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The Effect of Sodium Hexametaphosphate on the Palatability of the Freeze-Dried Chicken

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THE EFFECT OF SODIUM HEXAMETAPHOSPHATE ON THE PALATABILITY OF THE FREEZE-DRIED CHICKEN

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

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INTRODUCTION

Freeze-drying has been generally regarded as the mildest method known for drying meats, but even this process has caused undesirable changes in meat quality. The texture of rehydrated freeze-dried meat has been found to be tougher and drier than untreated meats. In addition, the meat may have a "woody" texture. Apparently something has occurred during the freeze-dry process that reduced the water-holding capacity of the meat. This has been reflected in the meat's inability to become fully rehydrated.

Sodium hexametaphosphate (SHMP) has been used successfully to increase the water-holding capacity of meat and fowl. No study has been conducted to ascertain if SHMP might have a similar effect on freeze-dried chicken meat. The present study was undertaken to determine the effect of SHMP on the palatability of freeze-dried chicken meat.

REVIEW OF LITERATURE

Introduction of Freeze-Drying

The establishment of specific conditions of temperature and pressure in high vacuum, whereby the physical state of a food substrate could be maintained at a critical point for successful dehydration with greatly improved rehydration potentialities, was developed by Desrosier (1963) and called freeze-drying. The term freeze-drying has been used in a very loose sense. If accurately defined, Greaves (1961) has indicated it must be the drying by sublimation from a totally solid material. Under certain conditions water may exist as a liquid, solid, and/or vapor. The intersection of the three phase boundaries has been called the triple point. At 0.01° C, and with a pressure of 4.7 mm of mercury, water is in such a condition. The freeze-drying process has been designed to have water molecules pass from a solid phase to the vapor phase without passing through the liquid phase. The process has consisted of removing moisture from a frozen food without thawing. It has been done in a room, cabinet or chamber where heat has been applied to the food as low pressures have removed the water vapor. The food is kept frozen during the entire process (Desrosier 1963).

Freeze-drying, also known as lyophilization, was introduced in early 1926 by Carr, as a method of treating glands for pharmaceutical purposes and was developed during the second World War. It was a slow and expensive process and applied only to labile materials of high value such as pharmaceutical blood plasma and later penicillin (Birk 1964).

Luyet (1961) described freeze-drying as a three stage process. The first stage, freezing, resulted in a separation of water from the tissue in the form of ice crystals. During the second stage ice crystals were caused to sublime thus removing the water which had already separated from the tissue. The third stage was characterized by evaporation of residual water.

Effect of Freeze-Drying on Meat Quality

Freeze-drying of foods has been commercially established and bids to become a significant means for processing foods within the next decade (Heid and Joslyn 1967). Hamdy et al. (1958) pointed out that the drying texture and the decrease of meat hydration is one of the principal problems in the field of lyophilization of meat. Brockman (1962) also found freeze-drying of foods frequently results in rehydrated products which are characterized as dry, spongy, and tough with decreased acceptability. Connel (1957) stated that rehydrated meat was often tougher and drier than the original meat, and in addition, had a characteristic "woody" texture. These texture characteristics were usually ascribed to decreased ability of the meat protein to take up moisture during rehydration.

A great deal of research is presently being conducted on freeze-dehydration. However, the only major commercial application of freeze-dried chicken has been in the manufacture of dehydrated soups. The flavor of freeze-dried chicken used in dehydrated soups has been very satisfactory but the tenderness of the rehydrated meat has often been affected adversely. Seltzer (1961) found that the freeze-drying of a meat product such as chicken required unusual care or the product would be tough and stringy with poor shelf life. Only very tender chicken meat of excellent quality deserved the high cost of freeze-drying. He also pointed out that any method of drying, including freeze-drying, tended to toughen chicken meat. Harper and Tappel (1960) believed the freeze-drying can produce chicken of reasonably good rehydration characteristic that can be cooked by ordinary methods and yield a ready-to-eat product of good color and flavor. However, it has a dry texture and is tough.

Effect of pH and Water-Holding Capacity on Meat Quality

Hamm and Deatherage (1960) pointed out that quick freezing of raw muscle tissue did not decrease the hydration of muscle nor cause protein denaturation. They studied the denaturation of meat by means of determining the water-holding capacity, the buffer capacity at different pH values, and the measurement of the quantity of dyes bound by the acidic and basic groups of muscle proteins. Connell (1961) believed freeze-dried raw meat and fish were, after reconstitution and cooking, distinctly tougher and less juicy than untreated cooked controls. The toughness developing during freeze-drying appeared to be associated with a loss of the water-holding capacity of the muscle. The water-holding capacity, according to Connell (1961), meant the ability of the muscle protein to hold water firmly in the form of a gel.

