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EFFECTS OF SODIUM CHLORIDE AND CONDENSED PHOSPHATES ON THE WATER-HOLDING CAPACITY, pH AND SWELLING OF CHICKEN MUSCLE

INTRODUCTION

THE EFFECT of sodium chloride (NaCl) and condensed phosphates on water-holding capacity, pH and meat swelling has been adequately demonstrated by several investigators (Swift and Ellis, 1956; Wierbicki et al., 1957b; Hamm, 1960; Shults and Wierbicki, 1972). Sodium salts of condensed phosphates increase the pH of chilled meats, thus increasing their water-holding properties; sequestering of heavy metal and calcium ions in meats contribute also to the water-holding capacity; and apparently some polyphosphates can split actomyosin into components with higher water-holding properties (Hamm, 1960; Wierbicki et al., 1963; Yusui et al., 1964; Shults and Wierbicki, 1972). However, the exact mechanism by which NaCl and polyphosphates, in combination, affect the meat is not clearly defined.

Shults and Wierbicki (1972) found that tetrasodium pyrophosphate was the most effective food-grade phosphate for increasing the meat pH, swelling and the water-holding capacity of beef muscle. Maximum effects on reduction of the meat shrinkage (reciprocal of water-holding capacity) were obtained by the addition of 0.5% pyrophosphate or tripolyphosphate. Higher levels of phosphate concentrations had little additional effect on the swelling or the water-holding capacity, especially in the presence of 1% NaCl. Sodium hexametaphosphate or metaphosphate had only small effects on the beef muscle.

Some research on the use of NaCl and phosphates in chicken meat has been conducted, using both light and dark meat. Froning (1965, 1966) reported that the addition of polyphosphates (Kena) to ground chicken meat in a range of 0.5–1.0% was desirable for improving the quality of chicken rolls. He reported that an addition of 6% polyphosphates to the chilling water significantly reduced cooking losses and increased moisture retention in cooked chicken rolls. Mountney and Arganosa (1962) and Schermerhorn and Stadelman (1964) reported that a concentration of 4% or more of polyphosphates added to the chilling water decreased water uptake. This decrease became very pronounced at a concentration of 12%.

The objectives of these studies were to determine the relative effects of NaCl and different condensed phosphates on swelling and pH of raw, white chicken meat and the water-holding capacity of the cooked meat, with emphasis on the water-holding capacity (reciprocal of meat shrinkage).

METHODS & MATERIALS

Meat

The raw material utilized for these studies was fresh, boneless breast of chicken (broilers). Skin and fat were removed and the meat was ground through a 3/16-in. grinding plate and thoroughly mixed. The ground meat was stored in a refrigerator (2–4°C) before use.

Additives

The food-grade, condensed phosphates studied were: Sodium tripolyphosphate (TPP), sodium hexametaphosphate (HMP), tetrasodium pyrophosphate (PP), a commercial preparation of HMP (Foodfos), Kena FP-28 (a mixture of TPP, PP and sodium acid pyrophosphate), and Curafos 22-4 and 11-2 (commercial mixtures of TPP and HMP). Kena FP-28 is a special mixture of polyphosphates recommended for use in poultry products. All phosphates studied were obtained by the courtesy of Calgon Corporation, Pittsburgh, Pa. Other commercial mixtures, Curafos 22-4 and Curafos 11-2, are not specifically recommended by the manufacturer for use in poultry.

The phosphates and NaCl were dissolved first in distilled water. Meat samples were weighed out and various solutions were added in the ratio of 10 ml solution to 100g of meat. When additions of NaCl were higher than 1.5% in the meat, the appropriate amount of salt was added directly to 100g ground meat samples along with 10 ml of water or the phosphate solution. The whole was mixed and used after standing in the refrigerator overnight. All determinations were run twice in duplicate. The data reported are averages of four readings.

Methods

Meat shrinkage (water-holding capacity). The water-holding capacity was determined by the method of Wierbicki et al. (1957a) with modifications by Shults and Wierbicki (1972).

