SENSORY ASSESSMENT OF SHRIMP EXPOSED TO PHOSPHATE TREATMENTS FOR MOISTURE CONTROL

By

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Proper use of water retention agents in processing of shrimp remains in controversy relative to appropriate amounts applied and product consequences. In the absence of any regulations for specific limits, sensory assessments were conducted to determine sensory detection and consumer preference and acceptability for phosphate and moisture content in processed shrimp. A range of moisture contents was created by treating the shrimp in different sodium chloride (NaCl) and sodium tripolyphosphate (STP) concentrations to yield a matrix with cooked moisture contents ranging from 79 to 84%. The intent was to provide a range of product conditions relative to various customary phosphate treatments. Both trained and consumer sensory panels were used to assess product sensory consequences. A panel of 11 experts was trained to rate sensory attributes most commonly influenced by phosphate treatments. Descriptors included eight categories for aroma, flavor, texture, and appearance. A consumer panel was utilized to illustrate acceptability across all phosphate treatments. Both panels were presented with identical samples. The mode for daily sample presentation differed by NaCl concentration to avoid any bias for salt flavor. The trained panel was able to detect changes in sensory attributes with increasing exposure to NaCl and STP. Significant differences were observed in every attribute except for sour. However, their ability to detect had little influence on

the consumer panel's preference. For product with no prior exposure to NaCl, the untrained consumer panel scored significant differences across the various phosphate treatments for overall acceptance, firmness, and moisture perception categories. Depending on prior phosphate exposure, saltiness, firmness, moisture perception and overall liking were all significantly different for shrimp exposed to 1.5% NaCl. The highest mean rating for overall acceptance, aroma and flavor was for shrimp exposed to the 1.5% NaCl and the highest (4%) STP treatments. No significant differences were rated by the consumer panel for aroma or aftertaste.

CHAPTER 1
LITERATURE REVIEW

Introduction

Moisture is the single largest component of shrimp. It contains the water soluble nutrients that influence flavor. It can affect product color, curl, glossiness and transparency; and most importantly, it determines the texture, mouthfeel and mastication of the cooked products. Too little or excessive moisture content in shrimp can result in objectionable or inferior product quality. Low moisture results in dry and overcooked shrimp and high moisture content can cause a slippery texture or glassy appearance (Garrido 2004). Consequently, moisture is the dominant component on influencing shrimp quality, as the right amount significantly impacts preference by the consumer (Otwell 2004).

Some of the factors that can influence the final moisture content in shrimp are time of exposure to ice, ice slush and/or any water following Good Manufacturing Practices (GMPs, 21 CFR Part 110). Additional factors include the duration in frozen storage, product exposure to freezing and thawing cycles, and most importantly, how the product is cooked. Proper cooking requires knowledge of the shrimp size to account for the time required for the product to reach the internal temperature to reduce bacterial loads as recommended by federal authorities (21 CFR 123). It is also important to stop the cook or heating process with immediate cooling. If the shrimp is cooked at a processing plant, most commercial plants have cooking schedules to account for these controls. However, the majority of the shrimp consumed worldwide is either cooked at home or in restaurants. In many instances the shrimp is overcooked, either by consumers or by chefs. Mindful of these concerns, commercial practices have evolved with processing aids to help protect and retain moisture during harvest, processing, distribution, storage and buyer preparation. Phosphate applications are one of the most common controls.

Use of Phosphates

Naturally occurring phosphates such as adenosine triphosphate (ATP) are involved in muscle activities and water binding. The muscle food industries recognized this and were pioneers in using additional phosphates, a multipurpose group of compounds, to protect moisture content in edible muscle by increasing the water binding capability of the protein (Molins 1991). The initial compound of choice of the shrimp industry was sodium tripolyphosphate (STP), followed with the introduction of blends with additional ingredients to impart variable effects and applications (Otwell 1993). Currently, STP and various phosphate blends are often used to process other seafood products such as scallops, lobster tails, and various fish. The intended use is to protect the product moisture content during freezing, frozen storage, thawing and cooking. The moisture loss that is often reported after the cooking of shrimp is caused by a volatilization of water, decrease in holding capacity of the denatured muscle proteins, and pressure created when connective tissue begins to shrink. The use of multivalent phosphates helps increase the protein water holding capacity due to ionic interactions with the muscle proteins. The addition of sodium tripolyphosphate (STP) has been most effective relative to smaller shrimp sizes. This is thought to be due to the larger surface-to-volume ratio of the small shrimp results in better absorption of STP into the volume (Erdogdu and others 2003). Similarly, in 1980, Crawford showed that the use of phosphates aided in the processing of cold water shrimp. The phosphate increased “case hardening” of the flesh, which enhanced removal of the shrimp shell from the cooked product.

Phosphates are also thought to impart textural quality and to reduce oxidative rancidity and development of other off-flavors by sequestering multivalent cations (Ellinger 1972). Studies and commercial trials have shown (Banks and others 1998) that phosphates reduce bacterial populations in meat, thus extending the shelf life of the product. Studies on the effect of polyphosphate on textural properties of meat products have not only shown improvements but the phosphate also help to stabilize color, flavor, and sensory characteristics (Tenhet and others 1981). Phosphates have also been known to prevent the formation of struvite, a problem common in the canning industry with tuna and salmon. Struvite are transparent crystals of magnesium ammonium phosphate, often mistaken by consumers as glass shards (Ellinger 1972). Sodium hexametaphosphate blends have been used in the scallop industry to remove crystalline precipitates, also known as white spots (Fisher 1993).

Consumer Perceptions

Previous studies have demonstrated a consumer preference for properly phosphated shrimp. Phosphated implies the product was treated with some form of phosphating agents to control moisture content. Garrido and others (1993) demonstrated that consumers (n=125) significantly preferred phosphate treated shrimp products over the untreated controls. In a taste panel designed to evaluate phosphate treated shrimp and scallops, it was shown with sensory triangle tests that over half of the consumers could detect the treated product, and their ability to detect these products increased as moisture content increased. In the same study, consumers indicated a preference for the treated product and rated the phosphated shrimp and scallops higher in the categories of general appearance, flavor, purchase value, and overall quality (Garrido and others 1993.) This work demonstrated that adding and retaining moisture can be beneficial rather than common adverse claims for adulteration.

Claims for moisture adulteration have occurred with products exposed to excessive phosphate treatments that diminished product quality. Abusive treatments can result in slimy, glassy product due to excessive water content (Love and Abel 1966). It should be stressed that there is no benefit to excessive treatments, and overexposure can result in adulterated products (Sturno 1987).

Patents

Patents regarding the use of phosphates in processing have been around for many years. An early patent filed in 1946 included the use of raw shrimp in an aqueous solution containing 2% by weight dibasic sodium phosphate for a period of two hours (Garnatz and others 1946). In the canning industry, it is common to encounter problems with struvite, a glasslike crystal formation. To avoid this problem, Ekkehard filed a patent describing the use of water soluble glassy alkali phosphate in an “amount sufficient to substantially suppress the crystallization of struvite” (Ekkehard and others 1949). In 1953, the improvement of fish meat was patented by exposure to a sodium chloride brine with polymeric phosphoric acid in concentration from 0.2–2.0% by weight. It claimed to improve taste, digestibility and also the stability of fish meat (Meyer 1952). A method of preserving frozen fish involving the use of sodium and potassium salts of molecularly dehydrated phosphoric acids was developed in order to inhibit the loss of moisture, soluble protein, minerals and vitamins (Mahon 1960). In the late 1960s, a patent was filed to increase the yield of bonito (a medium sized predatory fish) meat by treating with molecularly dehydrated phosphate such as STP or orthophosphate prior to cooking (Swartz 1969).

The use of polyphosphate in fish fillets, with or without the use of salt, was first patented by JH Mahon of Hagan Chemicals and Controls, Inc. in 1962. Sodium tripolyphosphate (STP) is used at concentrations between 1.0 and 2.0% incorporated in the water used to make the ice; as the ice melts and forms slush, the phosphate comes in contact with the shrimp and continues to preserve it. This is different from the phosphate soak, where the phosphate is used at a higher concentration and the phosphate is mixed into the water and added to the slush ice along with the shrimp.

Many other patents were filed regarding the use of phosphates in the 1970s and 1980s. One filed by McAuley in the UK was concerned with color, flavor, and water binding capacity improvements in fresh meats. It involved the addition of 0.3 to 0.7% acidic phosphate, with the preferred species identified as sodium and potassium salts of phosphoric and pyrophosphoric acids (McAuley 1984). The use of 0.3 to 1.0% solution of STP, hydrated with a solution containing citrus juice solids and also autolyzed yeast extract, was used in a patent which claimed to improve flavor and cook yield in patties prepared from certain meat cuts such as shank (Bender and others 1985). An abandoned patent filed in 1977 involved a process that comprised of "soaking whole, peeled and deveined shrimp in an aqueous solution that contained at least one phosphate salt, and thereafter freezing to preserve said shrimp to later cooking and consumption." It also included "carrying out said soaking step for sufficient time and in the presence of an effective amount of a trace metal salt selected from the group consisting of calcium salts, magnesium salts, and mixtures thereof, in order to substantially maintain the trace metal content in said shrimp, whereby said treated shrimp will have white tissue coloration and a natural tender texture after cooking" (Falci 1977).

A process describing flaked or crushed ice containing a moisture-binding phosphate used to store shrimp from the time it is harvested until it is processed was developed in 1981. STP concentrations between 1.0 and 2.0% were incorporated into the water used to make the ice; as it melted and formed slush, STP came in contact with the shrimp and continued to preserve it.

Regulations Concerning Phosphates

In the USA, phosphates have been affirmed as a "generally recognized as safe," or GRAS substance by the Food and Drug Administration in a review published in the December issue of the 1979 Federal Register (FDA 21 CFR 182.1810, 182.6760, 182.6787). Processors can use phosphates unrestricted so long as the product is used in amounts to achieve an "intended effect" and it is processed in accordance with the good manufacturing practices found at 21 CFR 182.1(b). Prior use of phosphates must be declared in the ingredient statement on the product label. Previous attempts have been made to establish regulatory limits at 0.5% residual phosphate expressed as P_2O_5. This regulatory proposal was never approved (FR Vol. 44 No. 244)

European regulations allow for certain levels of phosphoric acid and certain phosphates (including sodium tripolyphosphate) to be added individually or in combination, expressed as phosphorus pentoxide, or P_2O_5. For "unprocessed and processed mollusks and crustaceans frozen and deep frozen" the allowable level of added phosphate is 5g/kg, or 0.5% (expressed as P_2O_5). This is with the assumption that the naturally occurring level of phosphate in the shrimp product is approximately 5 g/kg P_2O_5, (calculated per phosphate content), which interprets to an allowable level of P_2O_5 in the product not to exceed 10 g/kg or 1.0%. This regulation is complicated in that measurement of 0.5% is in the cooked final product, after having followed the directions of cooking on the product package (European Council on Foods 1994).

The current guideline passed down from the poultry and red meat industry is 0.5% phosphates added to the product to "decrease the amount of cooked out juices" and to "help protect flavor." (9 CFR Part 381.147 and 9 CFR Part 318.7). However, this guideline assumes that the premeasured phosphate treatment as exposed to the product is completely incorporated. This assumption is not directly applicable to shrimp and other seafood muscle.

Phosphate Applications

Customary phosphate applications throughout the shrimp industry typically consist of exposing the raw shrimp to a phosphate solution with or without salt for a certain period of time with or without agitation. Vacuum tumbling, a practice borrowed from the meat industry, has also been used extensively to treat shrimp, assuming the agitation and changes in atmospheric pressure aids penetration. However, this type of treatment, even though proven very effective, can have an adverse affect on the quality of the shrimp, and requires special equipment. Therefore, most processing plants rely on static exposure to phosphate solutions.

Salt, specifically sodium chloride (NaCl), has been proven to improve the penetration and effects of the phosphate solutions. The salt also helps to improve the flavor as well as the necessary ionic interactions with the meat proteins. However, too much salt will increase osmotic pressure of the phosphate solutions which can decrease water retention. Previous studies with turkey breast have shown that sensory properties, such as binding, juiciness and flavor, were significantly improved by the presence of NaCl with phosphate solutions (Froning and Sackett 1985).

While the use of STP is the most common form for fresh fish and seafood, experiments have shown that the use of tetrasodium pyrophosphate was more effective in preventing drip loss in prepacked, chilled fish (Gibson and others 1973). This particular method involved automatic dipping or spraying lines to fish fillets, scallops, and shrimp before freezing. Based on experience and personal communication with numerous fish and phosphate distributors, the following phosphate concentrations are commonly used in commercial practice with seafood:

- Ice making 3% solution
- Dipping/washing 2–6% solution for 2–20 minutes
- Spraying 5–10% solution
- Tumbling 2–6% solution
- Injecting 5–8% solution
- Dry additions 0.3–0.5% to comminuted systems

Monitoring the Use of Phosphates

Phosphate additions to retain moisture in shrimp can be monitored by analyzing for total phosphorus and percent moisture. However, compositional summaries by Sidwell (1981) and

Sullivan and Otwell (1992) reported phosphate contents for shrimp can vary from 39 to 397 mg/100g expressed as P_2O_5. Likewise, percent moisture content was reported to range from 71.8% to 87.0% (Otwell 1994). Therefore, routine monitoring of phosphate residuals was complicated due to variation in the indigenous phosphorus and moisture content in the shrimp muscle (Garrido 1991).

In 1991, Garrido and Otwell conducted a series of studies that measured the moisture content for several tropical shrimp species (*Farfantepenaeus*) from various countries. The shrimp were followed from routine harvest through processing to assure authenticity for non-treated samples. They measured the total phosphorus and moisture content levels of 15 different raw and cooked shrimp prior to any exposure to phosphates. Total moisture and total phosphorus were also determined for the shrimp following various phosphate treatments. Upon harvest, the moisture content in the various raw shrimp species ranged between 74 to 76%. After traditional processing following established federal Good Manufacturing Practices, (21 CFR Part 110) the peeled shrimp can be expected to contain between 80 to 83% moisture. However, depending on residence time in the various processing steps, moisture values can range as high as 88% without any exposure to phosphate solutions. Thus the moisture content of peeled shrimp without any prior exposure to phosphates can range from 81 to 88%. Incorporation of phosphate treatments after peeling resulted in moisture levels of 83 to 86%. For this reason, moisture contents with or without phosphate treatments depend on the method of processing. Therefore, the study concluded that moisture values alone cannot be used to determine prior phosphate treatment of shrimp. Accompanying data was necessary regarding the phosphate content in the treatment of shrimp. Untreated shrimp analyzed for total phosphorus were found to contain between 150–250 mg/100g phosphorus. The levels of phosphorus in shrimp treated with STP were higher than 250 mg phosphorus/100 g edible meat. The moisture and total phosphorus results were consistent for all species studied; therefore, values previously reported in the literature most likely included shrimp samples of unknown history, which could have been previously exposed to phosphate treatments.

This study (Garrido and Otwell, 1994) also suggested that sensory assessments are important in determining phosphate treatments in shrimp. Overtreated shrimp can look translucent, shiny and glassy. A soapy feel may also be detected. The report specified that in order to detect or observe treatment in shrimp, it is easier for the product to be cooked. The current status of the phosphate industry is one of confusion.

CHAPTER 2
JUSTIFICATION AND APPROACH

The most important sensory characteristics of shrimp are texture, flavor, and mouthfeel. Moisture content plays a dominant role in all three of these factors. Too little moisture causes a dry, overcooked product and too much moisture leads to a chewy, watery product. Both are unappealing to the consumer. Phosphates can influence the sensory attributes by retaining moisture in the product throughout processing and eventual cooking. Correct moisture retention in shrimp production is important to the processor as an aid to the manufacture of shrimp relative to consumer acceptance and as weight loss carries an economic burden. Incorrect or abusive phosphate treatment can cause controversy over the question of an adulterated product; therefore, it is important to find a means to monitor for the consequence of phosphate use to retain moisture in shrimp.

Several different variables in the phosphate treatment process can affect the shrimp product. Soak times, temperature, concentration, and presence of salt are just a few of the variables. Different phosphate and salt levels can be combined to achieve various moisture levels in shrimp. The human palate is often one of the most important means of measuring acceptability, and the consumer is the ultimate judge of quality. Therefore, this study was conducted to determine if humans could detect phosphate use with shrimp and if they preferred the phosphated product.

It is hypothesized that sensory assessments can be used to detect and also demonstrate a consumer preference for phosphated shrimp. For this study, the approach was to prepare various phosphated shrimp for use with sensory panels to measure perception and preference.

CHAPTER 3
MATERIALS AND METHODS

Sample Collection and Treatment

To assure no prior use or exposure to phosphate agents, all shrimp samples were collected during three days of harvest on a commercial vessel trawling near Dulac, Louisiana. Approximately 800 lbs of white shrimp (*Penaeus setiferus*) were collected by customary trawling. Samples were transmitted to a local processing plant, deheaded, peeled and graded. Medium size shrimp, 31–35 tail count per pound, were used for this study. Samples were exposed to solutions containing different phosphate and salt combinations. The chosen phosphate was sodium tripolyphosphate (STP), produced by A & B Chemical Company of Loveland, Colorado. Ten pounds of peeled shrimp were treated in each solution. Twelve solutions included the combinations of 0, 1.5, 3.0, and 4.0% STP and 0, 1.5 and 2.5% sodium chloride (NaCl). The controls for the experiment were shrimp samples with no exposure to phosphates or NaCl (0%NaCl and 0% STP). Each treatment was applied for both a short term (one hour) and a long term (four hours) exposure in order to impart various moisture levels. Based on two exposure times for each of the twelve solutions, there were 24 initial phosphate treatments. The treatment solution to shrimp ratio was 2 lbs of solution to every 1 lb of product (w/w). The treatment solutions were maintained at 15°C (59°F) exposure. This method of application was chosen as opposed to tumbling because experience indicated tumbling can cause adverse product appearance. Samples were then drained, rinsed, weighed, and boxed with approximately five pounds of shrimp per each box. Water glaze was simply an addition of tap water to protect product during frozen storage. Shrimp were frozen in a blast freezer. Excess shrimp were also boxed and saved for preliminary analyses. All frozen boxes were shipped to the University of Florida where they were held in frozen storage (-10°C /14°F).

