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EFFECT OF SALT, PHOSPHATES AND OTHER CURING INGREDIENTS ON WATER-HOLDING CAPACITY OF LEAN PORK MEAT AND THE QUALITY OF RADAPPERTIZED HAM

Irradiated Food Products Group
Radiation Preservation of Food Division

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Food Engineering Laboratory
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Meat shrinkage of lean pork meat containing cure, sodium tripolyphosphate (TPP) or equivalent amounts of sodium pyrophosphate (PP) and varied concentrations of salt (NaCl) was investigated using the centrifugal method.

It was determined that; (a) the curing ingredients have very little effect on the meat shrinkage; (b) additions of 1 to 3% salt reduced the meat shrink from 34 to 14%; (c) additions of .3% TPP with 3 to 5% salt decreased the meat shrink to 5%; (d) the equivalent addition of PP was equally effective; and (e) no

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significant effect on the meat shrink was observed by increasing the TPP addition (over .3%) to the meat.

The quality of nonirradiated and irradiated smoke processed ham containing 3% salt and 0.3% TPP (or 0.217% PP) was as acceptable as the ham with 0.5% TPP (or 0.362% PP.). The product with 0.3% TPP had equally good color, flavor, and texture and was as resistant to rancidity development as the product with 0.5% TPP. Based on this data, the USDA allowed 0.5% TPP in cured hams can be reduced to a maximum allowance of .3% TPP for chunked and formed hams.

Preface

The investigations reported in this paper were conducted to determine the meat shrinkage of pork as affected by low concentrations of food grade phosphates, salt and meat curing ingredients. The resulting data was used in the formulation of chunked and formed smoke processed hams.

Results from these investigations have shown that an acceptable ham (both irradiated and nonirradiated) can be produced using 0.3% TPP (or .217% PP) and 3% salt.

These studies were undertaken as a research project of the Irradiated Food Products Division, Food Engineering Laboratory under Project 1T762724AH99D.

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EFFECT OF SALT, PHOSPHATES AND OTHER CURING INGREDIENTS ON WATER-HOLDING CAPACITY OF LEAN PORK MEAT AND THE QUALITY OF RADAPPERTIZED HAM.

INTRODUCTION

Today the use of phosphates for processing of ham and other cured products is a common industrial practice. Sodium tripolyphosphate (TPP), sodium pyrophosphate (PP), disodium phosphate, sodium hexametaphosphate, and sodium acid pyrophosphate, single or in combination, not to exceed 0.5% in the finished product, are allowed by the U.S. Department of Agriculture Meat Inspection Regulations for the use in cured pork products (USDA, 1970).[1] The purpose of the use of phosphates is to "decrease amount of cooked out juices" during processing (cooking) of the products.

Numerous commercial blends and mixtures of the phosphates, with and without other salts, are available. The main effect of the phosphates, particularly the polyphosphates, is an elevation of the pH of the meat and restoration of the water-holding ability of the meat which begins to decrease with the onset of the rigor mortis (Ellinger, 1972[2]; Hamm, 1960[3]; Hamm and Grau, 1955[4]; Wierbicki et al. 1962[5], 1963[6]). Polyphosphates such as TPP and PP, are particularly effective in this respect. Their effect is greatly increased when used in a combination with the common salt (sodium chloride) (Hellendoorn, 1962[7];

[1] - USDA. 1970. Department of Agriculture, Meat Inspection Regulations, Title 9, Chapter III, Subchapter A, Code of Federal Regulations, para. 318.7 (4) - Approval of Substances for Use in the Preparation of Product.

[2] - Ellinger, R. H. 1972. "Phosphates as Food Ingredients". CRC Press, The Chemical Rubber Co., 18901 Cranwood Parkway, Cleveland, Ohio 44128.

[3] - Hamm, R. 1960. Biochemistry of meat hydration. Adv. in Food Res. 10: 355.

[4] - Hamm, R. and Grau, R. 1955. The Effect of phosphates on the bound water of meat. Dtch. Lebensmitt. Rdsch. 51: 106.

[5] - Wierbicki, E., Tiede, M. G. and Burrell, R. C. 1962. Determination of meat swelling as a method for investigating the water-binding capacity of muscle protein with low water-holding forces. 1. The methodology. Die Fleischwirtschaft 14: 948.

[6] - Wierbicki, E., Tiede, M. G. and Burrell, R. C. 1963. Determination of meat swelling as a method for investigating the water-binding capacity of muscle protein with low water-holding forces. 2. Application of the swelling methodology. Die Fleischwirtschaft 15: 404.

[7] - Hellendoorn, E. W. 1962. Water-binding capacity of meat as affected by phosphates. 1. Influence of Sodium chloride and phosphates on the water retention of communited meat at various pH values. Food Technol. 16: 119.

Mahon, 1961[8]; Sherman, 1961a[9], 1961b[10]; Shults et al. 1972[11]; Shults and Wierbicki, 1973[12], 1974[13]).

In addition to an increase in pH, the water-holding capacity of meats is increased by the use of the polyphosphates due to their sequestering ability for the alkaline-earth and heavy metal ions naturally present in meats (Ellinger, 1972[2]; Hamm, 1956[14]. The sequestering ability of polyphosphates may also have a beneficial effect on preventing the development of oxidative off-flavors and off-odors as well as on preventing discoloration of fresh and cured meats (Ellinger, 1972[2]; Timms and Watts, 1958[15]; Watts, 1954[16]).

8 - Mahon, J. M. 1961. Tripolyphosphate-salt synergism and its effect on cured meat volume. Proceedings, Thirteenth Research Conference, Am. Meat Inst. Foundation, Chicago, Ill. March 23-24.

9 - Sherman, P. 1961a. The water-binding capacity of fresh pork. 1. The influence of sodium chloride, pyrophosphate and tripolyphosphate on water absorption. Food Technol. 15: 79.

10 - Sherman, P. 1961b. The water-binding capacity of fresh pork. 3. The influence of cooking temperature on Water-binding of lean pork. Food Technol. 15: 90.

11 - Shults, G. W., Russell, D. R. and Wierbicki, E. 1972. Effect of condensed phosphates on pH, swelling and water-holding capacity of beef. J. Food Sci. 37: 860.

12 - Shults, G. W. and Wierbicki E. 1973. Effects of sodium chloride and condensed phosphates on the water-holding capacity, pH and swelling of chicken muscle. J. Food Sci. 38: 991.

13 - Shults, G. W. and Wierbicki, E. 1974. Effects of condensed phosphates on the pH, water-holding capacity and meat swelling properties of pork muscle. Tech. Rpt. TR-74-22-FL, U.S. Army Natick Labs., Natick, MA 01760.

14 - Hamm, R. 1956. Fleischmineralien and Fleischqualität. Calcium, Magnesium und Zink und ihre Bedeutung fur Wassenbindung des Fleisches. Die Fleischwirtschaft 8:240.

15 - Timms, M. J. and Watts, B. M. 1958. Protection of cooked meats with phosphates. Food Technol. 12: 240.

16 - Watts, Bm. M. 1954. Oxidative rancidity and discoloration in meat. Adv. Food Res. 5: 1.

The polyphosphates also increase the binding properties of fresh and cured meats by increasing solubility of the muscle proteins, actomyosin and myosin, particularly in the presence of sodium chloride (Ellinger, 1972[2]; Hamm, 1960[3]; Wierbicki et al. 1963[6]; Yasui et al. 1964[17]). This effect of polyphosphates in combination with sodium chloride is the basis for the development and industrial processing of so-called "sectioned-and-formed" ham and other "restructured meat products" (Mandigo, 1974[18]; Wierbicki and Heiligman, 1973[19]). The binding effect of polyphosphates and sodium chloride was further increased by mechanical treatment of cured and uncured meat muscles (Rahelic et al., 1974 [20]; Shults et al., 1972[11]; Shults and Wierbicki, 1973[12], 1974[13]; and Wierbicki and Heiligman, 1973[19]).

