6 - 41 EFFECTS OF LOW SODIUM CHLORIDE LEVELS AND SODIUM TRIPOLYPHOSPHATE ON THE SHELF-LIFE OF TEMPERATURE ABUSED MEAT PRODUCTS

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The contribution of NaCl in comminuted meat products is to extract myofibrillar proteins which coagulate and form a stable emulsion-type product. NaCl also contributes to flavor and antimicrobial activity. Sodium tripolyphosphate (STPP) is a common ingredient of phosphate blends used to improve the quality of meat products. Reduction of NaCl in meat products is popular these days due to reports implicating Na^+ in the development of hypertension. Since the antimicrobial activity of products with reduced NaCl and STPP is largely unknown, this study was designed to test the shelf-life of comminuted meat products formulated with varying NaCl levels and with STPP. Comminuted meat products were formulated with equal amounts of fresh lean (4.5% fat) bull meat and fresh pork trimmings (55% fat). Varying amounts of NaCl brine (3.7, 3.0, 2.1% NaCl in the water phase of the product) were tested in the absence and presence of 0.36% sodium tripolyphosphate (STPP). The meat batters of each of three replicate experiments were extruded into 30x105 mm test tubes (20/treatment); inoculated with heat activated (60°C, 15 min) Clostridium sporogenes PA 3679 spores (10/g); heat processed to 70°C; sealed with sterile vaspar; and, incubated at 20°C for temperature abuse. Reduction of the NaCl level, especially to 2.1% brine, resulted in high ($P<0.05$) product losses during thermal processing. STPP minimized weight and fat losses of low NaCl products. Initial cooked product pH values (6.10) were increased to 6.35 with STPP in the formulation. Growth of mesophilic anaerobic microorganisms; development of gas; and, product spoilage (putrefaction) were rapid in low brine (2.1%) products. Under these conditions, however, STPP did not delay microbial growth and gas production at any of the NaCl levels tested. Thus, even though STPP improves binding of low NaCl comminuted meat products, its antimicrobial activity appears to be doubtful when the products are abused (20°C) and their pH values are above 6.0.

INTRODUCTION

The possible involvement of sodium in hypertension has prompted various authorities to recommend reducing dietary intakes of salt (NaCl). Since certain cured meats contain relatively high amounts of Na^+ they are prime targets for lowering NaCl levels. As NaCl levels are reduced in meat products flavor, texture, binding and water holding capacity, as well as preservative capacity may be reduced (17, 20-22, 24, 28). The meat industry therefore may turn to the use of various polyphosphates to partially replace NaCl, especially now that polyphosphates are approved for use in a wider range of meat products in the United States (29).

The effectiveness of several polyphosphates in improving binding, water holding capacity and quality of various meat products has been reported by several researchers (5, 6, 19, 23, 27, 28). The preservative capacity of reduced NaCl/polyphosphate combinations, however, has not been clearly defined (3, 9, 15, 15, 22, 25, 31). Since most polyphosphates have alkaline properties, the pH of the cured meat system containing the reduced NaCl/polyphosphate combination may increase. This effect may increase the problem of reduced NaCl in regard to preservative capacity, since both NaCl reduction and increased pH tend to favor microbial growth.

Thus, the objectives of the present study were to study the shelf-life during abuse (20°C) of comminuted meat products formulated with varying levels of NaCl brine and with sodium tripolyphosphate (STPP).

MATERIALS AND METHODS

Processing: Frankfurter-type emulsions were formulated with equal amounts of fresh lean (4.5% fat) bull meat and fresh pork trimming (55% fat). Three levels of NaCl (2.4%, 1.8% and 1.2%) were tested both in the absence and presence of 0.36% STPP. Inclusion of STPP in the formulation raised the ionic strength of the 1.8% and 1.2% NaCl treatments to 0.42 and 0.31, respectively, which were equivalent to the ionic strength of the 2.4% and 1.8% NaCl levels tested alone. Other common ingredients were water (10%), ice (10%), corn syrup solids (0.5%), dextrose (0.5%), white pepper (0.25%), nutmeg (0.0625%), sodium erythorbate (0.03%) and sodium nitrite (0.01%).

