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EFFECTS OF CONDENSED PHOSPHATES ON THE PH, WATER-HOLDING CAPACITY AND MEAT SWELLING PROPERTIES OF PORK MUSCLE

G. W. Shults, et al

Army Natick Laboratories
Natick, Massachusetts

January 1974

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AD776336

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
US ARMY NATICK LABORATORIES
Natick, MA 01760

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
Effects of Condensed Phosphates on the pH, Water-Holding Capacity and Meat Swelling Properties of Pork Muscle.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)
G. W. Shults and E. Wierbicki

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1973	17	14

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 1G762713A033	FL-179
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U. S. Army Natick Laboratories Natick, MA 01760

13. ABSTRACT

Sodium salts of pyrophosphate (PP), tripolyphospate (TPP), hexametaphosphate (HMP), metaphosphate (MP) and four commercial blends of phosphates (Kena, Foodfos, Curafos 22-4 and Curafos 11-2) were investigated for their effects on water holding and swelling of Longissimus and Semimembranosus pork muscles. The phosphate addition varied from 0.25 to 1.0% in the meat. Combined effects with salt (0.5 to 1.5% NaCl) were also investigated. The greatest reduction in the loss of natural juices during heating at 70°C (water-holding capacity) and the greatest increase in the swelling (with and without NaCl additions) were achieved by adding PP, TPP, and Curafos 11-2; followed by Curafos 22-4 and Kena; with practically no effecty by Foodfos, MP and HMP.

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DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Phosphates (Condensed)	6					
Absorption	7					
Water Holding Capacity	7					
Meat	7,4					
Swelling	7					
Meat Swelling	7					
Pork	7,4					
Muscle Proteins	7					
Shrinkage (Meat)	4					

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Security Classification

AD

TECHNICAL REPORT

TR-74-22-FL

Effects of Condensed Phosphates on the pH, Water-Holding Capacity and Meat Swelling Properties of Pork Muscle

by

G. W. Shults and E. Wierbicki

Project: 1G762713A033

FL-179

January 1974

Food Laboratory
U. S. Army Natick Laboratories
Natick, Massachusetts 01760

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FOREWORD

These experiments were initiated as a continuing investigation on the effects of condensed phosphates on the physical properties of meats. The objectives of these experiments were to determine if lower concentrations of food-grade phosphates could be used in combination with sodium chloride and to determine the best phosphate for use in pork to reduce meat shrinkage.

Results from these tests have shown that the level of phosphate addition can be reduced from 0.5% to 0.3% when used in combination with 1.0% sodium chloride. Tetrasodium pyrophosphate had the greatest effect on the shrinkage, meat swelling and pH of the pork samples.

These studies were undertaken as a research project of the Irradiated Foods Products Division, Food Laboratory, under Project 1G762713A033.

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INTRODUCTION

The effects of condensed phosphates on the water-holding capacity and meat swelling properties of fresh and cured meats has been reported by many investigators (Grau, et al (1953, 1959), Swift and Ellis (1956), Hamm (1960), Mahan (1961), Sherman (1961a, 1961b) and Wierbicki (1957a, 1957b, 1963). Much of this earlier work was performed using fresh and cured pork due to the important role played by condensed phosphates in the production of cured pork products.

Recent research has demonstrated the importance of the condensed phosphates in fresh and cooked meats. The use of sodium tripolyphosphate, alone or in combination with sodium hexametaphosphate, has been allowed by the U. S. Department of Agriculture, Consumer and Marketing Service, in cooked beef and fresh beef prepared for further cooking (USDA 1970). The usage level allowed was 0.5 percent addition in the finished product. Shults and Wierbicki (1972 and 1973) showed that tetrasodium pyrophosphate and sodium tripolyphosphate had the greatest effects on the water-holding capacity and meat swelling properties of chicken and beef muscle. However, it was found that when phosphates were used in combination with sodium chloride, lower concentrations of phosphates could be used. In the case of pyrophosphate and tripolyphosphate optimal effects on the pH, swelling and water-holding capacity were achieved with 0.25% concentration when used with 1% NaCl.