The increase of water-holding capacity of cured and uncured meats with the addition of phosphate and sodium chloride was in turn responsible for an increase in the tenderness of meats (Kampstra and Saffle, 1959[21]).

Based on the overall knowledge on the water-holding and binding properties of polyphosphates and sodium chloride in meats, the objectives of this investigation were: (1) to determine the minimal amounts of the polyphosphates, TPP and PP, on the optimal water-holding capacity of lean pork meat, with and without other curing ingredients; and (2) to determine the quality of cured, smoked hams using the optimal additions of TPP and PP with other, commonly used, curing ingredients.

17 - Yasui, T., Fukusawa, T., Takahashi, K., Sukamishi, M. and Hashimoto, Y. 1964. Phosphate effects on meat. Specific interaction of inorganic polyphosphates with myosin B. J. Agr. Food Chem. 12: 399.

18 - Mandigo, R. M. 1974. Restructured meat products. Proceedings, 27th Am. Reciprocal Meat Conference, Texas A & M Univ., College Station, Texas; 16-19 June: 403.

19 - Wierbicki, E. and Heiligman, F. 1973. Shelf stable cured ham with low nitrite-nitrate additions preserved by radappertization. Proceedings, Int. Symp. Nitrite in Meat Products, Zeist, The Netherlands, Sept. 10-14; PUDOC, Wageningen: 189.

20 - Rahelic, S., Pribis, Vjera and Vicevic, L. 1974. The influence of mechanical treatment of cured muscles on some characteristics of pasteurized canned pork. 20th European Meeting of Meat Research Workers, Dublin, Ireland, 15-20 September.

21 - Kamstra, L. D. and Saffle, R. L. 1959. The effects of a pre-vigor infusion of sodium hexametaphosphate on tenderness and certain chemical characteristics of meat. Food Technol. 13: 652.

In our previous experiments on lean beef (Shults et al., 1972)[11], lean chicken meat (Shults and Wierbicki, 1973)[12] and lean pork (Shults and Wierbicki 1974)[13], it was shown that PP and TPP were the most effective polyphosphates on the water-holding capacity and that the minimal additions of the polyphosphates to obtain the desired effect was about 0.25 to 0.30%. Therefore, only TPP and PP were used in this investigation. According to Neraal and Hamm (1973)[22], TPP was rapidly hydrolyzed in meats to PP and orthophosphate, and it was the PP moiety of TPP which was mainly responsible for the increase of the water-holding capacity of meats. Therefore, in our investigation an emphasis was placed on the effect of sodium salt of TPP ($Na_5P_3O_{10}$, molecular weight of 378) versus equivalent additions of sodium salt of PP ($Na_4P_2O_7$, molecular weight of 266) on the water-holding capacity of pork lean meat and the quality of smoked, processed ham.

Raw Material

The raw material utilized for this study was lean meat of skinned, defatted boneless hams, 6 to 8 kg weight. The meat was ground through a 4.8-mm grinding plate and thoroughly mixed. The ground meat was stored in a refrigerator (2°C to 3°C) before determination of shrinkage.

Additives

Food-grade salt (NaCl), sodium ascorbate (Na-Asc), sodium erythorbate (Na-Eryth), sodium nitrate ($NaNO_3$) sodium nitrite ($NaNO_2$) sodium tripolyphosphate (TPP, $Na_5P_3O_{10}$) and sodium pyrophosphate (PP, $Na_4P_2O_7$)were the additives. The polyphosphates were obtained by the courtesy of Merck Chemical Corp., Pittsburgh, PA. The polyphosphates and NaCl were dissolved first in tap water followed, when applicable, by dissolving Na-Asc, Na-Eryth, $NaNO_3$ and $NaNO_2$. Meat samples were weighed and various solutions were added in the ratio of 10 ml of solution to 100 g meat. When additions of NaCl were higher than 1.0% in the meat, the appropriate amounts of salt were added directly to 100-g meat samples with 10 ml of the phosphate solutions with other additives. The meat and the additives were combined, thoroughly mixed, and stored overnight at 2°C to 5°C. All shrinkage determinations were run twice in duplicate. The shrink data reported were averages of four replicates.

Methods.

Meat Shrinkage (reciprocal of water-holding capacity). The meat shrinkage was determined by the method of Wierbicki et al. (1957)[23]. Each tube for the shrinkage determination contained 20 g meat plus the additives, including the solvent (tap water).

21 - Kamstra, L. D. and Saffle, R. L.1959. The effects of a pre-vigor infusion of sodium hexametaphosphate on tenderness and certain chemical characteristics of meat. Food Technol. 13: 652.

22 - Neraal, R. and Hamm, R. 1973. Enzymic breakdown of added tripolyphosphate and diphosphate in meats. 19th European Meeting of Meat Research Workers, Paris, France, 2-7 September.

23 - Wierbicki, E., Kunkle, L. E. and Deatherage, F. E. 1957. Changes in the water-holding capacity and cationic shifts during the heating and freezing and thawing of meat as revealed by a simple centrifugal method for measuring shrinkage. Food Technol. 11:69.

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 shrinkage determination.

Experimental Ham.

Fresh, raw, pork hams (6 to 8 kg weight) were skinned, deboned, and all visible cartilage, ligaments, tendons, connective tissue, lymph glands and surface and internal fat were removed. The skinned, defatted, boneless hams were then sectioned into chunks 70 to 750 g and mixed for 20 minutes in a Hobart food mixer with the curing brine. The brine was added at the 15 percent level, i.e., 15 kg brine per 100 kg meat. The composition of the curing brines (pickles) is given in Table 1. After mixing, the ham chunks were loosely stuffed into No. 11 Union Carbide, prestuck (perforated), easy-peel casings, then tightly packed into rectangular stainless steel wire cages, dimensions 9 x 13 x 75 cm, and refrigerated overnight at 2°C to 3°C before smokehouse processing.

The cured raw product was processed in a smokehouse (a pilot scale model, Atmos Corporation) in accordance with the following schedule.

Time	Dry bulb temperature	Wet Bulb temperature
1 hour without smoke	65°C	49°C
2 hours with smoke	65°C	49°C
5 hours with smoke	77°C	57°C
2 hours with smoke	82°C	65°C

Cooking continued without smoke until the internal temperature of the hams was 70°C (enzyme inactivation temperature) and then continued at a dry bulb temperature of 77°C without steam until the weight of the ham containing 0.3% TPP was 100% of the weight of the raw ham prior to curing (total additional time of the processing was 1 hour and 45 minutes). After cooking, the hams were chilled to 5°C or less (internal temperature) within 12 hours, and then kept in a refrigerator at 2 to 3°C (72 hours maximum) until cut and packaged. The finished product was "medium smoked", "light brown" in color without "added substance", as required by the USDA regulations for smoked ham (USDA, 1970). The smoked, processed hams, were cut into 12.7 mm thick rectangular slices and packed in flexible pouches of the outside dimensions of 140 mm x 191 mm. The pouch material was 0.025 mm (1.0 mil) polyiminocaproyl (Nylon 6) as the outside layer, 0.0090 mm (0.35 mil) aluminum foil as the middle layer, and 0.051 mm (2 mil) chemically bonded polyethylene terephthalate-medium density polyethylene (3M Scotchpack 9) as the inside (food contacting) layer.

Irradiation.

Vacuum-packed ham slices were frozen to -30°C and then gamma-irradiated in the frozen state (-30°$\pm$10°C) using the Natick Research and Development Command's

Cobalt-60 source at a dose rate of 1.18×10^5 rads per minute. The dose received was 3.3 to 4.1 Mrad. This is a radiation sterilizing dose for ham under the 12D concept for the destruction of C. botulinum (Anellis and Werkowski, 1968)[24]. After irradiation, the ham samples were stored at room temperature (21°C to 25°C) until evaluation was performed. The nonirradiated, vacuum-packed control ham samples were stored in a -29°C freezer.