Hamm (1960) found the decrease of meat hydration was caused by drying and occurred only in the pH range from 4.5 to 6.5. The maximum decrease of the water-holding capacity was at approximately pH 5.0. At pH 6.0-6.5 and pH 4.5 meats had the same ability to rehydrate as fresh meat. These results indicated that in the isoelectric range of dried meat less charged protein groups were available for binding water than in the fresh muscle. The decrease of negative protein charges results at pH value I.P.

He pointed out that quick-freezing of muscle did not decrease the hydration of muscle nor cause protein denaturation. Quick-freezing caused a very small but significant increase of the water-holding capacity of meat. Hamm (1960) postulated that this was probably a mechanical loosening of tissue structure due to the formation of tiny ice crystals inside the cells. The "loosening" of protein structure produced by quick-freezing caused a small increase of free protein charges available for binding water. Thus, the influence of freeze-drying on the water-holding capacity of meat was not due to the freezing process but to the process of dehydration.

Bendall (1946) found that meat with a high pH had a higher water-holding capacity when heated than meat heated at its normal pH. Therefore, the network of new cross linkages formed by heat denaturation could not completely overcome an increase of hydration caused by the lowering or rising of the pH of raw meat. Hamm (1959) found a relationship existed between water-holding and swelling capacity of meat. The cause of both was the interaction between meat protein and water.

Grau (1953) found that the water-holding capacity of meat was very low at the normal pH of meat which he gave as being about 5.5. He stated that the isoelectric point of meat was about 5.0 and at the normal pH the net charge of muscle protein was at a minimum. He found that by the addition of a base the water-holding capacity increased. A reverse effect was caused by the addition of acid. Swift et al. (1959) also found that increasing pH increased water retention.

Suden et al. (1964) pointed out that rehydration of the freeze-dried fillets was not influenced by either pH of the hydrating solution or pH of the meat. Fat content had little effect on rehydration. An increase in pH was noted during the dehydration process.

Miller et al. (1968) indicated that the water-holding capacity was lower at pH 5.5 than at higher pH values. The mean value for water-holding capacity was the greatest for the samples having the highest pH. There was a decrease in the water-holding capacity as the fat level of the meat was increased due to the increase in the moisture to protein ratio.

Hamm (1959) stated that grinding increased the meat water-holding capacity by increasing the number of polar groups available for binding with the water molecule and water was bound better when added after the meat was ground. Swift et al. (1959) found that the relative ability of muscle to hold added moisture was predictable on the basis of the original proportions of moisture and protein. These workers found that water retention was inversely related to protein content and the ratio of moisture to protein was directly related to water retention. Juiciness and tenderness varied more with the changes in moisture content than in fat content.

Chemical Properties of Sodium Hexametaphosphate

Clark (1966) stated that sodium hexametaphosphate, also called sodium polymetaphosphate, has a chemical formula $Na_6P_6O_{18}$ or $Na_6(PO_3)_6$ and a molecular weight of 612. It has been derived from Graham's salt $(NaPO_3)_n$ and obtained when any form of sodium metaphosphate has been melted and then allowed to solidify. It has been known for many years that the polyphosphates are strong complexing agents. Modern theory of polyelectrolytes, as supported by experimental studies on a number of such substances, indicated that all polyelectrolytes tended to bind their counter ions firmly. This action has been cited (Clark 1966) to be working in the case of the polyphosphates, and in addition, there also appeared to be a specific complexing activity which could be attributed to one or two individual PO_4 groups. In general, it has been found that the chain phosphates (especially the longer-chain materials) formed complexes with a wide variety of cations.

In studying the ionization behavior of some polymetaphosphates, Betra (1965) found the degree of ionization of some sodium polyphosphate used in the food industry was determined with sodium ion electrodes. The degree of dissociation of the polyphosphates was inversely proportional to the number of P atoms in the chain or the ring of the polyphosphates.

Effect of Sodium Hexametaphosphate on the Water-Holding Capacity of Meat

Morse (1955) studied the effect of phosphates on meat. He pointed out that by changing the pH the phosphates increased water-holding capacity and appeared to improve emulsification of fats. Advantages of the use of polyphosphate include less cook-out of juice, less "shrink" or "purge". In carefully controlled experiments this was as high as an additional 5% retained juice. Morse also cited the improved ham color, fat-pocket elimination, and the higher moisture. Hall (1955) stated that by the use of molecularly dehydrated phosphates undesirable changes in color of cured meat was inhibited. Brissey (1955) found that the addition of a mildly alkaline salt would increase the pH of the meat and reduce the "shrink", "purge", or "cooked out" of smoked or canned hams and other cooked and cured meats.