For this report the water-holding capacity studies (WHC) on the effects of food-grade phosphates in pork muscle are presented. These studies included the following investigations: (1) effects on the pH and WHC of the additions of tripolyphosphates in small increments up to 1 percent concentration, with and without 1 percent sodium chloride; (2) effects on two separate muscles, longissimus and semimembranosus; (3) effects of the addition of six food-grade phosphates (tripolyphosphate, pyrophosphate, hexametaphosphate, Foodfos[1], Curafos 11-2[1] and Curafos 22-4[1]) on the pH, meat swelling and WHC of longissmus muscle, with and without 1 percent sodium chloride; (4) effects on the pH and WHC of salt additions up to 10 percent concentration, with 0.5 percent tripolyphosphate or 0.5 pyrophosphate; and (5) the effects on the WHC and pH when varying concentrations of tripolyphosphate and hexametaphosphate are added to the pork with and without 10 percent water.

[1]Commercial preparations of food-grade phosphates: Foodfos (hexametaphosphate, 64% P_2O_5), and Curafos 11-2 and Curofos 22-4 (commercial combinations of tripolyphosphates and hexametaphosphate).

The purposes of these investigations on the physical properties of pork muscles were to determine: (1) if lower additions than 0.5% of food-grade phosphates could be used; (2) the best food-grade phosphate for use in pork to reduce meat shrinkage; and (3) on approximate concentration of tripolyphosphate and hexametaphosphate in the commercial blends especially formulated by industry for use in pork products.

EXPERIMENTAL

Materials

The raw material utilized in these experiments was fresh, non-frozen boneless pork. The muscles studied were the longissmus and semimembranosus. The pork was chilled, 5-7 days post mortem. After removal of cover fat and visible connective tissue, the pork was ground through a 3/16 in. grinding plate and thoroughly mixed prior to each test.

The additives used were sodium chloride and the following food grade phosphates: sodium tripolyphosphate (TPP), sodium hexametaphosphate (HMP), tetrasodium pyrophosphate (PP) and three blends of commercial phosphates, Foodfos, Curafos 22-4 and Curafos 11-2. (All phosphates were obtained by the courtesy of Calgon Corp., Pittsburgh, Pa.) These additives were added directly to ground pork, mixed thoroughly, and held overnight in a refrigerator (at 2 to 4°C) prior to evaluation.

METHODS

The water-holding capacity (meat shrinkage) was determined by the method of Wierbicki et al (1957a) with the following modifications:

a. The dimensions of the tubes were 180 mm long with a top chamber 35 mm in diameter (outside) and the bottom chamber 20 mm in diameter. The bottom section of the tube was graduated in divisions of 0.1 ml from 0-10 ml.

b. Meat samples (with or without additives) were 20 g. Each meat sample was run twice in duplicate. Each shrink datum tabulated or presented in the figures is an average of four tube readings with a standard deviation of less than ±5% (relative).

c. The heating times and temperatures varied, depending upon the experiment. The minimum heating time of the meat, with and without the additives, required to obtain representative shrink data was confirmed to be 30 min, as shown in a preliminary experiment on checking the methodology (Shults et al, 1972). Unless otherwise indicated, 30 min. heating time was used for the shrink determination.

d. After heating, the samples were centrifuged at 900G (100 rpm) for 15 min. using an International Model V centrifuge and the amount of juices lost during heating and centrifuge measured. This loss of juices, or the meat shrinkage, is expressed as percent of the total weight of the samples.

The meat swelling (water-binding capacity) was determined by the method of Wierbicki et al (1962). A 50-g sample of pork with or without additives, was blended at room temperature in a high speed blender with 150 ml of distilled water for 90 seconds. 35 g of the meat slurry were weighed in duplicate into 40 ml heavy glass centrifuge tubes. The samples were centrifuged at room temperature (21-25°C) for 15 min. at 1000 rpm in an International Model V centrifuge. After centrifugation the volume (in ml) of the supernatant liquid was collected in a graduate. The percent swelling was determined by the following formula (Wierbicki et al, 1962) where X is the grams of absorbed H_2O per 100 g meat and S is the supernatant.

$$X = 300 - (11.43 \times S) = \% \text{ Swelling}$$

Calculation

Weight of slurry 35 g: weight of meat in the slurry 8.75 g; weight of added water in the slurry (35-8.75) g; S = supernatant in ml (1 ml = 1 g).

$$\begin{aligned} \% \text{ Swelling} &= \left\{[(35\text{-}8.75) - S]\ 18.75\right\} \times 100 \\ &= (3\text{-}S/8.75) \times 100 \\ &= 300\text{-}(100/8.75) \times S \\ &= 300\text{-}(11.43 \times S). \end{aligned}$$

All determinations were run twice in duplicate.