Meat swelling (water-binding capacity). The method by Wierbicki et al. (1962) was used with modifications by Shults and Wierbicki (1972).

pH readings. The pH of the meat samples was read by immersing the electrodes directly into the meat, using a Beckman Zeromatic pH meter. Readings were taken prior to weighing the samples for the shrink determination.

Statistical analysis. The data were subjected to statistical analysis using analysis of variance (Steel and Torrie, 1960) and multiple range test (Duncan, 1955).

RESULTS & DISCUSSION

Effects of polyphosphates

The effects of the various phosphates (added at a 0.5% level) on the pH, swell-

Table 1—Effects of phosphates with and without sodium chloride on the pH, swelling and water-holding capacity of chicken muscle

	0% NaCl				1.0% NaCl			
Polyphosphates	pH	% Swelling	% Shrink	Multiple Range Test[a]	pH	% Swelling	% Shrink	Multiple Range Test[a]
Tetrasodium pyrophosphate	6.3	188	22		6.3	203	13	
Kena FP-28	6.1	185	24		6.0	191	15	
Sodium tripholyphosphate	6.1	180	25		6.2	191	16	
Curafos 22-4	6.1	183	29		6.0	185	18	
Curafos 11-2	5.9	146	29		6.0	174	18	
Sodium hexametaphosphate	5.9	151	28		5.8	171	19	
Foodfos	5.9	137	29		5.8	171	19	
Control (No phosphates)	5.7	102	31		5.7	125	22	

[a] Significance at the 5% level; applies to percent shrink only.

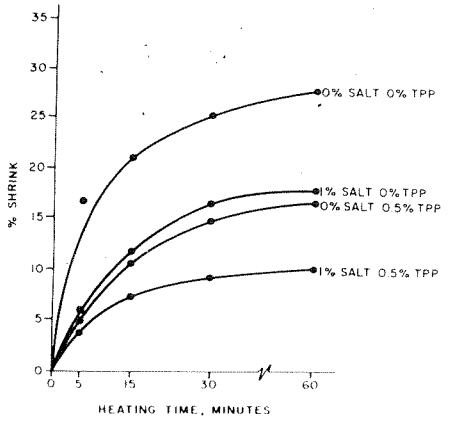

Fig. 1—Effect of heating time at 70° C on the shrinkage of chicken muscle.

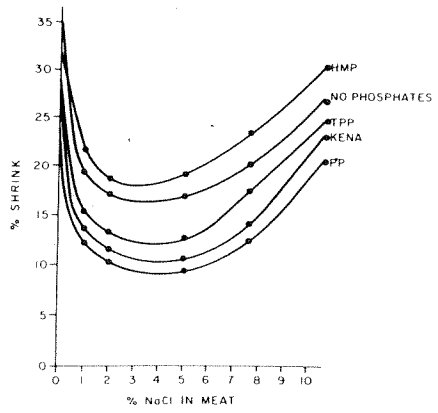

Fig. 2—Effect of NaCl on the shrinkage of chicken muscle at 70° C.

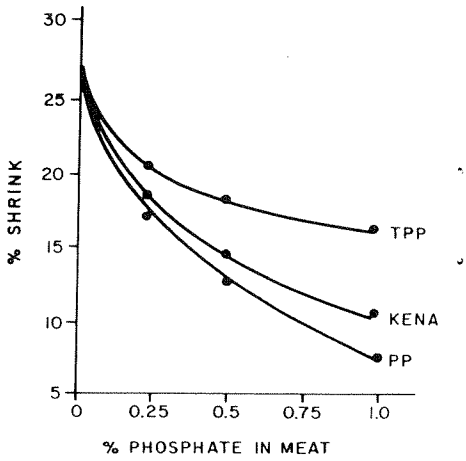

Fig. 3—Effect of polyphosphates, without NaCl, on shrinkage of chicken muscle at 70° C.

ing and water holding capacity (WHC) are shown on Table 1. These phosphates were tested with and without 1% NaCl added to the ground chicken meat. In the samples without NaCl, pyrophosphate (PP) exerted the greatest effects on the pH, swelling and WHC followed by Kena, TPP and Curafos 22-4. Analysis of the WHC data showed that PP caused significantly lower shrinkage than the other phosphate samples. No statistical differences were found between the Kena and TPP samples, but they had significantly less shrinkage than Curafos 22-4, Curafos 11-2, HMP and Foodfos samples. The addition of 0.5% PP resulted in a 9% reduction of shrinkage in the cooked meat and 86% increase in swelling of the raw meat.