Grau (1955) pointed out that the water retention of meat was dependent upon pH and mineral content. He stated that at a high pH meat has good water retention and that this retention dropped with a lowering of the pH and was at its lowest at pH 5.5. He stated further that many salts, such as sodium chloride, phosphates, citrates, and lactates, produced a "swelling" or "imbibition" in meats.

Dopner (1955) observed that hexametaphosphates did not permit sausage meats to retain an overload of added water. However, when the water was increased, more water was lost during cooking.

Bendall (1958) observed marked differences in the volume of ground meat treated with a polyphosphate solution as compared with the volume of ground meat treated with polyphosphate plus sodium chloride. He suggested that these volume differences could be explained in terms of the difference in ionic strength of the two solutions since they both had the same pH. Phosphate was regarded as having a specific swelling effect on lean meat. The chief structural protein actin and myosin united after the animal's death to form rigid and inextensible filaments of actomyosin. Actomyosin could be split into its component protein, actin and myosin, by treatment with polyphosphate. Only pyrophosphate and tripolyphosphates showed a specific effect, resulting in a water-binding effect greater than was obtained by salt alone.

Hellendoorn (1962) claimed that one of the main functions of the phosphate salts should be their promotion of the water-binding property of meat. From his experiments with cation exchangers Hamm (1955) concluded that calcium caused the meat to form bridges between the protein fibers and this played an important part in meat hydration.

Displacement of bound calcium by sodium, by means of ion exchange or by precipitation, would give rise to greater hydration. Grau et al. (1953) pointed out that in the same way the promoting effect on swelling by polyphosphates could by explained.

Hellendoorn (1962) concluded that the water-binding was enhanced by the addition of the phosphates on the alkaline side of pH 7 but is depressed on the acid side of pH 7. The addition of phosphate salts has increased in both cases the ionic strength. He confirmed the conclusions of Klotter (1961) that the polyphosphates resulted in a diminution of the swelling of meat when cold but augmented swelling after heating. Hellendoorn further stated that instead of the positive effect expected, a marked depressing effect on the water-binding was observed with a higher concentration of the salt. The cause of this depression was not clear. He concluded that the elimination of the calcium from the meat has nothing to do with water-binding capacity. Inklaar (1967) demonstrated by dialysis and extraction centrifugation procedures, with and without the addition of phosphates, that phosphates do not complex with the calcium-bound to meat proteins. Inklaar's results indicated that about 60% of the calcium and 20% of the magnesium naturally present in meat were firmly bound to the meat proteins and were not available to react with added phosphates.

Popp and Muhlbrecht (1958) took the view that polyphosphates did not increase the water absorption capacity of meat, but on the contrary, they merely restored the water absorption ability possessed before slaughter of the animal. Klotter (1961) supported this belief. Klotz (1951) stated that the high pH value of alkaline polyphosphate changed the protein configuration and led to a binding of the potassium and sodium ions by proteins. Sherman (1961) found the addition of sodium chloride, tetrasodium pyrophosphate or alkaline polyphosphate improved fluid retention of meat. The phosphates were particularly effective, but this was not attributed to their ability to complex calcium and magnesium ions. Fluid retention was related to anion absorption of the phosphate solutions. Fluid retention at 0°C showed a significant statistical correlation ($P > 0.05$) with pH of the aged solution-meat mixture. The pH also influenced the degree of solubility of actomyosin. The ionic strength of the solutions employed was important only in so far as it controls the rate of ion absorption by the meat. The greater the ionic strength the greater the absorption of ions. In all tests Sherman conducted, irrespective of the additive used, water retention increased linearly with the increase of anion and cations absorbed. Polyphosphate produced greater water retention per unit concentration of anions or cations absorbed than did sodium chloride or magnesium chloride.

Dopner (1955) found that cooked phosphate-treated sausage showed less shrink than untreated sausage due to retention of juices during boiling. Reiner (1955) emphasized the effect of phosphates on muscle swelling and water-binding. Swelling was produced by phosphates and citrates due to binding magnesium and calcium from the meat thus enabling the meat to increase water absorption. He decided that the "phosphate effect" was due to pH-increasing and salting actions especially at a higher pH. Fat emulsification and viscosity were considered of minor importance.

