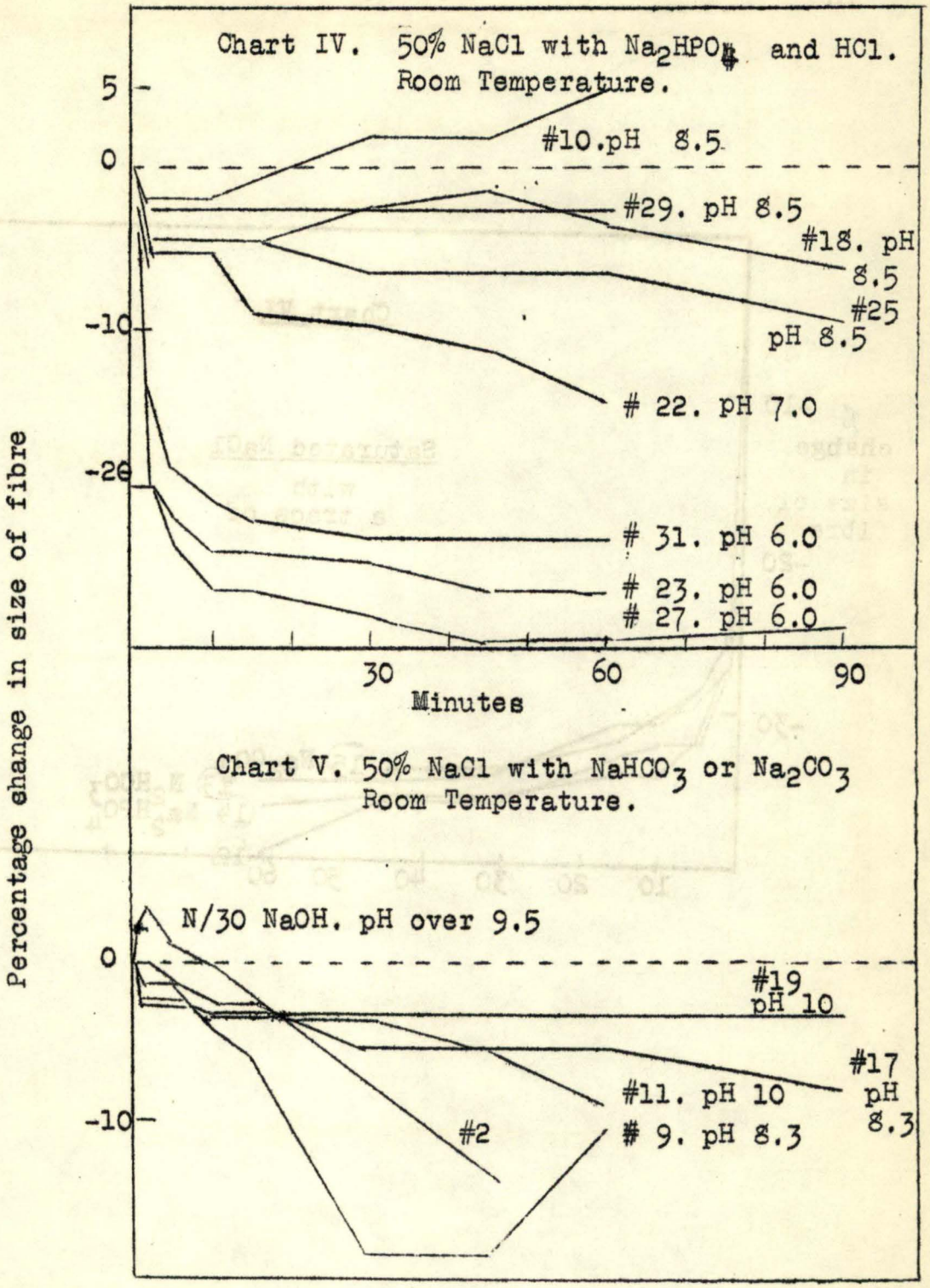


Chart IV. 50% NaCl with Na_2HPO_4 and HCl.
Room Temperature.
5
0
-10
-20
#10.pH 8.5
#29. pH 8.5
#18. pH 8.5
#25 pH 8.5
22. pH 7.0
31. pH 6.0
23. pH 6.0
27. pH 6.0
30
60
90
Minutes
Percentage change in size of fibre
Chart V. 50% NaCl with $NaHCO_3$ or Na_2CO_3
Room Temperature.
N/30 NaOH. pH over 9.5
0
-10
#19 pH 10
#17 pH 8.3
#11. pH 10
9. pH 8.3
#2