In samples with 1% NaCl added, no signfificant differences were found in the shrink data for PP and Kena samples. However, PP sample was significantly lower than samples with 22-4, 11-2, HMP and Foodfos. The swelling data show that PP had the greatest effect and Kena and TPP were equally effective. The results indicate that PP is the most effective phosphate, followed by Kena and TPP. The addition of 1% NaCl and 0.5% PP resulted in a total reduction in shrinkage of 18% in the cooked meat and 101% increase of swelling in the raw meat.

Effects of heating time on meat shrinkage

Figure 1 shows relative effects of TPP, NaCl and a combination of TPP and NaCl on the water-holding capacity (reduction of meat shrinkage) of white chicken meat during heating at 70°C for 5–60 min. The data indicate a synergistic effect of TPP and NaCl on water-holding capacity of the meat. They also indicate that 30 min heating time used throughout this study is sufficient to obtain the relative effects of the additives on the water-holding capacity of chicken meat.

Effect of NaCl concentration

Figure 2 shows the effects of NaCl concentration ranging from 0–10% on the meat shrinkage at 70°C when it was used alone and in combination with 0.5% of TPP, Kena, PP and HMP. The addition of 1% NaCl dramatically decreased the meat shrinkage. Reduction in shrinkage of the meat continued up to a concentration of 3–5% NaCl, depending on the phosphate. Over 5% NaCl concentrations had an adverse effect on the meat shrinkage. The presence of the phosphates did not alter this trend. However, there was a definite synergistic effect, with the exception of HMP. The greatest relative effect in reducing the meat shrinkage was shown by PP, followed by Kena and TPP. With the exception of HMP, the effect of NaCl and other condensed phosphates on chicken meat is similar to the effect found previously for beef (Shults and Wierbicki, 1972).

Effect of phosphate concentrations on meat shrinkage

To test the effects of phosphate concentrations up to 1% on meat shrinkage, the three most promising phosphates, PP, Kena and TPP, were evaluated with and without NaCl. Figure 3 shows the results of the three phosphates on meat shrinkage when tested without NaCl. The greatest effect was shown by PP. At 0.5% concentration, PP and Kena showed only slight differences. TPP showed a lesser effect on the shrinkage; a very small additional reduction in meat shrinkage oc-

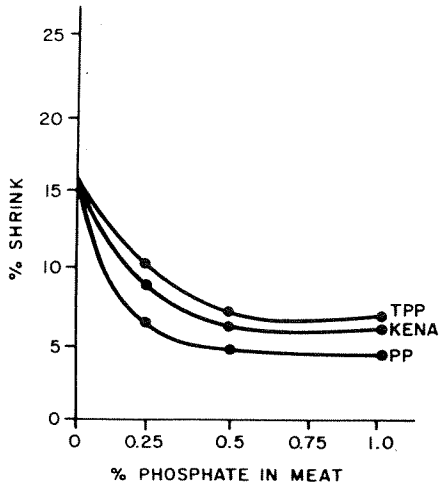

Fig. 4—Effect of polyphosphates and 1% NaCl on the shrinkage of chicken muscle at 70° C.

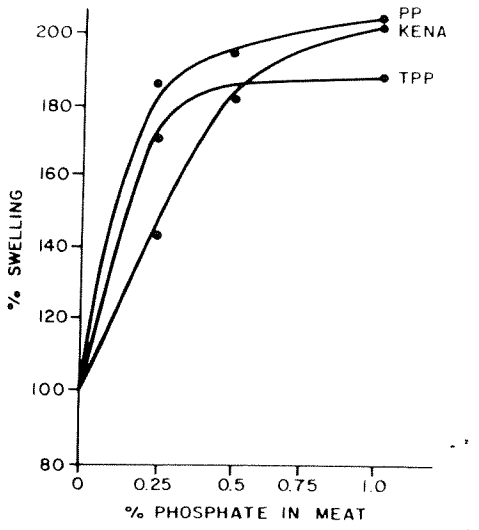

Fig. 5—Effect of polyphosphates, without NaCl, on the swelling of raw chicken muscle.

curred when the concentration of TPP was increased from 0.5–1.0%. Kena and PP continued to show a significant reduction of meat shrinkage up to a 1.0% concentration.