Sensory Evaluation.

The ham samples were evaluated by a trained technological panel of 8 panelists for the following quality characteristics: color, odor, flavor, texture, and appearance.

The following intensity ratings were used: 1 - extremely poor; 2 - very poor; 3 - poor; 4 - below fair, above poor; 5 - fair; 6 - below good, above fair; 7 - good; 8 - very good; and 9 - excellent. The samples were also evaluated for preference by the trained technological panel and by a consumer type panel, using the 9-point hedonic scale for preference according to Peryam and Pilgrim (1957)[25]. Scores of 5 to 9 indicate an acceptable product. The ham samples were served cold, and after heating (wrapped in aluminum foil) in an electric oven preheated to 121°C, until the internal temperature of the ham slices reached 62.8°C.

Thiobarbituric Acid (TBA) values.

The TBA values were determined on vacuum-packed irradiated and nonirradiated ham samples stored up to 3 months and on nonirradiated samples stored in open pouches in a refrigerator (2-3°C) up to six weeks. The method of Tarladgis et al. (1960)[26] was used, giving the TBA values in terma of mg malonaldehyde per 1000 g ham.

Statistical Analysis.

The data for the sensory evaluation of the ham samples were subjected to statistical analysis using analysis of variance and multiple range test. (Steele and Torrie), (1960)[27].

[24] - Anellis, A. and Werkowski, S. 1968. Estimation of radioresistance values of microorganisms in food products. Applied Microbiol. 16 (9): 1300.

[25] - Peryam, D. R. and Pilgrim, F. J. 1957. Hedonic scale method for measuring food preferences. Food Technol. 11(9), Supplement: 9.

[26] - Tarladgis, B. G., Watts, B. M. and Younathan, M. T. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Am. Oil Chem. Soc. 37: 44.

[27] - Steel, R. G. and Torrie, J. H. 1960. "Principles and Procedures of Statistics". McGraw-Hill Book Company, New York.

RESULTS AND DISCUSSION

Effect of TPP vs. PP on water-holding capacity.

In our previous experiments on lean beef (Shults, et al., 1972)[11], lean chicken meat (Shults and Wierbicki, 1973)[12] and lean pork (Shults and Wierbicki, 1974)[13], it was shown that the most efficient polyphosphates for obtaining an optimal water-holding capacity (WHC) of the meats during heating at 70°C are TPP and PP and the minimal phosphate additions to the meat to achieve the intended purpose is 0.3% (8.2 millimoles (mM)) in comparison with 0.5% (136 mM) which is the maximal addition permitted by the USDA. The additions of PP were in the equivalent molar concentrations of 8.2 mM and 13.6 mM, which resulted in the additions to meat of 0.22% and 0.36%, respectively.

Table 2 presents the results on the shrinkage of lean pork meat with the additions of 13.6 and 8.2 mM TPP and PP without salt (NaCl) and with 1.0 and 2.4% salt. The shrink data in these series of experiments indicate the loss of moisture in percent of the total weight of the pork samples (including 10% added water) during heating at 70°C for 30 minutes according to the method of Wierbicki et al. (1957)[23]. Potable, tape water (instead of distilled water) was used in these experiments to simulate the actual conditions in meat processing where tap water is used as the solvent for the curing ingredients during pickle preparation. The alkaline-earth metal ions in the tap water were sequestered by TPP or PP, decreasing to some extent the effectiveness of the phosphates on subsequent addition to the meat; in this way, more meaningful shrink data were obtained. The data given in Table 2 shows the effects of the phosphate and salt when added to meat: (a) the additions of TPP and PP increased the pH of the meat and, consequently, reduced the meat shrink; (b) addition of salt also decreased the shrink; the reduction in shrink was quite pronounced when the salt and the phosphates were added together. The data further indicate that the PP additions of 8.2 and 13.6 mM were equally effective as the 8.2 and 13.6 mM TPP additions, thus confirming the conclusion of Neraal and Hamm (1973)[22] that it was the PP moiety of TPP which was responsible for the WHC increase of meats.

Table 3 presents the effect of 13.6 mM and 8.2 mM additions of TPP and PP with 1.0 and 2.4% salt, on the shrinkage of lean ham meat by including other curing ingredients commonly used in ham processing: 150 ppm $NaNO_2$, 600 ppm $NaNO_3$, 275 ppm Na-Asc, and 275 ppm Na-Eryth. The curing ingredients other than salt and TPP or PP, in the concentrations used, have little effect on the WHC, as shown by the pH and the shrink data of the meat with the 10% tap water addition (Table 2) versus the 10% curing solution addition (Table 3). TPP and PP greatly increased the pH of the curing solutions from 6.1 without the phosphates to 7.8 to 9.5 with the phosphates, PP being more effective in this respect (Table 3). After mixing with the meat in the ratio of 10 ml curing solution per 100 g meat, the pH of the meat increased from 6.0 to 6.2-6.4. At this pH and in the presence of 1 or 2.4% salt, the meat shrink decreased from 29% to the level of 3 to 8%. The effects of salt and TPP or PP on the WHC were again demonstrated. The 2% shrink differences between the TPP vs. PP additions (Table 3) were well within the accuracy of the methodology at these low levels of the meat shrinkage ($\pm$ 0.1 ml accuracy of the meniscus reading for the total of less

than 1 ml juices released by 20 g meat samples with the additives at 70°C). Three additional experiments were conducted to elucidate further the effects of TPP vs. PP and their minimal additions to cured ham meat to obtain maximal reduction in shrink.

In the first experiment, the effect of the TPP and PP additions from 0 to 24.6 mM (in 4.1 mM increments) on the shrinkage of ground lean ham meat was investigated. On the weight basis, the additions of TPP varied from 0 to 0.9% (with 0.15% increments) and the PP additions from 0% to 0.66% (with 0.11% increments), respectively. Other additives to the meat were constant: 10% tap water, 2.5% salt and the small amounts of $NaNO_3$, $NaNO_2$, Na-Asc and Na-Eryth (cure), as specified previously. Figure 1 shows the data for percent shrink versus phosphate additions. The data indicate that the 8.2 mM additions of TPP or PP decreased the meat shrink to a minimum, with a plateau at the 12.3 mM and 16.4 mM additions followed by a small increase in the meat shrinkage at 24.6 mM phosphate additions. Overall, the data show that 8.2 mM additions of either TPP (0.3%) or PP (0.22%) were sufficient for controlling the loss of the meat juices of cured ham meat during cooking at 70°C.

In the second experiment a comparison was made of the effect of 0.5% (13.6 mM) TPP vs. 0.3% TPP (8.2 mM) on the shrink of cured raw meat at 60°, 70°, and 80°C. The greatest shrink was observed during the first 15 to 30 minutes of heating, as observed on beef and chicken meats (Wierbicki et al., 1957[23], 1962[5], 1963[6]; Shults et al., 1972[11]; Shults and Wierbicki, 1973)[12]. The general conclusion was that use of 0.3% instead of 0.5% TPP in cured ham meat is sufficient for the shrink control. An exception was the more efficient effect of 0.5% TPP on the shrink of the cured ham meat at 70°C heated for 45 minutes. We have repeated the experiment with the 0.5% TPP addition on another meat sample, derived from another ham (Figure 2, Sample II). The shrink of this sample was slightly higher at all heating times. This indicates a biological variation among muscles of different hams. The heating time of 30 minutes resulted in most of the meat shrink followed by only a slight increase with the increase of the heating time to 45 and 60 minutes.