The coarse ground lean bull meat, ice, salt and STPP (when used) were first chopped in a Meissner model VE bowl chopper (RMF Steel, Kansas City, Missouri) at high bowl speed and 4,000 rpm blade (six blades) speed for a constant time of 20 bowl revolutions. The other ingredients (pork trimmings, spice, nitrite, water) were then added and the mixture was emulsified to a final temperature of 15°C. The batters were extruded with a hand stuffer into 30 x 105 mm test tubes (25/treatment) and inoculated with heat-activated (80°C, 15 min) spores (10/g) of Clostridium sporogenes P.A. 3679. The spore inoculum was introduced with a syringe as a 0.5 ml suspension. The inoculum was sporulated according to the procedure described by Santo Goldini et al. (16). The inoculated test tubes were heated in an 80°C water bath to a final temperature of 70°C, sealed with sterile vaspar, and incubated at 20°C.

Testing: The total volume of material released and the fat separated during cooking of the batters in test tubes (4/treatment) were drained, collected and measured. Also the difference in product weight before and after cooking was determined. The difference in weight was expressed as percent weight loss, while the volume of total material and fat released were expressed as ml lost per 10 g of raw emulsion. Fat, moisture and NaCl concentrations in cooked batters were analyzed according to standard AOAC procedures (1). Raw and cooked batter pH values were determined in a 1:9 product:water blend with a Corning calomel electrode connected to a Corning model 125 pH meter.

After processing and during storage (20°C) products were analyzed for total mesophilic anaerobic (37°C, 24-48 hr) and total aerobic (22°C, 48 hr) counts. Samples of 30 g were blended with 270 ml of sterile peptone (0.1%) water and serially diluted with 0.1% peptone diluent. The dilutions were used to inoculate peptone yeast extract agar (4) in Lee tubes (11) and APT agar in plates for anaerobic and aerobic counts, respectively. Production of gas was visually checked on a daily basis and it was detected as air bubbles or separation of the vaspar from the product. Tubes with gas were checked for product breakdown and putrefaction.

Data Analysis: The study consisted of a complete 3 x 2 factorial design (3 NaCl levels x 2 STPP levels) with three replicates. The data were analyzed by analysis of variance and when the F values were significant, Fisher's least significant difference (LSD) was used to separate significant effects among treatment means. The gas production data from the three replicates were combined by computer and presented as percentage of tubes showing gas on specified days during storage (20°C).

RESULTS

Emulsion Losses: Losses during cooking (Table 1) increased ($P<0.05$) as the NaCl level was reduced to 1.2%. STPP prevented these losses. This was expected since STPP is the main ingredient of phosphate blends used in meat processing.

Table 1. Losses during cooking of meat batters in test tubes (Means ± SEM, 3 replicates).

Variable	NaCl (%) + STPP (%)						LSD
	2.4 + 0	1.8 + 0	1.2 + 0	2.4 + 0.36	1.8 + 0.36	1.2 + 0.36	(0.05)
Weight loss (%)	3.3 ± 0.7	4.1 ± 0.4	11.6 ± 2.0	2.4 ± 1.0	2.7 ± 0.8	2.6 ± 2.8	1.1
Total (ml/100g)	1.6 ± 0.4	2.3 ± 0.5	10.6 ± 1.1	1.2 ± 0.4	1.3 ± 0.4	1.2 ± 0.4	0.8
Fat (ml/100g)	0.3 ± 0.1	0.7 ± 0.2	3.5 ± 0.4	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.3

STPP, sodium tripolyphosphate; LSD, least significant difference.

Composition: Since the products were cooked in test tubes and no draining or appreciable dehydration was involved during cooking, fat and moisture contents were similar among the various

treatments (Table 2). Data from similar products cooked in frankfurter casings, however, have indicated that draining and dehydration during thermal processing resulted in significantly reduced fat levels when the NaCl level was low (1.2%). Pairs of treatments with and without STPP had similar levels of NaCl and brine ([% NaCl / % NaCl + % moisture] x 100) . This indicated manufacture of acceptable products that could be used for valid microbiological comparisons between treatments.

Table 2. Composition (%) of meat batters cooked in test tubes (Means ± SEM, 3 replicates).

	NaCl (%) + STPP (%)						LSD
Variable	2.4 + 0	1.8 + 0	1.2 + 0	2.4 + 0.36	1.8 + 0.36	1.2 + 0.36	(0.05)
Fat	25.9 ± 0.5	27.1 ± 0.6	25.8 ± 1.1	25.3 ± 1.9	26.2 ± 1.8	25.8 ± 0.3	1.3
Moisture	57.8 ± 0.6	57.1 ± 0.2	57.9 ± 0.4	58.1 ± 1.7	58.0 ± 1.8	58.5 ± 0.4	1.5
NaCl	2.3 ± 0.2	1.8 ± 0.1	1.2 ± 0.1	2.2 ± 0.1	1.8 ± 0.1	1.2 ± 0.1	0.1
Brine	3.8 ± 0.3	3.0 ± 0.1	2.1 ± 0.1	3.6 ± 0.2	3.0 ± 0.1	2.1 ± 0.1	0.2

STPP, sodium tripolyphosphate; LSD, least significant difference.