The pH of the meat samples was read directly using a Beckman pH meter. The readings were taken prior to weighing the samples for the shrink determination.

Statistical analyses were determined by analysis of variance and Duncan's (1955) multiple range test.

RESULTS AND DISCUSSION

Addition Levels of Tripolyphosphate

The results on the addition levels of TPP are given in tables 1 and 2. **Table 1** shows the results on the longissimus muscle with and without 1 percent salt addition. Statistical analysis of the data, using the multiple range test, shows no significant differences were found in the addition of either 0.3, 0.4 or 0.5 percent tripolyphosphate, both with and without sodium chloride. The addition of 0.1 or 0.2 percent TPP did not significantly effect the WHC of the pork. The addition of 1.0 percent TPP was significantly different from the other addition levels when 1.0 percent NaCl was added, but it was not found significantly better than the 0.5% TPP addition when salt was not present.

Table 2 gives the results of TPP addition levels in semimembranosus muscle. Again, no significant differences were found between 0.3 and 0.4 or 0.5 percent TPP additions. These results show that 0.3 percent TPP addition is sufficient to reduce the shrinkage in pork muscle. Additions up to 0.5 percent resulted in only minor improvements and were not significant. The addition of .1 or .2 percent TPP did not significantly affect the meat shrinkage. The addition of 1.0% TPP with and without NaCl was found significantly better for the reduction of meat shrinkage than the other addition levels.

Effect of Various Phosphates

Table 3 lists the results on the pH, swelling and WHC of longissimus dorsi muscle when six food-grade phosphates or combination of phosphates were added. Pyrophosphate had the greatest effect on the pH, swelling and WHC followed by TPP and Curafos 11-2. Statistical analysis of the WHC data shows no significant differences between the pyrophosphate, TPP and Curafos 11-2 samples. No significant differences were found between the shrinkage values for TPP, Curafos 11-2 and Curafos 22-4 samples. Hexametaphosphate and Foodfos did not affect the pH and swelling properties of the loin muscle and had only minor effects on the meat shrinkage (WHC).

Table 4 shows the data on the pH, swelling and WHC of pork meat when the six phosphates or combination of phosphates were added without 1 percent sodium chloride. The pyrophosphate again had the greatest effects on the pH and swelling followed by

TPP and Curafos 11-2. No statistical differences were found in the WHC for the TPP, pyrophosphate and Curafos 11-2 samples. The conclusions drawn from Tables 3 and 4 are: (1) pyrophosphate had the greatest effects on the pH and swelling of the pork meat followed by TPP and Curafos 11-2; (2) pyrophosphate had the greatest effect on the WHC of the pork in the presence of 1% NaCl but it was not significantly better than TPP and Curafos 11-2 (3) hexametaphosphate and Foodfos had little or no effects on the factors studied.

The data on the condensed food-grade phosphates showed that tripolyphosphate and Curafos 11-2 yielded almost identical results on pH, swelling and WHC. Curafos 11-2 is reportedly a combination of TPP and hexametaphosphate. Table 5 shows the results of various concentrations of TPP and hexametaphosphate in an attempt to approximate the combination of Curafos 11-2. The results show in both samples with and without 10 percent water added that a combination of 0.3 percent TPP and 0.1 percent hexametaphosphate yielded the same results as 0.4 percent TPP. Both were rated significantly better than the other concentrations of the two phosphates. This means in all probability that Curafos 11-2 is composed mainly of TPP with only a small amount of hexametaphosphate. Additionally, from all results obtained, little justification can be made for using the combination of phosphates, Curafos 11-2 in place of tripolyphosphate.