In the third experiment the effect of salt on the meat shrink at 70°C (heating time 30 minutes) was determined in the lean ham samples to which were added: tap water; curing solution; and the curing solution plus 8.2 mM of TPP (0.3%) or PP (0.22%). The data of this experiment are given in Fig. 3. The data clearly indicate that: (a) the curing solution containing the commonly used concentrations of $NaNO_3$, $NaNO_2$, Na-Asc and Na-Eryth has no effect on the meat shrink in comparison with adding the tap water (solvent) alone; (b) the equivalent additions (8.2 mM) of TPP and PP are equally effective in reducing the shrink: (c) addition of 1 to 3% salt continuously reduced the meat shrink from 34% to 14% when used without phosphates, or from 34% to 5-6% when used with the phosphates; (d) a plateau in the meat shrink resulted at the salt additions from 3 to 5%, followed by an increase in the meat shrink with the increase of the salt addition from 5 to 10%. This confirms our results on the effect of salt, with and without TPP or PP, on the shrink during heating at 70°C of lean beef (Shults et al.,1972)[11],

chicken meat (Shults and Wierbicki, 1973)[12] and uncured pork (Shults and Wierbicki, 1974)[13]. The overall results of these experiments indicate that 0.3% TPP (8.2 mM) is the optimal amount of TPP needed for controlling shrink in cured ham meat. The addition of the phosphate to the meat can further be reduced to 0.22% by using the equivalent molar addition of PP (8.2 mM) instead of adding TPP. The only drawback of using PP, instead of TPP, is the difficulty of dissolving PP in tap water during pickle preparation, particularly when the salt content in the curing brine is higher than 15%. However, this difficulty can be overcome by vigorous stirring of the brine and slight heating during preparation. Heating has no detrimental effect on the PP and salt, which have to be dissolved first, followed by chilling to 3 to 5°C, prior to adding other curing ingredients ($NaNO_3$, $NaNO_2$, Na-Asc and Na-Eryth).

Experiments on smoked processed ham.

a. Yield data. Fresh, raw hams, 6½ to 8½ kg, were deboned, skinned, defatted, cut into pieces of 70 to 750 g and processed as "cut-and-formed" smoked ham, as given under "Methods.". Five experimental pickles (Table 1) were used. Each pickle was mixed with meat in the ratio of 40 kg meat plus 6 kg pickle. Each ham-pickle mixture was sufficient to make four experimental hams per group. All the cured hams were processed simultaneously in the smokehouse under the conditions specified under "Methods". The smokehouse processing was discontinued when the ham group with 0.30% TPP (8.2 mM) reached an internal temperature of 70°C and the estimated yield of 100% to the raw ham meat prior to mixing with the pickle. All hams contained the same additions of $NaNO_2$, $NaNO_3$, Na-Asc and Na-Eryth (Table 1) along with 3.0% salt, the amount needed to get the maximal WHC, according to Fig. 3. The variables were the additions of TPP and PP (13.6 and 8.2 mM) and no-phosphate.

Table 4 presents the data for ham yields after the smokehouse processing and overnight chilling in a 2 to 3°C cooler. The average yield of the reference group containing 0.3% (8.2 mM) TPP was 100.7%. The yields of the other three ham groups with the phosphates were 99.4 to 101.1%. The yield differences among the four phosphates groups were statistically insignificant. A slightly lower yield was obtained on the no-phosphate hams (97.6%), as was expected. Normally, in our laboratory experiments on no-phosphate cured hams, the yield out of smokehouse seldomly exceeded 90%. Analysis of the raw material showed that the pH in the raw (green) hams used in this experiment was rather high (pH 5.9). This might attribute to the relatively high yield of the no-phosphate hams. In addition, the method of curing and the long-time smokehouse processing used in this experiment could be another factor contributing to the relatively high yield of no-phosphate hams.

b. Sensory evaluation. Sensory evaluation by our trained technological panel for color, odor, flavor, texture, appearance, and preference resulted in high scores for the quality attributes of the hams in each group. Both nonirradiated hams, served cold (Table 5) and after heating (Table 6), as

as well as the irradiated counterparts served cold (Table 7) and after heating (Table 8), received high scores for quality attributes tested. There were no significant differences among the hams processed using the five different pickles.

Four tests for preference were done on the ham samples by a consumer type panel, 35 panelists per test. Five ham samples, each sample representing ham processed by a different cure, were tested in each session. Two tests were on nonirradiated ham samples, and two tests on irradiated ham samples, served either cold or after reheating. The results of these tests are given in Table 9. There were no significant differences among the five ham samples in two tests: (1) irradiated samples, served cold and (2) nonirradiated samples, served hot (Table 9). Slightly lower, but significantly less preferred at 0.5 level, were the ham samples cured with 13.6 mM (0.36%) PP, nonirradiated, served cold, and irradiated, served hot (Table 9). However, these differences could be attributed to biological variations from sample to sample, rather than the effect of the cure.

To elucidate the effect of irradiation on the ham quality, the data given in Table 9 were tabulated as the irradiated and nonirradiated samples and statistically analyzed (t-test). Table 10 presents the results.

Among the 10 paired comparisons, only two nonirradiated samples received significantly higher scores over the irradiated samples; (1) ham cured with 13.6 mm (0.5%) TPP, and (2) no-phosphate ham. In both instances, the ham samples were served cold; when served hot, there were no significant differences. When all the preference scores for nonirradiated ham samples were pooled and compared with the irradiated samples, the resulting mean score for the nonirradiated samples was higher by 0.31 point of the hedonic scale over the irradiated samples, and the difference was statistically significant (Table 10).

The mean score for the irradiated ham samples of 6.70 indicates a highly acceptable product, and the difference of 0.31 point from the nonirradiated ham was well within the capability of the panel members to express their preferences. This is shown by the standard deviations from the means of 1.37 and 1.47 points on the hedonic scale (Table 10).

c. TBA values. The TBA values are used in foods as an index of oxidative rancidity (Ellinger, 1972[2]; Tarladgis et al., 1960[26]; Timms and Watts, 1958[15]; Watts, 1954)[16], and TPP, PP and hexametaphosphate exhibit protective action against rancidity development as reported by Ellinger (1972)[2]. Therefore, the hams processed with the TPP and PP cures and without the phosphates were subjected to the TBA-values determination. Two types of tests were run: In the first experiment 1/2 inch (12.5 mm) ham slices were put into the pouches and stored unsealed in a refrigerator at 2°C to 3°C for 1, 2, 4, and 6 weeks prior to the TBA-values determination. The results are given in Table 11. The data indicate that all the ham samples have very low TBA-values, far below 10 mg malonaldehyde per 1000 g ham, a threshold for

organoleptic detection of the rancidity. There is no indication that the no-phosphate ham samples have significantly higher TBA values than the phosphate ham samples. Apparently, the smoking and the nitrite used provided enough protection against the development of rancidity. Nitrite is probably the main protective agent in this respect, since the TPP and salt-processed, smoked, cooked pork slices of the same thickness, stored under the same conditions, showed a rapid increase of the TBA-values during storage (Wierbicki and Heiligman, 1973)[19].

In another test, vacuum packed, irradiated ham samples, stored at room temperature (21°C to 25°C) and vacuum-packed, nonirradiated samples, stored in a -29°C freezer were tested for the TBA-values after 1 week and 3 months' storage. The results are given in Table 12.

As was expected, the nonirradiated, frozen stored samples, had very low TBA-values, and there was no increase with the storage time. The irradiated samples have slightly higher TBA-values, as a result of the consumption of the residual oxygen in the pouches during irradiation. After this initial increase, the TBA-values in vacuum-packed, irradiated foods remain unchanged even after nonrefrigerated storage over two years, the longest storage time investigated (unpublished results on irradiated beef, chicken, pork sausage and bacon). Consequently, no increase in the TBA-values was expected in the irradiated ham samples stored for 3 months, as shown in Table 12.

CONCLUSIONS.

1. The overall results on the water-holding determinations of lean ham meat and on the smoked processed ham indicate that 0.3% (8.2 mM) sodium tripolyphosphate (TPP) is sufficient to decrease the amount of cooked out juices during the processing of cured hams.

