Polyphosphate and pH interactions in comminuted meat products.

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Introduction

Various phosphates are used in foods to improve water binding, emulsification, yield, color, texture, flavor, etc. (Hamm, 1970; Shults et al., 1972; Mahon et al., 1970; Ellinger, 1972). In meat products, phosphates can affect the buffering capacity, sequester metal ions, and influence the system through their polyanionic properties (Steinhauer, 1983). They can, thus, improve cooking yields through binding and moisture retention; improve stability of cured meat color; and, decrease oxidative rancidity. In general, phosphates have been used in foods for fulfillment of specific functional objectives, while their influence on microbial growth has not been established (Tompkin, 1984).

The effectiveness of phosphates in improving water holding capacity in meat products is greater when used in combination with salt (NaCl) (Hamm, 1970; Shults and Wierbicki, 1973; Shimp, 1983; Trout, 1984). This has resulted in recent studies examining various phosphates as partial replacers of salt in meat formulations. Several recent publications have indicated that phosphates have improved cooking yields and maintained the quality of low salt meat products (Puolanne and Terrell, 1983; Whiting, 1984; Madril and Sofos, 1985a; Sofos, 1985). Madril and Sofos (1985a) studied six phosphates in a comminuted meat product with 1.25% salt and reported that cooking yields and product quality were improved with sodium acid pyrophosphate (SAPP), tetrasodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP) and sodium tetrametaphosphate (TTPP). Sodium hexametaphosphate (SHMP) and a longer chain glassy sodium hexametaphosphate (GHMP) did not improve the yield of the low salt formulation.

Even though phosphates have not been used for antimicrobial activity in meat products (Tompkin, 1984), several recent studies have examined their antimicrobial influence in conjunction with low salt or nitrite and sorbate formulations (Ivey and Robach, 1978; Roberts et al., 1981b; Nelson et al., 1983; Wagner and Busta, 1983; Madril and Sofos, 1985a). Other studies, however, reported no microbial inhibition by phosphates (Ivey et al., 1978; Roberts et al., 1981a; Sofos, 1985). Sodium acid pyrophosphate (SAPP) has been reported as one of the more effective phosphates in microbial inhibition (Nelson et al., 1983; Madril and Sofos, 1985; Molins et al., 1985a,b). In contrast, sodium tripolyphosphate (STPP) has shown limited antimicrobial activity in reduced salt meat formulations (Nelson et al., 1983; Nielsen and Zeuthen, 1983; Madril and Sofos, 1985a; Sofos, 1985).

While alkaline phosphates, such as STPP, increase pH of meat products, SAPP decreases pH values. Higher pH values are influential in improving binding of meat products, while reduced pH improves preservation. The action of phosphates, however, in improving meat binding has been attributed to increases in pH values and ionic strength (Trout, 1984). Phosphates that increase pH, such as STPP, have shown no major influence on the antimicrobial activity of reduced salt meat products, while acidic phosphates, such as SAPP, have improved both binding and preservation (Madril and Sofos, 1985a).

The objectives of these studies were to differentiate the effect of SAPP on the binding and antimicrobial activity of low salt comminuted meat products from the influence of a reduced pH on these parameters. Furthermore, studies were also designed to examine the influence of SAPP and STPP, tested in combination on a reduced salt formulation, on product binding and shelf-life.

Materials and Methods

The experiments to differentiate the effects of pH and SAPP on binding and shelf-life consisted of 5.5 kg meat emulsions manufactured in a Meissner, model VE bowl chopper (RMF Steel, Kansas City, MO). The influence of the SAPP and STPP combination was tested in 400 g batches emulsified in a Kitchen Aid mixer and a Sunbeam Le Chef food processor.

Ingredients: The meat formulations included lean (5% fat) beef (45%) and pork (55% fat) trimmings (55%). Salt levels tested were 1.2-1.3 and 2.4-2.5%; SAPP, 0.15, 0.30 and 0.50%; and STPP, 0.15 and 0.30%. Other ingredients included ice (8%), water (8%), dextrose (0.5%), corn syrup solids (0.5%), white pepper (0.25%), nutmeg (0.0625%), sodium erythorbate (0.03%), and sodium nitrite (0.01%). Regression equations were developed with miniature emulsions to determine the amount of acid (1 M HCl) or alkali (1 M NaOH) needed to achieve desired raw (5.6, 5.9, 6.2) and cooked product (5.7, 6.0, 6.3) pH values. These equations were developed according to procedures described by Trout (1984).