Effect of Salt Addition on the WHC and pH

Figure 1 shows the effect of sodium chloride, alone and in combination with 0.5% TPP and PP on WHC of pork meat. Sodium chloride was added in concentrations up to 10 percent. The data show that the maximum effects of the NaCl is obtained around 2 percent addition in all instances. The differences between TPP and pyrophosphate at the 2 percent salt concentration were found to be insignificant, but there were significant differences between the phosphate samples and the sample without the phosphates at the 2 percent NaCl level. The pH values for these samples are listed on Table 2. Only small differences are found between the TPP and pyrophosphate samples. The maximum effect on the pH is found between the 2 and 5 percent sodium chloride conditions.

CONCLUSIONS

1. No significant differences were found in the meat shrinkage of both pork muscles studied when 0.3, 0.4, 0.5 percent TPP were added. This was found in samples with and without 1.0 percent NaCl added. However, significant differences were found between 0.1-0.2 versus 0.3-0.5% TPP additions.

2. The addition of 0.1 or 0.2 percent TPP did not significantly affect the meat shrinkage.

3. Pyrophosphate had the greatest effects on the pH, swelling and water-holding capacity of the pork loin muscle, but the differences in shrinkage values of the pyrophosphate, TPP, and Curafos 11-2 samples were not significant. No significant differences were found between the shrinkage values for TPP, Curafos 11-2, and Curafos 22-4 samples.

4. Hexametaphosphate and Foodfos did not affect the pH and swelling properties of the loin muscle and had only minor effects and meat shrinkage (WHC).

5. A combination of 0.1% HMP and 0.3% TPP was rated equal to 0.4% TPP addition to the meat. Both were rated significantly better than the other combinations of the phosphates.

6. Maximum effects of sodium chloride additions were found between 2 to 5 percent concentrations.

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Table 1. Effect of sodium tripolyphosphate concentrations on the pH and water-holding capacity of pork muscle Longissimus

Sample			Water-Holding Capacity (Ml Juice) Replications[1]					Duncans
% NaCL	%TPP	pH	1	2	3	Average	% Shrink	Multiple Range[2]
0	0	5.3	7.9	8.8	7.1	7.67	38.3	
0	.1	5.4	7.5	7.6	7.0	7.37	33.9	
0	.2	5.5	7.4	6.8	7.4	7.20	36.0	
0	.3	5.6	6.6	6.8	6.7	6.70	33.5	
0	.4	5.7	6.1	6.9	6.0	6.33	31.6	
0	.5	5.8	6.4	5.8	5.7	5.97	29.8	
0	1.0	6.0	5.1	5.4	5.5	5.33	26.6	
0	0	5.3	7.9	8.8	7.1	7.67	38.3	
1	0	5.2	5.1	7.3	7.0	7.13	35.6	
1	.1	5.5	7.0	6.3	6.5	6.60	33.0	
1	.2	5.5	6.0	6.5	5.7	5.73	28.6	
1	.3	5.6	4.7	5.4	4.5	4.87	24.3	
1	.4	5.7	4.8	4.5	4.1	4.47	22.3	
1	.5	5.7	4.0	4.4	4.3	4.23	21.1	
1	1.0	5.9	2.5	3.7	2.5	2.90	14.5	

[1]Ml. juice/20 g. meat: 70°C Water Bath, time – 30 minutes

[2]Significance at the 5% level

Table 2. Effect of sodium tripolyphosphate concentrations on the pH and water-holding capacity of pork muscle semimembranosus

Sample			Water-Holding Capacity (Ml Juice) Replications[1]					Duncan Multiple
% NaCl	% TPP	pH	1	2	3	Average	% Shrink	Range Test[2]
0	0	5.4	7.5	8.0	8.0	7.83	39.1	
1	0	5.4	7.2	7.8	7.2	7.40	37.0	
1	.1	5.5	7.7	7.6	7.4	7.56	37.8	
1	.2	5.6	6.7	6.8	6.8	6.76	33.8	
1	.3	5.7	4.7	5.4	5.7	5.27	26.3	
1	.4	5.8	4.8	5.1	5.6	5.17	25.8	
1	.5	5.8	5.1	5.1	5.0	5.07	25.3	
1	1.0	6.0	3.0	3.4	3.7	3.37	16.8	
0	.1	5.5	7.6	7.4	7.6	7.53	37.6	
0	.2	5.6	7.2	7.8	7.6	7.53	37.6	
0	.3	5.7	6.8	6.1	6.9	6.60	33.0	
0	.4	5.8	6.5	7.1	6.9	6.83	34.1	
0	.5	5.8	6.7	6.8	6.5	6.67	33.3	
0	1.0	6.0	5.5	5.7	5.8	5.67	28.3	

[1] Ml. juice/20 g. meat: 70°C water bath – 30 minutes; 10 percent water added.