Product pH: Cooking resulted in pH increases of 0.13 units in the no-STPP treatments and 0.06 units in the treatments formulated with STPP (Fig. 1). Cooked pH values of treatments with STPP were 0.21-0.28 units higher than treatments with STPP. This increase in pH, however, which favors water and fat retention and improves yields may be detrimental to product shelf-life, especially in low NaCl formulations. With storage at 20°C, pH values decreased. These decreases, however, became significant ($P<0.05$) more rapidly in treatments with low NaCl (2.1% brine), irrespective of presence or absence of STPP.

Microbial Growth: Growth of mesophilic anaerobic and aerobic microorganisms was very rapid in the low brine (2.1%) cooked batters during storage at 20°C (Fig. 2 and 3). Within 4 days these counts reached levels above 10^6 CFU/g, while with 3.0% brine the counts were higher than 10^6/g in 7 days. At the regular brine level of 3.7% high counts (>10^6/g) were reached only after 12 days of storage. These results indicate that reduction of the presently used NaCl levels in products of this type may result in more rapid microbial growth. In addition, inclusion of STPP in the formulation did not delay microbial growth at a given NaCl level. Any influence that STPP may have on microbial growth was probably masked by the increase in pH caused by the addition of STPP to the formulation. Nielsen and Zeuthen (10) also found no influence of STPP on the growth of Brochothrix thermosphacta and Serratia liquefaciens in refrigerated bologna-type products. A low pH phosphate blend, however, was inhibitory. Roberts et al. (14) reported that 0.3% of a polyphosphate blend increased toxin production by Clostridium botulinum in a 5.5-6.3 pH pork slurry. In contrast, the same polyphosphate reduced botulinal toxin production in a pork slurry of pH in the range of 6.3-6.8 (15).

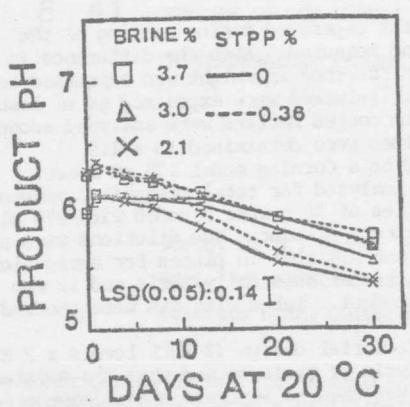

Fig. 1. Product pH during storage.

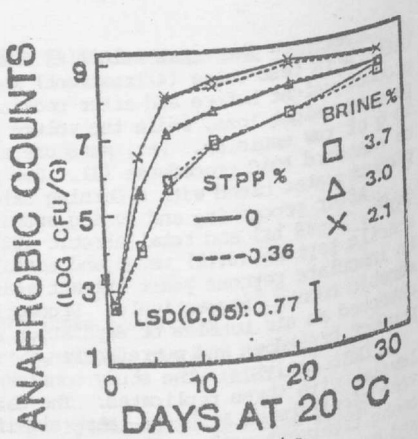

Fig. 2. Anaerobic counts.

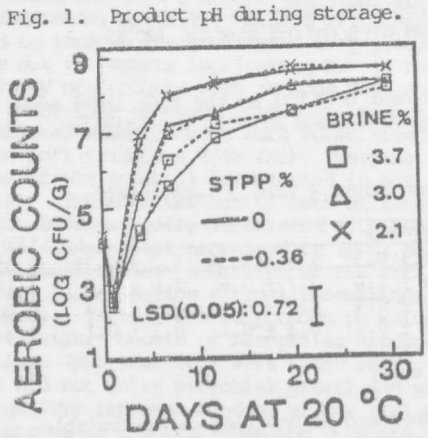

Fig. 3. Aerobic counts.

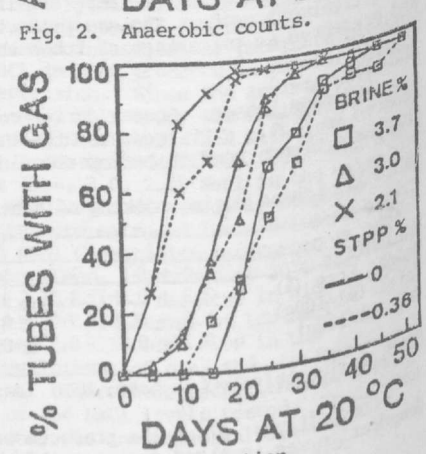

Fig. 4. Gas production.

