THE INFLUENCE OF SODIUM TRIPOLYPHOSPHATE ON HOT PORCINE MUSCLE

By

ZUEN-YEN WU

Bachelor of Science

Taiwan Provincial Chung-Hsing University

Taichung, Taiwan

1961

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1968

THE INFLUENCE OF SODIUM TRIPOLYPHOSPHATE ON HOT PORCINE MUSCLE

Thesis Approved:

R. L. Henrickson
Thesis Adviser

George V. Odell

D N Duncan
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author is sincerely grateful to Dr.R.L. Henrickson, Professor of Animal Science, for his assistance and guidance throughout this program of graduate study and in the preparation of this thesis.

Appreciation is extended to Drs. George V. Odell and L. E. Walters for helpful suggestions and constructive criticisms of this manuscript.

Special appreciation is extended to his brother, Dr. Albert Sun, and sister, Mrs. Angela Hsi, for their continuous help and encouragement throughout the study.

Finally the author wants to express his gratitude to his parents, who have made all this possible.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Prior to the last decade a few workers concentrated on the action of the polyphosphate in processed meat. Mahon (1963) emphasized that salt and tripolyphosphate act synergistically to increase the cured meat volume. Sherman (1961) was credited with finding that polyphosphate controls the rate of ion absorption in meat. The greater the ionic strength of the meat, the greater will be the absorption of the $H^{+}OH^{-}$ ions. On the other hand, the influence of pH has been widely reported (Hamm et. al., 1953; Hashimoto et. al., 1959; Mohler and Kiermeier 1955...etc.). The pH of meat depends upon both its pre- and post slaughter history. It is affected also by the addition of neutral salts and polyphosphate. At the isoelectric point of meat, (pH 5.0 -5.5), fluid retention is at a minimum. Thus, any additive that significantly changes the pH will increase the fluid retention of isoelectric meat whether such additive is acidic or basic. But Mahon (1963) was of the opinion that adding 0.2 to 0.5% sodium tripolyphosphate to cold meat only increased the pH by 0.1 to 0.3 units. Such a small increase in pH cannot, by itself, account for the pronounced effect of tripolyphosphate on the fluid retention in processed meats.

In "Hot" porcine muscle rigor mortis and the formation of lactic acid have not been accomplished before application of heat such as in cured meat. Based on Mahon's work, the pH will have less significance when neutral salts and tripolyphosphate are added to the "Hot" porcine muscle. If so, the end result will be that the meat will remain above the isoelectric point and fluid retention properties will remain advantageous. On the other hand, the rigor mortis is a factor influencing meat tenderness. Recent studies have indicated that meat is tender immediately after slaughter, but becomes less tender during the next 24 to 72 hour period. Emphasis has been placed on the occurrence of rigor mortis. The question remains whether polyphosphate will prevent the actin and myosin from forming actomyosin, or whether it has only a specific swelling effect on lean meat.

All the published information on this subject has been concerned with cold processed meat. Little attention has been given to the "Hot" porcine muscle. The objectives of this investigation are to determine the effect of sodium tripolyphosphate on "Hot" porcine muscle. Careful attention will be given to the pH change, volume, and water binding capacity.

CHAPTER II

LITERATURE REVIEW

The Biochemistry of Hot Porcine Muscle

Many physiological and biochemical changes occur in muscle that influence the quality of the meat product. When blood is removed from the neat animal, physiological processes are stopped. According to Briskey (1959), the major chemical changes, after death in the muscle, were the production of lactic acid from anaerobic glycolysis, and break down of creatine phosphate, which served as mechanisms for resynthesis of ATP from ADP. The balance between resynthesis and breakdown of ATP was lost when the store of creatine phosphate was depleted, according to Bendall (1951) and Lawrie (1953). Dephosphorylation exceeded the rephosphorylation so that the actual ATP level began to fall.

The glycogen in the muscle is converted to lactic acid when blood circulation ceases. Briskey (1959) stated that the initial pH was dependent upon the severity of the death struggle and depletion of glycogen. In general, the pH will fall to a value of 5.5 to 5.6. At this pH level the enzymes normally active are inhibited, but other enzymes are permitted to act initially on protein denaturation. Individual

proteins such as actin and myosin changed. New forms of protein are synthesized. In vivo actin and myosin are prevented from association by adenosine triphosphate.

Henrickson and Smith (1967) conducted experiments which indicated that the rate of pH fall or breakdown of ATP during the onset of rigor mortis is also important in determining water binding capacity. The production of lactic acid causes the muscle fibers to contract and the spaces between the fibers become filled with fluid.

Muscle Structure and Rigor Mortis

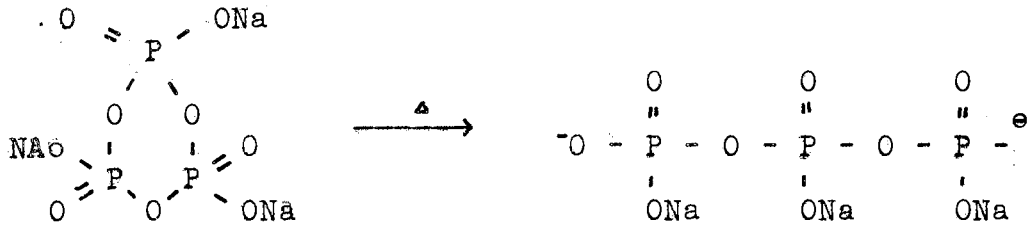
The contractile structure of striated muscle, including the overlapping filaments containing the two principle structural proteins actin and myosin, has been discussed by Huxley and Hanson (1959). Filaments of actin extend to the Z-line, the boundary of the sarcomere, and slide in and out of the A-band. The A-band is composed of myosin filaments. If a cross section through this area of overlapping were made, each myosin filament would be surrounded by six filaments of actin. Changes in the length of the sarcomere were observed when the actin and myosin filaments moved past each other and the complex, actomyosin, was formed by cross linkages from the myosin to the actin.

Rigor mortis and physiological contraction were postulated to be the same by Bendall (1951). Work by Marsh (1954) confirmed this as a slow and irreversible physiological contraction. Partmann (1963) indicated that the

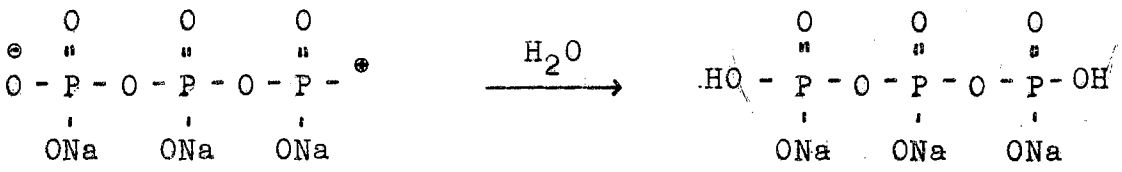
mechanisms were the same in both cases. Briskey et. al., (1962) developed an apparatus that permitted studies of rigor mortis. Onset of rigor mortis was found to vary from two min. to eight hrs. after death. The striking differences seen in the course of rigor mortis were attributed to: (a) variation in membrane resistance against autolytic processes or acidification; (b) deviations in post mortem release of calcium and other ions by muscle proteins; (c) differences in the relation between the velocity of glycolytic ATP resynthesis and its breakdown.

The Chemical Properties of Tripolyphosphate and its Effect on Meat

Thilo and Wieker (1957) reported that the ring structure of sodium trimetaphosphate was ruptured at high temperatures to give a linear double ion molecule:

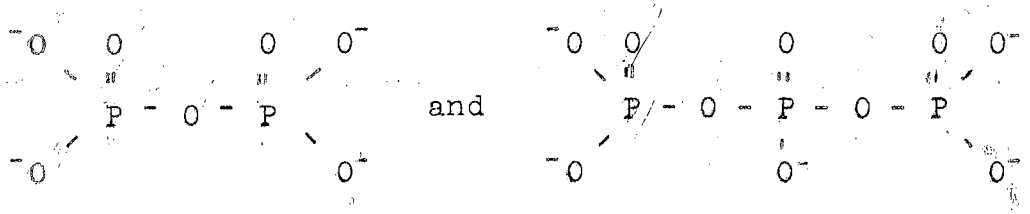


When this double ion molecule meets water, the positive hydrogen ion will add to the negative oxygen atom at one end of the polyphosphate chain while the hydroxy ion adds to the positive phosphorus at the other end of the chain to form sodium tripolyphosphate:



Campbell and Kilpatrick (1954) have shown that the rate of hydrolysis of $P_3O_{10}^{5-}$ ions is a first order reaction at a particular pH value. Van Wazer et. al., (1955) described how, in highly acidic solutions, the hydrogen ion seems to displace the sodium ion as a catalyst, so that addition of sodium chloride as swamping electrolyte results in a diminution in reaction rate in opposition to its acceleration action under less acidic conditions.

Gimblett (1960) has suggested that the hydrolysis of low molecular and probably high-molecular, polyphosphates occurs through the formation of an activated complex by chelation of the water, hydroxonium ion or hydrated metal ion with a $-\overset{\overset{O}{\uparrow}}{\underset{\underset{O}{\downarrow}}{P}}-O-\overset{\overset{O}{\uparrow}}{\underset{\underset{O}{\downarrow}}{P}}-O-$ group. This might explain the results of Grau (1953), and of Mohler and Kiermeier (1953). They found that increasing the alkalinity of meat increased its ability to retain moisture. This work agreed with Bendall (1954) who concluded that increased ionic strength produced the swelling observed in the use of orthophosphates and polyphosphates. He proposed that this behavior of pyrophosphate is probably due to its ability to hydrolyze the bond between (I) and (II).



(I) (II)

Both of these are found in the compound adenosine triphosphate, which is the source of the energy for muscular contraction, and also in inorganic triphosphate (II). Thus, the triphosphate would be expected to behave in the same manner as pyrophosphate. The fact that pyrophosphates, under certain conditions, split actomyosin, yielding actin and myosin, has been adequately demonstrated by Straub (1943).

Tripolyphosphate-salt Synergism and its Effect on Meat Volume

Bendall (1954) reported that orthophosphate, pyrophosphate, calgon and phosphate glass all increase the uncooked volume of mice or rabbit muscle by 10% - 20% when added at an over-all concentration of 0.5% to a mixture of equal parts of meat and water. On cooking, the volume falls to between 65 and 75% of the volume of fresh meat. These effects are about the same as that of sodium chloride at an overall concentration of 1%.