[2] Significance at the 5% level.

Table 3. Effect of several phosphates on the pH, swelling and water-holding capacity of pork loin muscle

% NaCl	% Phosphate	pH	% Swelling	% Shrink[1]
0	0	5.4	68	37
1	0	5.4	68	32
1	0.5 tripolyphosphate	5.8	89	20
1	0.5 pyrophosphate	5.9	108	17
1	0.5 hexametaphosphate	5.5	66	28
1	0.5 Foodfos	5.5	77	30
1	0.5 Curafos 22-4	5.7	80	22
1	0.5 Curafos 11-2	5.8	91	19

[1]Shrink determination: 70°C for 30 minutes.

Phosphate	% Shrink	Duncans Multiple Range Test*
0.5% pyrophosphate	17	
0.5% Curafos 11-2	19	
0.5% tripolyphosphate	20	
0.5% Curafos 22-4	22	
0.5% hexametaphosphate	28	
0.5% Foodfos	30	
No phosphate	37	

*Significance at the 5% level.

Table 4. Effect of several phosphates on the pH, swelling and water-holding capacity of pork loin muscle – No salt addition

% Phosphate	pH	% Swelling	% Shrink[1]
0 – no phosphate	5.3	43	33
0.5 tripolyphosphate	5.8	60	25
0.5 pyrophosphate	5.9	80	26
0.5 hexametaphosphate	5.5	54	30
0.5 Foodfos	5.6	54	31
0.5 Curafos 22-4	5.6	43	30
0.5 Curafos 11-2	5.8	60	26

[1] Shrink determination: 70°C for 30 minutes

Phosphate	% Shrink	Duncans Multiple Range Test*
0.5% tripolyphosphate	25	
0.5% pyrophosphate	26	
0.5% Curafos 11-2	26	
0.5% Curafos 22-4	30	
0.5% hexametaphosphate	30	
0.5% Foodfos	31	
No phosphate	33	

*Significance at the 5% level

Table 5. Effect of varying concentrations of Hexametaphosphate and Tripolyphosphate on the water-holding capacity of pork muscle semimembranosus

Samples					Replications[1]					
% HMP	% TPP	% NaCl	% Added H_2O	pH	1	2	3	4	Ave.	% Shrink
0	0	0	0	5.8	6.3	6.4	6.4	6.2	6.30	31.5
0	0	1	0	5.8	5.3	5.6	5.2	5.3	5.35	26.7
0	.4	1	0	5.8	3.2	3.5	3.1	3.4	3.30	16.5*
.1	.3	1	0	5.9	3.4	3.6	3.1	3.1	3.30	16.5
.2	.2	1	0	5.9	4.9	4.4	4.9	4.9	4.80	24.0
.3	.1	1	0	5.9	5.1	4.6	5.0	4.7	4.85	24.2
.4	0	1	0	5.9	5.6	5.1	5.6	5.2	5.45	27.2
0	.4	1	10	5.8	4.5	4.6	4 5	4.4	4.50	22.5
.1	.3	1	10	6.0	4.3	4.3	4.7	5.2	4.75	23.7
.2	.2	1	10	6.0	5.5	6.3	5.6	6.0	5.86	29.3
.3	.1	1	10	6.0	5.9	6.3	6.5	6.7	6.10	30.5
.4	.0	1	10	5.9	6.7	7.0	6.6	7.2	6.87	34.2
0	.0	1	10	5.9	7.0	7 0	6.9	7.0	6.97	34.9
0	.0	0	10	5.85	7.6	8.0	7.7	7.6	7.72	38.6