Morse (1955) claimed that the pH adjustment of intact meat to 7.0-7.4 enabled meat fibers or proteins to hold their normal water content, although certain phosphates have a marked effect on viscosity of proteins in aqueous solution. Even though certain phosphate salts, especially trisodium phosphate, were good emulsifiers, there was doubt that the effect on fat was the principal benefit to be derived. In addition to the increase in water-holding capacity brought about by pH change with the use of phosphate, there was some effect upon the surface characteristics of meat. The citrates and phosphates showing the best results in comminuted meats were also good metal-sequestering agents.

Application of Sodium Hexametaphosphate

Kamstra and Saffle (1959) reported on the effects of a prerigor infusion of sodium hexametaphosphate on tenderness and certain chemical characteristics of meat. These results indicated highly significant differences ($P > 0.01$) in tenderness of hams infused with SHMP versus hams infused with water only. The pH and color were improved by adding acid to the SHMP infusion. The glycogen level of treated hams was higher than the control hams after 72 hours.

Carpenter et al. (1961) reported on cow rounds infused with 10, 15, and 20% solutions of SHMP and a 15% solution plus various levels of lactic acid. Tenderness, as reported by taste panel, and shear-press values were improved by pre-rigor infusion of all solutions and no one level improved tenderness more than any other level.

Rust (1963) injected 2-inch steaks with a 0.03 M solution of sodium hexametaphosphate equivalent to 0, 5, 10, and 15% of the weight of the steaks; the 10% quantity of SHMP enhanced flavor and increased juiciness and tenderness.

Miller and Harrison (1965) marinated steaks in 0.03 M sodium hexametaphosphate solution for 1, 2, or 6 hours and reported that marination was of little value in improving the eating quality of the steaks.

Spencer (1962) chilled chicken fryer carcasses for six hours in ice water containing 10 oz. of polyphosphate per gallon of water. The rate of microbial spoilage was found to be less for the polyphosphate treated chickens when determined by plate count, ultra violet, fluorescence, and off-odors. Shelf-life was increased by 1-2 days. Polyphosphate treated meat resulted in greater tenderness and juiciness but there were no significant differences in flavor and shear-press measurements.

May et al. (1962) chilled eviscerated chicken carcasses in 0, 4, 8, and 10 ounces of Kena phosphate mixture per gallon of slush ice solutions for 6 hours. They found that water uptake of the carcasses during chilling was significantly greater for low-level (4 oz./gal.) phosphate solution than for any other treatment. Water uptake of carcasses in high-level (10 oz./gal.) phosphate solution was significantly lower than that in the other treatment. During cutting up of carcasses all phosphate-treated groups lost significantly more weight than the controls and phosphate treatment significantly reduced weight loss of cut up carcasses during storage. Treatment did not significantly influence flavor of white or dark meat but treated groups had higher mean flavor scores. In both cases, the high-level (10 oz./gal.) phosphate treated groups gave significantly juicier and more tender white meat than other groups.

Klose et al. (1963) found that the water absorption during chilling of the chicken carcasses was appreciably less for the polyphosphate-treated carcasses than for the controls but moisture retention in the cooked meat was 2 to 5% greater. Polyphosphate reduced the drip and caused a color change in the chilled carcasses but not in the cooked meat. It produced a small but statistically significant reduction in shear-force value of the cooked meat for chicken fryers. Differences in taste might have been associated with a slight saltiness imparted by the polyphosphates.

EXPERIMENTAL PROCEDURE

Thirty-six chicken breasts, purchased at a local market, were used for this investigation. The investigation consisted of two separate studies. The breasts were coded and assigned to study and treatment within study using a table of random digits.

Study I

Treatment and Preparation. Four breasts were used for each cooking period and a cooking period required 3 days to complete. Each breast received a different treatment.

The breasts assigned to Treatment 1 were marinated for 12 hours at a temperature of 4° C. The marination solution was a 25% sodium hexametaphosphate (SHMP) solution which was prepared fresh for each cooking period.

Breasts assigned to Treatment 2 were not marinated in any solution prior to further preparation.

Breasts assigned to Treatment 3 and 4 received no marination in SHMP at any time.

On the second day of each cooking period the breasts receiving Treatment 1, 2, and 3 were cooked and freeze-dried. Treatment 1 breasts were removed from the SHMP solution, placed on a wire rack and allowed to drain for 2 minutes. All samples were then cooked in individual pans in actively boiling water until the interior of the breast muscles reached a temperature of 88° C. Individual thermocouples were used for this measurement. The breasts were removed from the pans, placed on wire racks and allowed to reach ambient temperature. Each breast was then boned, skinned and cut into 13 mm cubes.

The samples were then freeze-dried in a Virtis freeze-dryer for 18 hours using a vacuum of 90 microns, a shelf temperature of -40° C, a condenser temperature of -45° C, and a stimulated heat energy at temperature of 15° C. A built in thermocouple system was used to determine temperatures of the samples.