Processing: The ground meats and other ingredients were mixed and chopped to 13°C in the bowl chopper or the food processor. The emulsions were then extruded into 25 mm cellulose frankfurter casings and cans (208 x 108) provided by American Can Company. The small batch emulsions were extruded with a hand-stuffer into 30 x 105 mm and 16 x 150 mm test tubes. Product in cans and small test tubes was inoculated with a suspension of *Clostridium sporogenes* spores. The inoculum was introduced with a syringe as a 1 ml suspension per can, and a 0.5 ml suspension per test tube. The inoculum size was 50 spores per gram for the canned product and 1000 spores per gram for the product in test tubes. The frankfurters were cooked to 70°C in a smokehouse, while the cans and test tubes were heat processed to 70°C in a water bath. The inoculated tubes (capped with vaspar) and the cans were stored for temperature abuse at 27°C.

Testing: Cooking yields, pH and shear force were determined in products extruded in large test tubes, uninoculated cans, and frankfurters. Shelf-life (gas production) was evaluated with inoculated small test tubes and cans.

Frankfurters (color, texture and flavor) were evaluated by a 10 member panel on a 9-point hedonic scale (9 - like extremely; 1 - dislike extremely). Texture of frankfurters was also evaluated as the force (kg) needed to shear a 2 cm frankfurter sample (Madril and Sofos, 1985).

Proximate analysis and salt concentrations were determined according to standard procedures (AOAC, 1975). Weight losses were expressed as percent of initial raw weight. Inoculated test tubes and cans were monitored daily for gas production (swelling).

Statistical Analysis: The experiments were replicated 2-3 times and the results were analyzed by analysis of variance. Significant mean differences were determined with the LSD procedure.

Results and Discussion

Product Binding: Weight losses (%) increased as the initial pH of raw products decreased (Fig. 1). Cooking losses at pH values below 6.0 were similar. Increases in cooking losses were even more dramatic ($P<0.05$) at the salt level of 1.3% compared to 2.5%. Even at the low salt level, however, weight losses were acceptable when the pH value was 6.2, while at pH 5.6 the weight losses of even the 2.5% salt treatment were significantly ($P<0.05$) high (10%). At the same pH level (5.6), however, the 1.3% salt treatment had weight losses of 31%. These results indicate that meat emulsions of acceptable yield can be formed even with 1.3% salt when the pH value is high (6.2). In contrast, the weight loss of the treatment with 2.5% salt can be high if the pH is low (5.6). Thus, processors can form low salt meat products of acceptable yield if they can maintain a pH value above 6.0. Increased pH values, however, may be detrimental to product shelf-life.

Inclusion of SAPP in the low salt (1.3%) formulations reduced weight losses at all pH (5.6, 5.9, 6.2) levels tested (Fig. 1). At the pH of 5.6 the treatment with SAPP had a significantly ($P<0.05$) better yield than both the salt treatments (1.3 and 2.5%). Thus, SAPP improved cooking yields even at a low pH (5.6). The effect of SAPP was less pronounced at the pH of 6.2. At this high pH, however, the losses of the treatment with 1.3% salt were minimal. The treatment of 1.3% salt + 0.5% SAPP had an ionic strength equivalent to the treatment with 2.5% salt. Cooking losses of the SAPP treatments, however, were lower than the losses of the treatments with 2.5% salt. Therefore, the influence of SAPP in reducing cooking losses exceeded the influence of pH and ionic strength. This indicates that SAPP may have a specific phosphate ion effect in improving cooking yields, which exceeds the influence of changes in pH and ionic strength (Hamm, 1970; Trout, 1984). Thus, SAPP can improve meat binding even at lower pH values, and its influence is due to both an increase in ionic strength and a specific phosphate ion effect.

The improvement in binding with an increase in pH and presence of SAPP in the formulation is also indicated by the data on shear force (Fig. 2) and the proximate composition of the products (Table 1). The emulsions of lower binding (low pH, low salt) lost increased amounts of fat during cooking. The increased fat losses were reflected in the increases in protein and moisture contents on a percent basis (Table 1).

Table 1. Proximate composition.

Salt (NaCl %):	2.5	2.5	2.5	1.3	1.3	1.3	1.3	1.3	1.3
SAPP (%):	---	---	---	---	---	---	0.5	0.5	0.5
Raw product pH:	5.6	5.9	6.2	5.6	5.9	6.2	5.6	5.9	6.2
Fat	30.5^a	30.6^a	29.9^a	21.9^b	31.6^a	31.3^a	29.2^a	30.8^a	29.7^a
Moisture	53.4^a	54.0^a	55.0^a	59.0^b	53.3^a	54.5^a	54.8^a	54.3^a	55.5^a
Protein	12.1^a	11.3^a	11.0^a	16.0^b	12.1^a	11.5^a	12.3^a	11.4^a	11.4^a

Two replicates. Means in the same line with different superscript letters were significant at $P<0.05$. SAPP = sodium acid pyrophosphate