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Sample Analyses

Thawed samples were then analyzed for moisture, sodium, total salt, and phosphorus in raw state. Prior to analysis, samples were deglazed (thawed) using the revised Association of Official Analytical Chemists (AOAC) official method 967.13 for frozen shrimp and seafood. For this method, the contents are placed in a wire mesh basket and immersed in approximately four gallons of fresh water at 26 ± 3°C (80 ± 5°F) so that the top of the basket extends over the water level. Water at the same temperature is introduced from the bottom of the container at a flow rate of one to three gallons/minute. Upon product thawing, all material is transferred to a 12 inch No. 8 sieve. Without shifting the product, the sieve is inclined approximately 30° from the horizontal to facilitate draining. Two minutes from time placed on sieve, product is transferred to a previously weighed pan to determine drained weight of product.

Moisture analysis was performed using AOAC method 950.46 for drying under a vacuum. Samples were ground into a homogenous mixture with GE Deluxe Chopper food processor prior to placing approximately two grams of the blend in a tared aluminum pan. Sample weights were recorded before they were placed in a vacuum oven at 212°F (100°C) and less than 100 mg Hg for five hours. After the five hours, samples were cooled in a desiccator and reweighed to determine moisture lost based on weight change.

Total salt was measured using AOAC method 935.47, which involves the addition of HNO_3 under boiling conditions and concentrated aqueous $KMnO_4$. Phosphorus and sodium were analyzed using Environmental Protection Agency (EPA) method SW6010, which is based on AOAC methods 990.08 and 985.01, which require an inductively coupled plasma emission spectrometer apparatus.

Yields were determined by weight difference of the shrimp prior to cooking and immediately after cooling.

Sample Selection and Preparation

Table 3-1 provides the resulting compositions for the raw shrimp prepared through the 24 treatments. Sample coding first lists the STP concentration followed by the NaCl concentration and then the exposure time. For example, 0/0/L indicated a solution with a 0% STP, and 0% NaCl used for a long exposure time, and 3/1.5/S indicates a 3% STP 1.5% NaCl treatment solution with short exposure time. A progressive series in moisture contents was created mindful that similar moisture contents could have different properties depending on exposure to NaCl and exposure times. For example, both the 0/0/L and 1.5/1.5/L combinations had a raw moisture content of approximately 84% but the former had a sodium content of 57.70 mg/100g while the latter had a 231.50 mg/100g sodium content. The influence of these factors becomes more obvious during the panel judgments. Samples could not be identified by phosphorus level or moisture content alone, as a result, the basis for the coding system must rely on the combinations. Moisture levels can be achieved through a variety of soak times, salt, and phosphate concentrations. Phosphorus levels cannot be accounted by moisture content alone.

Sub samples from each phosphate treatments were thawed and then cooked followed by immediate chilling. The samples were cooked in a forced convection style cooker manufactured by Laitram Machinery, then immediately chilled. Samples were placed on a conveyer belt for 100 seconds to achieve a 165°F (73.8°C) internal temperature at the end of cooking. The steam tunnel had a continuous flow for even cooking at 100°F (37.7°C.) Shrimp were immediately cooled in ice slush for two minutes and then refrigerated until presentation to panelists, approximately four hours later.

The cooked samples were analyzed to obtain moisture and salinity content (AOAC methods 950.46 and 990.08).

The intent for selection of 12 samples across the 24 treatments was to assure a series of treatments that yielded a progressive increase in moisture levels. Table 3-1 shows the twelve combinations that were chosen from the original 24 treatments. A simple sample coding was used to identify product from each treatment. Exposure time variation was necessary only to achieve a gradient in moisture contents.

Panel sessions were conducted on samples prepared by exposure to treatments with similar salt concentrations. This allowed three sessions (0, 1.5 and 2.5% NaCl) so as not to influence the panelists with a possible preference to salt content. One session was held per day. On each day, 100 consumer panelists analyzed the samples, while 11 trained panelists observed the same samples, with only 4 different samples per day (each from the same salt concentration so as to avoid panel exhaustion.)

Trained Sensory Panel

A prescreened, pretrained sensory panel was used for the trained panel evaluation. The 11 member trained panel spent several weeks prior to testing refining their sensory skills and developing the lexicon and ballot for the shrimp samples. Further, panelists agreed to participate by signing a standard IRB (Institutional Review Board) agreement prepared in accordance with the University of Florida research protocol involving human subjects. Training for basic tastes was achieved by following guidelines outlined in the Sensory Evaluation Techniques, 3rd edition (Meilgaard and others, 1999) for the ranking and rating tests. The Spectrum Descriptive Analysis method, designed by Civille (1996), was used for the trained panel. This method is characterized by the panelist scoring the perceived intensities with reference to pre-learned intensity scales, which leads to high repeatability. The method provides an array of standard attribute names (lexicons) each with a set of standards to define the scale of intensity. Training took place over six weeks with panelists meeting once per week for an hour per session to become familiar with the basic tastes and standard references. This was important to reduce the variation between panelists.

After training, the selected panelists developed the final rating form used to analyze the shrimp samples (Appendix A). The form asked panelists to rate the shrimp in the categories of appearance, aroma, basic taste, flavor/mouthfeel, and texture. Additional space was provided for any extra comments regarding their impressions for the shrimp samples. All attributes were rated on a 0–10 with 0=least intense and 10=most intense with respect to each attribute. The responses were recorded and then averaged per salinity session to achieve group ratings.

Color, translucency, and plumpness were rated per the “Appearance of Shrimp” category. Standards were based on a standard picture scale of actual shrimp samples (Appendix C). These scales were created using white shrimp (*Penaeus setiferus*) treated to impart a range in appearance. Intensity was the only attribute for “Typical Shrimp Aroma.” Based on a sample of previously untreated shrimp, the panelists were instructed to rate similar samples as a 10, or the most intense shrimp aroma possible. The attributes for the “Basic Tastes” were all standardized using liquid solutions as outlined in the Sensory Evaluation Techniques manual (Meilgaard et al, 1999). “Sour” was created using different concentrations of citric acid in water. “Sweetness” utilized sugar in water, and “salty” incorporated table salt additions to water. “Bitter” was based on additions of caffeine to water. “Umami” was created using concentrations of monosodium glutamate in water. Panelists were instructed to take a small sip of each sample to familiarize themselves with the intensities and rate the shrimp accordingly. In the category of “Flavor and Mouthfeel,” the moisture scale was developed by using shrimp with different percent moistures based on previous moisture analysis. This scale was created by using shrimp that were treated in different manners to achieve the various intensities of the scale. Shrimp were soaked overnight in water and then overcooked to obtain the 0 example, and shrimp were exposed to an abusive phosphate treatment to achieve the 10 rating. Various combinations of cooking and treatment were used to create an array of moisture contents to complete the rest of the scale.

Panelists were given several definitions to assist in their ability to perceive the different attributes: Moisture was defined as “the degree of oil and/or water in the sample during chewing;” hardness/firmness was defined as the “perceived force required to compress a substance between molar teeth;” and chewiness was defined as the “number of chews required to masticate a sample at one chew per second and constant rate of force application to reduce to a consistence suitable for swallowing.” The “Typical Fresh Shrimp Flavor” was represented by a fresh, untreated white shrimp (*Penaeus setiferus*) sample that corresponded to a rating of 10. For the “Texture” attribute of chewiness, panelists were given a slice of Kraft American cheese (at room temperature) which represented a standard rating of two, as outlined in Meilgaard’s book (Meilgaard 1999).

The “Hardness/Firmness” scale was developed by using the Instron texture analyzer and different shrimp samples. The scale was developed using the same compression test as for testing the treated samples. Shrimp samples with known Instron readings were used to develop a scale shown in influence by moisture content as associated with compression (Table 3-2). “Aftertaste” was a subjective rating based on the intensity of the sensation experienced. Panelists were instructed to mark a 10 for severe aftertaste and a 0 if no aftertaste was detected. Aftertaste was defined as “the sensation following the removal of a taste stimulus that may comprise a continuation of the sensory quality perceived during the presence of the stimulus, or a different quality induced by salivary dilution, rinses with water, or the act of swallowing” (Lawless 1998).

Trained panelists were presented four samples per day over a time period of three days, similar to the procedures used for the consumer panel. Samples were rated one at a time, and panels lasted one hour each day. Special care was taken so that there were no outside influences. Unscented cleaners were used in the area where the shrimp were analyzed and the panelists were instructed not to wear any scented lotions or perfumes. Unsalted crackers and bottled water were provided for consumption in between each shrimp sample to cleanse the palate before tasting the next sample. Panelists were instructed not to discuss or compare their responses.

Consumer Sensory Panel

The untrained consumer panel consisted of 100 panelists per session (300 total) randomly selected from the University of Florida. Solicitation included signs posted outside of the sensory lab advertising a shrimp taste panel offering a small reward. Table 3-3 illustrates the demographic data collected from the 300 consumer panelists. Over 68% of the participants range in age from 18–24 years, and 90% eat shrimp at least once per month.

The panelists were presented with the different shrimp one at a time and asked to rate their acceptability for overall appearance, aroma, flavor, and overall liking on a 1-9 hedonic scale. A rating of one signified “Dislike extremely,” and a rating of nine signified “Like extremely.” The form also included questions with a 1–5 scale for saltiness, firmness, and moistness of the product. Word anchors for these questions ranged from “Not at all (descriptor)” for a one and “Too much (descriptor)” for a rating of five. A yes/no question for the prevalence of aftertaste promoted an intensity question with a “Yes” response. This offered choices of mild, moderate, and strong.

The experimental design used in this study was a Randomized Complete Block for each NaCl concentration. This design was evaluated with an Analysis of Variance test (ANOVA). Tukey's test was used at the 0.05% significance level.

Table 3-1. Raw data for moisture, phosphorus, sodium, and total salt in all 24 experimental sample combinations prepared to provide for a selection of test samples based on progressive changes in moisture content. Samples with an asterisk (*) samples represent the 12 products that were chosen to be cooked and presented to panelists.

Sample Codes	% Moisture	Phosphorus (mg/100g)	Sodium (mg/100g)	Total % Salt
0/0/S	82.79	169.00	72.75	0.19
0/0/L*	84.03*	132.33*	57.70*	0.11*
0/1.5/S	82.77	147.33	203.50	0.50
0/1.5/L*	83.44*	120.00*	159.00*	0.30*
0/2.5/S	82.31	143.66	131.00	0.31
0/2.5/L*	81.89*	127.33*	327.50*	0.66*
1.5/0/S	83.59	182.33	103.50	0.17
1.5/0/L*	84.33*	163.33*	102.50*	0.10*
1.5/1.5/S	83.14	180.00	214.00	0.38
1.5/1.5/L*	84.02*	164.66*	231.50*	0.38*
1.5/2.5/S	82.44	195.00	353.50	0.65
1.5/2.5/L*	84.10*	173.00*	392.50*	0.77*
3/0/S*	84.18*	217.33*	154.50*	0.12*
3/0/L	85.78	227.66	210.50	0.10
3/1.5/S*	83.65*	195.33*	260.00*	0.33*
3/1.5/L	84.89	251.66	330.50	0.47
3/2.5/S*	83.23*	220.66*	355.00*	0.54*
3/2.5/L	85.25	213.00	345.00	0.55
4/0/S*	84.95*	239.33*	190.50*	0.11*
4/0/L	85.57	296.33	314.00	0.15
4/1.5/S*	83.55*	250.33*	344.50*	0.52*
4/1.5/L	84.69	306.66	447.50	0.70
4/2.5/S*	83.60*	234.33*	396.50*	0.73*
4/2.5/L	83.88	333.33	668.00	1.16

Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure. 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure.

Table 3-2. Texture standards created in reference to compression measured with an Instron machine for use with the trained sensory panel. Moisture content (%) represents the cooked moisture content of the shrimp samples.

	Rating										
	0	1	2	3	4	5	6	7	8	9	10
Moisture %		84%		82%		80%		78%		76%	
Compression Force (N)	13				17						23

Note: Rating signifies panelist response, with corresponding moisture values and Instron reading. Type of test used was a compression test designed using a #2 probe and a 7mm gauge reading.

Table 3-3. Demographic data for the untrained consumer sensory panel used to rate the cooked shrimp samples.

Age Range			Ethnicity		Income		Consumption	
	Male	Female	Caucasian	160	<20,000	118	>1/day	1
<18	3	9	African American	25	20–35,000	43	1/day	1
18–20	46	79	Native American	2	36–50,000	30	2–3/week	11
21–24	38	43	Asian/Pacific Islander	52	51–75,000	17	1/week	38
25–50	32	33	Hispanic	42	76–100,000	22	2–3/ month	93
>50	12	5	Other	13	>100,000	30	1/ month	128
			Decline answer	6	Decline answer	40	1/ year	28
Total	131	169		300		300		300

Note: Consumption means average amount of shrimp products eaten by consumer.

CHAPTER 4
RESULTS AND DISCUSSION

Composition of Shrimp

Analyses were performed on the shrimp samples after the phosphate treatments (Table 4-1) prior to cooking and after cooking (Table 4-2). Resulting moisture content in the raw shrimp ranged from 82% to 85% as influenced by exposure time and phosphate concentration. The data is arranged according to increasing phosphate concentration used in the treatments. This illustrates how phosphorus content in the shrimp increases with the increasing phosphate treatment. Obviously the resulting phosphorus and corresponding phosphate content expressed as P_2O_5 increased in the raw shrimp treated with increasing concentrations and exposure time for the phosphating agent, STP. From these limited treatments, all treated products had total phosphorus contents in excess of 160 mg/100 g of raw shrimp. The strongest phosphate treatment, 4% STP, imparted a phosphorus concentration as high as 250 mg/100 g during one hour (short term) exposure. These raw concentrations tended to increase or decrease during cooking relative to the level of prior phosphate exposure (Figure 4-1). Total phosphorus in the cooked samples decreased in shrimp treated with higher concentrations of phosphate and less exposure time, but they increased in shrimp treated with no and lower levels of phosphate for longer exposure time (four hours.) This is thought to be because higher levels of sodium compete with the phosphate in absorption to the product and potential saturation of the binding sites. The shrimp muscle tissue may be limited in the carrying capacity for phosphates. Likewise, the longer exposure time may have allowed deeper penetration or absorption of the phosphates.

An additional explanation of the changes in phosphorus levels during cooking was due to the expected decreases in moisture content for all cooked shrimp (Figure 4-2). Large changes in moisture content for the samples from treatments with no or less phosphating agents suggest the amount of phosphates were not able to retain the moisture, and dehydration elevated the phosphorus content in the cooked shrimp. In contrast, the samples from the higher phosphate treatments were apparently able to better retain moisture such that some of the water soluble phosphorus levels decreased by leeching due to pressure from shrinking connective tissues and proteins exposed to heat. Moisture loss corresponded with the loss in product weight during cooking (Figure 4-3). Again, prior exposure to stronger phosphate treatments reduced weight loss during cooking.

A synergistic effect is obvious for the moisture retention by increasing concentrations of salt and phosphate. The higher salt concentrations aid the water binding capacity of the phosphates. These interactions clearly demonstrate the influence of phosphates in managing moisture levels in shrimp. For this reason, the composition and character of the raw shrimp differed substantially from that of the cooked shrimp and these changes could not be predicted by initial measures for moisture content alone. While the moisture content of the raw samples ranged between 82 to 85%, the resulting moisture contents after cooking ranged from 79 to 84%.

Interestingly, the ratio for moisture content to phosphorus levels revealed a distinct decreasing pattern for the samples previously exposed to increasing concentrations of the phosphating agent, STP (Figures 4-4 and 4-5). The pattern was more pronounced for the raw shrimp (Figure 4-4). These patterns could serve as a possible measure for phosphated shrimp relative to product assessment in sensory panels.

The compositional patterns for salt and sodium content were less obvious other than the expected increases with increasing exposure to higher salt concentrations (Figure 4-6 and 4-7). Likewise, the magnitude of change for sodium content was influenced by additions of sodium from the phosphating agent, STP as well as the salt. These results indicate use of salt definitely increases the salt level in the raw shrimp and these differences persist after cooking.

Trained Panel Sensory Assessments

Average ratings and significant differences detected by the trained panel are illustrated in the Tables 4-3 through 4-5. In keeping with the experimental design, these tables are arranged according to the separate panel sessions for shrimp exposed to different NaCl concentrations in order to avoid confounding influence of salt. Average results indicated that trained panelists rated significant differences for all sensory attributes relative to phosphate treatments, except sour. It was not unexpected that sour would be a minor characteristic influenced by the addition of salt or phosphate.