Hamm et.al., (1953) credited the polyphosphates with sequestering undesirable calcium, magnesium and zinc ions in raw meat, and so increasing the water binding properties. Swift and Berman (1959) demonstrated positive correlations

between the water retention of beef muscle and its pH and zinc content. These authors also reported that water retention in beef was inversely proportional to the calcium and magnesium content. On the other hand, Bendall (1954) and Sherman (1961) are of the opinion that sequestration of calcium and magnesium ions does not account for the effectiveness of the polyphosphates. Furthermore, Swifts and Ellis (1956) showed that small amounts of magnesium chloride slightly improved the water retention of beef. Wierbicki et. al., (1959) demonstrated that calcium chloride and magnesium chloride increase the fluid retention of beef heated to 70°C.

At the isoelectric point of meat, pH 5.0-5.5, fluid retention is at the minimum. Thus, any additive that significantly changes the meat pH will increase the fluid retention of isoelectric meat whether such additive is acidic or basic. Hamm et.al., (1957), Mohler and Kiermeier (1953), and Swift and Berman (1959), to mention but a few authors, showed that a large increase in pH favors fluid retention in meat. Mahon (1963) concluded that salt concentration and not pH adjustment is the key to maximum cured meat volume. However, adding 0.2 to 0.5% sodium tripolyphosphates to meat only increases the pH by 0.1 to 0.3 units. Such a small increase in pH cannot, by itself, account for the retention in processed meats.

Bendall (1954) pointed to differences between the volume of ground meat treated with polyphosphates and meat

treated with polyphosphate and salt. He suggested that the meat volume was a function of total ionic strength since the pH of both meat samples was essentially the same. Sherman (1961) stated that fluid retention in ground pork treated with sodium chloride is due to the degree of ion adsorption, and that ionic strength is important only insofar as it controls the rate of ion adsorption by meat. He also indicated that the absorption of ions from alkaline polyphosphate solutions was more complex. In this instance the anions were absorbed to a lesser extent than the cations. The ratio of anions to cations absorbed increased with increased pH of the solution meat mixture, after aging at 0°C., until it reached unity at approximately pH 7.4. This applied also when a solution containing sodium chloride plus alkaline polyphosphate was mixed with ground meat. The effect normally attributed to the ionic strength of the solution mixed with the meat samples may, therefore, be intimately related to the question of ion absorption.

Mahon (1963) reported that low salt concentrations of the order of 0.5% are detrimental to cured meat volume, and concluded that as salt concentration decreased, tripolyphosphate concentration must increase accordingly if cured meat volume is to be maintained.

This very brief glance at the literature suggests three possible methods by which the polyphosphates may increase fluid retention of meats. Namely, sequestration of

divalent ions in the meat, alkaline pH adjustment, and increased ionic strength.

Selection of Techniques

As a preliminary it was necessary to select techniques suitable for estimating the fluid absorption capacity of meat. Methods described in the literature on this subject fall into the following categories:

I) Estimation of water retention at 0°C.

a) Press method

This method has been used principally by Hamm and Grau (1953, 1957), and their co-workers and it has been described in great detail.

b) Sedimentation method (Mohler and Kierneier, 1953)

Ground meat is mixed throughly with water, or solutions of sodium chloride or phosphate, and allowed to stand for 20 hours. The water retained by the meat is calculated from its sedimentation volume.

c) Centrifuge method (Kormendy and Gantner, 1954)

Ground meat and water, or solutions of sodium chloride or phosphate, are mixed throughly and aged for approximately 24 hours at 0°C. The unabsorbed fluid is then isolated by centrifugation and measured.

The press method requires quite small samples of meat, 0.3 gram per test. The sedimentation and centrifuge methods employ larger sample weights and provide therefore, a measure of water absorption by more truly

representative samples. Furthermore, it is easier to carry out several determinations simultaneously by the latter two methods.

II) Estimation of water retention at elevated temperature

a) Heating meat solution mixtures without a preliminary removal of the water that is not retained at 0°C. (Swift and Berman, 1959).

Ground meat is mixed with water, or solutions of sodium chloride or phosphate, and kept at 0°C. for approximately 24 hours. The mixture is then heated at the desired temperature, usually 70° or 100°C., for a given time, and the free water removed by decantation or centrifugation.

b) Heating meat solution mixtures after a preliminary removal of water that is not retained at 0°C. (Hamm et.al., 1953).

The residue from method (Ic) is heated at 70°C. or 100°C. for a given time, and the free water removed by decantation or centrifugation.

The essential difference between these two methods is that in (a) the nitrogenous matter that passes into solution is not removed before heating the meat solution mixture. Thus method (a) bears a closer resemblance to what occurs in the cooking of meat in the normal way. Loss of soluble nitrogenous matter - in particular - meat proteins, by centrifugation prior to cooking, results in the meat showing reduced water retention at elevated temperatures. Swift and Ellis (1956) claimed that every gram of dissolved protein not removed by

centrifugation helped retain approximately 10 gram of water when the meat was cooked. Bendall (1954) also observed improved water retention under these conditions and concluded that proteins retain more water when coagulated in the sol form than when coagulated in the gel form.

Method Application and Data Calculations

According to Sherman (1961), to determine the conditions for optimum water retention at low temperature preliminary determinations were made on mixtures of ground meat with water, sodium chloride solutions and phosphate solutions. These were left at 20°C. or 0°C. for periods ranging from a half hour to 24 hours before removal of the unabsorbed fluid. Maximum absorption occurred in all cases when the meat solution mixtures were aged for 18-24 hours at 0°C. The percentage water retention per gram of meat was calculated as --

$$\frac{\text{volume (ml) of fluid added - fluid not absorbed (ml)}}{\text{weight of meat}} \times 100$$

The volumes of the residual meat samples, after removal of unabsorbed fluid, were determined by displacement.

To determine the water retention at elevated temperatures, two methods were developed by Sherman and were described as following:

Method I. The centrifuge tubes containing the meat residues from the estimation of water retention at 0°C. were fitted

with short, narrow, air condensers and heated for 20 minutes in a boiling water bath. The water released from the meat was decanted and estimated by the procedure described in the previous section.

$$\% \text{ water retention at } 100^{\circ}C = \% \text{ water retained at } 0^{\circ}C. - \frac{(\text{ml water released at } 100^{\circ}C)}{\text{weight of meat}} \times 100$$

Method II. When equal weights of solution and meat were used 10.0 gram ground meat were weighed into tared centrifuge tubes (50 ml capacity) and 10 ml distilled water, or aqueous solution of sodium chloride or commercial polyphosphate introduced by pipette. After mixing the meat and solution thoroughly with a glass rod the tubes were stoppered with rubber corks and left overnight, for a minimum of 18 hours at 0°C. Short, narrow, air condensers were then fitted to the tubes which were heated for 20 minutes in a boiling water bath. The fluid not absorbed by the meat was decanted and estimated as described previously.

$$\% \text{ water retention at } 100^{\circ}C = \frac{100 \times (\text{fluid added (ml)} - \text{fluid not absorbed (ml) by meat})}{\text{weight (g) of meat}}$$

In those tests, where the influence of meat solution ratio on water absorption at 0°C. and 100°C. was investigated, the same procedures were adopted as described above with the one difference that the weights of meat and volumes of solution were readjusted as required. In both methods for the deter-

mination of water retention the temperature was 100°C. and the volumes of the cooked meat residues were determined by water displacement.

CHAPTER III

EXPERIMENTAL PROCEDURES

Materials

The meat samples used were from five 16 to 18 month-old Hampshire gilts of similar genetic and management background, ranging in live weight from 200 to 230 pounds, provided by the Oklahoma State University swine herd. They were slaughtered by using conventional methods of stunning and bleeding. Each hog was skinned and dressed by standard procedures used in the Animal Science Meat Laboratories. The muscle samples were taken within fifteen minutes after the animal was slaughtered. The muscles, Semimembranosus and Beceps Femoris, were removed and the pH was measured and recorded. Each muscle was kept at body temperature (98.6°F. or 37°C.) before treatment.

Methods

The Effect of Sodium tripolyphosphate and Sodium Chloride on the Volume of Hot Porcine Muscle

The principal method employed in determining the volume was a modification of that described by Bendall (1954) and Swift and Ellis (1956). This involved adding a solution of sodium chloride and sodium tripolyphosphate in the pro-

portion of one ml of solution to one gm of meat, and a storage period of 12 hours.

(a) Solution preparation

The solutions used were 0, 0.5, 1.0, 1.5, 2.0, 3.0, and 4.0% of sodium tripolyphosphate in the presence of 0 to 6.0% salt. A total of 42 ratios of NaCl and sodium tripolyphosphate were prepared. Each solution was added to the porcine muscle at a temperature of 37°C.

The experimental design for the salt (NaCl) and tripolyphosphate ($Na_3P_3O_{10}$) was as follows:

TABLE I

THE EXPERIMENTAL DESIGN

Sodium chloride	% Sodium tripolyphosphate ($Na_3P_3O_{10}$)					
	0%	0.5%	1.0%	2.0%	3.0%	4.0%
0						
1.0						
2.0						
3.0						
4.0						
5.0						
6.0						

1% $Na_3P_3O_{10}$ = 1 gm $Na_3P_3O_{10}$ in 100 ml distilled water = 0.5% $Na_3P_3O_{10}$ in meat. Similarly, 1% NaCl = 0.5% NaCl in cured meat.

(b) The methods for water retention:

At cold temperature

The warm muscle samples, trimmed free of fat and connective tissue, were maintained at 37°C. Each warm muscle was ground through a 3 mm plate using an electric meat grinder. Duplicate 20 gm (± 0.02) portions of meat were placed in 50 ml capacity centrifuge tubes. To each tube 20 ml of NaCl - $Na_3P_3O_{10}$ mixed solution (which was prepared as described above) was added and the mixture was maintained at 37°C. These suspensions were mixed throughly with a stirring rod and allowed to stand for 2 hours at 37°C. then they were cooled at 0°C. for another ten hours. After cooling, the tubes were centrifuged for fifteen minutes at 3300 r.p.m. The volume of the unheated liquid supernatant was extracted and measured by a 25 ml graduated cylinder calibrated at 0.2 ml intervals. The unheated meat volume was mathematically calculated.

At heated temperatures

When equal weights of solution and meat were cooled and centrifuged, tubes containing the meat residues from the estimation of water retention at 0°C. were fitted with short, narrow, air condensers and heated for twenty minutes in a boiling water bath. The water released from the meat was decanted and estimated by the procedure previously described.

The Influence of Sodium Tripolyphosphate and Sodium Chloride on the pH Value of Hot Porcine Muscle

A Corning Model 10 pH meter was used in this study. Samples were drawn and the pH value was measured every ten seconds. After the cured meat reached room temperature, the pH was determined at two, twelve, twenty-four, and forty-eight hours after treatment. The pH of $Na_3P_3O_{10}$ - NaCl mixed solutions are shown in Table II.