Figure 4 shows the results obtained with 1% NaCl added to the meat samples. The same trends were obtained as for the samples without the NaCl. However, the data indicate that when NaCl is present, further reductions in meat shrinkage did not occur when the concentration of the three phosphates was increased from 0.5 to 1.0%. PP has the greatest effect on meat shrinkage in the range of 0.25–0.5%.

Effect of polyphosphate concentrations on swelling

The three phosphates that had the greatest effects on meat shrinkage were evaluated to determine their effects on meat swelling of the raw meat. Figure 5 shows the effect of PP, Kena and TPP without NaCl on meat swelling. PP and TPP showed the greatest effect on the swelling at a concentration of 0.25%. Kena showed little effect at the 0.25% level. The three phosphates yielded similar results at 0.5%. The sample with Kena continued to show improvement up to the 1.0% level, whereas TPP and PP showed very little improvement above 0.25%. The addition of the phosphates resulted in an 80–100% increase in the meat swelling.

Figure 6 shows the effects of the three polyphosphates in combination with 1% NaCl on the meat swelling. Compared to the results of Figure 5, 1% NaCl alone increased the meat swelling from 100 to 150%. In combination with the phosphates, the swelling increased by an additional 30–50%. With PP and TPP, the greatest initial effects on swelling were obtained at 0.25%, then increasing only slightly up to 1.0% phosphate additions. Kena increased continuously the meat swelling up to the 1.0% addition.

Table 2—Effect of combinations of polyphosphates and 1% NaCl on the water-holding capacity of white chicken muscle

Detm	ml of juice per 20g muscle										
no.	AAA[a]	AAB	ABB	AAC	ACC	BBB	BBC	BCC	CCC	ABC	1% NaCl
1	2.5	3.2	3.6	2.9	2.5	3.5	2.7	2.9	2.2	2.6	4.3
2	3.0	2.7	3.4	3.0	2.4	3.9	3.0	2.9	2.4	2.1	4.6
3	2.5	2.6	2.8	2.5	2.4	3.8	3.3	2.3	1.9	2.1	4.2
4	2.4	2.8	3.2	3.0	2.8	3.4	2.5	2.4	2.1	2.4	4.5
$\bar{X}$	2.60	2.83	3.25	2.85	2.52	3.65	2.87	2.62	2.12	2.30	4.40
(% Shrink)	(13.0)	(14.2)	(16.2)	(14.2)	(12.6)	(18.2)	(14.3)	(13.1)	(10.6)	(11.5)	(22.0)
	Multiple range test (Significance at the 5% level)										(Control)
P-combinations:	CCC	ABC	ACC	AAA	BCC	AAB	AAC	BBC	ABB	BBB	1% NaCl
ml/20g:	2.12	2.30	2.52	2.60	2.62	2.83	2.85	2.87	3.25	3.65	4.40

[a] A = sodium tripolyphosphate; B = sodium hexametaphosphate; C = sodium pyrophosphate

Effect of polyphosphate concentrations on pH

The effects of the three polyphosphates (PP, TPP, and Kena), with and without 1% NaCl, on the pH of the meat are shown in Figure 7. As the data indicate, the three polyphosphates increased the pH of the chicken meat. Pyrophosphate had the greatest effect, followed by Kena and TPP. These results confirm that there is a direct relationship between pH and the shrinkage and swelling of the meat. Addition of 1% NaCl slightly decreased the pH, while greatly increasing the water-holding capacity (decreased the meat shrinkage). This confirms generally accepted hypothesis that increase in the ionic strength of the media (caused by the addition of NaCl), in addition to pH, is responsible for the water-holding capacity of meats (Hamm, 1960; Wierbicki et al., 1963).