2. The equivalent addition of sodium pyrophosphate (PP) 8.2 mM) is equally effective to allow a reduction in the percent of the added phosphate to ham to the 0.22% level.

3. These additions of TPP or PP are sufficient also in uncured meats, as shown previously in our experiments on beef, chicken, and pork.

4. The present USDA Meat Inspection Regulations allowing the use of 0.5% phosphates in the meats can be amended to permit the use of 0.3% as the maximum level for sodium tripolyphosphate and sodium pyrophosphate.

REFERENCES

1. USDA. 1970. Department of Agriculture, Meat Inspection Regulations, Title 9, Chapter III, Subchapter A, Code of Federal Regulations, Para. 318.7(4) - Approval of Substances for Use in the Preparation of Product.

2. Ellinger, R. H. 1972. "Phosphates as Food Ingredients". CRC Press, The Chemical Rubber Co., 18901 Cranwood Parkway, Cleveland, Ohio 44128.

3. Hamm, R. 1960. Biochemistry of meat hydration. Adv. in Food Res. 10: 355.

4. Hamm, R. and Grau, R., 1955. The effect of phosphates on the bound water of meat. Dtch. Lebensmitt. Rdsch. 51: 106.

5. Wierbicki, E., Tiede, M. G. and Burrell, R. C. 1962. Determination of meat swelling as a method for investigating the water-binding capacity of muscle protein with low water-holding forces. 1. The methodology. Die Fleischwirtschaft. 14: 948.

6. Wierbicki, E., Tiede, M.G. and Burrell, R.C. 1963. Determination of meat swelling as a method for investigating the water-binding capacity of muscle protein with low water-holding forces. 2. Applications of the swelling methodology. Die Fleischwirtschaft 15; 404.

7. Hellendoorn, E. W. 1962. Water-binding capacity of meat as affected by phosphates. 1. Influence of Sodium chloride and phosphates on the water retention of communited meat at various pH values. Food Technol. 16: 119.

8. Mahon, J. M. 1961. Tripolyphosphate-salt synergism and its effect on cured meat volume. Proceedings, Thirteenth Research Conference, Am. Meat Inst. Foundation, Chicago, IL March 23-24.

9. Sherman, P. 1961a. The water-binding capacity of fresh pork. 1. The influence of sodium chloride, pyrophosphate and tripolyphosphate on water absorption. Food Technol. 15: 79.

10. Sherman P. 1961b. The water binding capacity of fresh pork. 3. The influence of cooking temperature on water-binding of lean pork. Food Technol. 15: 90.

11. Shults, G. W., Russell, D. R. and Wierbicki, E. 1972. Effect of condensed phosphates on pH, swelling and water-holding capacity of beef. J. Food Sci. 37: 860.

12. Shults, G. W. and Wierbicki E. 1973. Effects of sodium chloride and condensed phosphates on the water-holding capacity, pH and swelling of chicken muscle. J. Food Sci. 38: 991.

13. Shults, G. W. and Wierbicki, E. 1974. Effects of condensed phosphates on the pH, water-holding capacity and meat swelling properties of pork muscle. Tech. Rpt. TR-74-22-FL, U.S. Army Natick Labs., Natick, MA 01760.

14. Hamm, R. 1956. Fleischmineralien and Fleischqualität. Calcium, Magnesium und Zink und ihre Bedeutung fur Wassenbindung des Fleisches. Die Fleisch-wirtschaft 8: 240.

15. Timms, M. J. and Watts, B. M. 1958. Protection of cooked meats with phosphates. Food Technol. 12: 240.

16. Watts, B. M. 1954. Oxidative rancidity and discoloration in meat. Adv. Food Res. 5: 1.

17. Yasui, T., Fukasawa, T., Takahashi, K., Sukamishi, M. and Hashimoto, Y. 1964. Phosphate effects on meat. Specific interaction of inorganic polyphosphates with myosin B. J. Agr. Food Chem. 12: 399.

18. Mandigo, J. M. 1974. Restructured meat products. Proceedings, 27th Am. Reciprocal Meat Conference, Texas A & M Univ., College Station, Texas; 16-19 June: 403.

19. Wierbicki, E. and Heiligman, F. 1973. Shelf stable cured ham with low nitrite-nitrate additions preserved by radappertization. Proceedings, Int. Symp. Nitrite in Meat Products, Zeist, The Netherlands, Sept. 10-14; PUDOC, Wageningen: 189.

20. Rahelic, S., Pribis, Vjera and Vicevic, L. 1974. The influence of mechanical treatment of cured muscles on some characteristics of pasteurized canned pork. 20th European Meeting of Meat Research Workers, Dublin, Ireland, 15-20 September.

21. Kamstra, L. D. and Saffle, R. L. 1959. The effects of a pre-vigor infusion of sodium hexametaphosphate on tenderness and certain chemical characteristics of meat. Food Technol. 13: 652.

22. Neraal, R. and Hamm., R. 1973. Enzymic breakdown of added tripolyphosphate and diphosphate in meats. 19th European Meeting of Meat Research Workers, Paris, France, 2-7 September.

23. Wierbicki, E., Kunkle, L. E. and Deatherage, F. E. 1957. Changes in the water-holding capacity and cationic shifts during the heating and freezing and thawing of meat as revealed by a simple centrifugal method for measuring shrinkage. Food Technol. 11: 69.

24. Anellis, A. and Werkowski, S. 1968. Estimation of radioresistance values of microorganisms in food products. Applied Microbiol. 16(9): 1300.

25. Peryam, D. R. and Pilgrim, F. J. 1957. Hedonic scale method for measuring food preferences. Food Technol. 11(9), Supplement: 9.

26. Tarladgis, B. G., Watts, B.M. and Younathan, M.T. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Am. Oil Chem. Soc. 37: 44.