TABLE II

THE pH OF $Na_3P_3O_{10}$ - NaCl MIXED SOLUTION

Sodium chloride	pH of Sodium tripolyphosphate Solutions					
	0 %	0.50%	1.00%	2.00%	3.00%	4.00%
0	5.65	9.60	9.55	9.45	9.30	9.25
1.0	5.60	9.10	8.90	9.00	9.05	9.00
2.0	5.45	8.80	8.70	8.85	8.75	8.75
3.0	5.30	8.55	8.55	8.65	8.65	8.60
4.0	5.20	8.45	8.45	8.35	8.50	8.45
5.0	5.15	8.35	8.30	8.20	8.35	8.30
6.0	5.10	8.25	8.25	8.15	8.15	8.10

The sample pH were measured before treatment. The pH was read in both Biceps Femoris and Semimembranosus muscles of

five hogs and were as follows:

			pH			MEAN VALUE
Biceps Femoris:	6.8	6.65	6.55	6.75	6.45	6.65
Semimembranosus:	6.40	6.30	6.68	6.48	6.70	6.51

CHAPTER IV

RESULTS AND DISCUSSION

The effect of sodium chloride and sodium tripolyphosphate on volume of hot porcine muscle was examined at different ratios in solution. Two muscles, Semimembranosus and Biceps Femoris, were used. Figures I and II (Table III) indicate the results obtained with the Biceps Femoris muscle. The data show a close relationship between the sodium chloride concentration and the volume of meat at different concentrations of sodium tripolyphosphate. That is, an increased salt concentration increased the volume of meat in either cooked or uncooked porcine muscle. In the presence of 3% sodium chloride and 2% sodium tripolyphosphate, the cured meat reached a volume maximum. At other levels of sodium tripolyphosphate concentration, a sharp increase in cured meat volume was shown with higher salt levels. This suggests that the protein acquires a net positive charge which strongly attacts the negative tripolyphosphate ion. Actually, the low concentration of salt and tripolyphosphate would show a higher concentration of meat protein. The negatively charged tripolyphosphate ion is quickly absorbed by protein, resulting in a sharp increase in cured meat volume. The addition of more salt reduced the net

positive charge on the protein and slowly increases the meat volume at lower concentrations of tripolyphosphate. A still sharper increase with higher levels of tripolyphosphate results from the addition of more salt until the salt concentration increases to a certain high level that causes the net positive charge on the protein to shift towards zero and greatly reduces the cured meat volume as reported by Mahon (1963). Therefore, the salt concentration determines the rate of the protein-tripolyphosphate interaction.

Figures III and IV (Table IV) show the same relationship between the salt concentration and the volume of meat at different sodium tripolyphosphate levels and except in the case of 4% sodium tripolyphosphate, where the meat volume increased with salt concentration up to 3%, the volume decreased as the salt concentration increased. In these latter cases, the results agree with that of Mahon's (1963) who studied volume changes in cold cured meat.

There was no greater difference in meat volume in either cooked or uncooked Semimembranosus muscle when the salt concentration was increased to a certain level. Figures III and IV show the volume of uncooked tripolyphosphate treated meat increases to 38 ml in both cooked and uncooked meat at a 3% salt and 4% sodium tripolyphosphate level. At low salt levels - 1.0, 2.0 and 30% salt concentrations - the meat volume changes are larger with a different concentration of sodium tripolyphosphate. On the other hand, the meat volume changes show only slight differences at higher

Figure I. The Effect of Tripolyphosphate and Salt Concentration on the Volume of Uncooked Hot Porcine Muscle.
(Biceps Femoris)

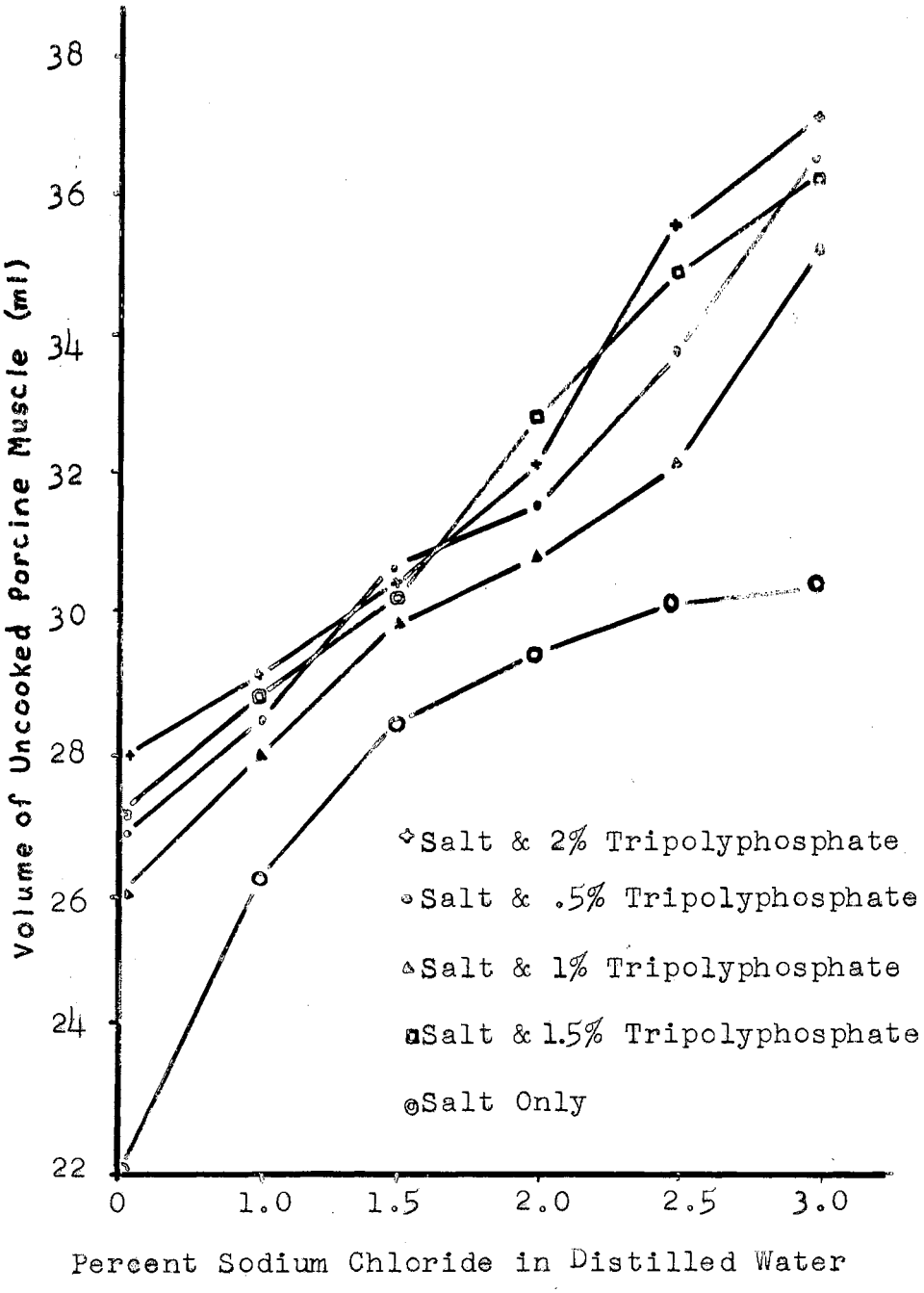


Figure II. The Effect of Tripolyphosphate and Salt Concentration on the Volume of Cooked Hot Porcine Muscle.
(Biceps Femoris)

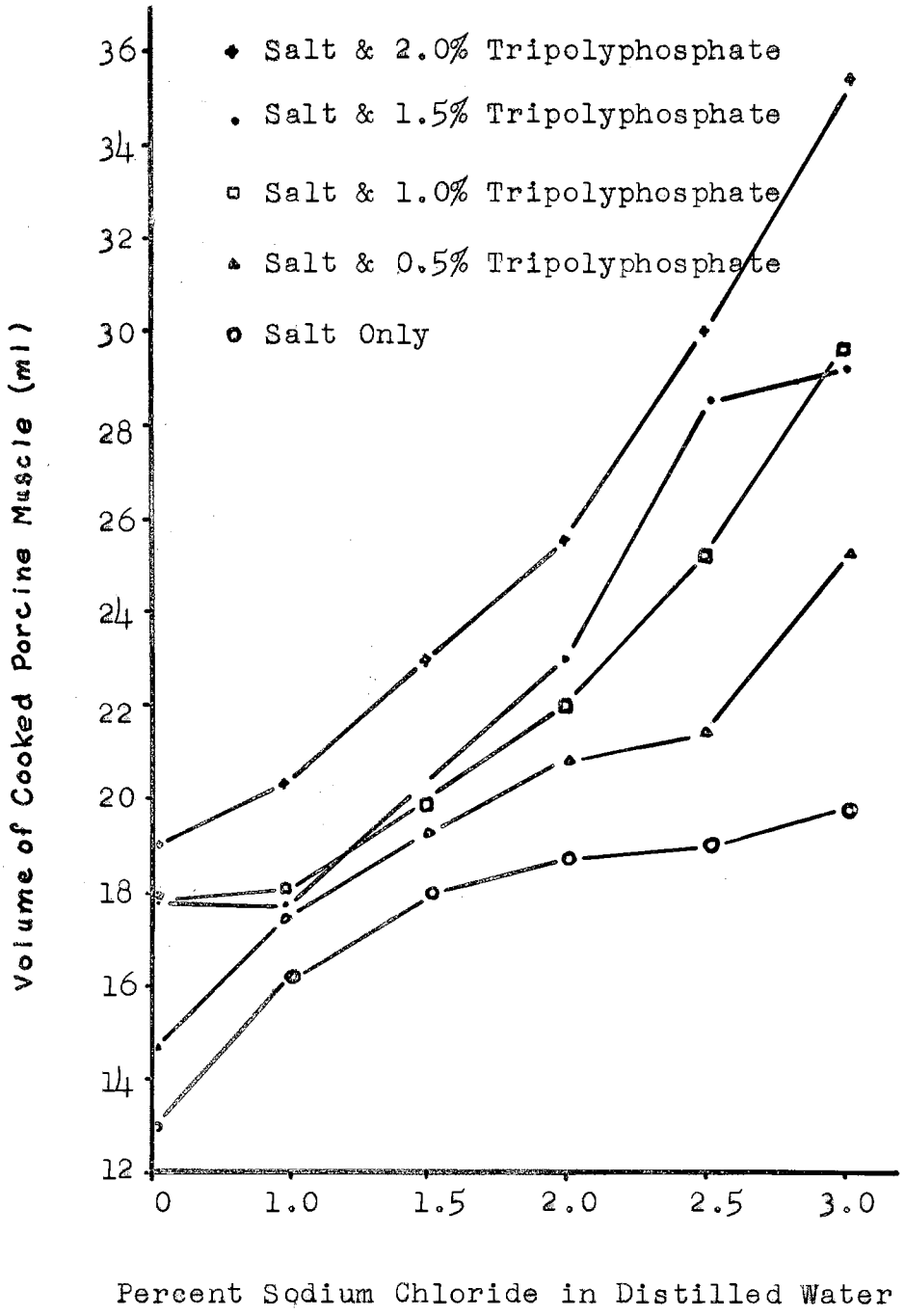


TABLE III

THE EFFECT OF TRIPOLYPHOSPHATE CONCENTRATION AND SALT CONCENTRATION ON VOLUME OF HOT PORCINE MUSCLE (BICEPS FEMORIS)