At the completion of the freeze-dry process the samples were packed into individual polyvinyl bags and stored at 4° C until subjective and objective evaluations were conducted.

On the third day (evaluation day) of each cooking period breasts were cooked and cubed using the same procedure that was used for Treatment 2 and 3.

All freeze-dried samples required rehydrations. Treatment 1 and 3 samples were rehydrated for 10 minutes in water which had been brought to the boiling point and then removed from the heat. Treatment 2 samples were rehydrated in 500 ml of a 2% SHMP solution. This solution was brought to the boiling point, the cubes added and removed from the heat. The samples were rehydrated for 10 minutes. Following rehydration all samples were drained and prepared for evaluation.

Evaluation. The samples were subjectively evaluated by a trained panel consisting of six individuals. The samples were scored for appearance, aroma, flavor, tenderness and juiciness using a 7-point hedonic scale (Appendix, Form 1). The samples were coded and randomized in order to eliminate bias.

Objective measurements included shear-press as measured by a L. E. E. Kramer Shear-Press instrument, pH determinations made on slurries (10 gram sample and 100 ml of distilled water), and moisture by evaporation.

Statistical Design and Analysis of Data. A randomized complete block design was used for this study. Each cooking period comprised a block and the study consisted of 6 blocks, or replications. Data from each measurement were analyzed by means of the analysis of variance. Duncan's Multiple Range Test and Dunnett's Test were used to establish significant differences among means.

Study II

Treatment and Preparation. This second study consisted of three cooking periods or blocks. Treatments 5, 6, and 7 were separately marinated in 6.25, 12.50, and 18.75% SHMP solutions, respectively; using the method described for Treatment 1. Treatment 8 was identical to Treatment 4.

Evaluation. Identical evaluation measurements and methods were used for this part of the investigation as for the previously described part.

Statistical Design and Analysis of Data. A randomized complete block design was used for this study, also. Each cooking period comprised a block and the study consisted of 3 blocks or replications. Data from each measurement were analyzed as were the data of Study I.

RESULTS AND DISCUSSION

Results were analyzed by analysis of variance and significance of differences among means established by Duncan's Multiple Range Test and Dunnett's Test. The analysis of variance of organoleptic scores and measurement and evaluation of treatment means by Duncan's Multiple Test have been given in Tables I and II. Means tested by Dunnett's Test have been given in Tables III and IV. Changes in weight of samples for the various treatments attributable to cooking, freeze-drying, and rehydration have been expressed as percent change from raw samples. These are shown in Tables III and IV.

Tenderness

SHMP treatment did not significantly influence tenderness of the breasts but samples treated with 12.50% and 18.75% SHMP solution marination and 2% SHMP rehydration received identical mean tenderness scores and were slightly more tender than the plain freeze-dried samples. Mean tenderness scores for 12.50% SHMP treatment indicated that the treated samples were similar in tenderness to the fresh cooked control. This was in agreement with other studies. Rust (1963) reported that steaks injected with SHMP were significantly more tender than untreated steaks, but there were no significant differences in tenderness among steaks

Table I. Analysis of Variance for Freeze-Dried Chicken Breasts Treated With Sodium Hexametaphosphate.

Source of variation	Degree of freedom	Sum of squares	Mean squares	F-value	Mean
Cooking loss	7	299.339	42.762	15.16**	26.87
Moisture content after rehydration	7	200.301	28.614	2.26NS	66.42
pH of raw meat	7	0.070	0.100	1.94NS	6.20
Shear press	7	165.548	23.649	6.37**	10.87
pH after cooking	7	0.294	0.042	10.23**	6.41
Appearances	7	17.860	2.551	16.50**	4.93
Aroma	7	8.208	1.172	5.99**	4.40
Flavor	7	26.174	3.739	25.86**	4.15
Tenderness	7	3.452	0.493	1.94NS	5.07
Juiciness	7	8.699	1.242	10.40**	4.48

**Significant at the 0.01 level of probability
NS Not significantly different

Table II. Duncan's Multiple Range Test*

Treatment	Plain freeze-dried	Fresh cooked	Marinated	Rehydrated
Cooking loss %	29.81^a	29.23^a	23.14^b	30.13^a
Shear Press	13.72^a	8.76^b	11.48^{ab}	11.56^{ab}
pH after cooking	6.32^a	6.30^a	6.53^b	6.40^a
Appearance	5.36^a	5.82^a	4.06^b	4.76^a
Aroma	4.76^{ab}	4.95^a	4.00^b	4.46^{ab}
Flavor	4.10	5.58	3.26	3.33
Juiciness	4.24^a	5.43^b	3.92^a	4.36^a

*Like subscripts within a row are not significantly different.