27. Steel, R. G. and Torrie, J. H. 1960. "Principles and Procedures of Statistics". McGraw-Hill Book Company, New York.

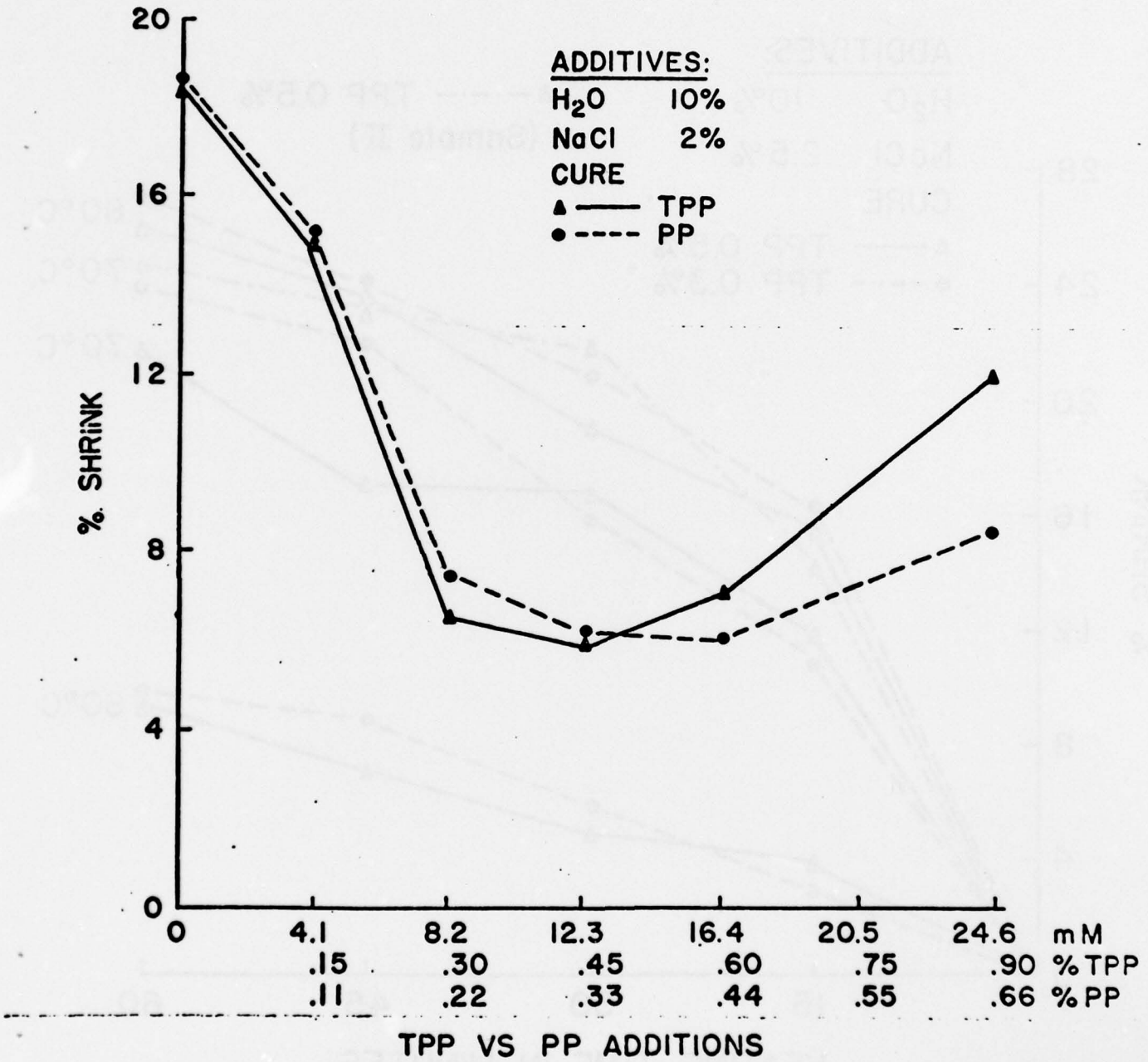

FIGURE 1 - EFFECT OF SODIUM TRIPOLYPHOSPHATE (TPP) VERSUS EQUIVALENT ADDITION OF SODIUM PYROPHOSPHATE (PP) ON THE SHRINK AT 70°C OF CURED HAM MEAT.

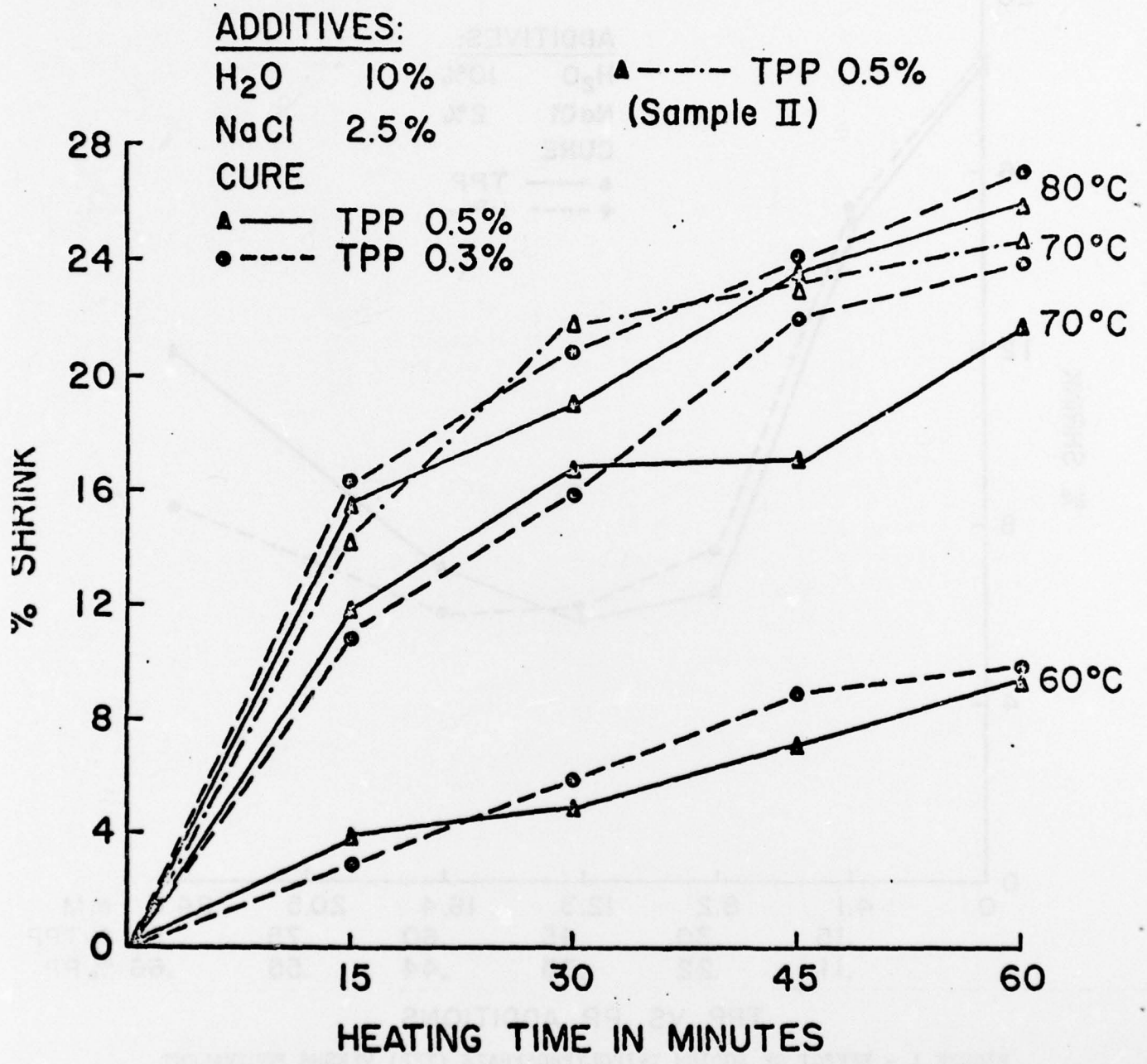

FIGURE 2 - EFFECT OF HEATING TIME AT 60°, 70° AND 80°C ON THE SHRINK OF CURED HAM MEAT WITH ADDED 0.5% VERSUS 0.3% SODIUM TRIPOLYPHOSPHATE (TPP)