% Salt added	Uncooked Volume (ml)					Cooked Volume (ml)				
	% Tripolyphosphate Added					% Tripolyphosphate Added				
	0	0.5	1.0	1.5	2.0	0	0.5	1.0	1.5	2.0
0	22	26	27	27.2	28	13	14.7	17.8	17.8	19
1.0	26.3	28	28.4	28.8	29	16.2	17.6	18	19.8	20.3
1.5	28.6	30	30.8	30.2	30.3	18	19.3	20	20.2	25.0
2.0	29.4	30.8	31.5	32.8	32	18.8	21	22	22	25.6
2.5	30.2	32.1	33.8	34.8	35.5	19	21.4	25.4	28.6	30.2
3.0	30.4	35.3	36.7	36.2	37	19.8	25.4	29.6	29.4	35.6

TABLE IV

THE EFFECT OF TRIPOLYPHOSPHATE CONCENTRATION AND SALT CONCENTRATION ON VOLUME OF HOT PORCINE MUSCLE (SEMIMEMBRANOSUS)

% Salt added	Uncooked Volume (ml)						Cooked Volume (ml)					
	% Tripolyphosphate Added						% Tripolyphosphate Added					
	0	0.5	1.0	2.0	3.0	4.0	0	0.5	1.0	2.0	3.0	4.0
0	22.1	24.8	25	26.2	27.5	32	13	15	16	16.4	19.7	28
1.0	25.1	26	28	27.4	31.3	34.9	14.8	16.4	17	18.9	27.6	31.4
2.0	26.1	26.6	29.3	30.5	33.6	36.2	17	18.4	22	23.9	31.8	34.6
3.0	27.4	30	31	32.5	34.8	38	17.8	23.5	25	28.6	33.6	37.8
4.0	29.3	33.2	33.5	34.2	35.3	35.6	19.6	28.7	29.6	32.6	34	34.4
5.0	29.6	34.6	35.7	35.9	35.5	36.6	20.8	30	32	33.9	34.4	35.7
6.0	30.8	37.4	37.8	36.8	37	37	21.8	32.1	36.2	34.8	35.6	35.7

salt levels (4.0, 5.0, and 6.0%) as shown in Figures III and IV, with different concentrations of sodium tripolyphosphate. This shows that addition of more tripolyphosphate has only a relatively small effect on cured meat volume at higher salt levels. Thus it is the salt that conditions meat to exhibit the pronounced salt-tripolyphosphate synergist that increased cured meat volume.

The effect of adding 0-6% sodium chloride to hot porcine muscle is shown schematically in Figures III-IV. In this study, sodium chloride solutions of different concentrations were added to both Beceps Femoris and Semimembranosus muscle. The increased volume from a low concentration of 1.0% sodium chloride to a higher concentration gave an accumulative curve relationship. Also, it appears that the results differ from that of Mahon's (1963) investigation. He has described that with increasing amounts of salt added to the meat, negatively charged protein first reduced the net negative charge to zero - the first salt induced isoelectric point - at which stage the cured meat volume was at a minimum. In other words, a low salt concentration of the order of 1.0% was more detrimental to cured meat volume than using no salt. Actually, no such situation was found in the data in this thesis. The difference between this study and Mahon's might be explained on the basis of the isoelectric point of the meat protein. The lactic acid was produced in only a small amount in the short treatment time of hot porcine muscle and the pH at this stage could be rather high.

Figure III. The Effect of Tripolyphosphate and Salt Concentration on the Volume of Uncooked Porcine Muscle.
(Semimembranosus)

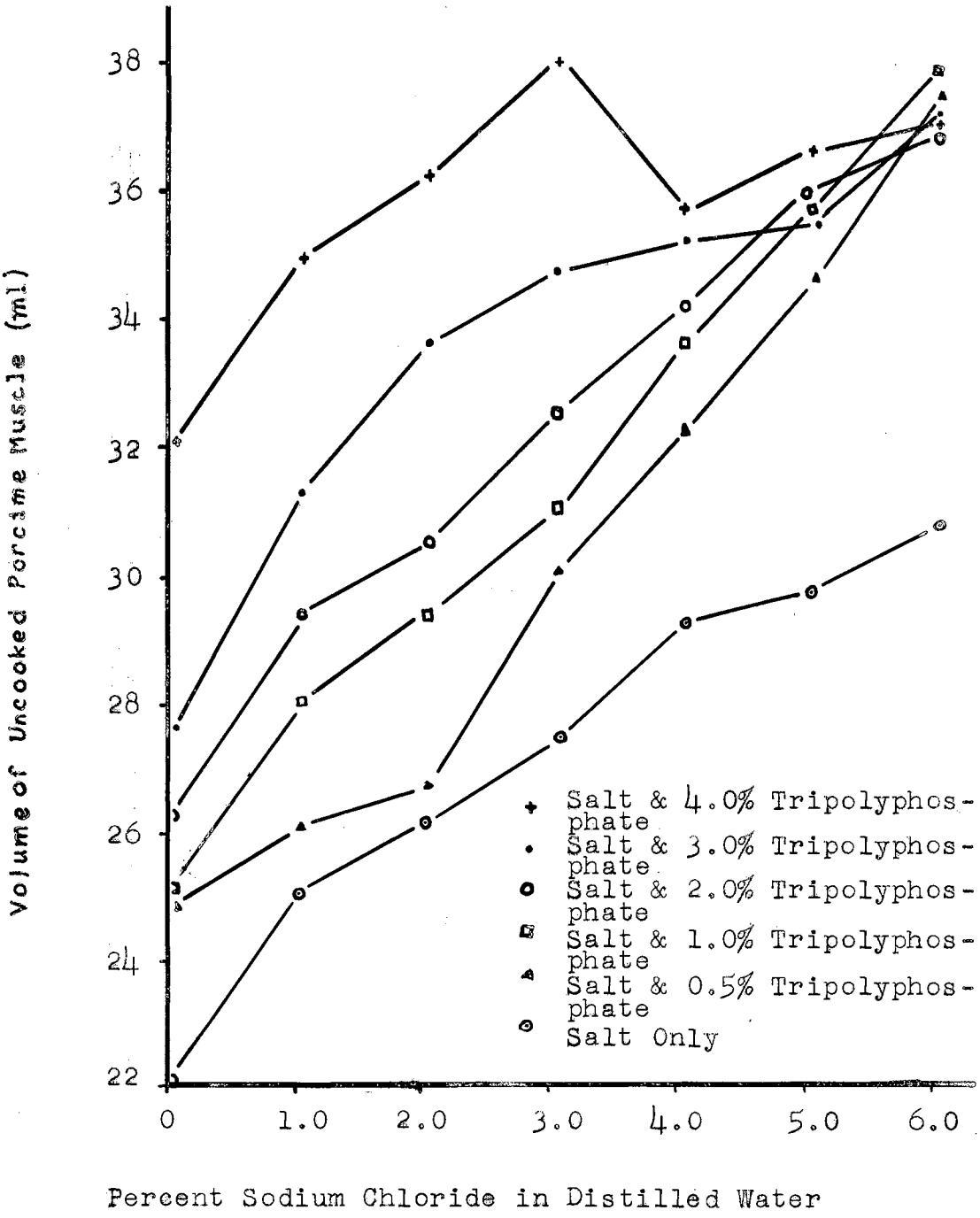
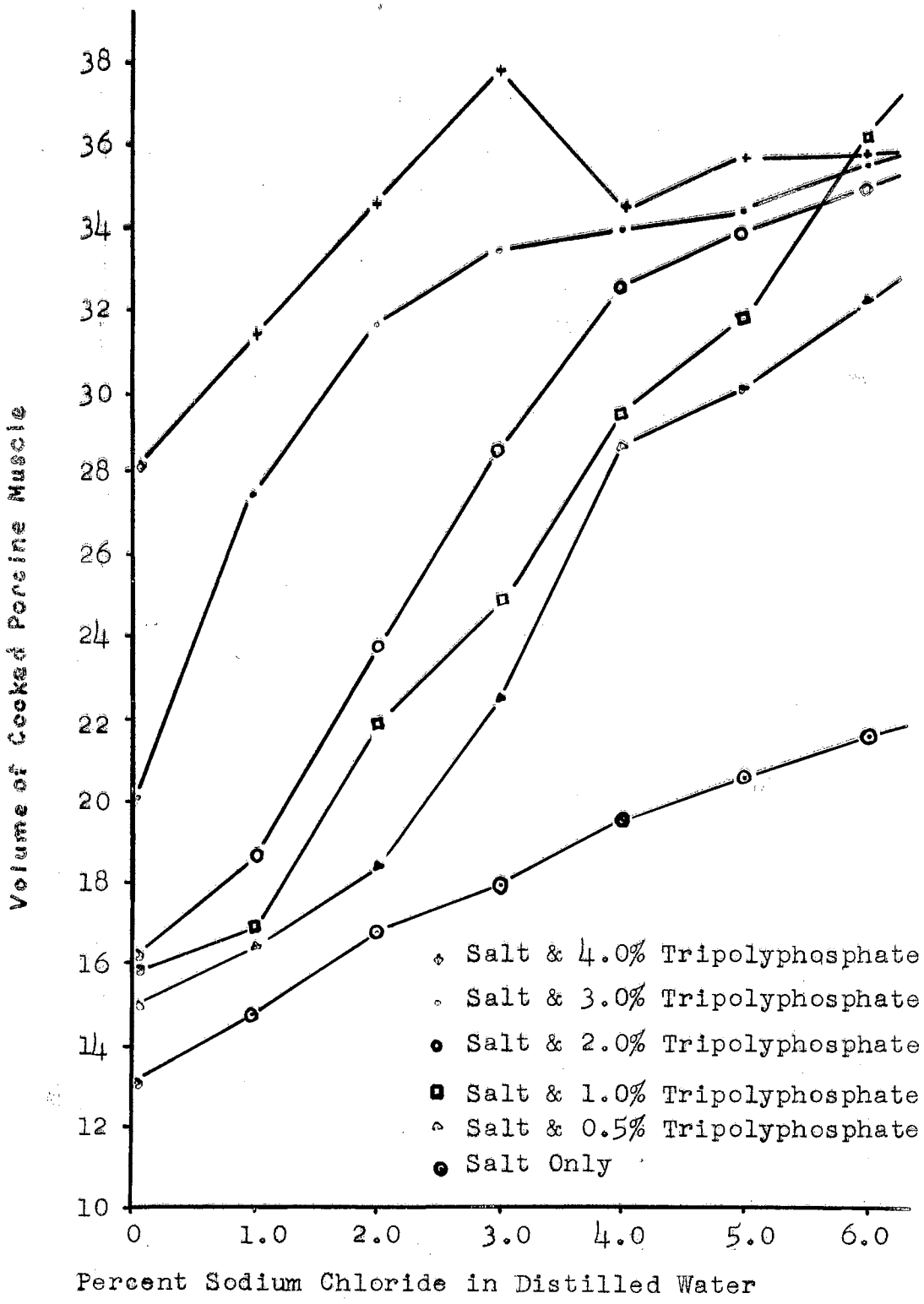