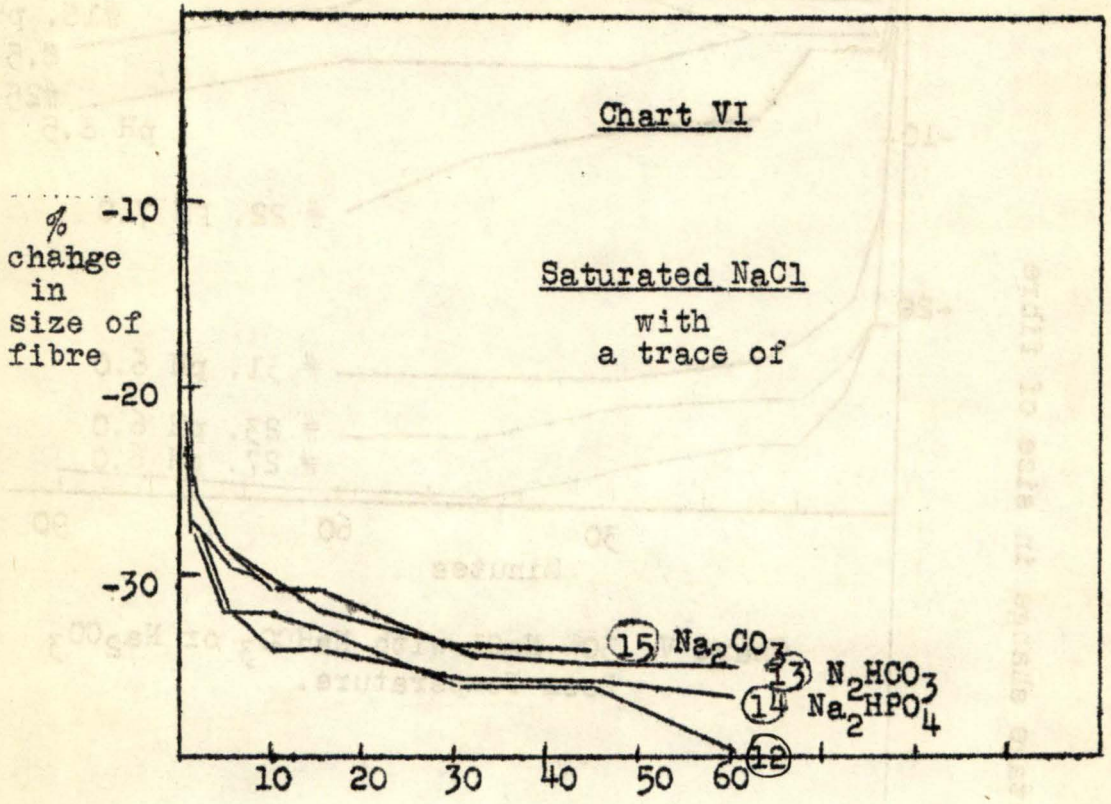
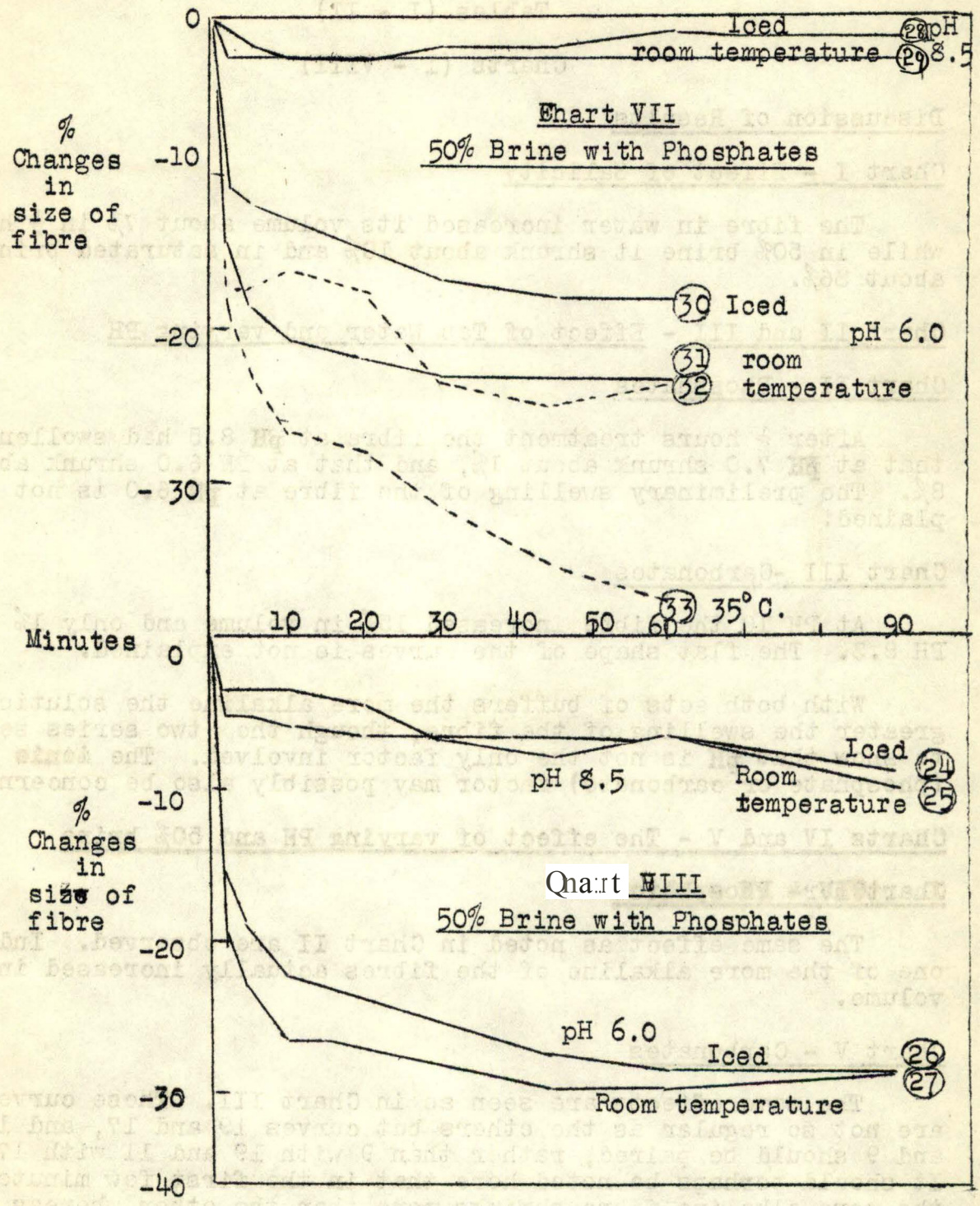