[1]Ml. juice/20 g. meat: 70°C water bath for 30 minutes

*Multiple Range Test
Significance at the 5% level

FIG. 1 EFFECT OF Na Cl CONCENTRATION ON THE WATER-HOLDING CAPACITY OF PORK MUSCLE

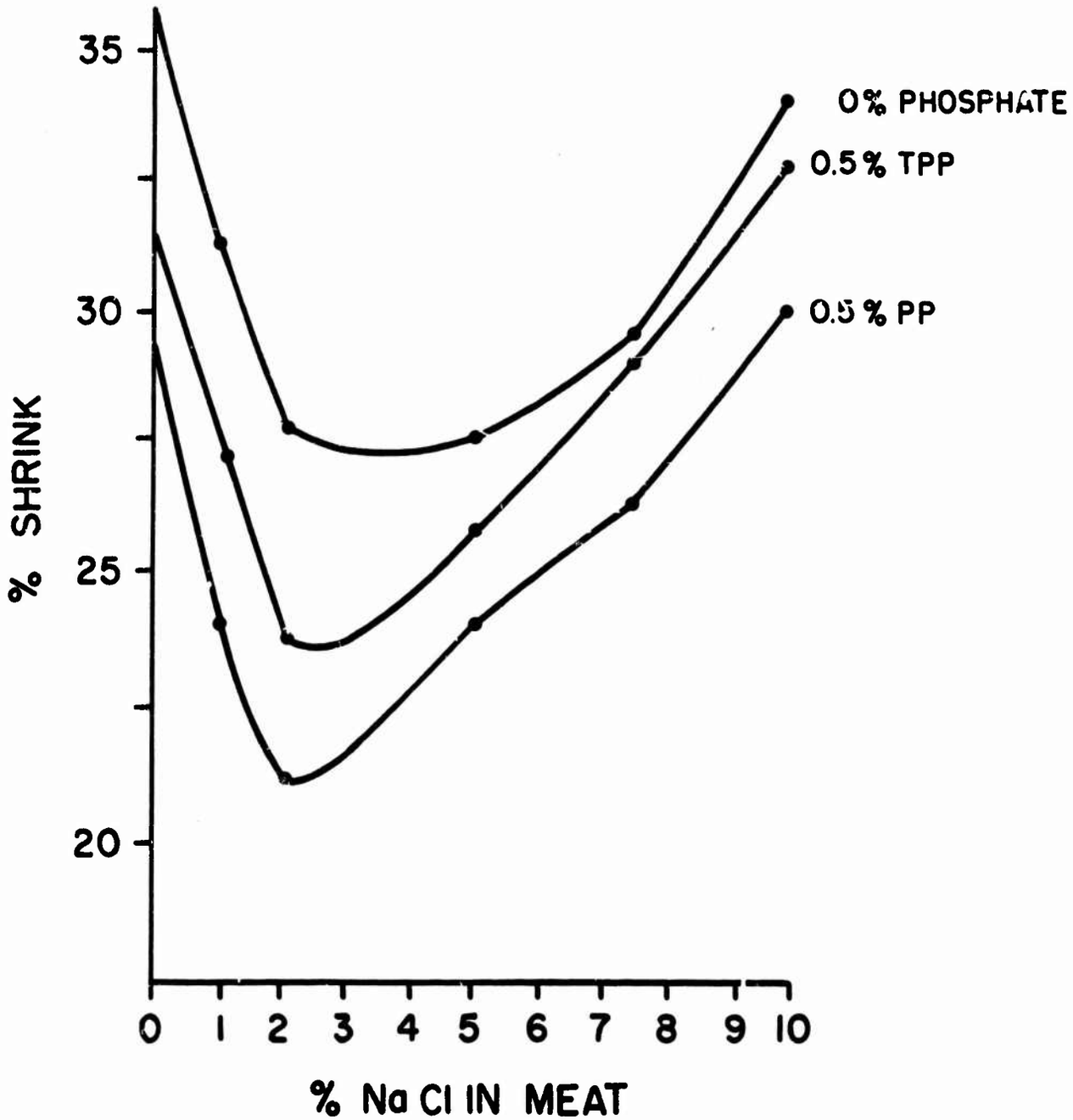

FIG. 2. EFFECT OF Na Cl CONCENTRATION ON THE ph OF PORK MUSCLE