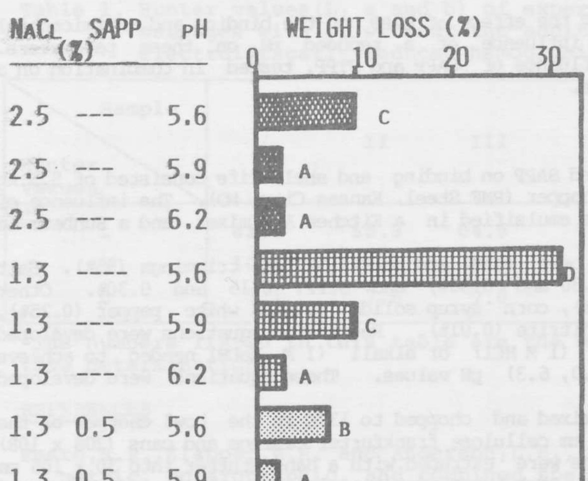

Fig. 1. Weight losses during cooking (70°C) of comminuted meat products formulated with varying levels (%) of salt (NaCl) and sodium acid pyrophosphate (SAPP) at different pH values (Two replicates; different superscript letters indicate significance at $P<0.05$).

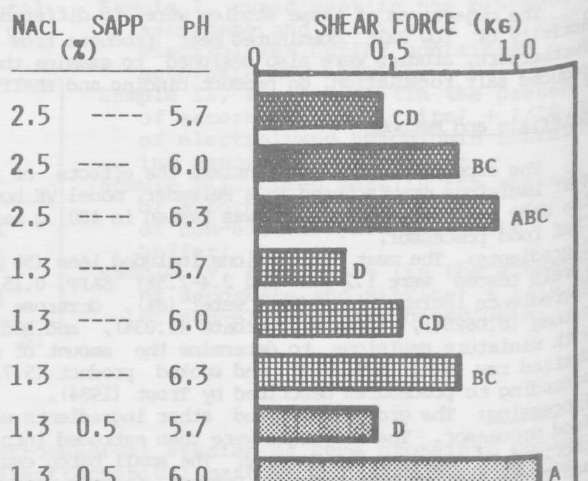

Fig. 2. Force (kg) needed to shear frankfurters formulated with varying levels (%) of salt (NaCl) and sodium acid pyrophosphate (SAPP) at different pH values (Two replicates; different superscript letters indicate significance at $P<0.05$).

The improvement in cooking yield with SAPP in the formulation of low salt (1.2%) is also demonstrated in the data of Figure 3. Weight losses, however, were significantly ($P<0.01$) lower in the treatment with 1.2% salt + 0.3% STPP. The pH of the treatment with STPP, however, was 6.25, while that of the treatment with SAPP was 5.69. In the absence of phosphate pH values were of 6.00-6.05, while the SAPP/STPP combination had a similar pH value (6.04). This SAPP (0.15%)/STPP (0.15%) combination had weight losses of 9.4% which were similar to the treatment with 2.4% salt (10.9%). This indicates that a combination of SAPP and STPP can be useful in low salt

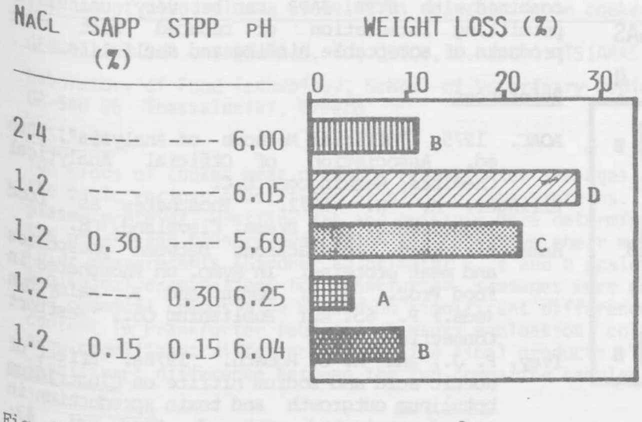

Fig. 3. Weight losses during cooking (70°C) of comminuted meat products formulated with salt (NaCl), sodium tripolyphosphate (STPP) and sodium acid pyrophosphate (SAPP). (Three replicates; different superscript letters indicate significance at P<0.01).

(1.2%) meat formulations, where it can improve binding, without increases in pH, which may be detrimental to shelf-life. Thus, such a treatment can take advantage of the beneficial effects of STPP on binding and the beneficial effects of SAPP on both binding and especially shelf-life.

Product Quality: Reduction in the salt level resulted in frankfurters of less acceptable color, texture and flavor. These results agree with previous findings (Sofos, 1983). Decreases in pH intensified the negative influence of low salt on product quality (Table 2). Addition of SAPP to the 1.2% salt level improved the quality of the low salt products, especially at the pH values of 6.0 and 6.3. In general, acceptability of frankfurters with 1.3% salt + SAPP was equivalent to frankfurters with 2.5% salt. Thus, SAPP can improve not only binding, but also the quality of meat products formulated with reduced salt levels.

Table 2. Sensory evaluation scores.

Salt (NaCl %):	2.5	2.5	2.5	1.3	1.3	1.3	1.3	1.3	1.3
SAPP (%):	---	---	---	---	---	---	0.5	0.5	0.5
Raw product pH:	5.7	6.0	6.3	5.7	6.0	6.3	5.7	6.0	6.3
Color	6.3	6.0	5.4	5.8	5.7	5.4	6.0	6.4	5.1
Texture	4.8^{ab}	6.5^{a}	5.7^{ab}	2.3^{bc}	4.4^{abc}	5.7^{ab}	3.5^{bc}	6.7^{a}	5.1^{ab}
Flavor	5.8^{ab}	6.7^{a}	5.5^{ab}	3.2^{ab}	4.9^{abc}	6.2^{abc}	4.4^{bc}	7.0^{a}	4.3^{bc}

Two replicates. Means in the same line with different superscript letters were significant at P<0.05. SAPP = sodium acid pyrophosphate. Evaluated on a 9-point hedonic scale (9 - like extremely; 1 - dislike extremely).

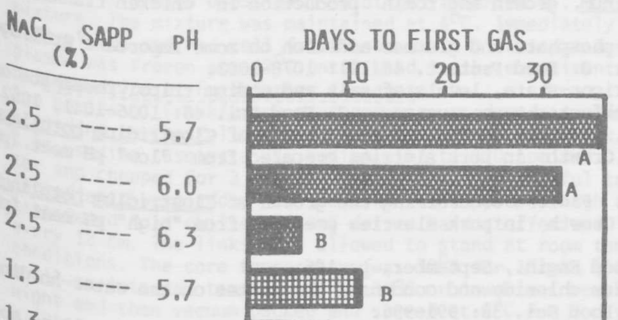

Fig. 4. Days of storage at 27°C for detection of gas in products inoculated with Clostridium sporogenes spores (50/g). (Two replicates; different superscript letters indicate significance at P<0.05).

Product Shelf-life: Production of gas in products inoculated with C. sporogenes spores and abused at 27°C was delayed with reduced pH values and increased salt level (Fig. 4). The 2.5% salt level, however was less effective in delaying gas production at pH 6.3 than the low salt level (1.3%) at pH 6.0 and 5.7. This demonstrates the danger involved in formulating meat products of high pH levels, in order to improve binding. Addition of SAPP improved shelf-life at all pH levels. It, thus, appears that in addition to binding SAPP also delays microbial growth and extends product shelf-life (Nelson et al., 1983; Wagner and Busta, 1983; Madril and Sofos, 1985a,b). The data of Figure 4 also demonstrate that the influence of SAPP in extending product shelf-life was in excess of the influence of reduced pH on microbial inhibition. Inhibition of gas production by SAPP was more pronounced at pH 6.0 compared to pH 5.7 and 6.3. This observation cannot be readily explained, but it may be related to the mechanism of antimicrobial activity by SAPP. Roberts et al. (1981a,b) also found a phosphate blend to be more effective against spoilage and Clostridium botulinum in a higher than a lower pH range.

As reported earlier (Sofos, 1985; Madril and Sofos, 1985a) STPP did not improve the shelf-life of the low salt (1.2%) treatment, while SAPP was effective in delaying gas production (Fig. 5). The combination of SAPP (0.15%) and STPP (0.15%) with 1.2% salt, however, was as effective as the 2.4% salt and the treatment with 0.30% SAPP in delaying spoilage. This finding, coupled with the high yield of the SAPP/STPP treatment (Fig. 3) demonstrates the potential usefulness of this combination in reduced salt meat products.

Thus, SAPP has a positive influence on binding, and especially, shelf-life that exceeds the effect due to changes in product pH. When combined with STPP, SAPP can be very useful in permitting formulation of reduced salt meat products of acceptable binding and shelf-life.

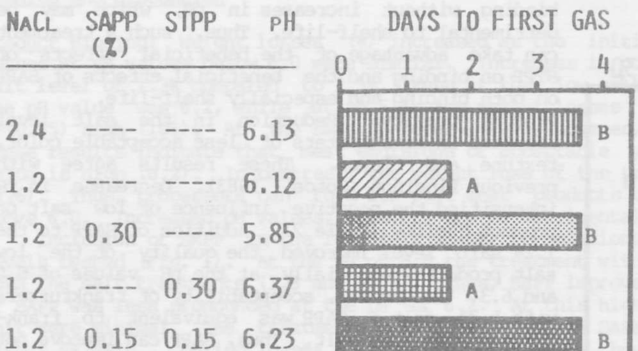

Fig. 5. Days of storage at 27^{o}C for detection of gas in products inoculated with Clostridium sporogenes spores (1000/g). (Three replicates; different superscript letters indicate significance at P<0.01).

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