Chart VI
% change in size of fibre
-10
-20
-30
Saturated NaCl
with
a trace of
15 Na_2CO_3
13 N_2HCO_3
14 Na_2HPO_4
12
10
20
30
40
50
60


0
-10
-20
- 30
% Changes in size of fibre
Iced
room temperature
28 pH 8.5
29
Chart VII
50% Brine with Phosphates
30 Iced
pH 6.0
31 room
32 temperature
33 35° C.
10 20 30 40 50 60 90
Minutes
0
-10
-20
-30
-40
% Changes in size of fibre
pH 8.5
Iced
Room temperature
24
25
Chart VIII
50% Brine with Phosphates
pH 6.0
Iced
26
27
Room temperature

Tables (I - II)

Charts (I - VIII)

Discussion of Results

Chart I - Effect of Salinity

The fibre in water increased its volume about 7% in ½ hour while in 50% brine it shrank about 10% and in saturated brine about 36%.

Chart II and III - Effect of Tap Water and varying PH

Chart II - Phosphates

After ½ hours treatment the fibre at pH 8.5 had swollen 9%, that at pH 7.0 shrunk about 1%, and that at PH 6.0 shrunk about 8%. The preliminary swelling of the fibre at pH 6.0 is not explained.

Chart III -Carbonates

At PH 10 the fibre increased 15% in volume and only 1% at PH 8.3. The flat shape of the curves is not explained.

With both sets of buffers the more alkaline the solution the greater the swelling of the fibre, though the two series seem to show that pH is not the only factor involved. The ionic (phosphate or carbonate) factor may possibly also be concerned.

Charts IV and V - The effect of varying PH and 50% brine

Chart IV - Phosphates

The same effects as noted in Chart II are observed. Indeed one of the more alkaline of the fibres actually increased in volume.