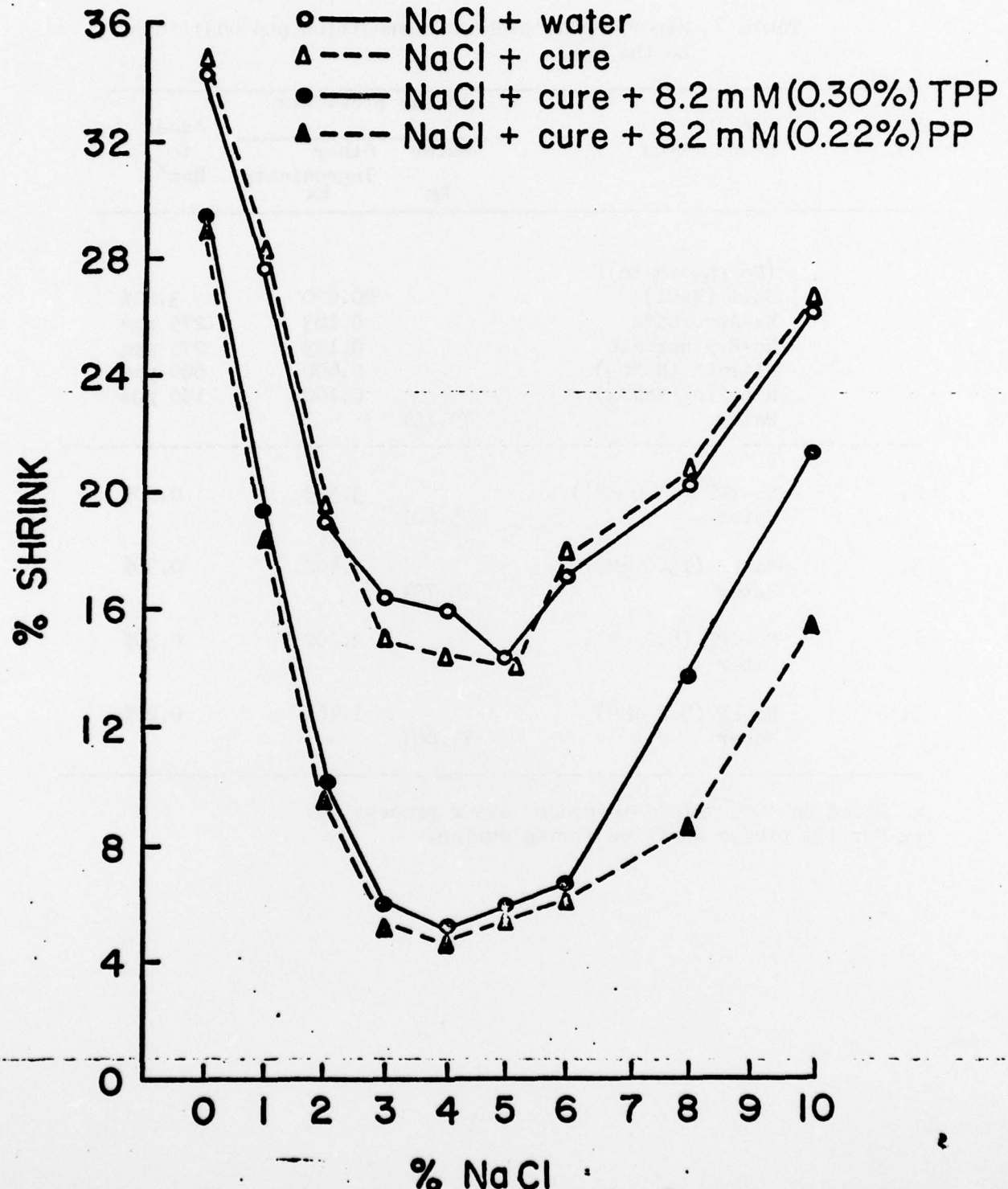

FIGURE 3 - EFFECT OF SALT (NACL) ON THE SHRINK AT 70°C OF HAM MEAT WITH ADDED WATER, CURE, AND 8.2 mM OF SODIUM TRIPOLYPHOSPHATE (TPP) VERSUS 8.2 mM SODIUM PYROPHOSPHATE (PP).

Table 1 Experimental pickles composition and additions to the ham.

Pickle No.	Pickle Composition	In the pickle:xx		Added to Ham[x]
		Water kg	Other Ingredients kg	
1.	(No phosphate):			
	Salt (NaCl)		20.000	3.00%
	Na-Ascorbate		0.183	275 ppm
	Na-Erythorbate		0.183	275 ppm
	Nitrate ($NaNO_3$)		0.400	600 ppm
	Nitrite ($NaNO_2$)		0.100	150 ppm
	Water	79.134		
2.	Na-TPP (13.6 mM[x])		3.333	0.50%
	Water	75.801		
3.	Na-PP (13.6 mM[x])		2.400	0.36%
	Water	76.734		
4.	Na-TPP (8.2 mM[x])		2.000	0.30%
	Water			
5.	Na-PP (8.2 mM[x])		1.467	0.22%
	Water	77.667		

x Based on 100% "yield-to-green" after processing.
xx For 15% pickle addition during curing.

Table 2 Effect of salt (NaCl) and sodium tripolyphosphate (TPP) versus sodium pyrophosphate (PP) on pH and shrinkage at 70°C of lean ham meat.

Additives: Amounts added to meat.	0% NaCl		1.0% NaCl		2.4% NaCl	
	pH	% Shrink	pH	% Shrink	pH	% Shrink
10% Tap water	6.1	31^{b}	6.0	18^{cd}	6.1	11^{def}
0.5% (13.6mM) TPP	6.3	16^{cde}	6.3	7^{f}	6.3	5^{f}
0.3% (8.2 mM) TPP	6.2	22^{bc}	6.3	11^{def}	6.3	4^{f}
0.36% (13.6 mM) PP	6.3	17^{cde}	6.4	7^{f}	6.3	6^{f}
0.22% (8.2 mM) PP	6.3	27^{ab}	6.3	12^{cdef}	6.3	7^{f}

Significance ($P < 0.01$)

Numbers with the same letters are not significantly different from each other.

Table 3 Effect of salt (NaCl) and sodium trpolyphosphate (TPP) versus sodium pyrophosphate (PP) in the presence of other curing ingredients on the pH and shrinkage at 70°C of lean ham meat.

Curing Ingredients: (Amounts added to meat)	Curing Soln. pH	Meat pH	Meat %Shrink
Curing Solution (cure)*	6.1	6.0	29[a]
Cure 1.0% NaCl 0.5% (13.6 mM) TPP	8.4	6.4	6
Cure 2.4% NaCl 0.5% (13.6 mM) TPP	8.4	6.3	3
Cure 2.4% NaCl 0.3% (8.2 mM) TPP	7.8	6.3	6
Cure 2.4% NaCl 0.36% (13.6 mM) PP	9.5	6.3	5
Cure 2.4% NaCl 0.22% (8.2 mM) PP	9.5	6.2	8[b]

*Curing Solution: 150 mg $NaNO_2$, 600 mg $NaNO_3$, 275 mg Na-ascorbate and 275 mg Na-erythorbate dissolved in 100 ml. water; 10 ml. solution per 100 g meat. Amounts added to meat: 150 ppm $NaNO_2$, 600ppm $NaNO_3$, 275 ppm Na-ascorbate and 275 ppm Na-erythorbate.

a. Significantly different from the other samples.

b Significantly different from the cure with 2.4% NaCl and 0.5% TPP.

($P < 0.05$)

Table 4 Effect of sodium tripolyphosphate (TPP) vs. sodium pyrophosphate (PP) on the yield of smoked hams.

Phosphates mM (%)	No. Rolls	Av. wt./roll, kg		Yields, % to:	
		Cured	Smoked	Cured	Green
TPP 13.6 (0.50)	4	10.29	9.04	87.9	101.1
PP 13.6 (0.36)	4	11.09	9.66	87.1	100.2
TPP 8.2 (0.30)	4	10.65	9.33	87.6	100.7
PP 8.2 (0.22)	4	10.20	8.81	86.4	99.4
None	4	10.64	9.03	84.9	97.6

Table 5 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on sensory characteristics of smoked ham, served cold.

Sensory Characteristic	TPP 13.6mM (0.50%)	PP 13.6mM (0.36%)	TPP 8.2mM (0.30%)	PP 8.2mM (0.22%)	No Phos	Sig Dif.
Color	7.0±1.48	7.4±0.78	7.5±0.70	7.5±0.71	7.2±0.93	NSD
Odor	7.1±1.11	7.5±1.00	7.1±1.14	7.5±0.87	7.4±0.86	NSD
Flavor	7.3±1.10	7.4±0.98	7.2±1.22	7.6±0.79	7.3±1.20	NSD
Texture	7.3±0.97	7.1±1.22	6.9±1.22	7.6±0.78	7.4±0.92	NSD
Appearance	6.7±1.45	7.2±0.99	7.1±1.09	7.4±0.99	7.1±1.14	NSD
Preference	7.0±1.34	6.8±1.25	6.8±1.35	7.4±1.05	7.1±1.14	NSD

Technological panel, n = 8 x 2

Mean scores, ± standard deviation

Table 6 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on sensory characteristics of smoked ham, served hot.