The significant differences detected for appearance suggested the increasing moisture content through increasing phosphate treatments changed the color of the cooked shrimp due to increasing muscle translucency and plumpness (Figure 4-8 through 4-10). Significant differences were noted for color at all NaCl concentrations except for the highest salt treatment, 2.5%. Average ratings for color displayed a decreasing trend, product appearing “lighter,” as STP concentrations increased (Figure 4-8). Differences were more obvious at lower NaCl concentrations. All samples fell within the “average” to “light” range for color. The related appearance measures for translucency were rated significantly different for all STP treatments, which suggest the panel could detect increasing translucency. Trained panel ratings for translucency significantly increased with increasing phosphate exposure (Figure 4-9). Sample ratings for translucency were similar across all salinities. This is a natural consequence of adding water. Even with minor additions, the trained panel had the ability to detect changes. This figure reveals a pattern that increased phosphate exposure causes the product to become more translucent, as to be expected with a white muscle food. Water increase diluted the concentration of the color and added to the transparency. The lost color was also due to the expansion of surface to volume ratio, which was noted as plumpness.

As illustrated by the significant differences, the panelists felt that product appeared plumper with the addition of phosphates and water (Figure 4-10). As expected, the addition of water obviously caused the product to expand. The lowest rating for plumpness(3.5) was that for no added phosphate and the highest ratings (>7.0) were that for cooked shrimp exposed to the highest phosphate concentrations. Relative to the average ratings, the trained panelist scored the cooked shrimp exposed to 4.0% STP as twice the apparent size as the same shrimp exposed to no STP. Plumpness was obvious but further training may be necessary to reduce variation in ratings at lower phosphate treatments.

Among the texture attributes, the trained panel scored significant differences for hardness/firmness, chewiness, and moisture. These were the most dramatic sensory attributes. The influence of higher phosphate treatments on increasing moisture content was also detected by ratings for moist mouthfeel (Figure 4-11). Added moisture in the shrimp product is thought to have a lubricating effect, thus giving the phosphated samples a softer mouthfeel. The trained panel detected a higher moistness as phosphate treatments increased. The panel detected a transition from dry to moist mouthfeel. A graph (Figure 4-12) illustrating how the samples rated against the maximum mechanical compressive force shows a decreasing trend as the phosphate concentration increases. In the texture ratings, the higher the mechanical Instron score, the firmer the product, as more compressive force was required to puncture the shrimp. As expected, those samples that had not been treated with phosphate were the firmest, or drier, and those that had the highest amount of phosphate treatment ranked the least firm, or moister. (Figure 4-13). Nontreated products often seem to be harder due to the dryer texture. The relation between increasing moistness and decreasing firmness with increasing phosphate exposure was detected as increasing mushy mouthfeel.

Chewiness was similar in response to hardness/firmness. These attributes are closely related. Figure 4-14 shows the same decreasing trend as the phosphate concentration increases. Chewiness and hardness/firmness exhibited an inverse relationship to moistness. The influence of phosphate seems to be that of a lubricant to decrease the perceptions of chewiness and hardness/firmness. Again, chewiness progresses to mushy mouthfeel as the phosphate treatments increased moisture in the shrimp.

For the flavor attributes of salty, sweet, sour, bitter, umami and general flavor, the most important significant differences were in saltiness and general flavor, except for the low NaCl level. Obviously increased exposure to salt in the phosphate treatments elevated detection for salty flavor (Figure 4-15). For example, 4/2.5/S, the strongest exposure in terms of both STP and NaCl, had the highest average rating for salty (6.5), which was considered to be above average. Saltiness also becomes the key factor in the general flavor attribute as the ratings also increase with the addition of NaCl (Figure 4-16).The addition of salty flavor through increasing treatments with increasing concentrations of STP and salt favorably influenced the trained panels detection ratings for flavor, yet there seems to be a threshold as the ratings for shrimp with the highest salt concentration drop at the highest phosphate concentration, perhaps due to the additional sodium from the phosphating agent.

As for the other basic tastes, no significant differences were observed in sweetness at the zero salt concentration. Significant differences for sweetness were only calculated as the phosphate concentration increased, which could suggest that the panelists had confusion in rating for sweetness. This is a common problem in trained panels for foods that are both sweet and salty. Bitter, umami, and aftertaste were only rated significantly different at the 2.5% salt concentration. This suggested that a high salt concentration plays a role in these attributes, or that the panelists detected something but were not sure as to how to rate or classify it. In the attribute of aroma, significant differences were only in the 2.5% NaCl concentration, where ratings ranged from a high (7.6) at the 1.5% STP concentration, and a low (6.0) at the 0% STP concentration.

Consumer Panel Assessments

The ratings by trained panelists based on standard references demonstrated the ability of humans to detect some significant differences relative to previous exposure to phosphate treatments, but most of the untrained consumer ratings were not influenced by these differences. Although the untrained consumers did detect some significant differences in overall acceptability, flavor, saltiness, firmness, moistness, and overall liking (Tables 4-6 through 4-8), there was no distinct pattern relative to the phosphate treatments (Figures 4-17 through 4-25). Mindful that the trained panel had the ability to detect significant differences in some plumpness and translucency (clarity), the data suggest that some consumers may be influenced while others are not. In the absence of a standard scale, consumer responses varied. This is often why commercial complaints are based on comparisons of two products. The influence of a phosphate treatment on appearance of the product is best judged by comparisons with a standard, as it is difficult to make these judgments based on one product alone. If only one product is judged at a time, ratings could be in either direction based on a personal preference.

The histogram of ratings for overall appearance varied significantly across all phosphated treatments (Figure 4-17), yet the average ratings per phosphate treatment simply ranged between Like Slightly (6) and Neither Like nor Dislike (5) on a 10 point rating scale. These ratings indicated that there were few differences between the samples based on overall appearance. The highest mean rating (5.9) was given to the 4% STP concentration with 2.5% added STP and the lowest (5.0) was at the 0% STP and 0% NaCl treatment combination.

Likewise, the patterns in average consumer ratings for flavor were similar across all phosphate treatments (Figure 4-19). Significant differences in consumer scores with increased phosphate did not appear until NaCl was used with the STP treatments (Tables 4-7 and 4-8). This reflects that a portion of consumers preferred the salty flavor. Recall from Table 4-1 that an increase in the phosphate and NaCl treatments increased the sodium and total salt contents of the samples. A histogram of saltiness ratings shows that NaCl concentrations were never considered a negative attribute (Figure 4-20). Therefore, treatments as high as 2.5% NaCl do not impart adverse consequences. Figure 4-21 shows that all ratings fall in the range of "Not quite salty enough" to "just right." In comparison with the trained panelists, the consumers had higher preference ratings for those samples that the trained panel rated higher in saltiness.

As with the trained panel, consumer detection and preference was most significant for the texture attributes. There was a pattern in the perception of firmness (Figure 4-13), but no adverse ratings (Figure 4-22). Significant differences again suggest that the role of lubrication through addition of moisture and phosphate favorably influenced consumer preference. Across all treatments, the majority of the panelists felt that it was "just right." The same inverse relationship between firmness and moisture influenced consumers just as with the trained panel (Figure 4-23). The detection of a firmer product corresponded with the detection of a dryer product. Across all treatment combinations, moisture content was rated as "just right" (Figure 4-24).

Consumer ratings for general Overall Liking suggested there was a slight difference in consumer preference (Figure 4-25). Consumer preference favored shrimp exposed to increasing concentrations of STP and salt. Salt influenced taste and moisture influenced firmness, both of which were favorable attributes. Interestingly, consumer preference did not diminish for shrimp exposed to phosphate treatments up to 4% STP which are considered strong or excessive for commercial use.

Conclusion

In terms of shrimp composition, moisture content, salinity, phosphorus, and sodium all increase with the addition of phosphate. Upon cooking, all samples experienced a loss in moisture content, but the amount of loss in moisture and corresponding product weight was less for shrimp exposed to increasing phosphate treatments. Based on these compositional changes, sensory differences in product could be detected and did influence some consumer preferences.

Responses from the trained panel indicate that humans have the ability to detect differences in color, translucency, moistness, and various flavors, with the most dramatic differences noted for the textural attributes of plumpness, harness/firmness, and chewiness. Increasing exposure to phosphate treatments including salt resulted in cooked shrimp products that were detected to be more translucent and plump with less color and softer texture. Likewise, the increasing additions of salt and sodium imparted a significant detection for salty flavor. No differences were detected for sour across all treatment combinations.

Although the trained panel could detect sensory differences due to phosphate treatments, preference of the consumer panel was only affected in limited categories. Consumers preferred the saltier, moister product. The added moisture gives a lubricating effect which imparts a softer mouthfeel that is preferable to the consumer and additions of salt were considered favorable. Untrained consumer panels were unable to distinguish appearance and color attributes without a standard reference or comparison.

These few differences noted by untrained consumer ratings did not influence their preference for “overall liking” of cooked shrimp exposed to phosphate concentrations as high as 1.5% STP for four hours or 4% STP for one hour. These treatments are consistent with commercial applications to protect moisture content in frozen and cooked shrimp. Contrary to some common industry complaints, the proper addition of phosphate does not impart adverse consequences to the shrimp product.

Table 4-1. Raw data for moisture, phosphorus, sodium and total salt in the 12 samples presented to panelists.

Raw Sample	% Moisture	Phosphorus (mg/100g)	P2O5 equivalent	Sodium (mg/100g)	Total % Salt
0/0/L	84.03	132.33	303.03	57.70	0.11
0/1.5/L	83.44	120.00	274.80	159.00	0.30
0/2.5/L	83.04	127.33	291.58	327.50	0.66
1.5/0/L	84.33	163.33	374.02	102.5	0.10
1.5/1.5/L	84.02	164.66	377.07	231.50	0.38
1.5/2.5/L	84.19	173.00	396.17	392.50	0.77
3/0/S	84.18	217.33	497.68	154.50	0.12
3/1.5/S	83.65	195.33	447.30	260.00	0.35
3/2.5/S	82.23	220.66	505.31	355.00	0.54
4/0/S	84.95	239.33	548.06	190.50	0.11
4/1.5/S	83.55	250.33	573.25	344.50	0.52
4/2.5/S	83.06	234.33	536.61	396.50	0.73

Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

Table 4-2. Cooked data for moisture, phosphorus, sodium and total salt in the 12 samples presented to panelists.

Cooked Sample	% Moisture	Phosphorus (mg/100g)	P2O5 equivalent	Sodium (mg/100g)	Total % Salt
0/0/L	79.10	141.00	322.89	49.55	0.12
0/1.5/L	79.66	138.00	316.02	130.50	0.25
0/2.5/L	81.86	136.00	311.02	265.00	0.54
1.5/0/L	81.71	179.00	409.91	104.50	0.08
1.5/1.5/L	82.25	169.00	387.01	232.00	0.34
1.5/2.5/L	82.90	174.00	398.46	353.50	0.68
3/0/S	81.21	211.33	483.94	141.00	0.14
3/1.5/S	80.40	181.00	414.49	179.00	0.32
3/2.5/S	81.75	205.00	469.45	436.00	0.44
4/0/S	83.57	181.67	416.02	166.00	0.10
4/1.5/S	82.73	215.00	492.35	102.90	0.42
4/2.5/S	82.43	218.00	499.22	133.50	0.63

Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

Table 4-3. Averaged responses based on ratings by trained panel for the shrimp samples exposed to treatments with 0% NaCl concentration. Significant differences were determined by ANOVA.

Sample	Mean	Rank	Sample	Mean	Rank
	Color			Bitter	
0/0L	5.0	a	0/0/L	0.5	a
1.5/0/L	3.5	b	1.5/0/L	0.2	a
3/0/S	2.9	bc	3/0/S	0.3	a
4/0/S	1.9	c	4/0/S	0.6	a
	Translucency			Umami	
0/0/L	1.9	c	0/0/L	0.8	a
1.5/0/L	5.1	bc	1.5/0/L	0.8	a
3/0/S	4.6	b	3/0/S	1.6	a
4/0/S	8.2	a	4/0/S	1.6	a
	Plumpness			Flavor	
0/0/L	3.5	c	0/0/L	4.5	a
1.5/0/L	5.1	bc	1.5/0/L	5.0	a
3/0/S	6.0	b	3/0/S	5.2	a
4/0/S	7.8	a	4/0/S	4.0	a
	General Shrimp Aroma			Aftertaste	
0/0/L	5.8	a	0/0/L	0.8	a
1.5/0/L	6.0	a	1.5/0/L	0.8	a
3/0/S	6.0	a	3/0/S	0.6	a
4/0/S	5.5	a	4/0/S	1.2	a
	Salty			Hardness/Firmness	
0/0/L	1.0	a	0/0/L	7.5	a
1.5/0/L	1.6	a	1.5/0/L	5.6	b
3/0/S	1.2	a	3/0/S	4.2	b
4/0/S	1.0	a	4/0/S	2.5	c
	Sweet			Chewiness	
0/0/L	1.4	a	0/0L	7.0	a
1.5/0/L	1.6	a	1.5/0/L	5.1	b
3/0/S	1.6	a	3/0/S	3.3	c
4/0/S	0.6	a	4/0/S	2.6	c
	Sour			Moistness	
0/0/L	0.8	a	0/0/L	3.0	c
1.5/0/L	0.5	a	1.5/0/L	3.6	bc
3/0/S	0.3	a	3/0/S	4.7	b
4/0/S	0.7	a	4/0/S	6.8	a

Note: Samples with the same letter ranking are not significantly different. Those with different letter rankings were statically different.
Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

Table 4-4. Averaged responses based on ratings by trained panel for the shrimp samples exposed to treatments with 1.5% NaCl concentration. Significant differences were determined by ANOVA.

Sample	Mean	Rank	Sample	Mean	Rank
	Color			Bitter	
0/1.5/L	3.8	a	0/1.5/L	0.3	a
1.5/1.5/L	2.8	ab	1.5/1.5/L	0.1	a
3/1.5/S	2.8	ab	3/1.5/S	0.0	a
4/1.5/S	2.2	b	4/1.5/S	0.0	a
	Translucency			Umami	
0/1.5/L	2.6	c	0/1.5/L	0.8	a
1.5/1.5/L	4.2	b	1.5/1.5/L	1.5	a
3/1.5/S	4.5	b	3/1.5/S	0.8	a
4/1.5/S	5.9	a	4/1.5/S	1.3	a
	Plumpness			Flavor	
0/1.5/L	4.9	b	0/1.5/L	5.6	b
1.5/1.5/L	5.7	b	1.5/1.5/L	6.5	ab
3/1.5/S	6.2	b	3/1.5/S	6.0	a
4/1.5/S	7.8	a	4/1.5/S	6.8	a
	General Shrimp Aroma			Aftertaste	
0/1.5/L	6.8	a	0/1.5/L	0.0	a
1.5/1.5/L	7.6	a	1.5/1.5/L	0.5	a
3/1.5/S	7.1	a	3/1.5/S	0.2	a
4/1.5/S	7.8	a	4/1.5/S	0.5	a
	Salty			Hardness/Firmness	
0/1.5/L	1.8	b	0/1.5/L	6.6	a
1.5/1.5/L	2.2	b	1.5/1.5/L	4.8	bc
3/1.5/S	2.1	b	3/1.5/S	6.0	ab
4/1.5/S	5.5	a	4/1.5/S	3.8	c
	Sweet			Chewiness	
0/1.5/L	1.0	b	0/1.5/L	6.0	a
1.5/1.5/L	1.6	ab	1.5/1.5/L	4.7	b
3/1.5/S	1.2	ab	3/1.5/S	5.3	ab
4/1.5/S	1.8	a	4/1.5/S	3.3	c
	Sour			Moistness	
0/1.5/L	0.2	a	0/1.5/L	4.8	b
1.5/1.5/L	0.2	a	1.5/1.5/L	4.5	b
3/1.5/S	0.0	a	3/1.5/S	4.8	b
4/1.5/S	0.1	a	4/1.5/S	6.8	a

Note: Samples with the same letter ranking are not significantly different. Those with different letter rankings were statically different.
Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

Table 4-5. Averaged responses based on ratings by trained panel for the shrimp samples exposed to treatments with 2.5% NaCl concentration. Significant differences were determined by ANOVA.

Sample	Mean	Rank	Sample	Mean	Rank
	Color			Bitter	
0/2.5/L	4.3	a	0/2.5/L	0.0	b
1.5/2.5/L	3.5	a	1.5/2.5/L	0.2	a
3/2.5/S	3.0	a	3/2.5/S	0.0	b
4/2.5/S	3.2	a	4/2.5/S	0.0	b
	Translucency			Umami	
0/2.5/L	2.6	c	0/2.5/L	0.3	b
1.5/2.5/L	4.8	b	1.5/2.5/L	1.6	a
3/2.5/S	5.3	b	3/2.5/S	2.1	a
4/2.5/S	6.9	a	4/2.5/S	1.3	a
	Plumpness			Flavor	
0/2.5/L	3.3	c	0/2.5/L	3.8	b
1.5/2.5/L	6.2	ab	1.5/2.5/L	6.6	a
3/2.5/S	6.0	b	3/2.5/S	6.9	a
4/2.5/S	7.6	a	4/2.5/S	4.8	ab
	General Shrimp Aroma			Aftertaste	
0/2.5/L	6.0	b	0/2.5/L	0.1	b
1.5/2.5/L	7.6	a	1.5/2.5/L	0.0	b
3/2.5/S	6.5	ab	3/2.5/S	0.1	b
4/2.5/S	6.8	ab	4/2.5/S	0.7	a
	Salty			Hardness/Firmness	
0/2.5/L	1.0	c	0/2.5/L	7.4	a
1.5/2.5/L	4.6	b	1.5/2.5/L	5.6	b
3/2.5/S	4.0	b	3/2.5/S	5.6	b
4/2.5/S	6.5	a	4/2.5/S	4.0	c
	Sweet			Chewiness	
0/2.5/L	0.6	b	0/2.5/L	7.0	a
1.5/2.5/L	1.9	a	1.5/2.5/L	5.6	b
3/2.5/S	1.3	ab	3/2.5/S	4.6	b
4/2.5/S	1.2	a	4/2.5/S	3.1	c
	Sour			Moistness	
0/2.5/L	0.2	a	0/2.5/L	3.2	c
1.5/2.5/L	0.1	a	1.5/2.5/L	5.5	b
3/2.5/S	0.3	a	3/2.5/S	5.5	b
4/2.5/S	0.3	a	4/2.5/S	7.3	a

Note: Samples with the same letter ranking are significantly similar. Those with different letter rankings were statically different.
Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour.)