Effect of polyphosphate combinations

Several combinations of sodium tripolyphosphate (designated as A) sodium hexametaphosphate (designated as B) and tetrasodium pyrophosphate (designated as C) were evaluated, along with 1% NaCl, for their effect on the WHC to determine a best combination for use in chicken meat. These combinations are listed in Table 2. The total amount of polyphosphates added to the sample was 0.45%. Each polyphosphate was added in 0.15% increments. Therefore, the sample listed AAA is 0.45% TPP, the sample listed

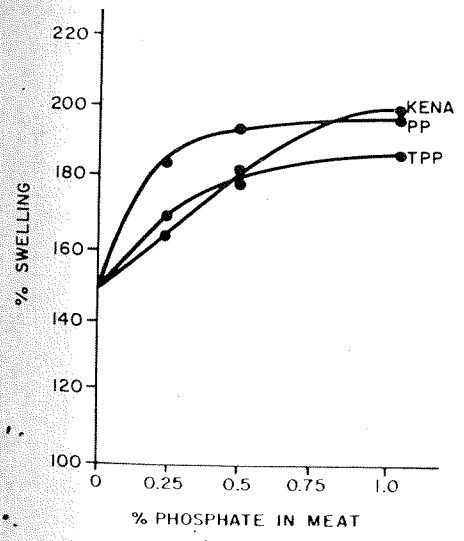

Fig. 6—Effect of polyphosphates and 1% NaCl on the swelling of raw chicken muscle.

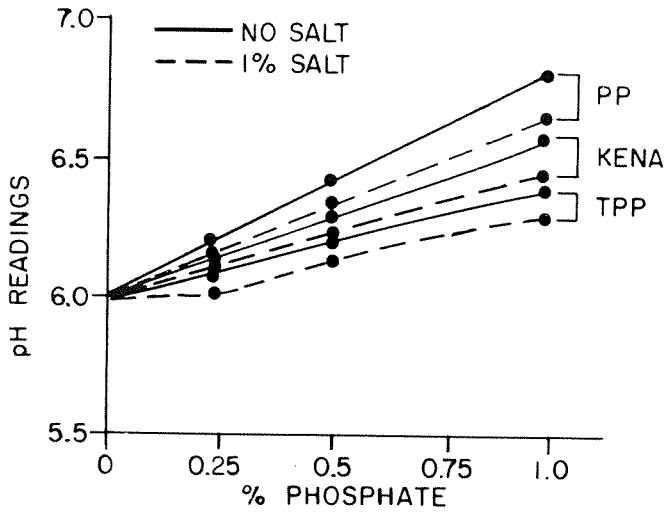

Fig. 7—Effect of polyphosphates, with 1% and without NaCl, on the pH of raw chicken muscle.

AAB is 0.3% TPP and 0.15% HMP and so forth. The shrink determinations were run four times in duplicate and the data statistically analyzed to determine differences among the combinations.

Statistical analysis showed that CCC (0.45% PP) yielded the lowest shrink values and was significantly different from all the other combinations except ABC (0.15% PP, 0.15% TPP and 0.15% HMP). However, ABC (TPP, HMP and PP), ACC (TPP and PP), AAA (TPP) and BCC (HMP and PP) were not significantly different.

CONCLUSIONS

THE OVERALL RESULTS indicate that at an addition of 0.25–0.5% sodium salts of (a) pyrophosphate; (b) a mixture of one part tripolyphosphate, one part hexametophosphate and one part pyrophosphate; (c) the commercial phosphate mixture, Kena FP-28; or (d) tripolyphosphate are the most efficient polyphosphates for the reduction of the loss of natural juices during cooking of chicken meat.

The reduction of the loss of natural juices during cooking is greatly increased when the polyphosphates are used in a combination with common salt, sodium chloride.

Addition of 0.3% polyphosphates to raw chicken meat before cooking is considered sufficient for obtaining optimum reduction of cooked-out juices from the meat during thermal treatment.

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