Chart V - Carbonates

The same effects are seen as in Chart III. These curves are not so regular as the others but curves 19 and 17, and 11 and 9 should be paired, rather than 9 with 19 and 11 with 17. It should perhaps be noted here that in the first few minutes the more alkaline fibre shrinks more than the other whereas later on the positions are reversed and become consistent with those of charts II, III, and IV. The lone curve (2) where alkalinity has been obtained with NaOH, and whose alkalinity may be considerably greater than any of the others shows actually a preliminary rise in volume; this may be a greater manifestation of this same pH phenomenon.

Chart VI - The effect of varying PH and saturated Brine

The salinity in these cases is so great that any ionic or pH effects are minimised.

Charts VII and VIII - The effects of temperature, and 50 per cent brine at different pH's

Chart VII

The pH's in this experiment were known to have kept constant (except in cases of curves 32 and 33).

For any one PH there is a greater shrinkage at a higher temperature than at a lower. This does not appear to be merely a difference in the velocity of the process because the changes have been followed until the curves have flattened out. That they flatten out would seem to indicate that the reaction has become completed.

Chart VIII shows the same phenomena as Chart VII. The pH's were known to have changed and so it would be unfair to superimpose these curves on those of Chart VII. Taken by themselves however these examples confirm the findings of Chart VII.

Summary of Experiment I

By measuring the width or diameter of muscle fibres before and during immersion in various saline solutions it has been shown that :-

(1) The salinity of the solution is a factor in the change in diameter, which increased in water, decreased slightly in 50 per cent. brine, and decreased greatly in saturated brine.

(2) That if the salinity of the brine is kept constant, the pH of the brine is also a factor in determining the change in diameter: the more alkaline the solution the greater the increase, or the smaller the decrease. If any one buffer salt mixture is used this is true, but the effect of a certain pH obtained with one buffer salt may not be the same as if that pH were obtained with another ion.

(3) If the salinity and the pH are constant, the temperature of the brine is also a factor in determining this change in diameter:- the higher the temperature the greater the shrinkage, or presumably, the smaller increase in diameter.

Experiment II

It was thought well to obtain a few measurements with respect to the behaviour of a mass of fish when immersed in brine.

To this end, several small, more or less cubical, masses of Haddock muscle, were obtained and their volume changes while immersed in brine determined.

These pieces of fish were carefully obtained with as little pulling and tearing as possible, and during treatment were immersed in the solutions in pint milk bottles. When the volumes were to be determined they were lifted out of these solutions, allowed to drain for some ten seconds, and then dropped into a 250 cc. graduate cylinder containing a known volume of water. As soon as the increase in volume of contents of the cylinder had been read the piece of fish (20 - 30 ccss) was removed and put back into its respective solution.

The solutions consisted of Tap water, of 50 per cent. saturated brine (Turk's Island Salt), and of saturated brine, all at room temperature (65°F). An attempt was made to control the pH of the solutions by adding a liberal pinch of disodium hydrogen Phosphate and titrating with Hydrochloric acid to the required pH. As will be seen in the tables however, these pH's did not remain constant and consequently it is difficult to know what significance can be read into the results, with regard to acidity effect. Consequently while each individual determination is recorded in the Tables and Charts, there has also been included an average curve made up from each of the three curves of each salinity. By comparing these three average curves, the true effect of salinity, in itself, is perhaps more readily seen.

Table III and Chart IX include all the measurements and calculations pertaining to this experiment. As will be seen the volume of the fish at each measurement is given and is also expressed as the percentage change from the original volume. These percentage changes are also recorded in graphic form in Chart IX.

Table III

Chart IX

It is readily seen from these results that within an hour or two in tap water these pieces of fish have increased in volume about 20 per cent. In 50 per cent. brine they have on the average increased in volume 3 or 4 per cent. In this connection it may be noted that curve 39 is somewhat inconsistent in place. It is suggested that possibly the record of the original volume of the portion of fish was in error, and that an decrease instead of increase in volume was thus obtained. In saturated brine the change in volume seems to take longer, an average loss of volume of about 9 per cent. being noted in eighteen hours.

There seems to be a tendency to confirm the pH findings of Experiment I, though as stated before, this is not well proven.

In explanation of the peculiar wanderings of the early part of the curves 34, 35, and 36, it may be pointed out that the 250 cc. graduate is graduated in 2 cc. divisions. It was attempted to read it to 1 cc., but one considers variations in drainage of the fish and such things, an error of 1 cc. in the reading is almost to be expected. All these vagaries of the curves are due to differences of but 1 cc. in the readings.