Figure IV. The Effect of Tripolyphosphate and Salt Concentration on the Volume of Cooked Porcine Muscle.
(Semimembranosus)



It was impossible to cause meat protein to cross the isoelectric range twice as described by Mahon. Although the addition of sodium chloride to meat does lower the pH value of meat protein slightly, as some hydrochloric acid is liberated through ion exchange in the muscle tissue, this treatment would not cause any drastic change in the pH value of hot muscular protein. It is therefore concluded that low salt concentrations of the order 1.0% are not detrimental to cured meat volume on hot processing.

Figures V and VI (Tables V and VI) show that adding sodium tripolyphosphate, alone, to hot porcine muscle has relatively little effect on water binding capacity (especially with the cooked treatment). This also shows a decrease in the percentage of water retention until 4.0% of sodium tripolyphosphate has been added. On the other hand, in the presence of 3.0% salt on Biceps Femoris muscle and 6.0% salt on Semimembranosus muscle, about 1.0% sodium tripolyphosphate exerts a maximum effect and little is accomplished by adding more tripolyphosphate. Figure VI also shows that in the presence of 3.0% salt the deviation of water binding capacity between uncooked and cooked meat decreased with increasing sodium tripolyphosphate concentration. There is not much difference in water binding capacity between cooked and uncooked porcine muscle. On the other hand, in the presence of 6.0% salt, there was no significance in the effect of tripolyphosphate on water binding capacity between cooked and uncooked meat. Both cooked or uncooked

Figure V. The Effect of Tripolyphosphate Concentration with 3 and 6% Salt Solution on Water Binding Capacity of Hot Porcine Muscle.
(Semimembranosus)

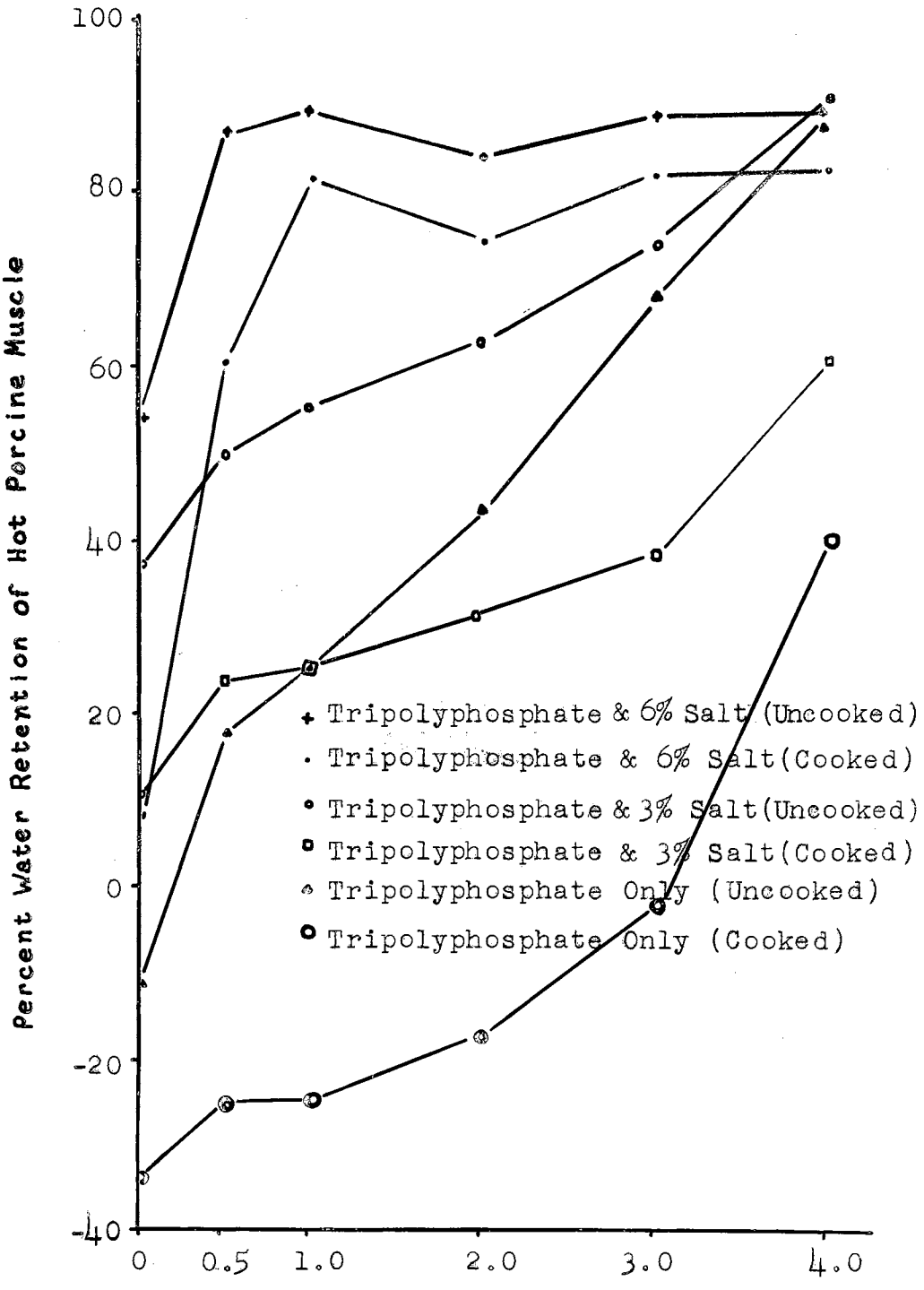


Figure VI. The Effect of Tripolyphosphate Concentration with 3.0% Salt Solution on Water Binding Capacity of Hot Porcine Muscle.

(Biceps Femoris)

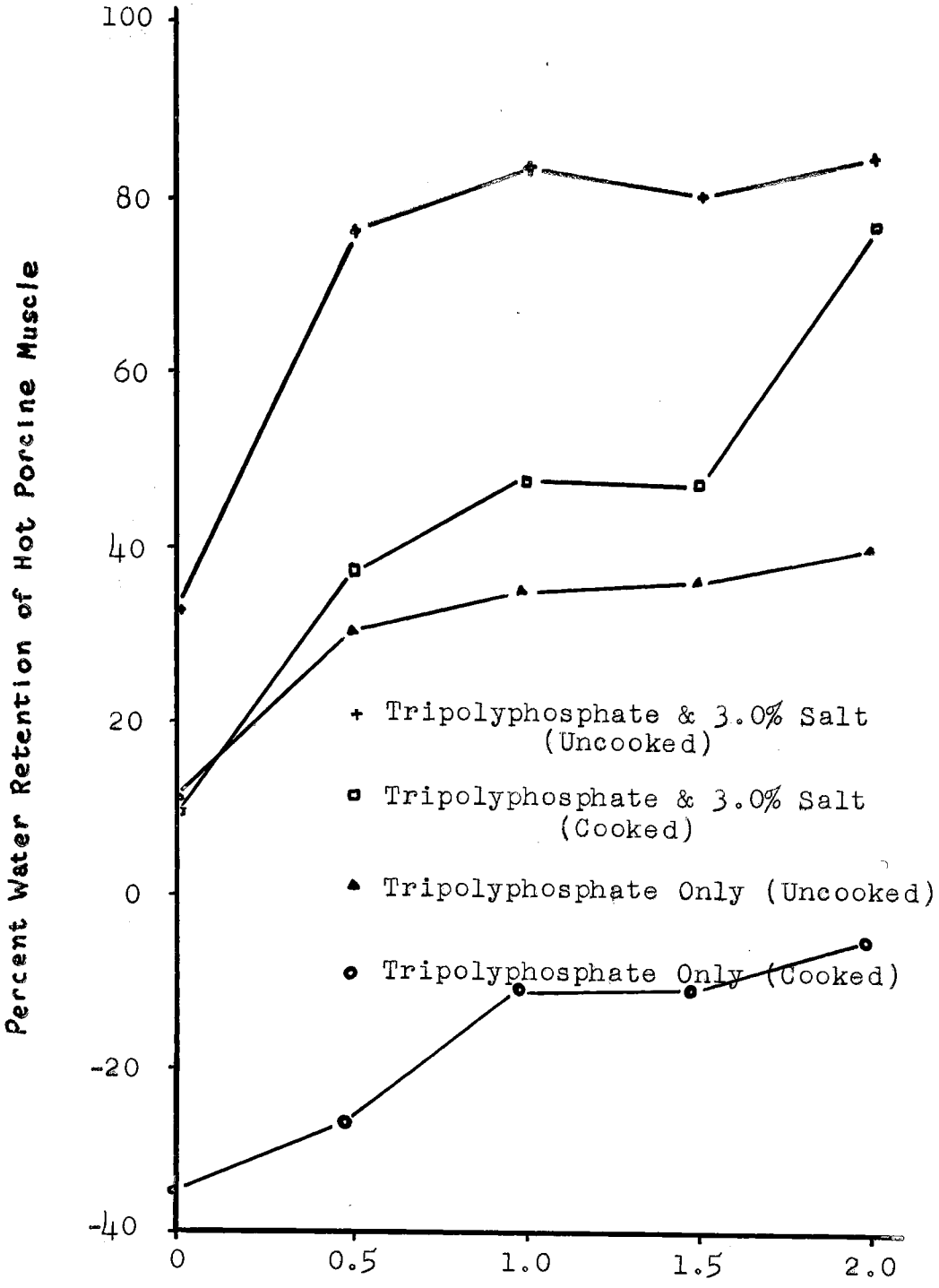


TABLE V

THE EFFECT OF TRIPOLYPHOSPHATE CONCENTRATION WITH 3 AND 6% SALT SOLUTIONS ON WATER BINDING CAPACITY OF HOT PORCINE MUSCLE (SEMIMEMBRANOSUS)