Gas Production: Results on gas production indicated that with a reduction in brine rate of gas production increased (Fig. 4). Inclusion of STPP in the formulation did not reduce the rate of gas production. The results of Table 3 also indicate that gas production was initiated ($P<0.05$) faster in test tubes containing products with low brine (2.1%). STPP did not delay initiation of gas production at ary of the NaCl levels tested. It can therefore be concluded that reduction in the NaCl level by 25% and 50% resulted in shortened product shelf-life and possibly safety. STPP did not improve shelf-life. The pH of treatments with STPP, however, was higher and this may have contributed to the lack of antimicrobial activity by STPP.

Table 3. Days of storage (20°C) for detection of first gas (mean ± SEM, 3 replicates).

NaCl (%) + STPP (%)						LSD
2.4 + 0	1.8 + 0	1.2 + 0	2.4 + 0.36	1.8 + 0.36	1.2 + 0.36	(0.05)
20.7 ± 1.2	13.3 ± 4.0	6.3 ± 1.5	16.3 ± 4.0	13.3 ± 2.3	6.7 ± 2.1	3.8

STPP, sodium tripolyphosphate; LSD, least significant difference.

DISCUSSION

The results on emulsion stability are in agreement with the literature (12, 20, 21, 32) and demonstrated that when the NaCl level was reduced by 50% (1.2% NaCl) weight losses were very high. This indicates that it may not be technologically possible and economically feasible to make a product of this type with such a low NaCl level. The results also agree with the literature in that STPP reduced weight losses during processing even at the low NaCl level (2, 5-8, 13, 18, 26, 30, 33). Thus, low NaCl (50% reduction) comminuted meat products can be manufactured successfully when STPP is included in the formulation.

It was reported by Hamm (5) that the influence of polyphosphates on meat hydration is due to their effect on pH and ionic strength, and also due to some specific effects from interactions of the phosphate anion with the myofibrillar proteins. These specific polyphosphate effects may include dissociation of actomyosin, sequestering of protein bound alkaline earth ions, and a specific phosphate effect through binding with the meat proteins. The actual importance and contribution of these specific phosphate effects, however, has been disputed (5, 27, 28). Recent studies by Trout (26) indicated that ionic strength and pH were the major factors in improving the cook yield of beef rolls. Ionic strength explained 53.5-59.4% of the variation in cook yield; pH explained 24.7-30.5%; and, the polyphosphates explained 4.7-8.9% of the variation. Therefore, the major action of polyphosphates on yield was through their action on pH and ionic strength. At lower pH (<6.0), however, the specific polyphosphate effects may be significant in improving overall yield. At appropriate pH values, however, the ionic strength contribution and specific effect of even acidic phosphates may also be important in reduced NaCl formulations. Under the conditions of the present study, however, and since STPP increased both pH and ionic strength, it is safe to assume that its major influence was through this action. Thus, STPP can be a major component of phosphate blends in order to restore binding of low NaCl comminuted meat products even at low pH values.

The increase in pH, however, by STPP as well as the reduction in NaCl may be detrimental to product shelf-life. As the data indicated, even though STPP restored binding and resulted in successful manufacture of low NaCl meat products, it did not have any effect on antimicrobial activity. Any influence of STPP on antimicrobial activity may have been overshadowed by the increased pH.

In general, there is much confusion relative to the antimicrobial activity of phosphates in food systems (25). Some reasons for this confusion may be due to the influence of phosphates on pH; the presence or absence and levels of other inhibitors (NaCl, nitrite, etc.) in the system; differences between various phosphates, their chain length, dissociation, hydrolysis, etc.; microorganisms under consideration; specific meat or other food products; and environmental factors involved in the study. Additional studies are needed with different phosphates in order to derive specific blends that will improve both functionality and shelf-life of low NaCl comminuted meat formulations.

Therefore, meat processors should be careful in their attempts to manufacture products with low NaCl levels. As the data have indicated, such products may be manufactured successfully when the pH is sufficiently high and a polyphosphate (e.g., STPP) is included in the formulation. The shelf-life and safety of such products, however, may be reduced, and these formulations may need additional ingredients or adjustments in processing in order to improve their storage stability. Meat processors should also be careful when they reduce their NaCl levels and manufacture comminuted meat products with a "25-30 % reduction in salt" as has been the case in the U.S.A. As the data have indicated wher the pH is ≥ 6.00 a NaCl level of 1.5-2.0% will give a stable emulsion and a good quality product even without STPP. These data have also indicated, however, that the shelf-life of such products may be reduced.

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