Table III. Analysis of Variance for the Percent Moisture Loss, Percent of Rehydration, and pH after Rehydration of Freeze-Dried Chicken Breasts.

Source of variation	Degree of freedom	Sum of squares	Mean squares	F-value	Mean
Freeze-dry loss (%)	5	344.584	68.916	65.516**	74.32
Percent rehydration from sample	5	915.426	183.085	62.334**	63.44
pH after rehydration	5	0.254	0.509	19.339**	6.61

** Significant at the 0.01 level of probability

Table IV. Dunnett's Test

Treatment	Freeze-dry loss (%)	Percent of rehydration from the dried sample	pH after rehydration
Plain freeze-dried	70.53	54.14	6.43
25% SHMP-marinated	70.39	57.14*	6.65
6.25% SHMP-marinated	78.21*	67.79*	6.70*
12.50% SHMP-marinated	78.74*	69.78*	6.67
18.75% SHMP-marinated	77.31*	67.15*	6.57

*Significantly different from control

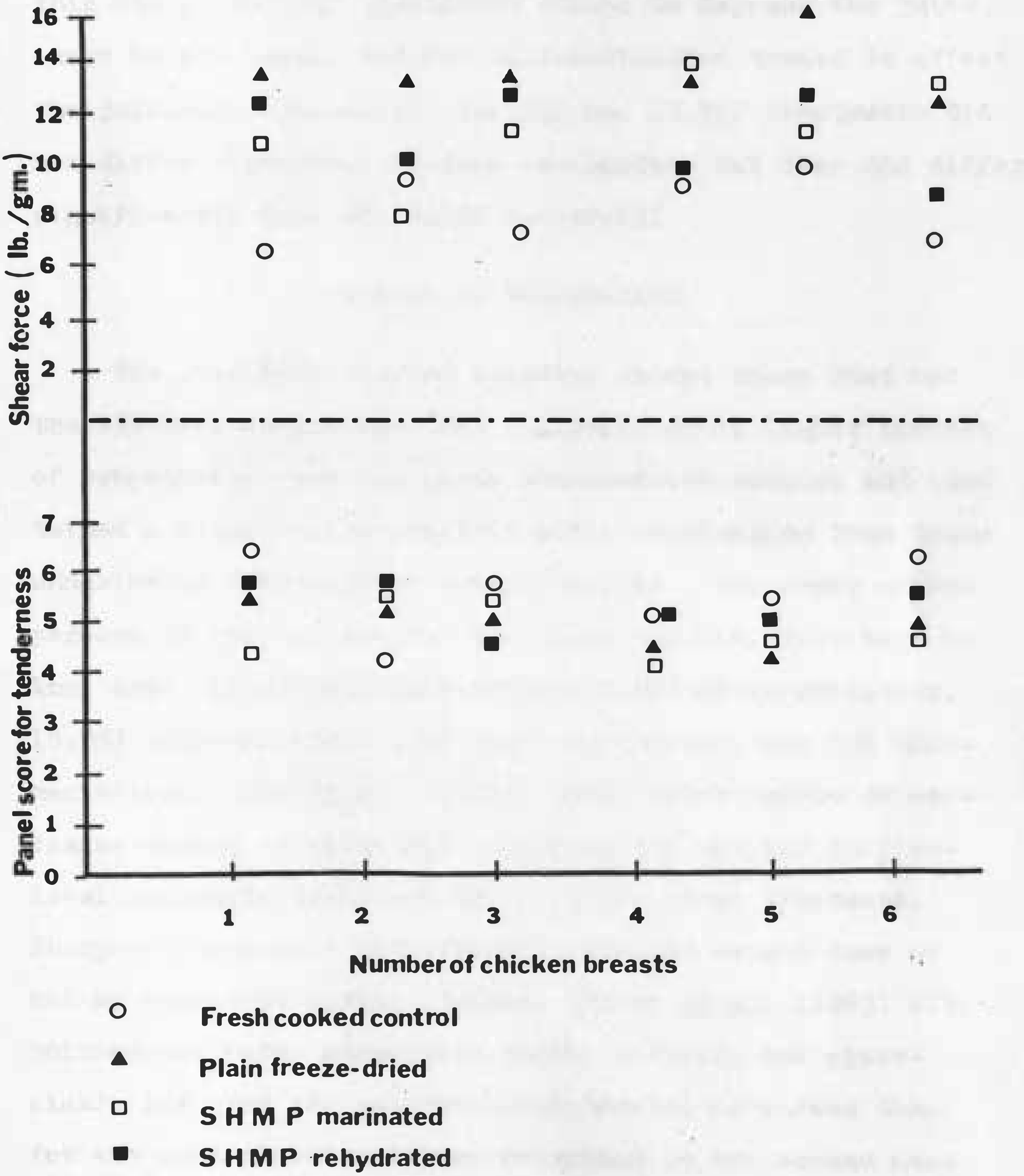
injected with 0.03 M solution of SHMP equivalent to 5, 10, and 15% of the weight of the steaks. May et al. (1963) stated that phosphates in the chill water for poultry increased tenderness of white meat, but no difference was found between treated and untreated dark meat.