Table 4-6. Significant differences in consumer panel between the different samples in the zero salt concentration as determined by ANOVA test.

Sample	Mean	Rank	Sample	Mean	Rank
	Overall Appearance			Firmness	
0/0/L	5.0	b	0/0/L	3.32 ± 0.82	a
1.5/0/L	5.1	ab	1.5/0/L	3.02 ± 0.56	b
3/0/S	5.6	a	3/0/S	2.92 ± 0.58	b
4/0/S	5.3	ab	4/0/S	2.65 ± 0.83	c
	Aroma			Moistness	
0/0/L	4.1	a	0/0/L	2.7	c
1.5/0/L	4.0	a	1.5/0/L	2.8	bc
3/0/S	4.3	a	3/0/S	3.0	b
4/0/S	4.4	a	4/0/S	3.3	a
	Flavor			Aftertaste	
0/0/L	4.8	a	0/0/L	1.4	a
1.5/0/L	4.9	a	1.5/0/L	1.5	a
3/0/S	5.0	a	3/0/S	1.5	a
4/0/S	4.6	a	4/0/S	1.5	a
	Saltiness			Overall Liking	
0/0/L	2.1	a	0/0/L	4.6	a
1.5/0/L	2.1	a	1.5/0/L	4.7	a
3/0/S	2.2	a	3/0/S	5.0	a
4/0/S	2.1	a	4/0/S	4.6	a

Note: (5% significance level Tukey's HSD=0.582)

Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

Table 4-7. Significant differences in consumer panel between the different samples in the 1.5% salt concentration as determined by ANOVA test.

Sample	Mean	Rank	Sample	Mean	Rank
	Overall Appearance			Firmness	
0/1.5/L	5.4	a	0/1.5/L	3.2	a
1.5/1.5/L	5.5	a	1.5/1.5/L	2.9	bc
3.0/1.5/S	5.4	a	3.0/1.5/S	3.0	ab
4.0/1.5/S	5.7	a	4.0/1.5/S	2.7	c
	Aroma			Moistness	
0/1.5/L	4.5	a	0/1.5/L	2.8	b
1.5/1.5/L	4.5	a	1.5/1.5/L	2.9	b
3.0/1.5/S	4.3	a	3.0/1.5/S	2.9	b
4.0/1.5/S	4.6	a	4.0/1.5/S	3.2	a
	Flavor			Aftertaste	
0/1.5/L	5.4	a	0/1.5/L	1.4	a
1.5/1.5/L	5.3	b	1.5/1.5/L	1.5	a
3.0/1.5/S	5.4	b	3.0/1.5/S	1.5	a
4.0/1.5/S	6.0	a	4.0/1.5/S	1.5	a
	Saltiness			Overall Liking	
0/1.5/L	2.3	b	0/1.5/L	5.4	b
1.5/1.5/L	2.2	b	1.5/1.5/L	5.5	ab
3.0/1.5/S	2.3	b	3.0/1.5/S	5.4	b
4.0/1.5/S	2.9	a	4.0/1.5/S	5.9	a

Note: (5% significance level Tukey's HSD=0.582)
Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

Table 4-8. Significant differences in consumer panel between the different samples in the 2.5% salt concentration as determined by ANOVA test.

Sample	Mean	Rank	Sample	Mean	Rank
	Overall Appearance			Firmness	
0/2.5/L	5.2	b	0/2.5/L	3.3	a
1.5/2.5/L	5.7	a	1.5/2.5/L	3.0	b
3/2.5/S	5.5	ab	3/2.5/S	2.9	b
4/2.5/S	5.9	a	4/2.5/S	2.6	c
	Aroma			Moistness	
0/2.5/L	4.4	a	0/2.5/L	2.5	c
1.5/2.5/L	4.5	a	1.5/2.5/L	2.8	b
3/2.5/S	4.5	a	3/2.5/S	3.0	ab
4/2.5/S	4.5	a	4/2.5/S	3.2	a
	Flavor			Aftertaste	
0/2.5/L	4.9	b	0/2.5/L	1.5	a
1.5/2.5/L	5.7	a	1.5/2.5/L	1.5	a
3/2.5/S	5.4	ab	3/2.5/S	1.6	a
4/2.5/S	5.6	a	4/2.5/S	1.4	a
	Saltiness			Overall Liking	
0/2.5/L	2.0	c	0/2.5/L	4.9	b
1.5/2.5/L	2.4	b	1.5/2.5/L	5.7	a
3/2.5/S	2.4	b	3/2.5/S	5.4	a
4/2.5/S	3.0	a	4/2.5/S	5.5	a

Note: (5% significance level Tukey's HSD=0.582)
Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

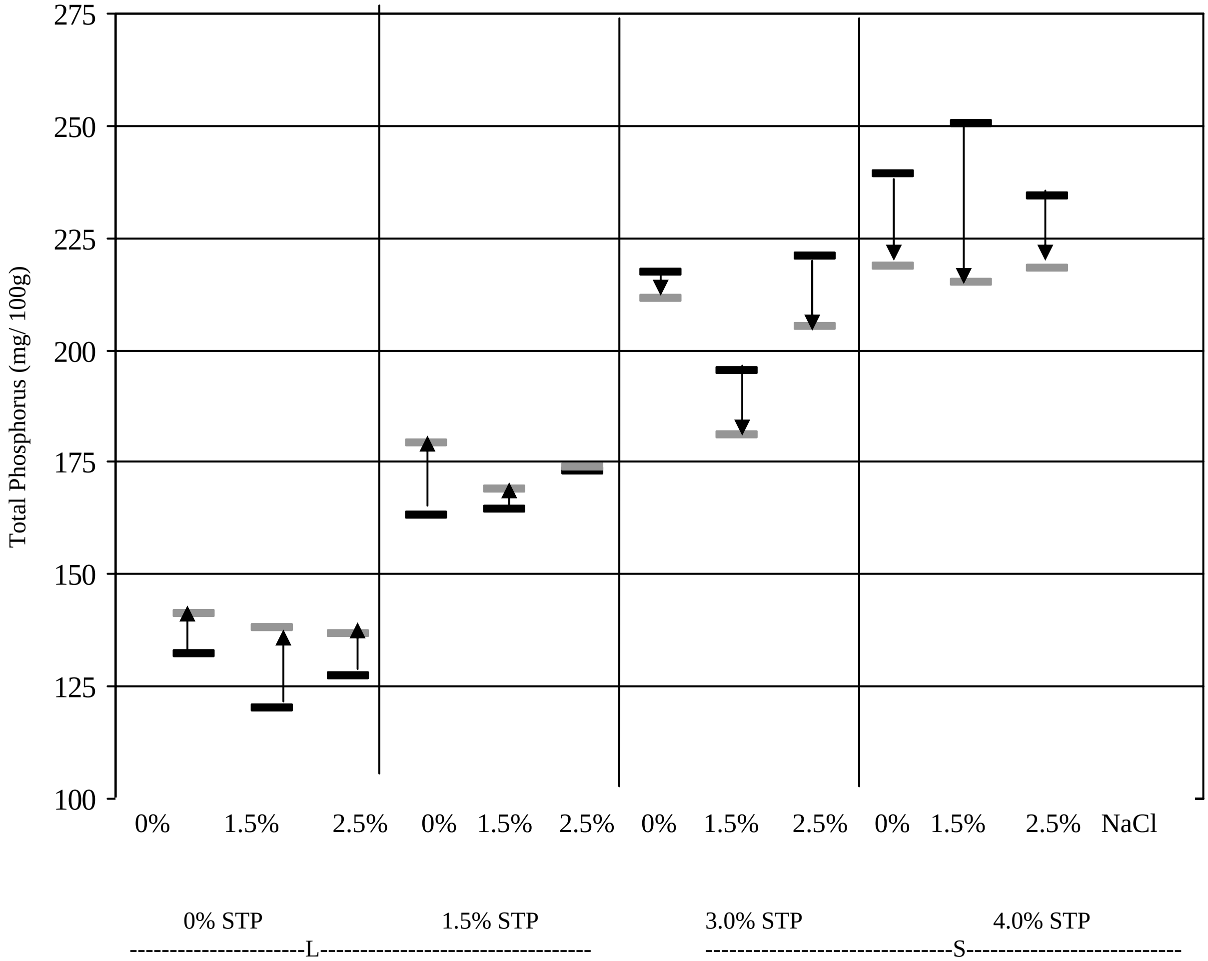


Figure 4-1. Total phosphorus change from raw to cooked shrimp samples previously exposed to different phosphate treatments. Samples are grouped by STP concentrations, increasing NaCl combinations (0, 1.5, and 2.5%), and exposure time (long=four hours, short=one hour.)

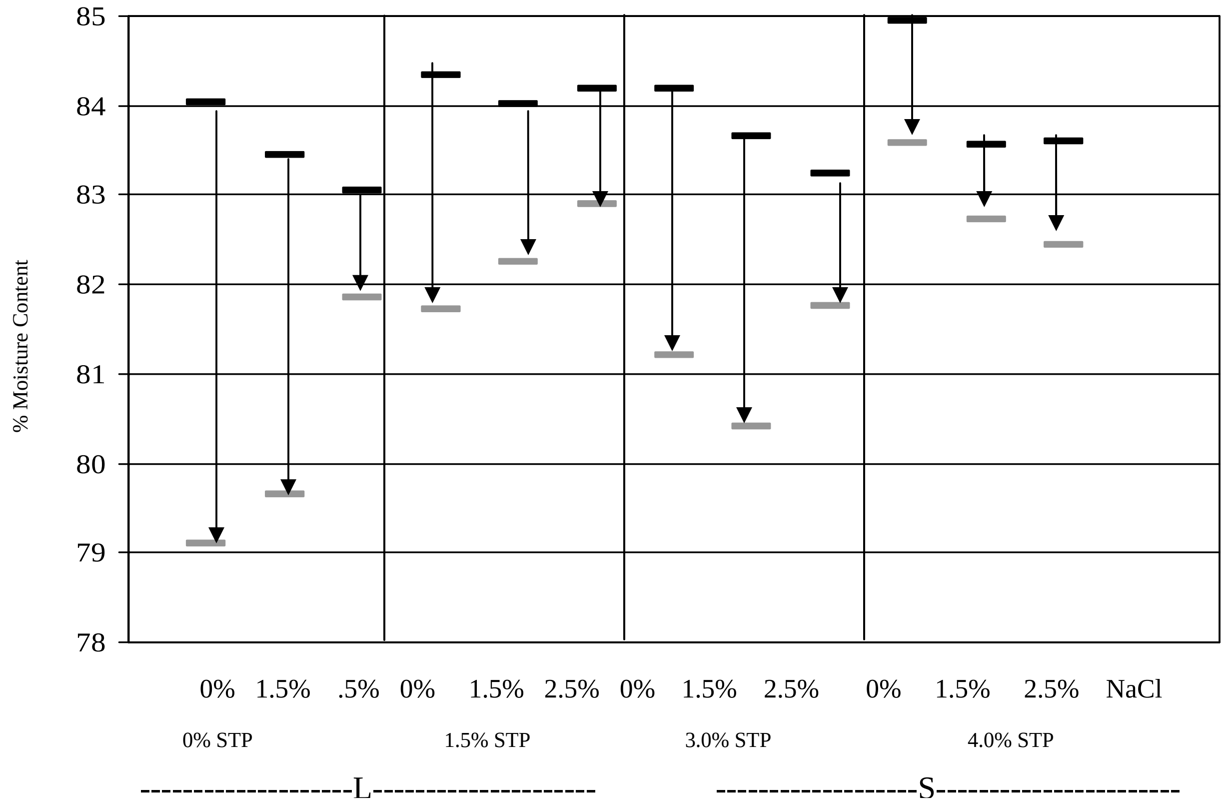


Figure 4-2. Moisture content change from raw to cooked shrimp samples previously exposed to different phosphate treatments. Samples are grouped by STP concentrations, increasing NaCl combinations (0, 1.5, and 2.5%), and exposure time (long=four hours, short=one hour.).

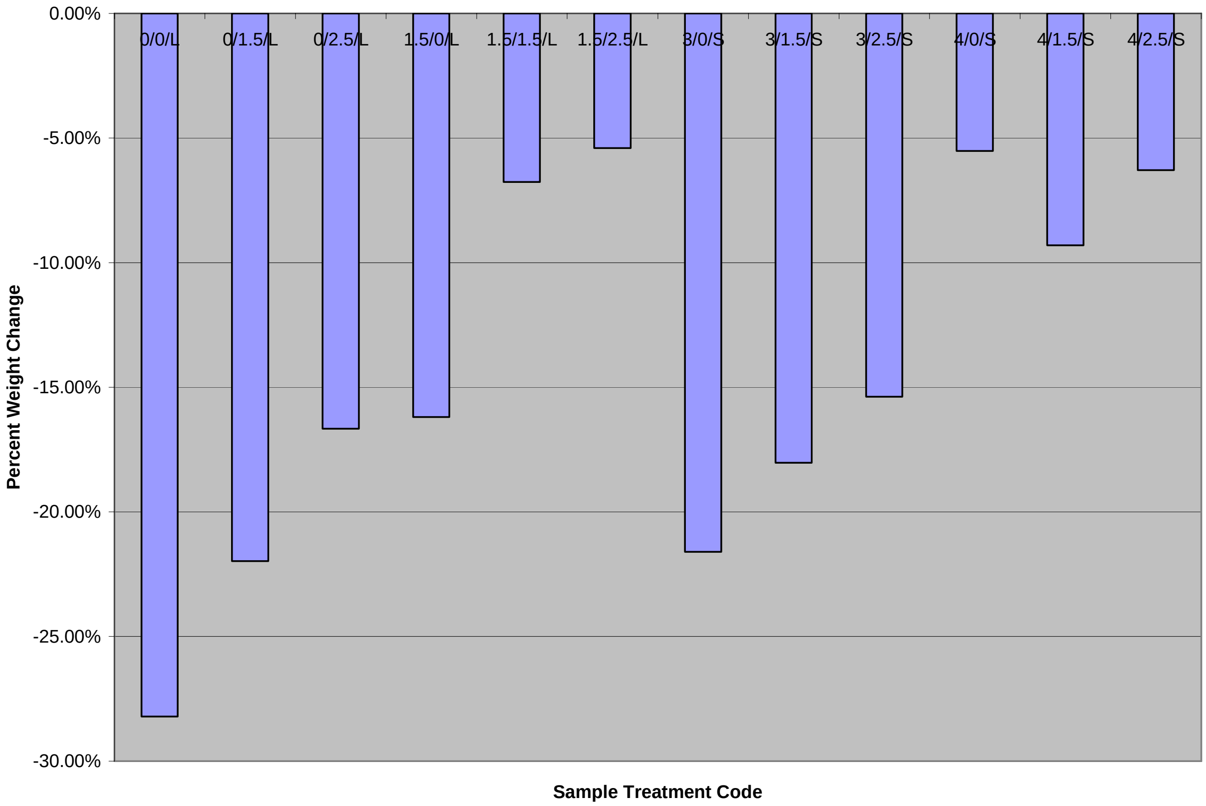


Figure 4-3. Influence of cooking on weight of samples treated with different combinations of STP and NaCl after cooking. Note: Percent change calculated from measurements taken at raw and cooked state. Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

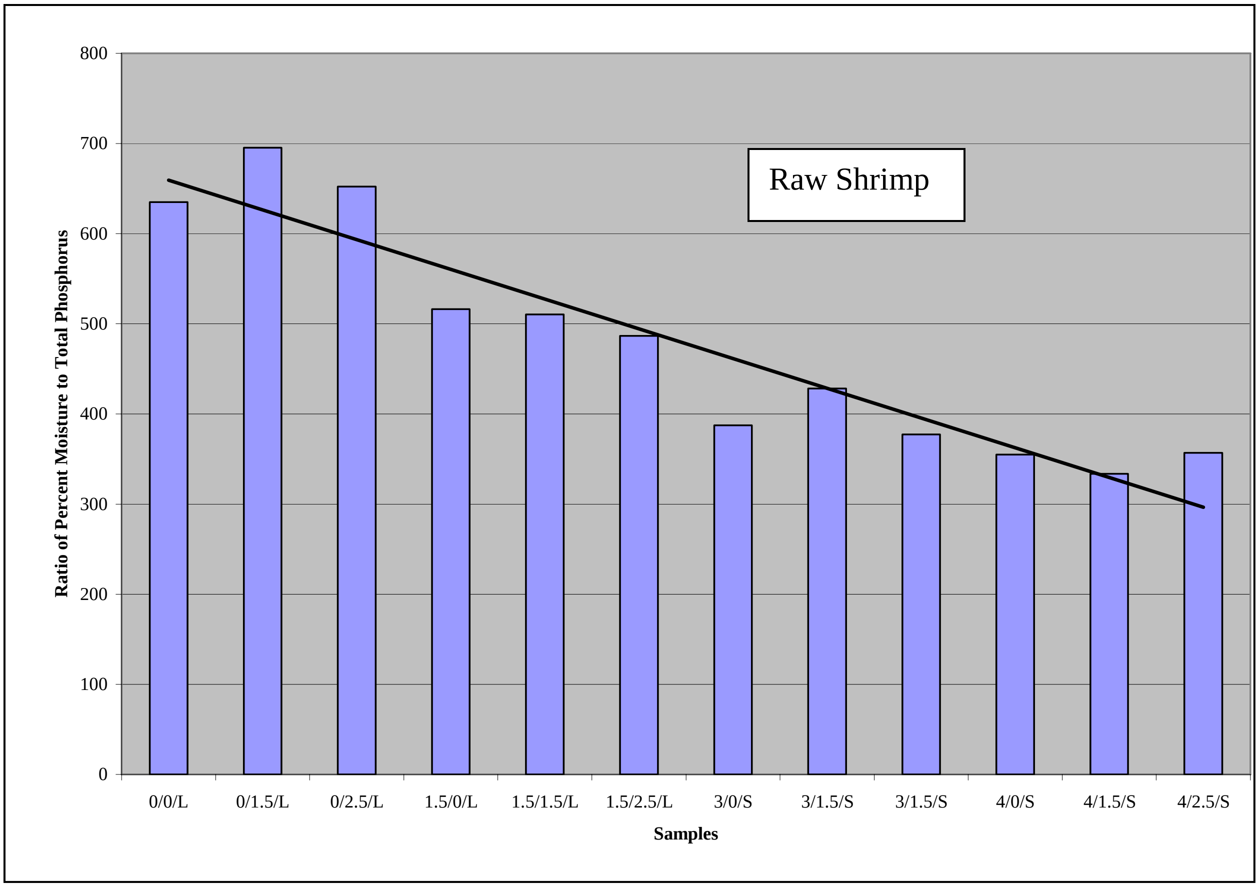


Figure 4-4. Ratio of percent moisture content to total phosphorus in raw shrimp samples exposed to different concentrations of STP and NaCl. Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

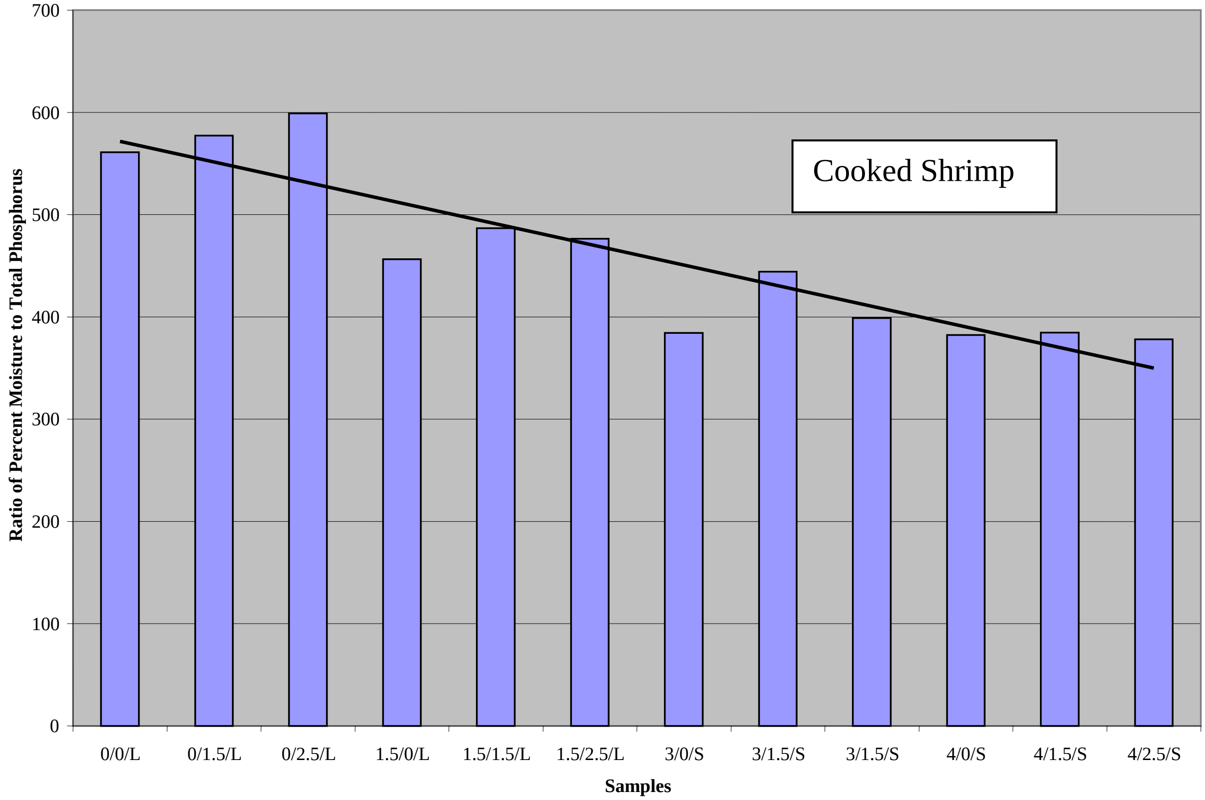


Figure 4-5. Ratio of percent moisture content to total phosphorus in cooked shrimp samples exposed to different concentrations of STP and NaCl. Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

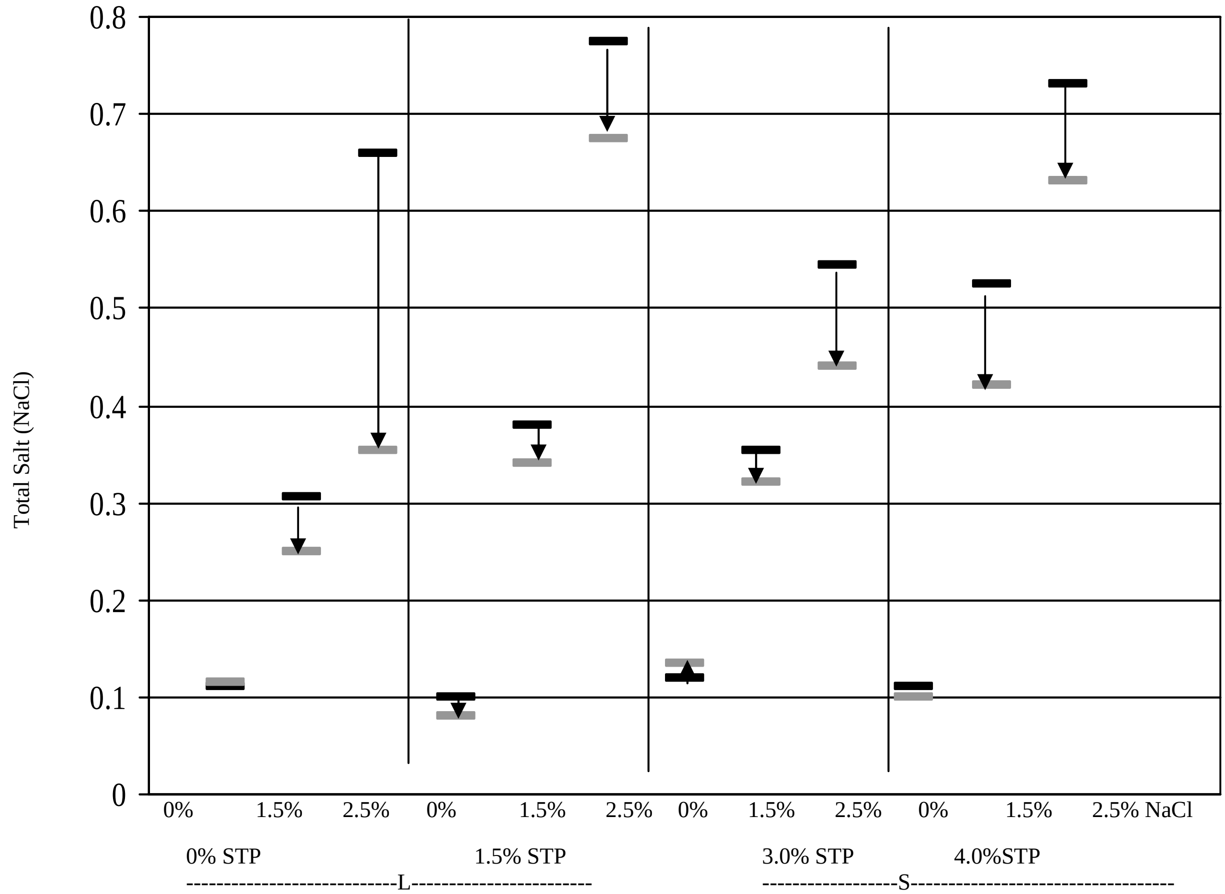


Figure 4-6. Total salt content change from raw to cooked shrimp exposed to different combinations of STP and NaCl. Samples are grouped by STP concentrations, increasing NaCl combinations (0, 1.5, and 2.5%), and exposure time (Long=four hours, s=one hour.)

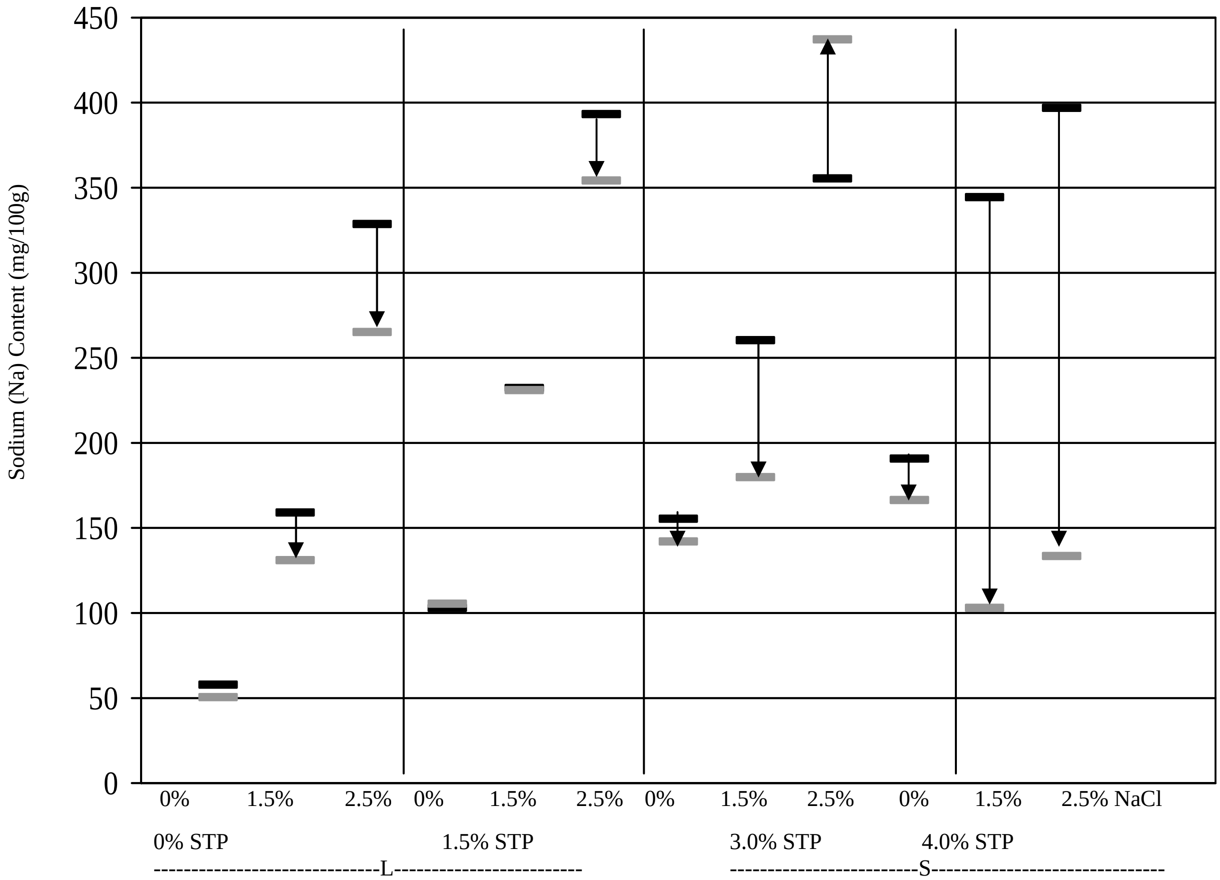


Figure 4-7. Sodium content change from raw to cooked shrimp exposed to different combinations of STP and NaCl. Samples are grouped by STP concentrations, increasing NaCl combinations (0, 1.5, and 2.5%), and exposure time (long=four hours, short=one hour.)

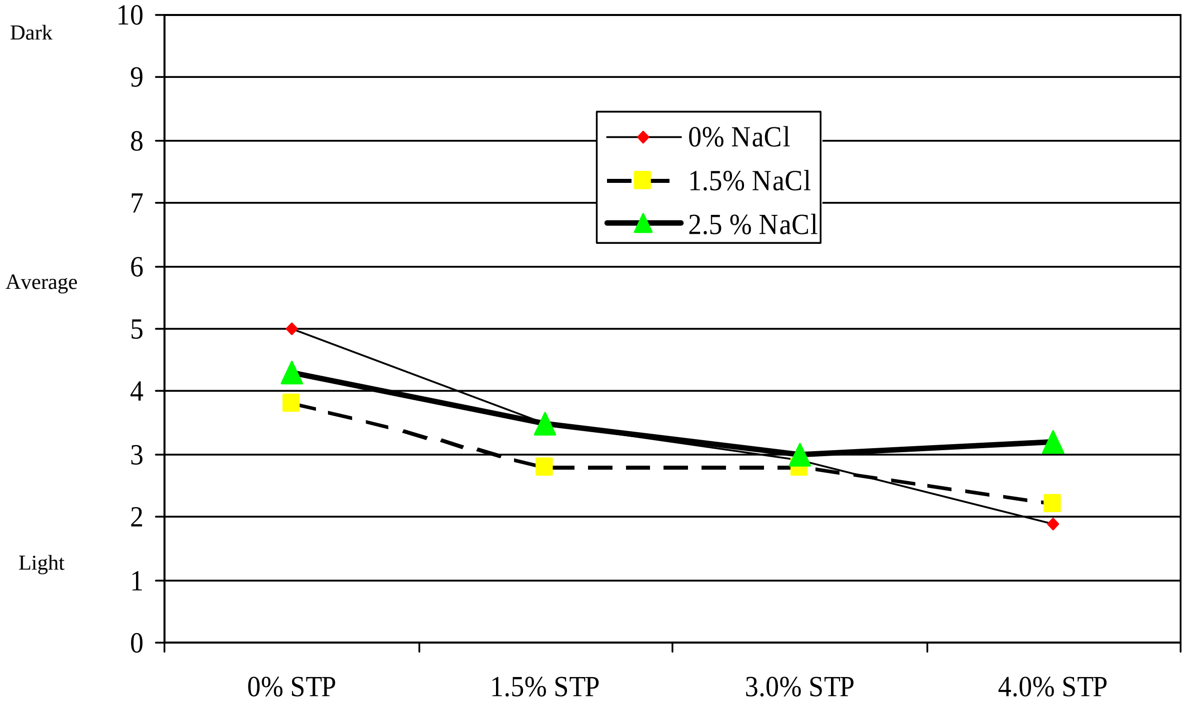


Figure 4-8. Average responses by trained panel regarding Color for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

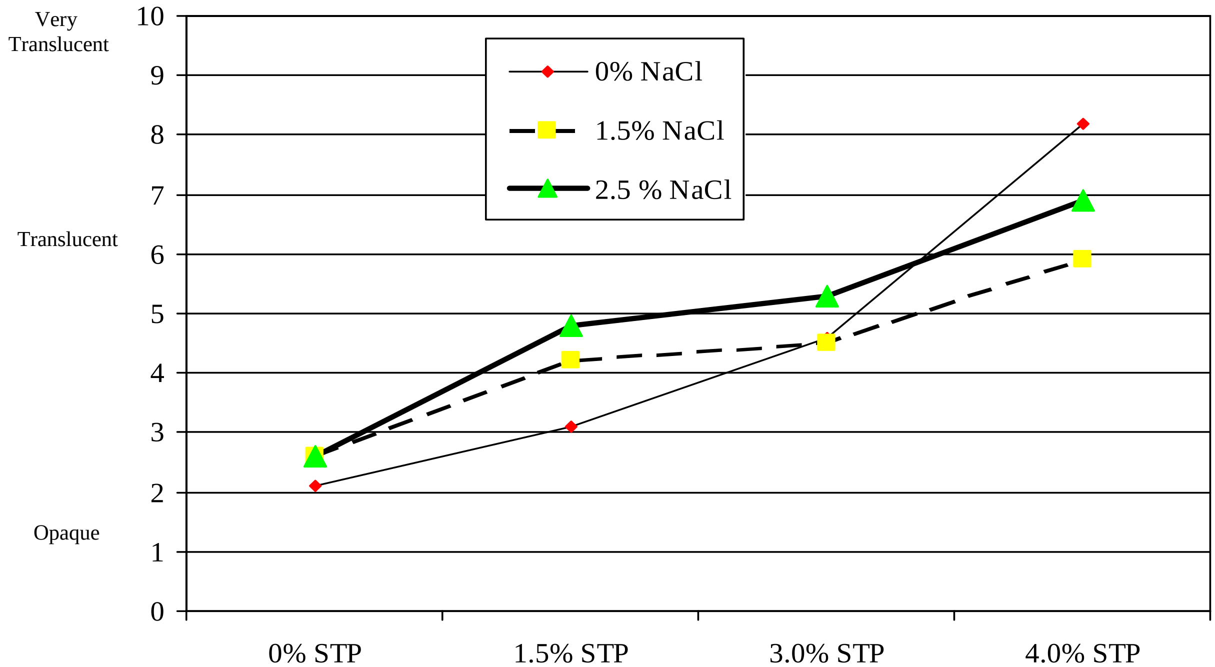


Figure 4-9. Average responses by trained panel regarding Translucency for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

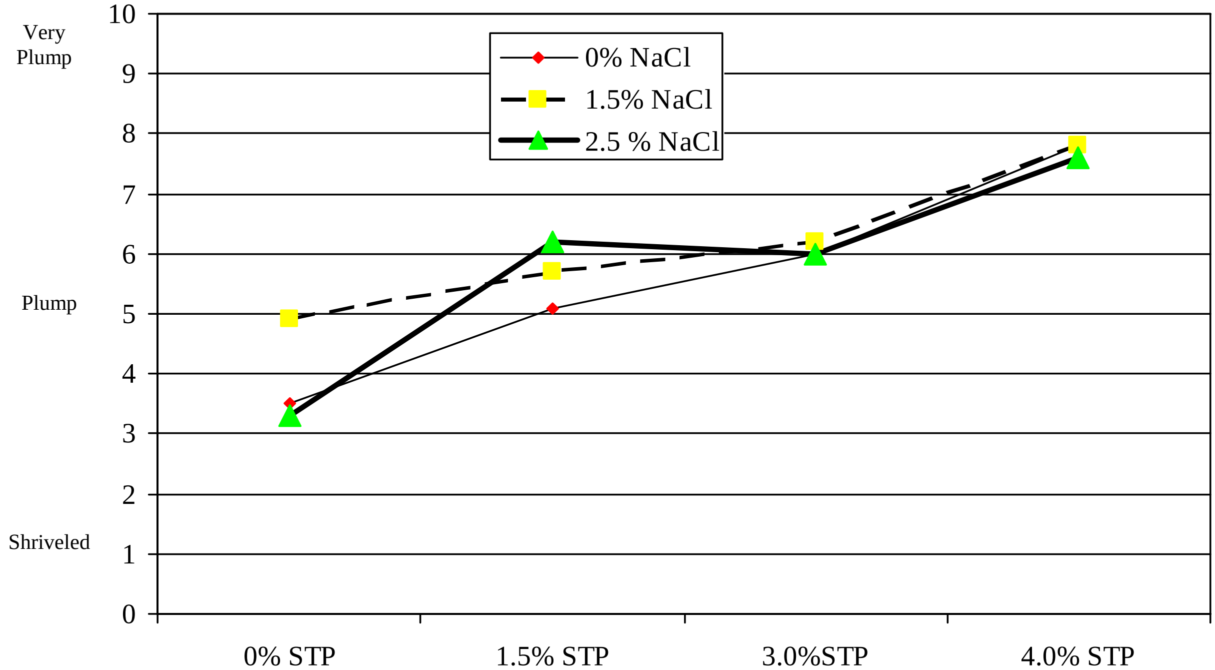


Figure 4-10. Average responses by trained panel regarding Plumpness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

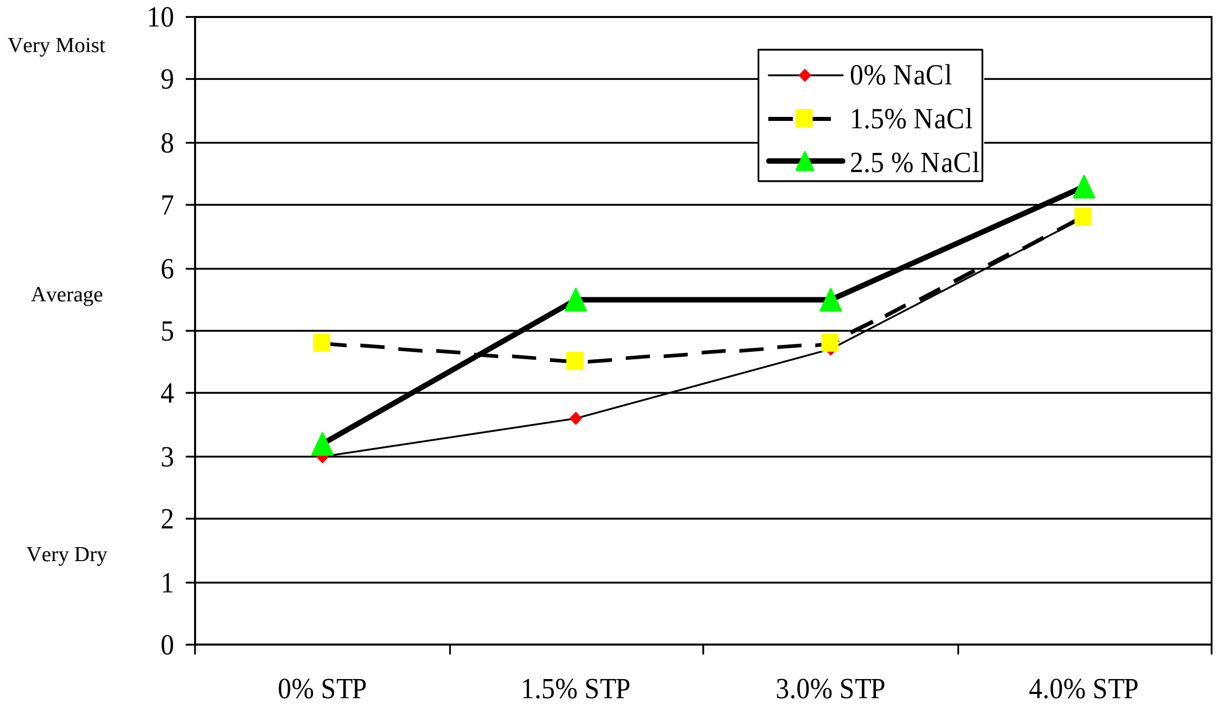


Figure 4-11. Average responses by trained panel regarding Moistness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

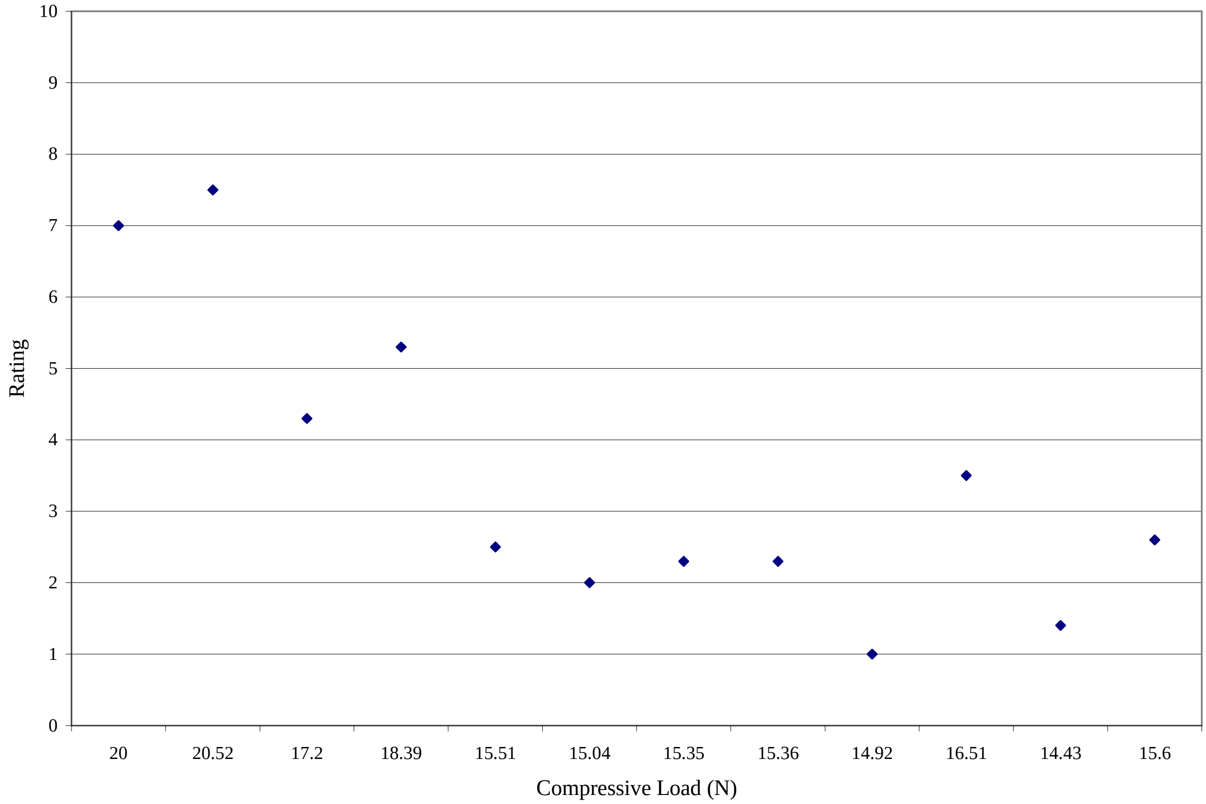


Figure 4-12. Texture ratings for trained panel corresponding to maximum compressive load (N) as measured by the Instron machine for shrimp samples of different STP and NaCl concentrations. Example coding: 0/0/L = 0% STP, 0% NaCl, Long term exposure (four hours). 4/2.5/S = 4% STP, 2.5% NaCl, Short term exposure (one hour).

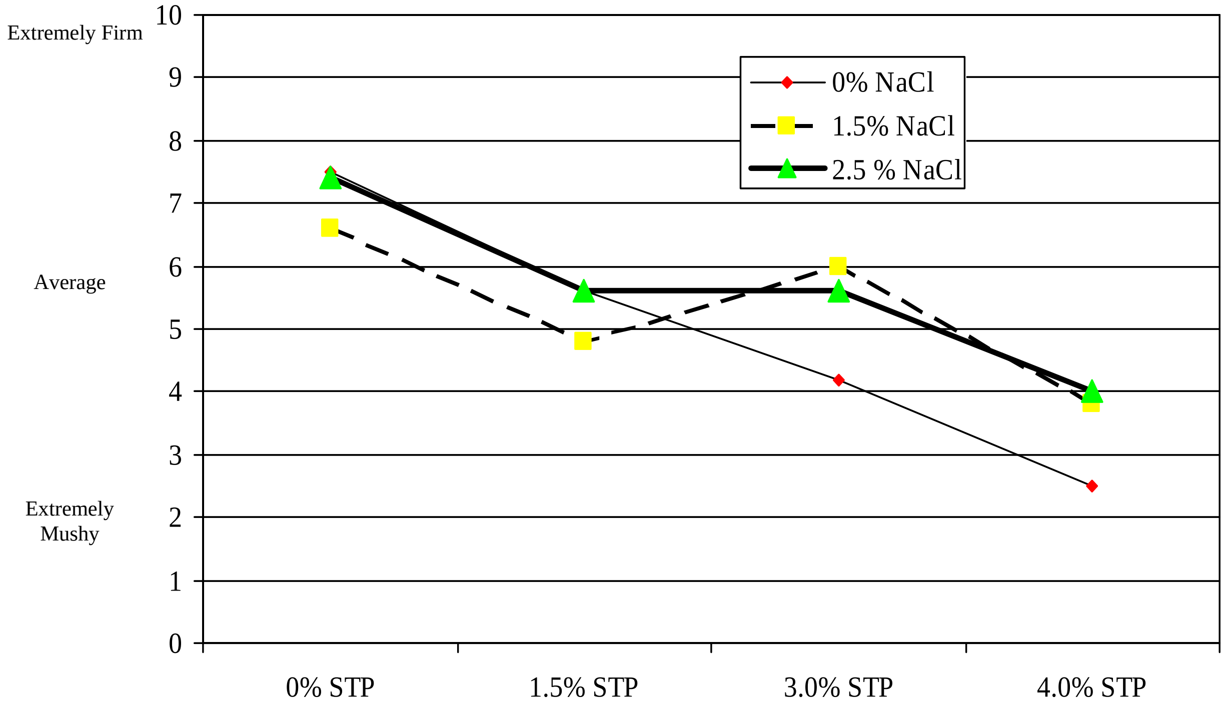


Figure 4-13. Average responses by trained panel regarding Hardness/Firmness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

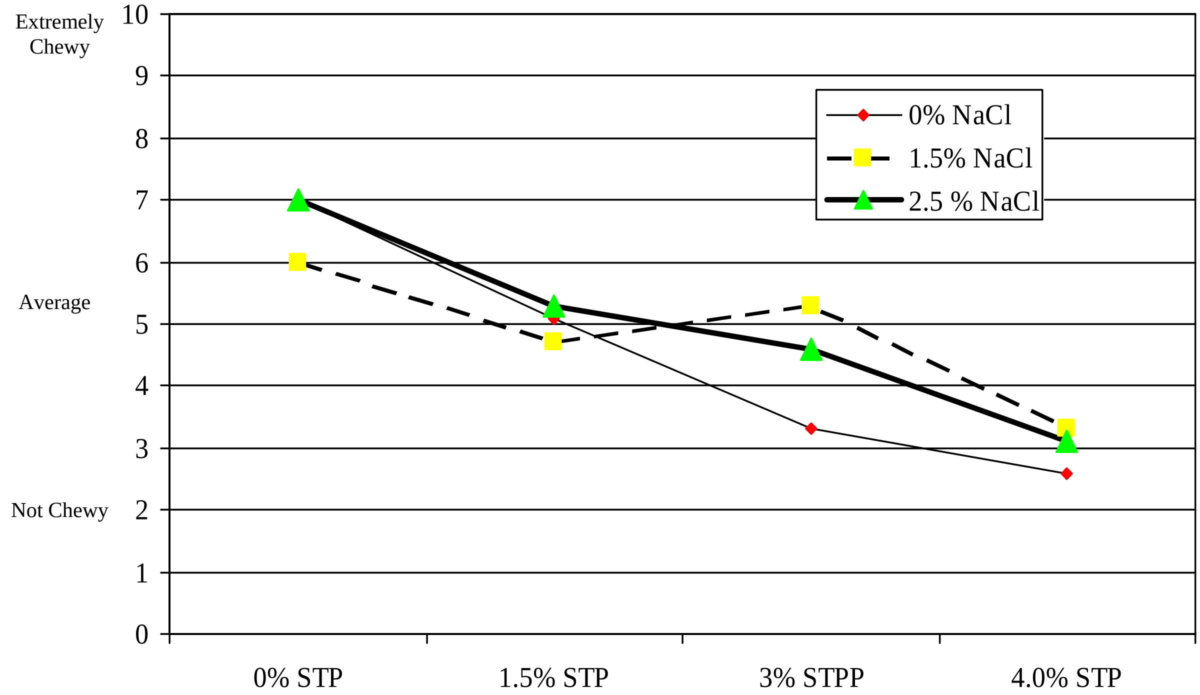


Figure 4-14. Average responses by trained panel regarding Chewiness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

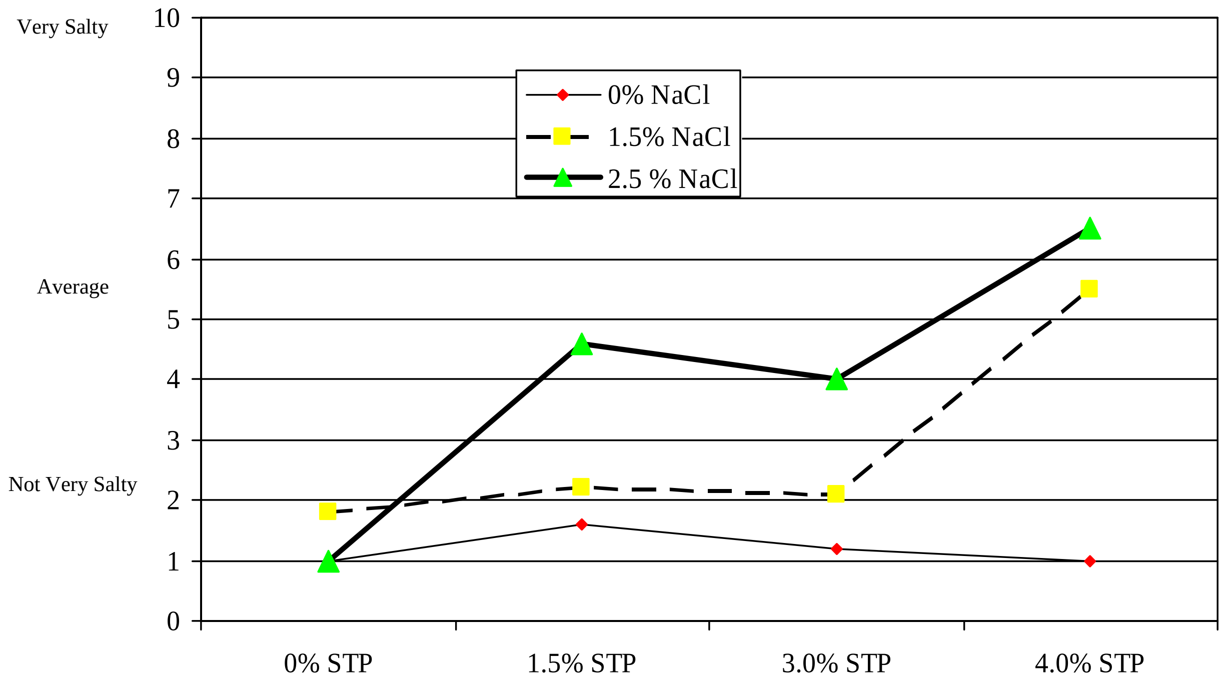


Figure 4-15. Average responses by trained panel regarding Saltiness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

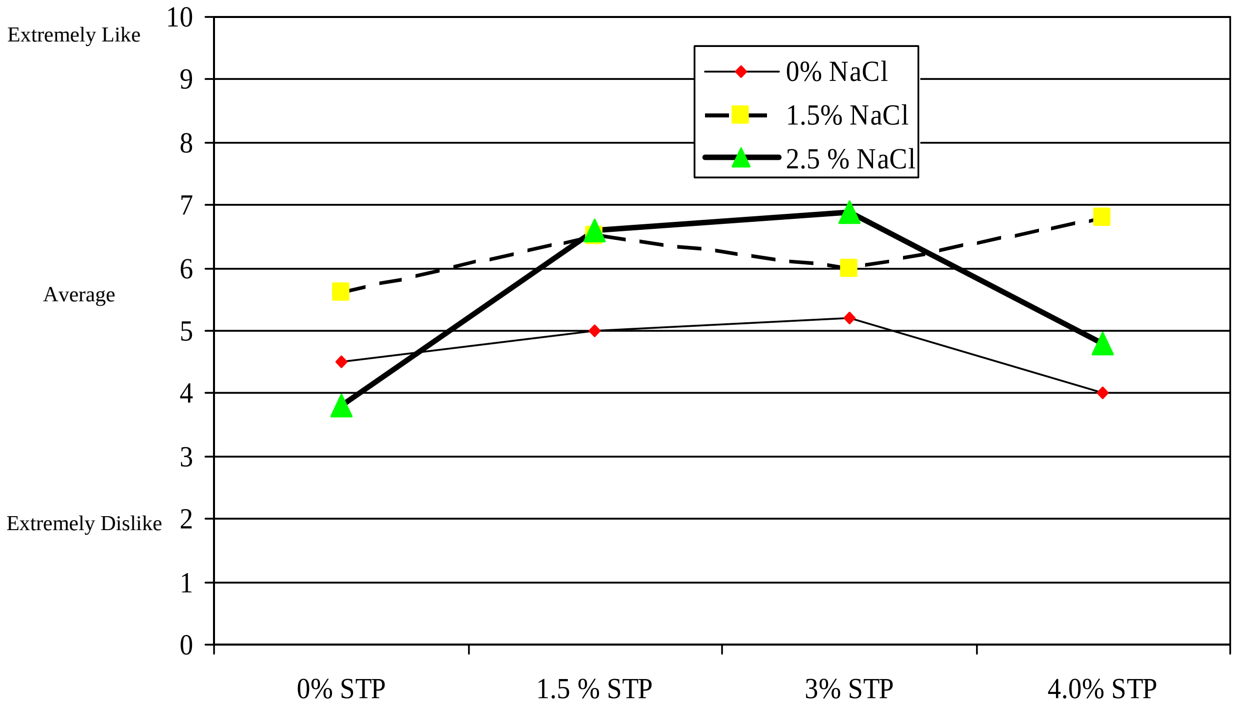


Figure 4-16. Average responses by trained panel regarding Flavor for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

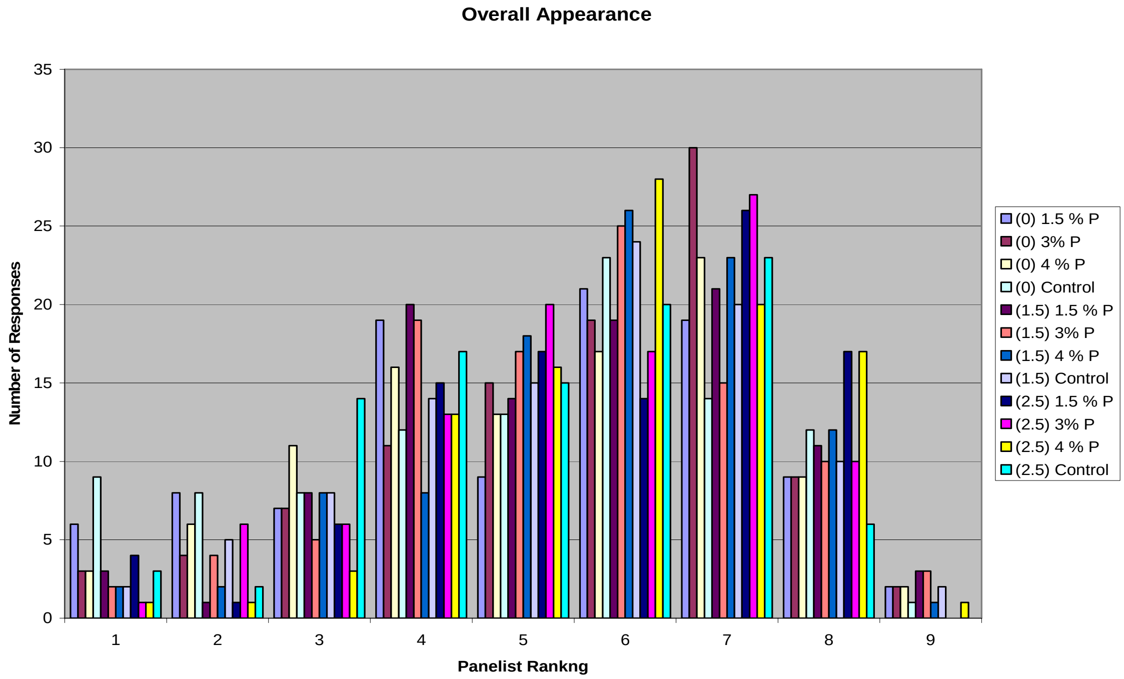


Figure 4-17. Histogram of overall appearance as rated by consumer panel for shrimp treated with different concentrations of STP and NaCl. Ratings ranged from extremely dislike (1) to extremely like (9).

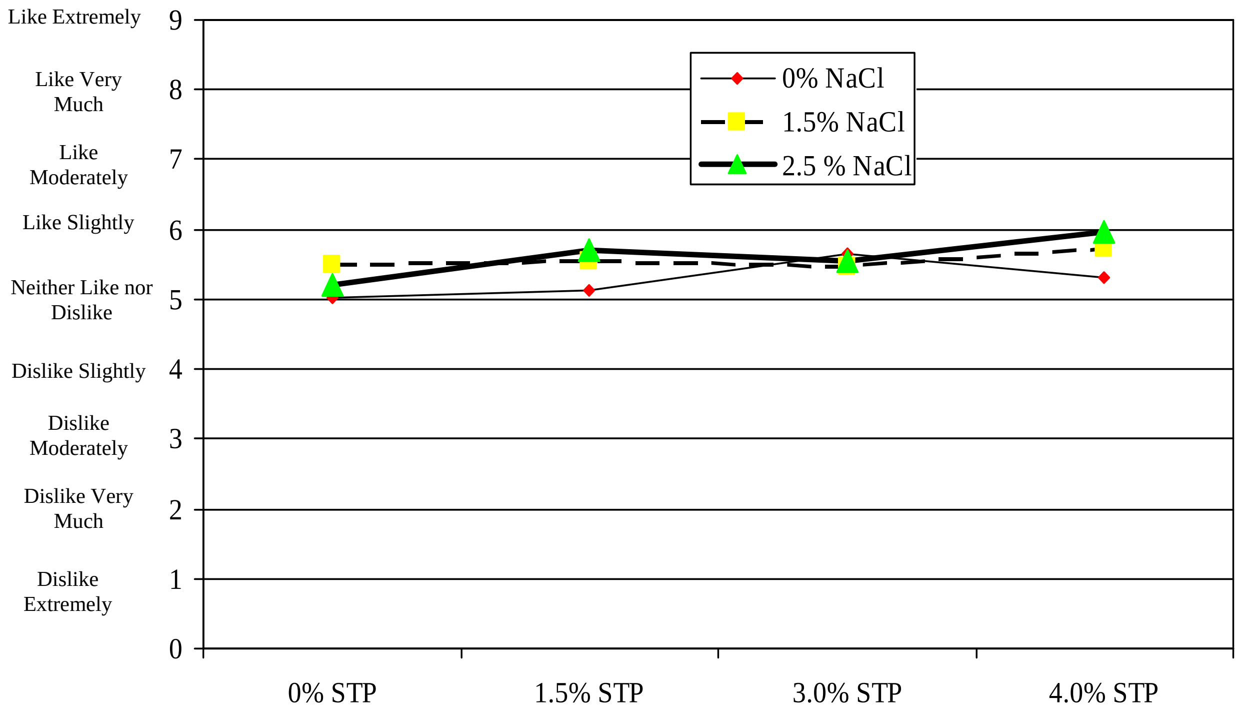


Figure 4-18. Average responses by consumer panel regarding Overall Appearance for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

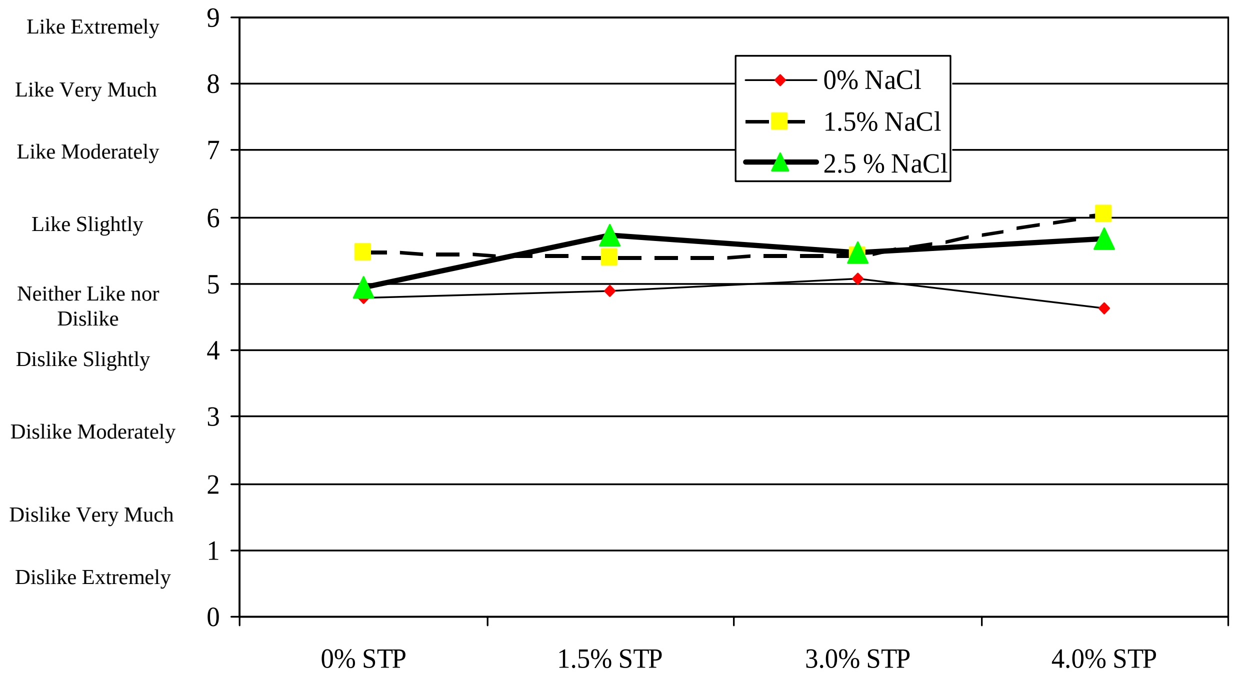


Figure 4-19. Average responses by consumer panel regarding Flavor for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

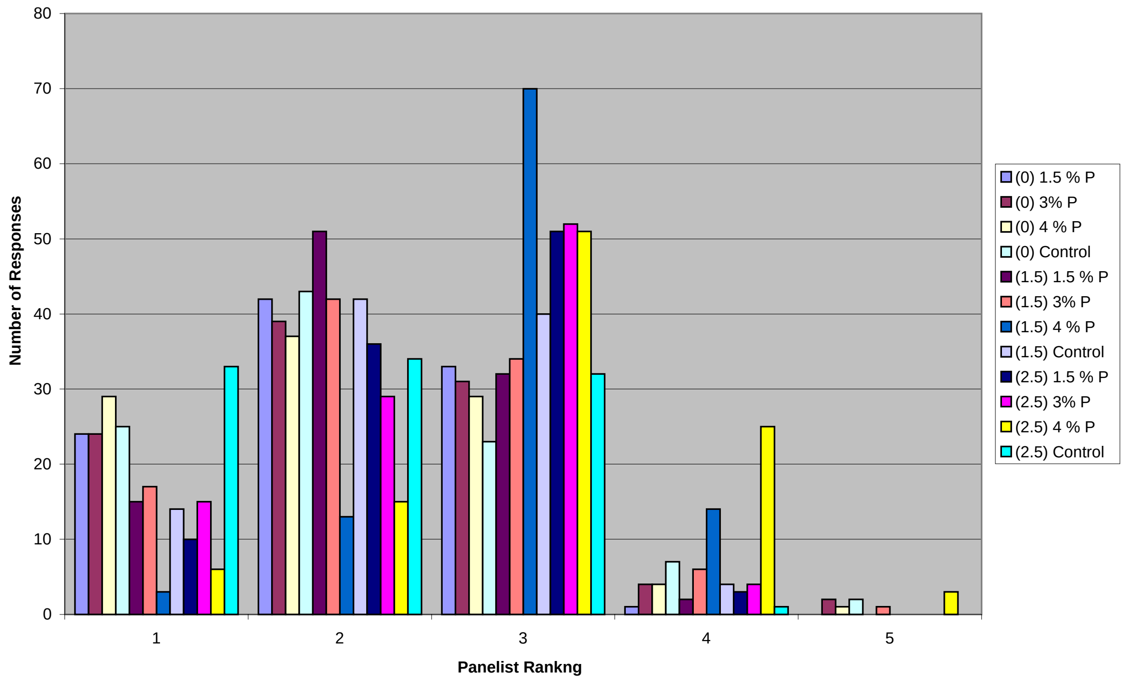


Figure 4-20. Histogram of saltiness as rated by consumer panel for shrimp treated with different concentrations of STP and NaCl. Ratings ranged from not salty enough (1) to much too salty (5).

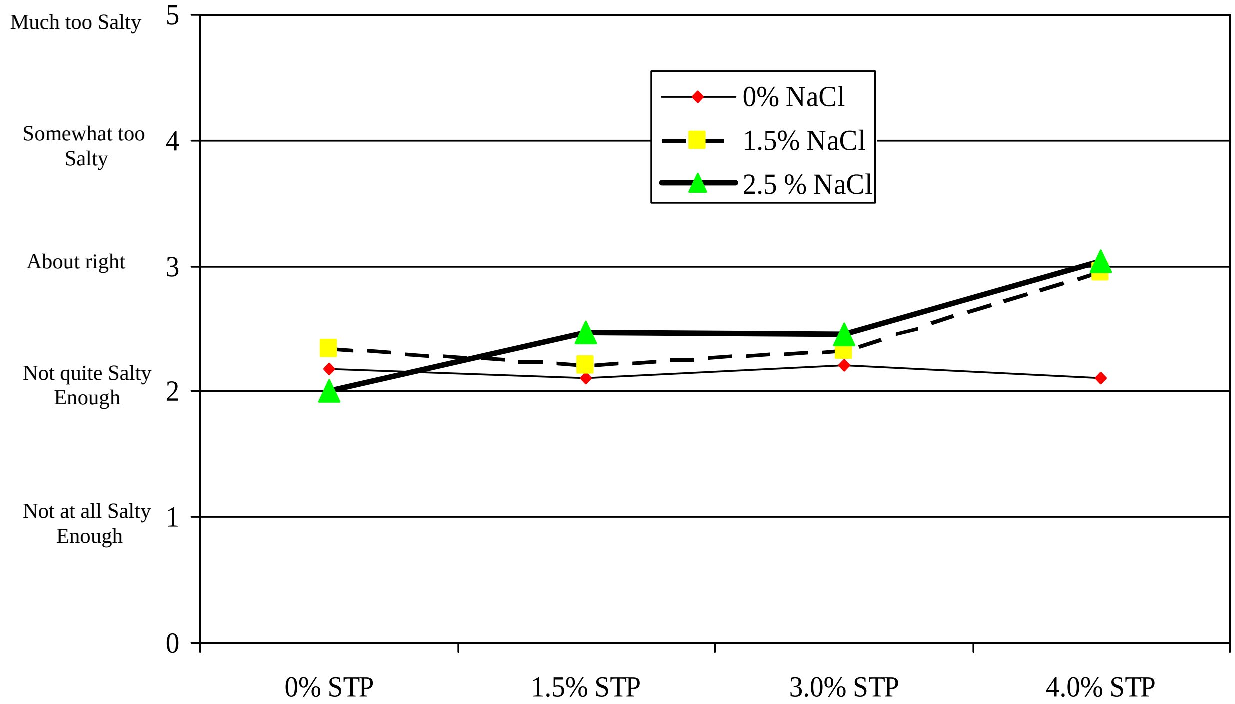


Figure 4-21. Average responses by consumer panel responses regarding Saltiness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

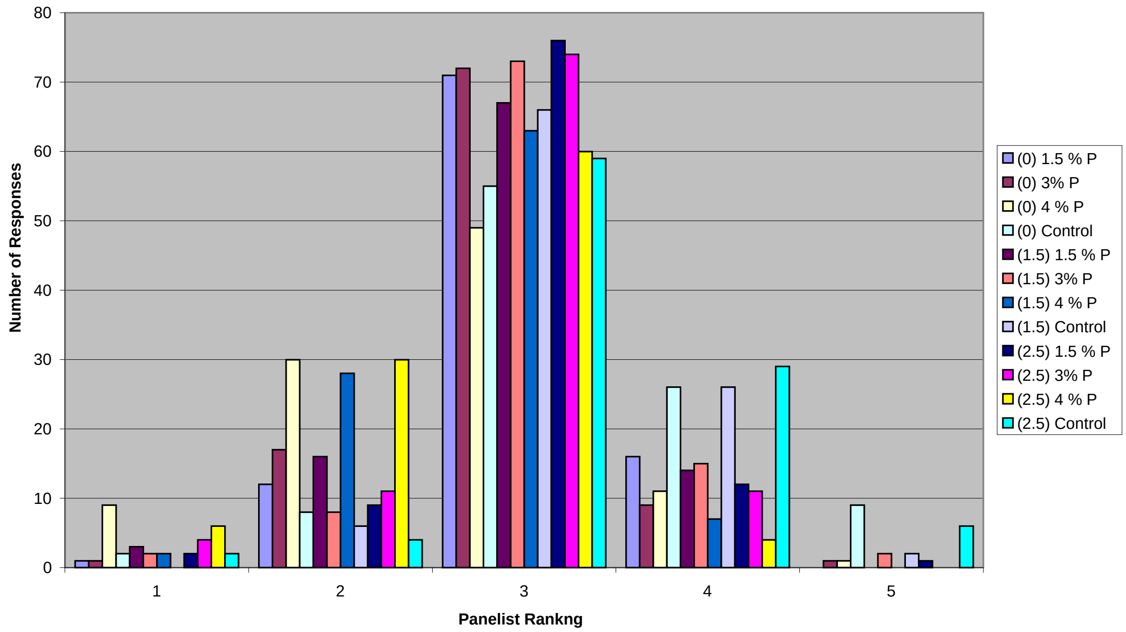


Figure 4-22. Histogram of firmness as rated by consumer panel for shrimp treated with different concentrations of STP and NaCl. Ratings ranged from not at all firm enough (1) to much too firm (5).

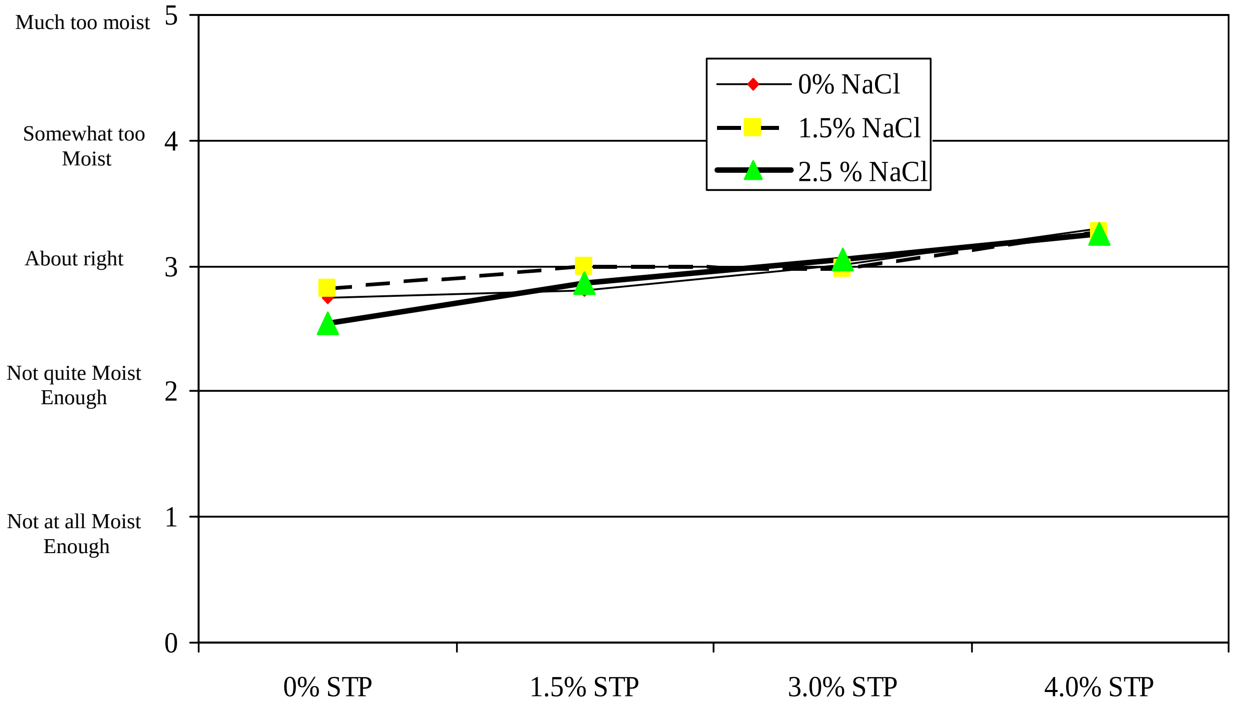


Figure 4-23. Average responses by consumer panel regarding Moistness for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to ratings are included on the vertical axis.

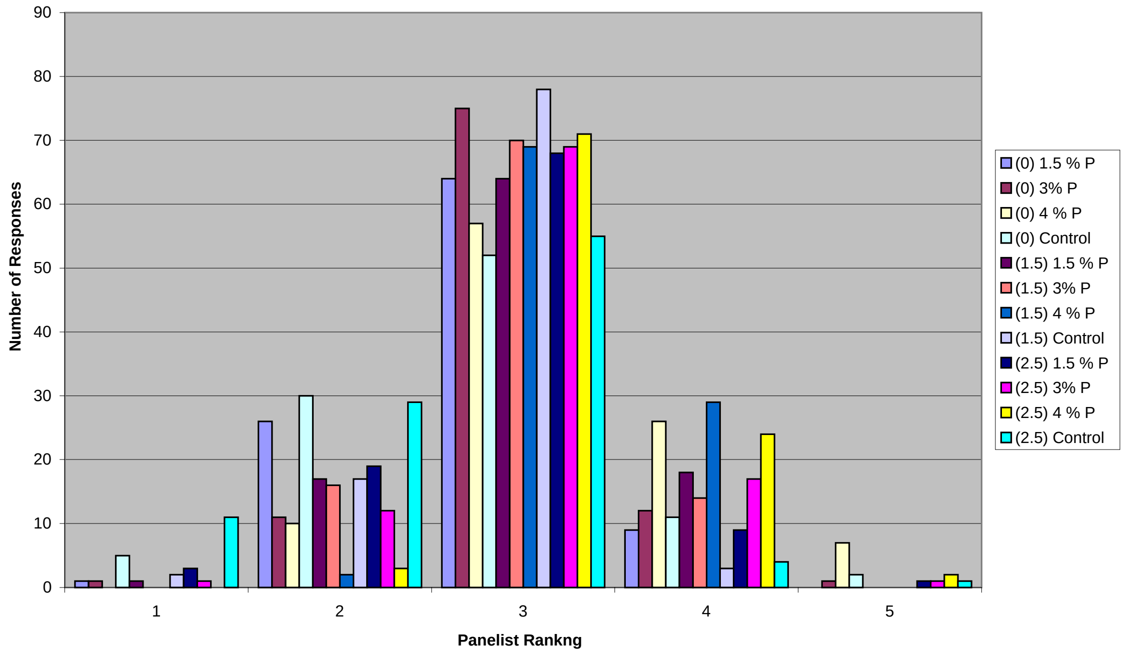


Figure 4-24. Histogram of moistness as rated by consumer panel for shrimp treated with different concentrations of STP and NaCl. Ratings ranged from not at all moist enough (1) to much too moist (5).

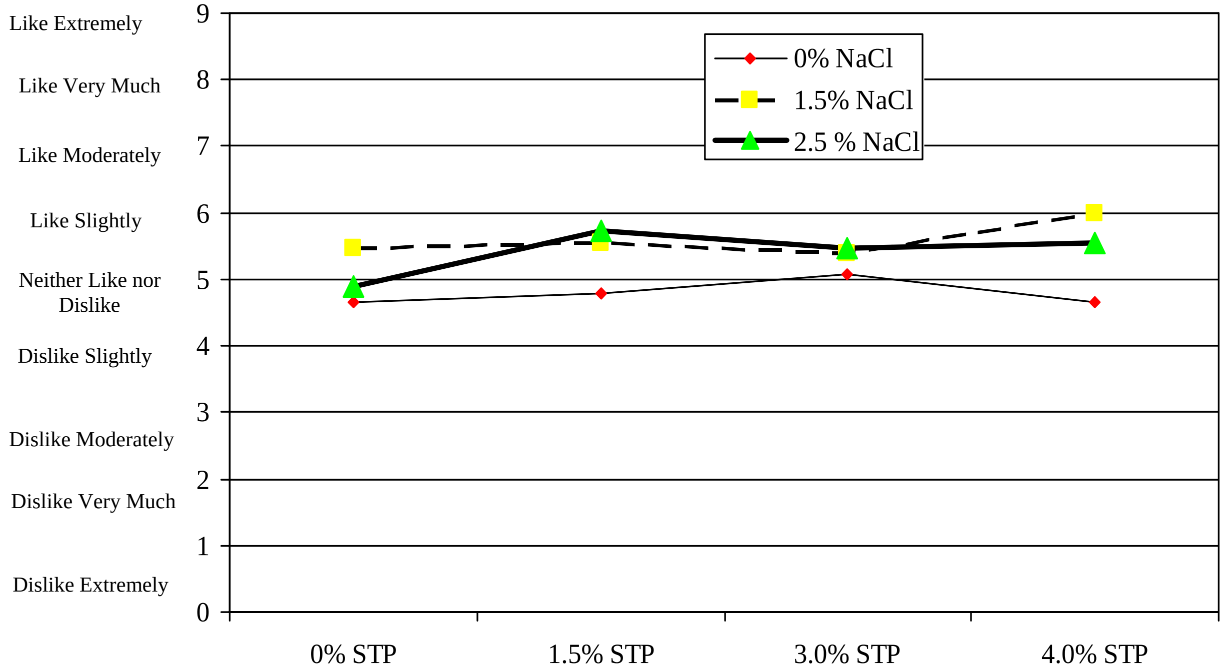


Figure 4-25. Average responses by consumer panel regarding Overall Liking for samples treated with different concentrations of STP and NaCl. Word anchors corresponding to rating are included on the vertical axis.

APPENDIX A
FORM PRESENTED TO TRAINED PANEL FOR SHRIMP CHARACTERIZATION

Shrimp Product Characterization Form
Form includes standards used in scales and corresponding ratings.

Panelist: ________________________________

Date:___________________________________

Sample Number:___________________________

APPEARANCE OF SHRIMP

<u>Color:</u>

Light										Dark	
0	1	2	3	4	5	6	7	8	9	10	

<u>Opacity/Translucency:</u>

Opaque					Translucent					Very Translucent	
0	1	2	3	4	5	6	7	8	9	10	

<u>Plumpness:</u>

Shriveled					Plump					Very Plump	
0	1	2	3	4	5	6	7	8	9	10	

AROMA

<u>General:</u>

Extremely Dislike										Extremely Like	
0	1	2	3	4	5	6	7	8	9	10	

BASIC TASTES

<u>Salty:</u>

Very Bland										Very Salty	
					Std5					Std10	
0	1	2	3	4	5	6	7	8	9	10	
	100		200		300		400		500		Mg of Na
	0.1		0.2		0.3		0.4		0.5	0.55	% NaCl

<u>Sweet:</u>

Not Very Sweet										Very Sweet	
0	1	2	3	4	5	6	7	8	9	10	
				Ritz							

Sour:
Not Very Sour — Very Sour

0	1	2	3	4	5	6	7	8	9	10
					Std5 0.38g					Std10 0.75g

Bitter:
Not Very Bitter — Very Bitter

0	1	2	3	4	5	6	7	8	9	10
					Std5 0.38g					Std10 0.71g

Umami:
Not-Umami like — Very Umami

0	1	2	3	4	5	6	7	8	9	10
					Std5 1/4tsp					Std10 1/2tsp

FLAVOR & MOUTH FEEL

Moisture:
Very Dry — Very Moist

0	1	2	3	4	5	6	7	8	9	10
	76%		78%		80%		82%		84%	

Flavor:
Extremely Dislike — Extremely like

0 1 2 3 4 5 6 7 8 9 10

Aftertaste:
None — Extreme

0 1 2 3 4 5 6 7 8 9 10

Aftertaste detected:____

TEXTURE

Hardness/Firmness:
Extremely Mushy — Extremely Firm

0	1	2	3	4	5	6	7	8	9	10	
13	14	15	16	17	18	19	20	21	22	23	Instron

Chewiness:
Not Chewy — Extremely Chewy

0	1	2	3	4	5	6	7	8	9	10
		Cheese								

DEFINITIONS

Moistness: The perceived degree of oil and/or water in the sample during chewing.

Hardness/Firmness: perceived force required to compress a substance between molar teeth.

Chewiness: Number of chews required to masticate a sample at one chew per second and constant rate of force application to reduce to a consistence suitable for swallowing.

APPENDIX B

FORM PRESENTED TO CONSUMER PANEL TO JUDGE ACCEPTABILITY OF SHRIMP

Question 1.
Please indicate your gender:

- Male
- Female

Question 2.
Which of the following ranges includes your age?

- Under 18
- 18-20
- 21-24
- 25-29
- 30-34
- 35-39
- 40-44
- 45-49
- 50-54
- 55-59
- 60-65
- Over 65

Question 3.
Which of the following represents your race?

- Caucasian
- African American
- Native American
- Asian or Pacific Islander
- Hispanic
- Other
- Decline to answer

Question 4.
Which of the following categories describes your household annual income before taxes?

- Under 20,000
- $20-35,000
- $36-50,000
- $51-75,000
- $76-100,000
- Over $100,000
- Decline to answer

Question 5.
How often do you eat shrimp (either at home or ordered out)?

- More than once a day
- Once a day
- 2-3 times a week
- Once a week
- 2-3 times a month
- Once a month
- Once a year

Question 6.

Please look at sample # (sample number here) but do not taste yet. Answer the following question about the APPEARANCE.
Please disregard the presence of the vein and indicate how much you like the OVERALL APPEARANCE.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question 7.
Please look at sample # (sample number here) but do not taste yet. Answer the following question about the AROMA.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question 8.
Please take a bite of cracker and a sip of water to rinse your mouth. The following questions deal with the TASTE, FLAVOR, MOISTURE and TEXTURE of the shrimp. Please taste just enough to be able to answer each question.
Please indicate how much you like the FLAVOR.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question 9.
Would you say that the SALTINESS of the product is….?

Not at all salty enough	Not quite salty enough	About right	Somewhat too Salty	Much too Salty
1	2	3	4	5

Question 10.
Would you say that the FIRMNESS of the product is….?

Not at all firm enough	Not quite firm enough	About right	Somewhat too Firm	Much too Firm
1	2	3	4	5

Question 11.
Would you say that the MOISTNESS of the product is….?

Not at all moist enough	Not quite moist enough	About right	Somewhat too moist	Much too moist
1	2	3	4	5

Question 12.
Does this product have an aftertaste?

Yes
No

Question 13.
How would you describe the AFTERTASTE of this product?

Mild aftertaste	Moderate aftertaste	Strong aftertaste
1	2	3

Question 14.
Please indicate how much you like the sample OVERALL.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

APPENDIX C
PICTURE SCALES USED FOR COLOR, PLUMPNESS, AND OPACITY

Trained panel characterization scales.

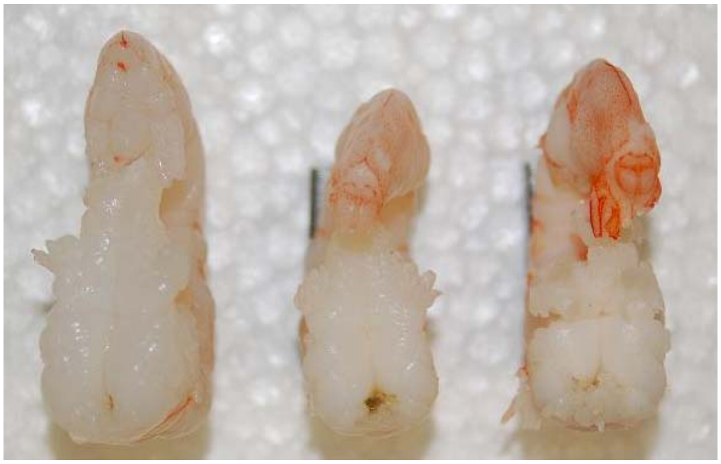
Opacity/Translucency

0	1	2	3	4	5	6	7	8	9	10

Plumpness

0	5	10
Shriveled	Plump	Very Plump

Opacity



10	5	0
Translucent		Opaque

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BIOGRAPHICAL SKETCH

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