With this point in view, Experiment III was devised. By starting with a slightly smaller piece of fish, a 100cc. graduate could be used, and these are graduated to 1 cc. differences. It is as easy to read to 0.5 cc. with this graduate as to 1.0 cc. with the 250 cc. graduate. If smoothness in the curve contour is any sign, then this change did result in an increased accuracy.

Experiment III

This experiment is very similar to that of #II, except that both weight changes and volume changes were followed, and that no attempt was made to vary the pH.

The pieces of fish were roughly in the form of rectangular blocks, and three pieces were put in each solution; one in which the myomere flakes were transferse to the block, one in which they were longtitudinal, and one in which they were transverse but rather stretched or pulled apart.

As in the last experiments the measurements and calculations have been incorporated in a composite table and in graphs, and also there has been included the average changes demonstrated in each of the three solutions.

Table IV

Chart X

It is seen from these graphs that: (1) In water the fish increase about 20 per cent. in volume in 1½ hours and then no more, while at the same time they have increased in weight to about the same extent. One would judge the increase in volume and weight to be both due to the absorption of water. (2) In 50 per cent brine the final increase in volume has taken place in 1½ hours and is about 10%, while these pieces of fish increase some 20 per cent. in weight. One would suppose that more salt was taken into the fish than water. Indeed #47 shows no volume increase but a considerable weight increase. (3) In the saturated brine we observe a marked decrease in volume, the downward slope of the curve still being marked even after three hours, when more than 30 per cent loss is shown. At the same time the loss of weight is but 10 per cent, indicating that so far as weight is concerned the loss of water is partially counteracted by an absorption of salt.

No conclusions have been drawn with regard to the influence of the direction or separation of the myomere flakes.

Summary of Experiments II and III

The changes in volume and weight of pieces of fresh Haddock when placed in water, in 50 per cent saturated brine, and in fully saturated brine, have been determined.

In water and 50 per cent brine the fish increased both in volume, and in weight, while in saturated brine a marked decrease in volume and lesser decrease in weight was noted.

The increase in volume was greater in water than in 50 per cent brine, but the increase in weight was greater in the brine.

The curves showing volume increase reach their height in one to two hours, whereas those showing decrease indicate this to be a much slower phenomenon.

There is some indication that acidity also affects these changes. In the water and 50 per cent brine solutions, the more alkaline the solution, the greater the increase in the volume which is noted.

General Conclusions

(1) Individual muscle (Haddock) fibres, or small pieces of fish show considerable volume and weight changes on immersion in brine.

(a) The velocity of these changes is much greater in the cases of the fibres than with small pieces.

(b) Those instances in which pieces of fish increased in volume showed a much more rapid change than when a decrease was noted.

(2) Salinity was the important factor in the change.

(a) Fibres and pieces of fish increased both volume and weight in water.

(b) Fibres showed little change in volume in 50 per cent brine, but pieces of fish showed a definite increase in volume and a larger increase in weight.

(c) Both fibres and pieces of fish showed marked decrease in volume in saturated brine, and pieces of fish showed a lesser decrease in weight.

(3) If salinity is constant, the acidity of the solution seems also to exert an effect: generally speaking, the greater the alkalinity, the greater the increase (or smaller the decrease) in volume and weight.

(4) If salinity and acidity are kept constant, temperature too exerts an effect; the higher the temperature, the greater the shrinkage or presumably, the smaller the swelling.