Sensory Characteristic	TPP 13.6mM (0.50%)	PP 13.6mM (0.36%)	TPP 8.2mM (0.30%)	PP 8.2mM (0.22%)	No Phos	Sig Dif
Color	7.1±0.83	7.0±1.06	7.3±0.66	7.1±1.30	7.2±0.63	NSD
Odor	7.5±0.50	7.4±0.58	7.5±0.50	7.5±0.61	7.5±0.50	NSD
Flavor	6.7±0.92	6.8±1.35	7.2±0.70	6.8±1.42	7.2±0.78	NSD
Texture	7.1±0.69	7.1±0.97	7.5±0.50	7.4±1.16	7.2±0.81	NSD
Appearance	7.4±0.78	6.7±1.45	7.5±0.61	7.1±1.56	7.3±0.68	NSD
Preference	6.6±1.06	6.7±1.54	7.2±0.73	6.8±1.63	7.0±0.83	NSD

Technological panel, n = 8 x 2

Mean scores, ± standard deviation

Table 7 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on sensory characteristics of irradiated (3.3-4.1 Mrad at -30°±10°C) smoked ham, served cold.

Sensory Characteristic	TPP 13.6mM (0.50%)	PP 13.6mM (0.36%)	TPP 8.2mM (0.30%)	PP 8.2mM (0.22%)	No Phos.	Sig. Dif.
Color	7.0±1.06	7.0±0.97	6.8±0.81	7.3±0.75	6.7±1.21	NSD
Odor	7.1±0.75	7.1±0.56	7.0±0.56	6.9±1.05	6.9±0.81	NSD
Flavor	6.3±1.15	6.6±0.93	6.7±0.92	6.7±1.10	6.5±1.37	NSD
Texture	6.8±1.03	7.1±0.75	7.1±0.79	7.2±0.73	7.0±0.87	NSD
Appearance	7.0±1.14	6.8±1.39	6.5±1.00	7.0±0.94	6.8±1.29	NSD
Preference	6.3±1.30	6.6±1.06	6.4±1.05	6.8±1.15	6.3±1.85	NSD

Technological panel, n = 8 x 2

Mean scores, ± standard deviation

Table 8 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on sensory characteristics of irradiated (3.3-4.1 Mrad at -30°±10°C) smoked ham, served hot.

Sensory Characteristic	TPP 13.6mM (0.50%)	PP 13.6mM (0.36%)	TPP 8.2mM (0.30%	PP 8.2mM (0.22%)	No Phos	Sig. Dif.
Color	6.8±0.95	6.3±0.90	6.4±1.45	6.9±0.78	6.7±0.86	NSD
Odor	7.3±0.66	7.2±0.78	7.0±0.79	7.0±0.75	6.8±0.73	NSD
Flavor	7.0±1.03	6.6±1.20	6.9±0.86	6.6±1.17	6.6±1.12	NSD
Texture	6.9±0.93	7.1±0.75	7.0±1.09	6.8±1.00	6.9±0.86	NSD
Appearance	7.1±1.09	6.7±1.27	6.6±1.77	7.2±0.81	6.7±0.98	NSD
Preference	6.6±1.06	6.5±1.32	6.5±1.11	6.5±1.22	6.4±1.36	NSD

Technological panel, n = 8 x 2

Mean scores, ± standard deviation

Table 9 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on preference of irradiated and nonirradiated (control) smoked ham.

Phosphate Additions	Served Cold		Served Hot	
	Mean ± Std. Dev. Irrad.[a]	Control	Mean ± Std. Dev. Irrad.[a]	Control
13.6 mM (0.50%) TPP	6.49±1.63	7.26±1.20	7.05±1.36	7.14±1.35
13.6 mM (0.36%) PP	6.37±1.61	6.71[b]±1.54	6.29[c]2.02	6.66±1.63
8.2 mM (0.30% TPP	6.34±1.33	6.89±1.60	7.00±1.83	7.00±1.46
8.2 mM (0.22%) PP	6.77±1.09	6.91±1.65	7.26±1.15	7.11±1.23
No phosphate	6.20±1.64	7.29±1.23	7.23±1.40	7.14±1.42
Sig. Difference	NSD	.05	.05	NSD

Consumer Panel n = 35

a 3.3-4.1 Mrad at -30°±10°C

b Sig. different from no phosphate sample.

c Sig. different from other four samples.

Table 10. Effect of irradiation on the preference of smoked ham.

Phosphate Additions	served[a]	n	Non-Irradiated Mean ± Std. Dev.	Irradiated[b] Mean ± Std. Dev.
13.6 mM (0.50%) TPP	C	35	7.26[c] ± 1.20	6.49 ± 1.63
	H	35	7.14 ± 1.35	7.05 ± 1.36
13.6 mM (0.36%) PP	C	35	6.71 ± 1.54	6.37 ± 1.61
	H	35	6.66 ± 1.63	6.29 ± 2.02
8.2 mM (0.30%) TPP	C	35	6.89 ± 1.60	6.34 ± 1.33
	H	35	7.00 ± 1.46	7.00 ± 1.83
8.2 mM (0.22%) PP	C	35	6.91 ± 1.65	6.77 ± 1.09
	H	35	7.11 ± 1.23	7.26 ± 1.15
No Phosphate	C	35	7.29[d] ± 1.23	6.20 ± 1.64
	H	35	7.14 ± 1.42	7.23 ± 1.40
Mean ± Std. Dev.	C+H	70	7.01[d] ± 1.37	6.70 ± 1.47

Consumer Panel

a C=Cold samples; H=reheated samples.

b 3.3-4.1 Mrad at $-30^{\circ} \pm 10^{\circ}$C.

c Sig. dif. from irradiated sample at .05 level.

d Sig. dif. from irradiated sample at .01 level.

Table 11 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on pH and TBA values of smoked, nonirradiated ham stored in open pouches at 2° to 3°C.

Phosphate Additions	1 week		2 weeks		4 weeks		6 weeks	
	pH	TBA*	pH	TBA*	pH	TBA*	pH	TBA*
13.6mM (0.50%) TPP	6.2	0.10	6.1	0.08	6.3	0.10	6.2	0.21
13.6mM (0.36%) PP	6.1	0.11	6.1	0.09	6.2	0.10	6.1	0.30
8.2mM (0.30%) TPP	6.1	0.13	6.1	0.07	6.2	0.08	6.2	0.15
8.2mM (0.22%) PP	6.2	0.11	6.2	0.07	6.3	0.14	6.4	0.10
No phosphate	6.0	0.09	5.9	0.11	6.1	0.15	6.1	0.19

* mg malonaldehyde per 1000 g ham.

Table 12 Effect of sodium tripolyphosphate (TPP) vs. equivalent additions of sodium pyrophosphate (PP) on pH and TBA values of irradiated and nonirradiated smoked vacuum-packed ham.

Phosphate Additions	1 Week				3 Months			
	Non-Irrad[a]		Irrad[b]		Non-Irrad[a]		Irrad[b]	
	pH	TBA[c]	pH	TBA[c]	pH	TBA[c]	pH	TBA[c]
13.6 mM (0.50%) TPP	6.3	0.10	6.3	0.18	6.2	0.12	6.2	0.16
13.6 mM (0.36%) PP	6.1	0.08	6.2	0.29	6.0	0.13	6.1	0.19
8.2 mM (0.30%) TPP	6.2	0.14	6.2	0.28	6.2	0.16	6.2	0.18
8.2 mM (0.22%) PP	6.3	0.07	6.4	0.18	6.2	0.12	6.2	0.20
No Phosphate	6.2	0.11	6.2	0.28	6.0	0.20	6.0	0.21

a Stored at -29°C

b 3.3-4.1 Mrad at -30° ± 10°C, stored at 21°C

c mg malonaldehyde per 1000 g ham.