Shear-Press

Mean scores for shear-press were similar to panel evaluation scores for tenderness. However, the results from the SHMP-marination indicated some variation between the two methods of evaluation. There were discrepancies in some cases when samples were judged tough by the taste panel and the shear-press values indicated them to be tender, and vice versa. (Figure 1) In most cases there was little discrepancy between taste-panel scores and shear-press values. This was in agreement with many workers who dealt with non-freeze-dried chicken including Wise and Stalman (1959), Shannon et al. (1957), Cameron and Ryan (1955), and Dodge (1959). Wells et al. (1962), however, found that these two methods of tenderness evaluation agreed on non-freeze-dried breast muscle but disagreed on freeze-dried breast muscle.

May et al. (1963) reported that a low level of polyphosphate (4 oz./gal.) in the chilled water for freshly killed eviscerated poultry significantly increased water uptake, whereas a high level (10 oz./gal.) significantly

Figure 1.- Difference of taste panel and shear force for tenderness



depressed it. However, they also reported increased juiciness ratings in direct proportion to phosphate levels. In this study the SHMP treatments seemed to depress the juiciness in all cases, the 25% SHMP-marination tended to affect the juiciness adversely. The 25% and 18.75% treatments did not differ significantly from one another but they did differ significantly from the 6.25% treatment.

Percent of Rehydration

The phosphate-treated samples, except those that had the 25% SHMP-marination, had a significantly higher percent of rehydration from the plain freeze-dried samples and contained a higher total moisture after rehydration than those unmarinated freeze-dried breast samples. The order of the percent of rehydration for the dried samples, from high to low, are: 12.50% SHMP-marination, 6.25% SHMP-marination, 18.75% SHMP-marination, 2% SHMP-rehydration, and 25% SHMP-marination. May <u>et al.</u> (1962) found water uptake of carcasses during chilling was significantly greater for low-level phosphate treatment than for any other treatment. Phosphate treatment significantly reduced weight loss of cut up carcasses during storage. Klose <u>et al.</u> (1963) also pointed out water absorption during chilling was appreciably less for the polyphosphate-treated carcasses than for the control but moisture retention in the cooked meat was 2 to 5% greater.

The SHMP-marinated samples, except those 25% SHMP-marination, had a significantly higher moisture loss than those of the untreated freeze-dried samples after the freeze-dry process, but there were no significant differences among the SHMP-treated samples.

Cooking Loss

SHMP treatments significantly reduced the cooking loss compared to the untreated freeze-dried samples. Morse (1955) pointed out that the advantages of the use of polyphosphate included less cook-out of moisture.

pH Value

The medium and high-level treatment samples both had higher pH value than the control samples ($P > 0.01$), as shown in Table V. The low-level treatment samples had a higher mean pH than the control but the difference was not significant. There were no significant differences among the pH values of fresh raw samples. The pH values after cooking were not significantly different among the cooked samples. Although the phosphate-treated samples had a slightly higher mean pH value, pH values after rehydration were not significantly different. The 6.25% level SHMP-marination samples had significantly higher pH value than