Table III

	Treatment: Pieces of fish were soaked in the solutions indicated below	Volume of pieces of fish, after soaking for x hours														
		pH	Original Volume		¾ hour		1½ hour		2¼ hour		pH	3 hours		pH	18 hours	
		orig	cc	% change	cc	% change	cc	% change	cc	% change	3 hr	cc	% change	12 hrs	cc	% change
34	Saturated Brine at room temp. with phosphates	8.5	34	0	35	+2.9	34	0	33	-2.9	8.5	33	-2.9	6.8	30	-11.7
35	Saturated Brine at room temp. with phosphates	7.0	30	0	31	+3.3	30	0	31	+3.3	6.8	30	0	6.6	28	-6.7
36	Saturated Brine at room temp. with phosphates	6.0	31	0	31	0	31	0	32	+3.2	8.0	31	0	7.0	29	-6.4
	Aver. of 34, 35, and 36			0		+2.1		0		+1.2			-1.0			-8.9
37	50% saturated Brine at room temp.+Na_2HPO_4	8.5	33	0	34	+3.0	35	+6.0	36	+9.1	8.0	36	+9.1	6.4	36	+9.1
38	50% saturated Brine at room temp.+Na_2HPO_4	7.0	21	0	22	+4.8	22	+4.8	22	+4.8	6,5	22	+4.8	6.2	23	+9.6
39	50% saturated Brine at room temp.+Na_2HPO_4	6.0	21	0	19	-9.6	20	-4.8	20	-4.8	6.0	20	-4.8	6.6	20	-4.8
	Aver. of 37,38 and 39			0		-0.6		+2.0		+3.0			+3.0			+4.6
40	Tap Water at room temp.with phosphates	8.5	17	0	18	+5.9	20	+17.6	21	+23.6	8.0	21	+23.6	6.2	22	29.4
41	Tap Water at room temp.with phosphates	7.0	20	0	22	+10.0	24	+20.0	24	+20.0	6.8	24	+20.0	5.8	24	+20.0
42	Tap Water at room Temp.with phosphate	6.0	21	0	23	+9.5	24	+14.3	24	+14.3	6.0	24	+14.3	6.0	23	+9.5
	Aver. of 40,41 and 42			0		+8.5		+17.3		+19.3			+19.3			+19.6

Table IV

No.	Treatment: Pieces of fish as below were soaked in the brines indicated	Weight of fish after soaking for x hours: Weights: original gms.	original % change	½ hour gms.	½ hour % change	1½ hour gms.	1½ hour % change	3 hours gms.	3 hours % change
43	Saturated Brine, myomeres longitudinal	12.5	0	12.5	0	11.7	-6.4	11.5	-8.0
44	Saturated Brine, myomeres transverse	10.2	0	10.2	0	9.6	-5.9	9.2	-9.8
45	Saturated Brine, myomeres separated	14.4	0	14.4	0	13.3	-7.6	12.6	-12.5
	Average of 43,44, and 45		0		0		-6.6		-10.1
46	50% saturated brine, myomeres longitudinal	11.2	0	13.0	+16.1	13.5	+20.6	14.0	+25.0
47	50% saturated brine, myomeres transverse	12.2	0	13.3	+9.0	13.3	+9.0	13.6	+11.5
48	50% saturated brine, myomeres separated	12.2	0	15.0	+23.0	15.6	+27.8	16.3	+33.6
	Average of 46,47, and 48		0		+16.0		+19.1		+23.4
49	Tap Water, myomeres longitudinal	13.2	0	14.5	+9.8	15.3	+15.9	15.8	+19.7
50	Tap Water, myomeres transverse	9.0	0	9.9	+10.0	10.1	+12.2	10.8	+20.0
51	Tap Water, myomeres separated	11.9	0	14.0	+17.6	14.5	+21.8	15.3	+28.6
	Average of 49,50, and 51		0		+12.8		+16.6		+22.8

Table IV

No.	Treatment: Pieces of fish as below were soaked in the brines indicated	Volume of fish after soaking for x hours: Original volume cc.	Original volume change	¾ hour cc.	¾ hour change	1½ hour cc.	1½ hour change	3 hours cc.	3 hours change	final pH
43	Saturated Brine, myomeres longitudinal	13	0%	11	-15.4%	10	-23.0%	9	-38.0%	6.7
44	Saturated Brine, myomeres transverse	10	0	9	-10.0	8	-20.0	7.5	-25.0	"
45	Saturated Brine, myomeres separated	14	0	13	-7.1	11	-21.4	9	-35.7	"
	Average of 43, 44, and 45		0		-10.8		-21.5		-32.9	"
46	50% saturated brine, myomeres longitudinal	11	0	12	+9.1	12	+9.1	12	+9.1	"
47	50% saturated brine, myomeres transverse	12	0	12	0	12	0	12	0	"
48	50% saturated brine, myomeres separated	12	0	13	+8.3	14	+16.7	14	+16.7	"
	Average of 46, 47, and 48		0		+5.8		+8.6		+8.6	"
49	Tap Water, myomeres longitudinal	12	0	14	+16.7	15	+25.0	15	+25.0	"
50	Tap Water, myomeres transverse	9	0	10	+11.1	10	+11.1	10	+11.1	"
51	Tap Water, myomeres separated	11	0	13	+18.2	14	+27.2	14	+27.2	"
	Average of 49, 50, and 51		0		+15.3		+21.1		+21.1	"

Chart IX.

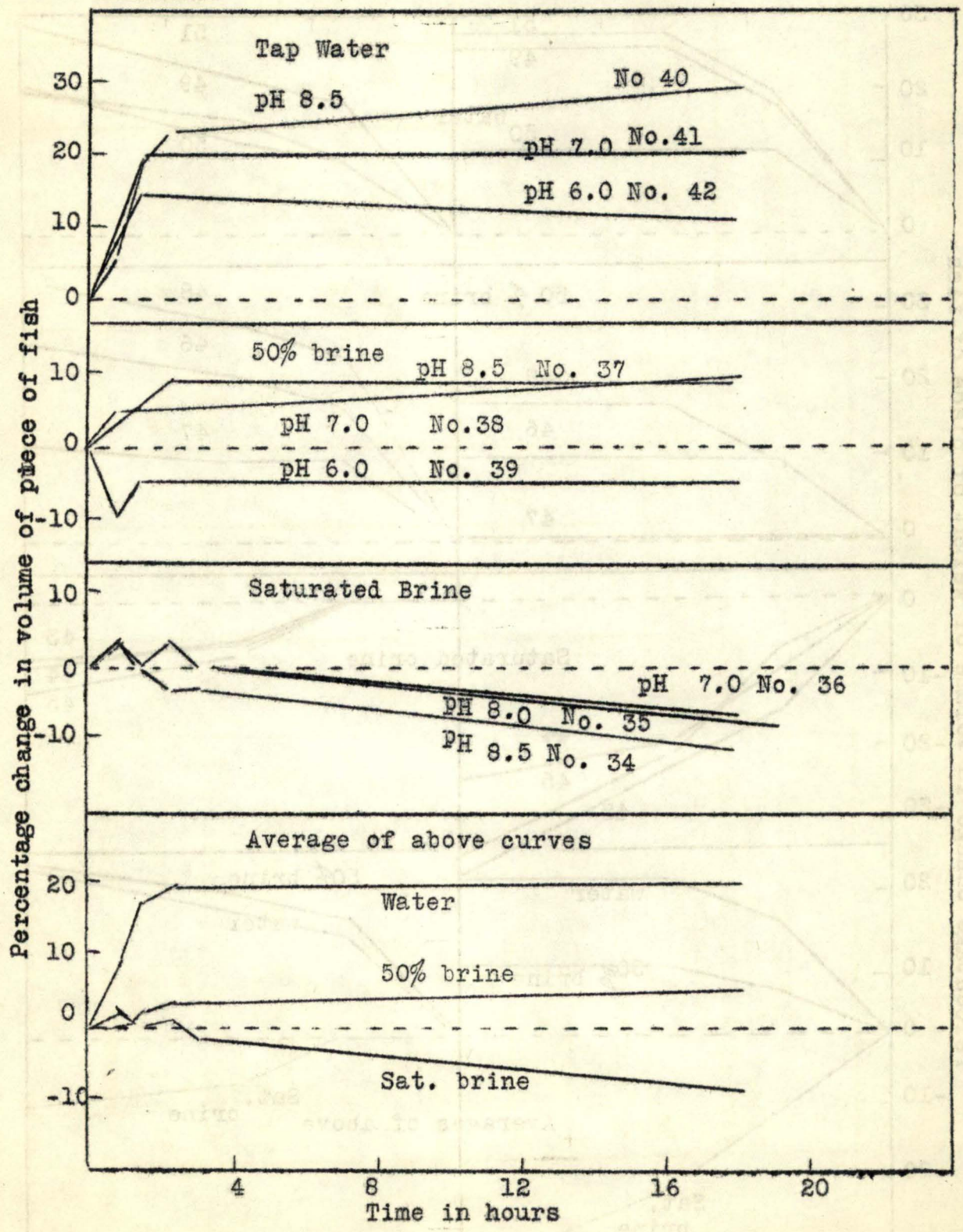
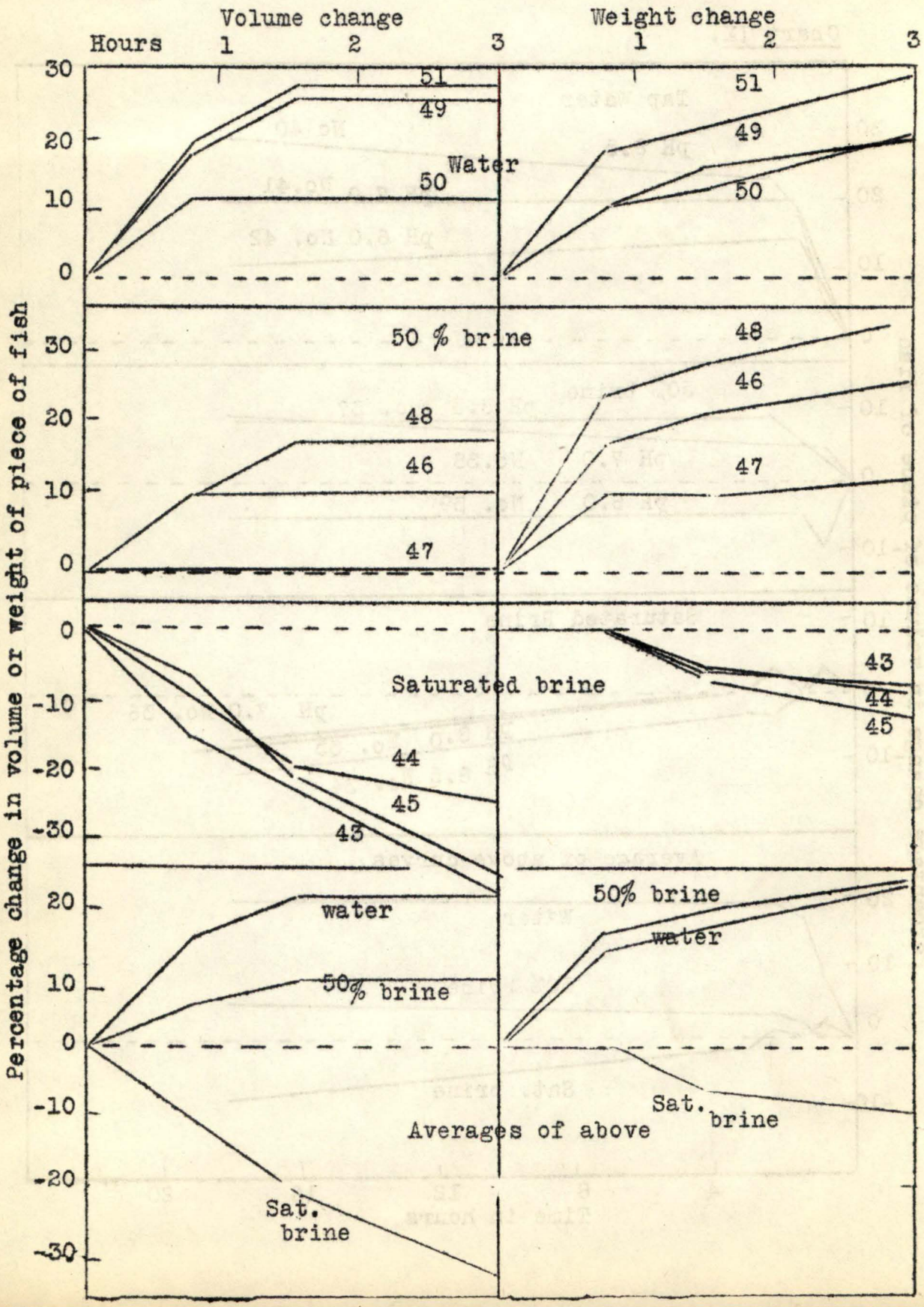

Tap Water
pH 8.5
No 40
pH 7.0 No.41
pH 6.0 No. 42
30
20
10
0
50% brine
pH 8.5 No. 37
pH 7.0 No.38
pH 6.0 No. 39
10
0
-10
Saturated Brine
pH 7.0 No. 36
pH 8.0 No. 35
pH 8.5 No. 34
10
0
-10
Average of above curves
Water
50% brine
Sat. brine
20
10
0
-10
Percentage change in volume of piece of fish
4
8
12
16
20
Time in hours

Chart X


Volume change
Weight change
Hours
1
2
3
Percentage change in volume or weight of piece of fish
30
20
10
0
-10
-20
-30
51
49
50
Water
50 % brine
48
46
47
Saturated brine
43
44
45
water
50% brine
Averages of above
Sat. brine