% Tripoly-phosph-ate	% Uncooked Fluid Retention			% Cooked Fluid Retention		
	Control	3% Salt*	6% Salt	Control	3% Salt	6% Salt
0	10.5	37	54	-34	-11.0	9
0.5	24	50	87	-25	17.5	60.5
1.0	25	55	89	-25	25.0	81
2.0	31	62.5	84	-18	43.0	74
3.0	37.8	74	88.5	- 3	68.0	81.5
4.0	60	90	88.5	40	89.0	82

TABLE VI

THE EFFECT OF TRIPOLYPHOSPHATE CONCENTRATION WITH 3% SALT SOLUTION ON WATER BINDING CAPACITY OF HOT PORCINE MUSCLE (BICEPS FEMORIS)

% Tripoly-phosph-ate	% Uncooked Fluid Retention		% Cooked Fluid Retention	
	Control	3% Salt	Control	3% Salt
0	10	32	-35	- 1
0.5	30	76.5	-26.5	27
1.0	35	83.5	-11	48
1.5	36	81.0	-11	47
2.0	40	85.0	- 5	78.0

meat showed more than 80% water binding capacity at a 1.0% tripolyphosphate level. With the addition of more tripolyphosphate little effect on water retention of either cooked or uncooked cured meat was observed. These data show that salt is the key to water binding capacity of hot porcine muscle.

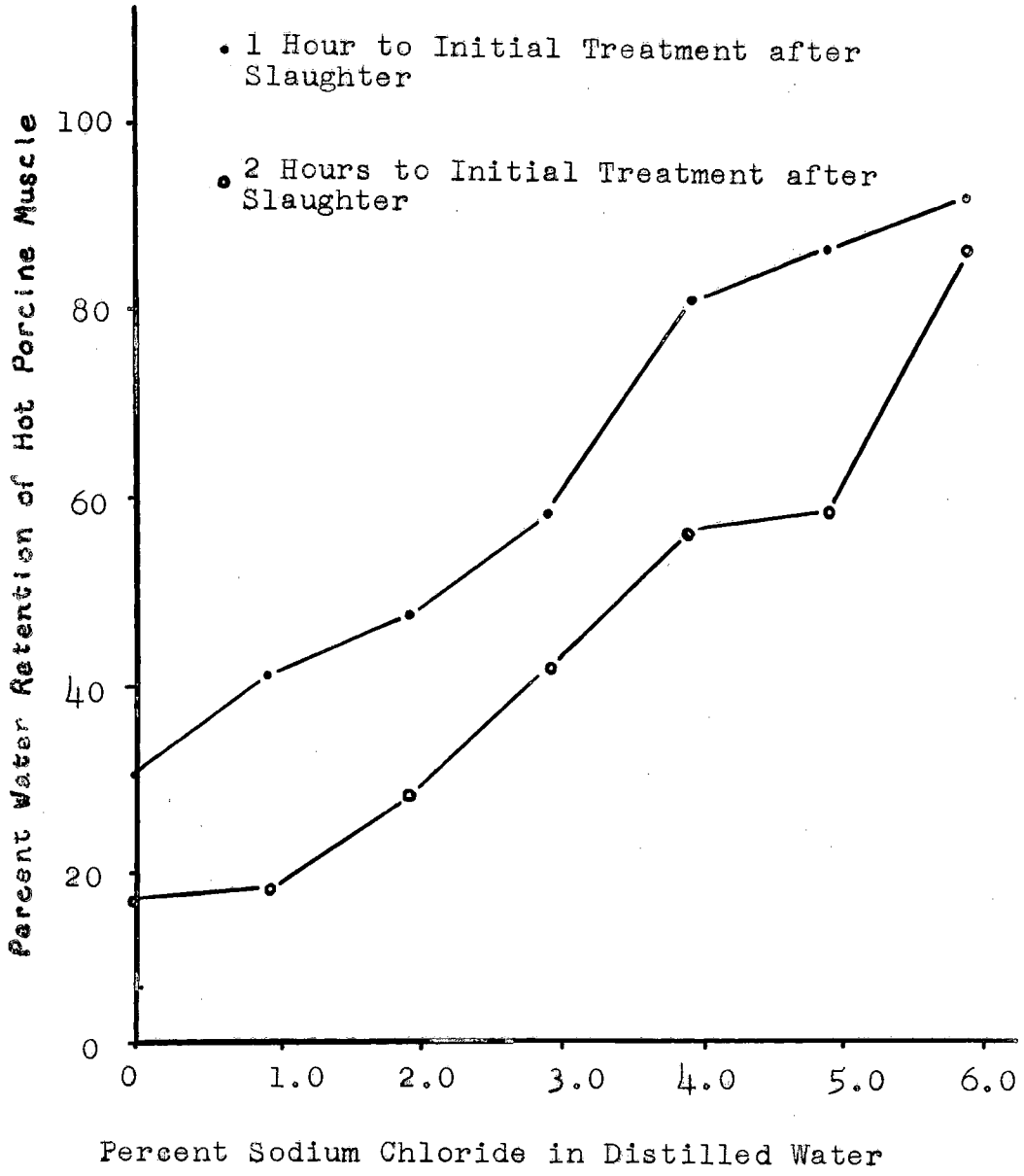
TABLE VII

THE EFFECT OF TIME TO INITIAL TREATMENT AFTER SLAUGHTER ON WATER BINDING CAPACITY OF UNCOOKED HOT PORCINE MUSCLE IN THE PRESENCE OF 1.0% SODIUM TRIPOLYPHOSPHATE AND 0-6% SALT (SEMIMEMBRANOSUS)

Treatment Time	Percent Water Binding Capacity						
	Salt Concentration						
	0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%
One hour after Slaughter	29	40	46	57	80	85	90
Two hours after Slaughter	16	17	27	60	55	57	84

The temperature of treatment and the time of treatment initiation after slaughter are important in increasing the water binding capacity of hot porcine muscle. The shorter

Figure VII. The Effect of Time to Initial Treatment after Slaughter on Water Binding Capacity of Uncooked Hot Porcine Muscle in the Presence of 1.0% Sodium Tripolyphosphate and 0-6% Salt. (Semimembranosus)



the holding time period after slaughter the greater the volume will be for the cured meat. Figure VII indicates that 40% of the water binding capacity was obtained by treating 1.0% sodium tripolyphosphate and 1.0% salt concentration starting one hour after slaughter. If the meat was treated with tripolyphosphate two hours after slaughter the water binding capacity dropped to 27% with the same level of salt added. This is perhaps due to the enzyme activities which were high immediately after the animal was killed as the pH decreases very rapidly when the waiting time is prolonged. It has already been demonstrated in our laboratory that the higher the meat pH is during treatment the higher the volume will be. Almost all the chemical and physical changes in the meat occurred during the first two hours after slaughter. It is therefore advisable that the treatment should be started immediately after slaughter. The treatment temperature is also an important factor in this process. Holding the cured meat at room temperature for more than twelve hours will cause; (1) the bacteria to grow and spoil the meat, (2) inactivation of certain enzymes and (3) irregular volume changes. Therefore, the method recommended for use is a slightly modified method of cold processing developed by Swift and Ellis (1956). That is, holding the cured meats for the first two hours after treatment at 37°C., then storage at 0°C. The purpose of holding this body temperature for two hours is to reduce the enzyme activity, to inhibit pH decreases to the isoelectric point and, further,

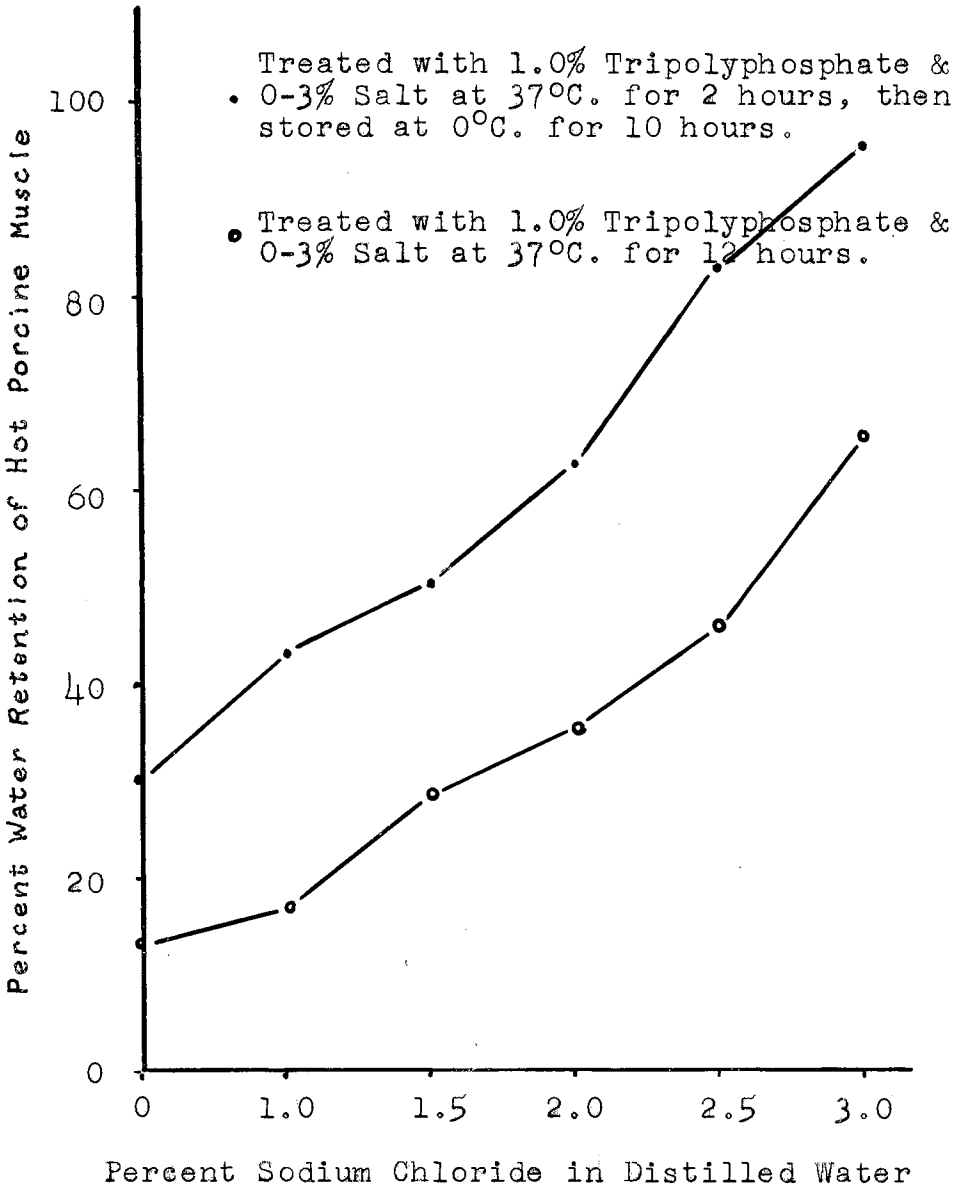
to obtain the optimum water retention on hot processing in a short period of time. Figure VIII shows that the volume increased up to 32% as compared with those which were held at 37°C. for longer time periods with 1.0% sodium tripolyphosphate and 2.5% salt concentration. In the latter case, the color of the meat also changed to pale grey which is not desirable for meat products.

TABLE VIII

THE EFFECT OF TREATMENT TEMPERATURE ON WATER BINDING CAPACITY OF UNCOOKED HOT PORCINE MUSCLE IN THE PRESENCE OF 1.0% SODIUM TRIPOLYPHOSPHATE AND 0-3% SALT. (BICEPS FEMORIS)

Treatment Temperature	Percent Water Binding Capacity					
	Salt Concentration					
	0%	1.0%	1.5%	2.0%	2.5%	3.0%
Twelve hours at 37°C.	30	43	50	62	82	95
Two hours at 37°C. Ten hours at 0°C.	13	16	28	35	45	64

Figure VIII. The Effect of Treatment Temperature on Water Binding Capacity of Hot Porcine Muscle (Biceps Femoris)



The measurement of pH was very difficult. A Corning model 10 pH meter was used in this study. Samples were drawn and the pH values measured within 10 seconds. The temperature of the samples was elevated to 25°C. before measurement in order to obtain more uniform results with accuracy. Tables IX and X show that the mean pH values were obtained for each experiment and that slight differences were noted with individual muscles of five hogs. This data also shows that increasing the salt concentration will decrease the pH of cured meat when the amount of sodium tripolyphosphate was kept constant. Further increasing the waiting time periods will decrease the pH. The results agree with those of Sherman's (1961) who described that the effect normally attributed to the ionic strength of the solution mixed with the meat samples may therefore be intimately related to the question of ion absorption. He suggested that fluid absorption at low temperatures involves two mechanisms:

(a) Ion absorption

Factors influencing absorption include ageing time and temperature, the solution/ meat ratio employed, and the ionic strength of the solution mixed with the meat. The ions absorbed are held by electrostatic attraction to the ion groups of opposite charge on the meat proteins. In turn, water molecules are bound electro-statically by these ions.

TABLE IX

pH VALUES IN BICEPS FEMORIES

% Sodium tripoly-phosphate	% NaCl added	pH			
		1 hr.	12 hrs.	24 hrs.	48 hrs.
0.5	0	6.33	6.24	6.09	6.10
	1.0	6.22	6.15	5.97	6.08
	1.5	6.15	6.20	6.10	6.02
	2.0	6.00	6.17	6.03	5.98
	2.5	5.97	6.08	5.94	5.93
	3.0	5.93	6.03	5.96	5.94
1.0	0	6.42	6.21	6.32	6.30
	1.0	6.38	6.15	6.16	6.14
	1.5	6.35	6.10	6.14	6.14
	2.0	6.28	6.05	6.15	6.11
	2.5	6.25	6.00	6.12	6.07
	3.0	6.15	6.03	6.10	6.02
1.5	0	6.8	6.48	6.43	6.42
	1.0	6.56	6.41	6.40	6.38
	1.5	6.44	6.27	6.28	6.25
	2.0	6.42	6.30	6.26	6.27
	2.5	6.43	6.33	6.16	6.20
	3.0	6.08	6.29	6.17	6.10
2.0	0	6.88	6.46	6.24	6.40
	1.0	6.65	6.35	6.20	6.37
	1.5	6.53	6.35	6.15	6.27
	2.0	6.48	6.26	6.22	6.26
	2.5	6.42	6.25	6.21	6.24
	3.0	6.42	6.26	6.17	6.27

*The first two hours temperature held at 37°C., then samples were placed at 34°F. for the next pH measurement.

TABLE X

pH VALUES IN SEMIMEMBRANOSUS

% Sodium tripoly-phosphate	% NaCl added	pH			
		2 hrs.*	12 hrs.	24 hrs.	48 hrs.
0.5	0	6.07	5.92	5.93	5.89
	1	5 97	5.98	5.99	5.95
	2	5.94	6.02	5.98	5.94
	3	5.94	6.01	6.01	5.97
	4	5.97	6.05	6.00	5.97
	5	5.98	6.00	6.03	6.01
	6	6.00	6.02	6.00	6.00
1.0	0	6.24	6.15	6.12	6.02
	1	6.22	6.12	6.06	6.04
	2	6.07	6.06	5.99	6.00
	3	6.04	6.05	5.96	5.95
	4	6.03	6.04	5.93	5.94
	5	6.00	6.04	5.97	5.96
	6	5.90	5.99	5.94	5.96
2.0	0	7.70	6.56	6.42	6.40
	1	6.45	6.35	6.25	6.24
	2	6.33	6.35	6.25	6.24
	3	6.30	6.34	6.16	6.17
	4	6.26	6.35	6.17	6.17
	5	6.25	6.17	6.07	6.07
	6	6.18	6.10	6.03	6.02

(cont.)

X (Continued)

% Sodium tripoly-phosphate	% NaCl added	pH			
		2 hrs.*	12 hrs.	24 hrs.	48 hrs.
3.0	0	6.96	6.63	6.55	6.49
	1	6.80	6.57	6.51	6.48
	2	6.80	6.53	6.42	6.37
	3	6.70	6.45	6.34	6.31
	4	6.63	6.43	6.30	6.27
	5	6.62	6.42	6.28	6.24
	6	6.53	6.36	6.24	6.22
4.0	0	7.24	7.14	6.86	6.51
	1	7.14	6.78	6.48	6.33
	2	6.90	6.76	6.40	6.30
	3	6.86	6.48	6.25	6.20
	4	6.69	6.36	6.15	6.08
	5	6.65	6.35	6.10	6.07
	6	6.45	6.34	6.22	6.05

* The first two hours temperature held at 37°C., then samples were placed at 34°F. for the next pH measurement.

(b) Solubilization of meat proteins (Particularly actomyosin)

Ageing time and temperature, the solution/ meat ratios employed, and the pH and ionic strength of the solution mixed with the meat all influence this process. In the case of alkaline phosphates other factors, possibly configurational, also appear to be involved. The history and pH of the meat influence both mechanisms.

In this pH study, we found that adding 0.5% to 4% sodium tripolyphosphate with 6% salt to the porcine muscle, the pH values were held constant at the values of 6.0 $\pm$ 0.1 and the water binding capacity was held at a range of 86 to 89% as shown in Figure V. This indicated that if the pH was fixed at a value of 6.0 and 6% of salt was added, increasing tripolyphosphate will not greatly influence the final volume of cured meat. The results of this work indicate no difference in the effect of tripolyphosphate on porcine muscle between hot processing and cold processing but the obvious advantage of hot processing has been pointed out in industrial applications.

CHAPTER V

CONCLUSIONS

From the results and discussion, certain conclusions may be drawn as follows:

(1) Salt concentration and not pH changes is the key to maximum cured meat volume in both hot and cold processing.

(2) Low salt concentrations of the order of 1.0% are not detrimental to hot processing meat.

(3) One percent tripolyphosphate and 6.0% sodium chloride gave maximum meat volume in hot processing meat.

(4) Salt and tripolyphosphate act synergistically to increase both hot and cold muscle volume and gave swelling effects and fine texture in cooked meat.

(5) Comparing the volume of cooked or uncooked porcine muscle, increasing the tripolyphosphate while holding the same level of sodium chloride increased the volume of both cooked and uncooked muscle until a certain amount of sodium tripolyphosphate was added. On the other hand, the volume of both cooked and uncooked Semimembranosus tissue reached the same volume or were unchanged.

(6) The time of initiating the treatment after slaughter is very important. The shorter waiting period greatly increases the meat volume and avoids the growth of microorganisms, drastic changes of pH, and inactivation of enzymes.

(7) Temperature also plays an important role in the salt treatment. Best results could be obtained holding the treated meat for two hours, then storing it at 0°C.

(8) The pH decreased with increasing salt concentration in hot processing meat when tripolyphosphate was at a constant concentration.

(9) Increasing tripolyphosphate with 6.0% sodium chloride did not affect the pH value of uncooked Semimembranosus muscle after 48 hours storage. The volume changes with increasing tripolyphosphate concentrations were not significant at this salt level.

CHAPTER VI

SUMMARY

Two porcine muscles, Semimembranosus and Biceps Femoris, from both hams were used in these studies. The meat samples were taken from five 16 to 18 month old Hampshire gilts.

The results indicate that the volume changes of either cooked or uncooked porcine muscle have been shown to have a close relationship with sodium chloride concentration at different sodium tripolyphosphate levels. Low salt concentrations in the order of 1.0% are not detrimental to hot processed meat. Salt and tripolyphosphate acted synergistically to increase both hot and cold muscle volume and gave swelling effects and fine texture to the cooked meat. The volume of both cooked and uncooked Semimembranosus tissue showed no differences at 4% sodium tripolyphosphate with 3% sodium chloride. The maximum meat volume was found when 1.0% sodium tripolyphosphate was used with 6% sodium chloride in Semimembranosus muscle, and 2.0% sodium tripolyphosphate was used with 3.0% sodium chloride in Biceps Femoris muscle.

The data obtained in this study on pH changes show that this is not the key to maximum cured meat volume, but that

salt concentration is the important factor in both hot or cold processing. The pH decreased with an increased sodium chloride concentration in hot porcine meat when sodium tripolyphosphate was held at a constant concentration. Increasing sodium tripolyphosphate does not affect the pH value of uncooked Semimembranosus muscle after 48 hours storage. The volume changes in this mixed solution were small.

An important factor which influences the volume change is the time period after slaughter. Shortening the waiting period before treatment will greatly increase the meat volume and avoid the growth of microorganisms, the drastic changes of pH, and inactivation of enzymes. Temperature also plays an important role in the salt treatment. Best results could be obtained by holding the treated meat at body temperature for two hours and then storing at 0°C.

A SELECTED BIBLIOGRAPHY

Bendall, J. R. 1954. "Swelling effects of phosphates on lean meat." J. Sci. Food Agr. 5, 468-475.

Bendall, J. R. 1951. "The shortening of rabbit muscle during rigor mortis. The relation to the breakdown adenosine triphosphate and creatine phosphate and to muscle contraction." J. Physiol. 114: 71.

Briskey, E. J. 1959. "Changes occuring during rigor mortis and subsequent ripening of muscle tissue." Proc. 12th Recip. Meat Conf. p. 108.

Briskey, E. J., R. N. Sayre, and R. G. Cassens. 1962. "Development and application of an apparatus for continuous measurements of muscle extensibility and elasticity before and during rigor mortis." J. Food Science. 27: 560.

Campbell, J. W., and G. E. Kilpatrick. 1954. J. Am. Soc. 54, 119.

Gimblett, F. G. R. 1960. Trans. Plastics Inst. 28-65. Inorg. Polymer Chem. 379-384.

Hamm, R., R. Grau, and A. Bauman. 1953. "Water binding capacity of mamalian muscles. The influence of pH values on the water binding of ground beef muscles." Biochem. Z. 325, 1-11.

Hamm, R., and R. Grau. 1956. "Estimation of water binding by meat." Fleischwirtschaft. 8, 733-736.

Hamm, R., and R. Grau. 1957. "Water binding capacity of mammalian muscle. Estimation of water binding by muscle." Z. Lebensm-Untersuch U. Forsch.

Hamm, R. 1956. "Calcium, magnesium and zinc and their significance for water binding and color of meat." Fleischwirtschaft. 8-266.

Hashimoto, Yoshio, T. Fukazawa, R. Niki, and T. Yasui. 1959. "Effect of storage conditions on some of the biochemical properties of meat and on the physical properties of an experimental sausage." Food Research. 24, 185-197

Henrickson, R. L., and R. E. Smith. 1967. "Effect of rapid processing on the properties of freshly slaughtered pork." Transactions of the ASAE. 10, 185-187.

Hexley, H. E., and J. Hanson. 1959. "The structure basis of the contraction mechanism in striated muscle." Annal of New York Academy of Science. 81, 403.

Kormenday, L. 1955. "Factors affecting the water absorption and the water binding capacity of meats. The water binding capacity of the flesh of various animals." Elelmez. Ipar. Budapest. 9, 345-349 (1955).

Kormenday, L., and G. Gantner. 1954. "Procedure for determining the water absorption and water binding capacity of meat." Elelmez. Ipar. Budapest. 8, 172-179.

Lawrie, R. A. 1953. "The relation of energy rich phosphate in muscle to myoglobin and to cytochrome-oxidase activity." Biochem. J. 55-305.

Mahon, J. H. 1963. "Tripolyphosphate-salt synergism and its effect on cured meat volume." Proceeding of the Thirteenth Research Conference.

Marsh, B. B. 1954. "Rigor mortis in beef." J. Sci. Food Agric. 5-70.

Mohler, K., and F. Kiermeier. 1953. "The action of inorganic phosphates on animal protein. The effect on the swelling of meat proteins." Z. Lebensm-Untersuch. U. Forsh. 96, 90-98.

Mohler, K., and F. Kiermeier. 1955. "The action of inorganic phosphates on animal protein. V. The influence of pH on the binding of water by coagulated meat roast." Z. Lebensm-Untersuch U. Forch. 100, 260-266.

Partmann, W. 1963. "Post-mortem changes in chilled and frozen muscle." J. Food Sci. 28, 15.

Sherman, P. 1961. "The water binding capacity of fresh pork. I. The influence of sodium chloride, phyrophosphate and polyphosphate on water absorption." Food Technol. 15, 79.

Straub, F. B. 1943. "On the specificity of the ATP-effect." Studkes Inst. Med. Chem. Univ. Szeged. Vol. 3, 39.

Swift, W. E., and M. D. Berman. 1959. "Factors affecting the water retention of beef. I. Variation in composition and properties among eight muscles." Food Technol. 13, 365.

Swift, C. E., and R. Ellis. 1956. "The action of phosphates in sausage products. I. Factors affecting the water retention of phosphate-treated ground meat." Food Technol. 13, 365.

Thilo, E., and G. Wiekei. 1957. Z. Elektnochem. 61, 24.

Van Wazer, J. R., E. J. Griffith, and J. F. McCullough. 1955. J. Am. Chem. Soc. 77, 287.

Wierbicki, E., M. G. Tiede, and R. C. Burrell. 1959. "Effects of pH on the water holding capacity of meat as determined by three different methods for water holding determination." Presented at Annual I.F.T. meeting in Philadelphia.

APPENDIX

TABLE XI

THE EFFECT OF SALT - TRIPOLYPHOSPHATE ON VOLUME OF HOT PORCINE MUSCLE (Biceps Femoris)

Treatment Salt/tripoly-phosphate ratio (%)	Volume, unheated (ml) Experiment 1	2	3	Mean	S.E.
2.0-0.5	29.6	31.4	30.6	30.5	0.9
2.5-0.5	31.1	32.8	31.4	32.1	0.9
3.0-0.5	35.6	36.6	36.4	36.2	0.5
2.0-1.0	29.6	32.5	32.4	31.5	0.5
2.5-1.0	33.	32.	36.4	33.8	2.3
3.0-1.0	35.6	34.8	39.6	36.7	2.5
2.0-1.5	31.6	31.2	34.4	32.8	1.7
2.5-1.5	34.6	33.4	36.4	34.8	1.1
3.0-1.5	37.	35.	36.6	36.2	1.05
2.0-2.0	33.5	33.6	31.	32.7	1.40
2.5-2.0	36.0	37.2	34.3	35.5	1.40
3.0-2.0	37.0	38.2	37.	37.4	.70

TABLE XII

THE EFFECT OF SALT-TRIPOLYPHOSPHATE ON VOLUME OF HOT PORCINE MUSCLE (Biceps Femoris)

Treatment Salt/tripoly-phosphate ratio (%)	Volume, heated (ml) Experiment 1	2	3	Mean	S.E.
2.0-0.5	20.	21.4	21.6	21.	0.24
2.5-0.5	21.2	21.8	22.2	21.4	0.14
3.0-0.5	24.8	24.6	26.8	25.4	1.7
2.0-1.0	21.	21.6	22.4	22.	0.24
2.5-1.0	22.6	21.	32.6	25.4	6.2
3.0-1.0	29.	26.8	33.	29.6	3.1
2.0-1.5	23.4	21.6	21.	22.	1.2
2.5-1.5	28.	27.6	29.2	28.6	0.8
3.0-1.5	29.4	28.4	30.4	29.4	1.0
2.0-2.0	25.2	24.2	27.4	25.6	1.6
2.5-2.0	28.2	28.6	33.8	30.2	3.1
3.0-2.0	32.8	34.	39.6	35.6	3.6

TABLE XIII

THE EFFECT OF TRIPOLYPHOSPHATE ON VOLUME OF HOT PORCINE MUSCLE (Semimembranosus)

Salt/tripoly-phosphate ratio (%)	Volume, unheated (ml)		Mean	S.E.
	Experiment 1	2		
3.0-1.0	30.6	31.4	31.	0.5
4.0-1.0	31.	36.	33.5	3.9
5.0-1.0	35.2	36.2	35.7	0.5
6.0-1.0	37.4	38.2	37.8	0.5
3.0-2.6	33.6	31.4	32.5	1.5
4.0-2.0	33.	35.4	34.2	1.5
5.0-2.0	33.4	37.4	35.4	2.8
6.0-2.0	35.6	38.	36.8	1.5
3.0-3.0	34.	35.2	34.6	0.8
4.0-3.0	34.6	36.	35.3	0.3
5.0-3.0	35.4	35.6	35.5	0.01
6.0-3.0	36.2	38.	37.1	0.5
3.0-4.0	38.6	37.4	38.	0.2
4.0-4.0	36.6	34.4	35.5	0.5
5.0-4.0	37	36.4	36.7	0.01
6.0-4.0	37	37.4	37.2	0.01

TABLE XIV

THE EFFECT OF TRIPOLYPHOSPHATE ON VOLUME OF HOT PORCINE MUSCLE (Semimembranosus)

Salt/tripoly-phosphate ratios (%)	Volume, heated (ml)		Mean	S.E.
	Experiment 1	2		
3.0-1.0	24.6	25.4	25.	0.5
4.0-1.0	27.6	31.6	29.6	2.8
5.0-1.0	30.	34.2	32.1	2.8
6.0-1.0	35.2	37.2	36.2	1.4
3.0-2.0	30.2	24.	28.6	4.3
4.0-2.0	30.6	34.6	32.6	2.8
5.0-2.0	30.4	37.4	33.9	4.9
6.0-2.0	32.	37.6	34.8	3.9
3.0-3.0	32.	35.2	33.6	2.4
4.0-3.0	33.6	34.4	34.	0.5
5.0-3.0	34.2	34.6	34.4	0.1
6.0-3.0	35.5	35.6	35.6	0.1
3.0-4.0	38.	37.6	37.8	0.5
4.0-4.0	34.6	34.2	34.4	0.1
5.0-4.0	35.7	35.7	35.7	0.0
6.0-4.0	35.6	35.7	35.7	0.01

VITA

Zuen-Yen Wu

Candidate for the Degree of

Master of Science

Thesis: THE INFLUENCE OF SODIUM TRIPOLYPHOSPHATE ON HOT PORCINE MUSCLE

Major Field: Food Science

Biographical:

Personal Data: Born in Amoy, China, January 23, 1939, the son of Su-Hou and Peh-Ching Wu.

Education: Received the Bachelor of Science degree in Agricultural Chemistry from Taiwan Provincial Chung-Hsing University, Taiwan, China, in 1961; completed the requirements for the Master of Science degree from Oklahoma State University in July, 1968.

Professional Experience: Entered the Chinese Army in 1962 and was a second lieutenant in the Air Force; taught at Fang-Yen High School in 1963-64; Research Assistant at Case-Western Reserve University, 1968.