Table V. Summary of pH Changes During Various Treatments

Treatment	No.	Fresh	Marinated	Cooked	Freeze-dried	Rehydrated
Plain freeze-dried	1	6.10		6.25		6.40
	2	6.20		6.30		6.45
	3	6.05		6.25		6.35
	4	6.15		6.25		6.40
	5	6.20		6.30		6.35
	6	6.05		6.25		6.45
Fresh cooked control	1	6.20		6.40		
	2	6.00		6.25		
	3	5.95		6.15		
	4	6.15		6.30		
	5	6.20		6.25		
	6	6.25		6.30		
2% SHMP-rehydrated	1	6.15		6.45	6.50	6.55
	2	6.20		6.30	6.45	6.65
	3	6.25		6.35	6.50	6.70
	4	6.20		6.40	6.45	6.55
	5	6.15		6.30	6.55	6.70
	6	6.25		6.45	6.55	6.65
25% SHMP-marinated	1	6.15	6.10	6.50		6.60
	2	6.10	6.25	6.55		6.70
	3	6.15	6.20	6.60		6.65
	4	6.05	6.15	6.40		6.60
	5	6.20	6.20	6.55		6.60
	6	6.10	6.10	6.50		6.65
18.75% SHMP-marinated	1	6.20	6.25	6.50		6.60
	2	6.20	6.20	6.40		6.50
	3	6.30	6.30	6.45		6.60
12.50% SHMP-marinated	1	6.20	6.25	6.40		6.60
	2	6.25	6.30	6.45		6.70
	3	6.25	6.25	6.50		6.65
6.25% SHMP-marinated	1	6.20	6.25	6.45		6.65
	2	6.25	6.25	6.50		6.65
	3	6.20	6.30	6.50		6.65
Fresh cooked control	1	6.15		6.25		
	2	6.10		6.25		
	3	6.15		6.30		

any others. Several workers, Hamm (1959), Swift et al. (1960), and Sherman (1962) have expressed the opinion that one of the functions of polyphosphate is to increase water-holding capacity of meat and that part of the effect is attributable to change in pH. Hamm (1959) stated that polyphosphates increased hydration only at pH values greater than 5.5 and that the effect increased with increasing pH.

Appearance

Appearance evaluation showed a statistically significant difference between the SHMP-marination treatment samples and the untreated samples. The SHMP-marination seemed to have a deleterious effect on appearance. Fresh cooked control and plain freeze-dried samples had a significantly more acceptable appearance than SHMP-treated samples. The 25% SHMP-marination affected the appearance adversely. The 12.50% and 18.75% treatment samples did not differ significantly from one another, but they did differ significantly from the 6.25% treatment samples.

Aroma and Flavor

Aroma and flavor scores were similar to appearance scores. Fresh cooked samples and plain freeze-dried samples were significantly superior for aroma and flavor to SHMP-treated samples which were not significantly different from one another. However, the 25% SHMP-marination sample received the lowest aroma and flavor score; it had a salty bitter flavor and after taste. The 18.75% marination sample also seemed to have a bitter taste and was slightly salty.

SUMMARY AND CONCLUSIONS

A randomized complete block design utilizing thirty-six chicken breasts was employed to evaluate the effects of marination in 6.25%, 12.50%, 18.75%, and 25% levels of sodium hexametaphosphate solution prior to freeze-drying. There were nine blocks of four breasts each. These nine blocks were divided into two parts. The first part consisted of six blocks. Two breasts of each block were marinated by different methods. The first was marinated with 25% SHMP solution prior to cooking, the second was rehydrated with 2% SHMP solution during rehydration. The remaining two breasts were not treated with sodium hexametaphosphate, the first only freeze-dried, and the other was cooked fresh for each block. The second part consisted of three blocks. Three breasts were separately marinated by 6.25%, 12.50%, and 18.75% SHMP solutions. The control samples were cooked fresh, as described above, for each block.

Tenderness was not significantly affected by SHMP-marination as measured by panel evaluation scores or by L. E. E. Kramer Shear-Press. Marination resulted in significant change in juiciness or pH. The juiciness was somewhat depressed by phosphate treatment. A significant difference in color was noted between the SHMP-treated and untreated samples. The phosphate-treated samples had significantly inferior color to untreated samples. Flavor and aroma scores were similar to appearance scores. Fresh cooked samples and plain freeze-dried samples were preferred for aroma and flavor over the SHMP-treated samples.

The phosphate treated group, except those 25% level SHMP-marination, had a significantly higher percent of rehydration than the freeze-dried samples, and contained a higher moisture content after rehydration than the plain freeze-dried samples.

There were no significant differences among treatment for percent of moisture after freeze-drying. Freeze-dried loss of SHMP-marinated samples was 3 to 5% greater than that of the plain freeze-dried samples.

The data suggested that marinating chicken breasts in different concentrations of sodium hexametaphosphate solution overnight gave variable results and was of little value in improving the eating quality of the freeze-dried chicken but did tend to affect appearance, aroma, and flavor adversely.

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APPENDIX

Form I

Name______________________________Date_______________

Chicken cubes should be creamy in color, have a compact and non-stringy appearance. The aroma should be pleasant and mild. The flavor should be mild and pleasant and the texture firm and slightly chewy. The cubes should be moist and not watery, dry or powdery to the tongue.

Key:

7 Excellent
6 Very good
5 Good
4 Fair
3 Poor
2 Very poor
1 Unacceptable

Samples

Code:				
Appearance				
Aroma				
Flavor				
Tenderness				
Juiciness				

Comments: