Descriptive Sensory Analysis of Broiler Breast Fillets Marinated in Phosphate, Salt, and Acid Solutions

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ABSTRACT Sensory attributes of fully aged broiler breast fillets marinated in a 6% NaCl solution containing 2% sodium tripolyphosphate (2P), 2% citric acid (2C), 2% acetic acid (2A), 1% citric acid plus 1% phosphate solution (1C), or 1% acetic acid solution plus 1% phosphate (1A) were studied. A 6% NaCl (6S) solution with no additives was used as control. Oven-cooked samples (177°C oven; 75°C internal temperature) were evaluated by a 9-member trained descriptive analysis sensory panel that rated the intensities of 26 different flavor and texture attributes using 15-point line scales. Data were analyzed using general linear model SAS procedures to determine significant differences ($P \leq 0.05$) in individual sensory attributes due to marination treatment. All sensory attributes were scored in the low intensity range (1.5 to 5.0). Brothy, vinegar, and residual particles were the only individual attributes rated significantly different ($P \leq 0.05$) due to treatment. Multivariate analyses indicated that all sensory attributes formed 2 dimensions that explained 57% of variation in the data. The low intensity values for texture attributes indicated possible negative consequences due to phosphates, salt, and acids when used with fully aged fillets.

(Key words: broiler fillet, sensory, marination, flavor, texture)

INTRODUCTION

The quantity of marinated poultry breast meat continues to grow as the demand for new further-processed items increases. Reports have indicated that some textural and color problems in finished cooked products can be attributed to addition of polyphosphates (Young and Lyon, 1994). Commercial marination involves addition of a solution of water, salt, phosphate, and sometimes flavorings and other ingredients, by means of soaking, blending, tumbling, or injecting (Smith and Acton, 2001). Marination reportedly increases product value by enhancing flavor, improving or preserving color, tenderizing muscle, increasing juiciness, and extending shelf life by reducing off-flavors. The consumer benefits from this practice through the perception of enhanced quality, and the processor benefits from increased yield and longer shelf life.

Raw poultry muscle is composed of about 21% protein, 75% water, and 3% fat. Typical marinade solutions are made of 90% water, 6% salt, and 4% sodium tripolyphosphate. This formula is based on an average of a total 10% pickup (weight difference before and after marination, expressed as a percentage of initial weight). Marination with acids or phosphates may cause pH changes and unfolding of secondary protein structure to allow more water to be absorbed and bound to the protein molecules. USDA limits total phosphate in the finished product to no more than 0.5%.

Marination may also benefit product quality by allowing the addition of spices and flavorings to add or enhance flavor. Marinades containing phosphates tend to reduce rancidity development and warmed-over flavor, increase shelf life, and improve color of poultry meat. With increased water-holding capacity, products tend to be perceived as more juicy and tender. Through the action of the salt and phosphate on the myofibrils and connective tissue, the structure of the muscle fibers may be weakened to increase the perception of tenderness (Schults and Wierbicki, 1973; Goodwin and Maness, 1984).

Weak organic acids, such as citric and acetic acids, are components of flavored marinades used with meats in limited quantities. Acetic and citric acids differ respectively in molecular weight (60.1 vs. 192.1), carbon atoms (2 vs. 6), and carboxy groups (1 vs. 3). These acids have been used to some extent on beef muscle (Aktas and Kaya, 2001) and are believed to influence the collagen

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Abbreviation Key: 2P = 2% phosphate solution; 2A = 2% acetic acid solution; 2C = 2% citric acid solution; 1A = 1% acetic acid + 1% phosphate solution; 1C = 1% citric acid + 1% phosphate solution; 6S = 6% NaCl solution; GPA = generalized Procrustes analysis.
connective tissue to cause some tenderization. In a free-choice profiling experiment on acid solutions, Rubico and McDaniel (1992) demonstrated that different acids have different sensory characteristics. The characteristics of muscle tissue marinated in acids along with phosphates and salt have not been studied extensively. The purpose of this study was to determine the sensory descriptive profiles of broiler breast muscle marinated in solutions containing sodium chloride, sodium polyphosphate, and acetic or citric acid.

**MATERIALS AND METHODS**

Broilers, commercially grown and processed in a local poultry plant under normal operating conditions, were obtained as fully aged whole carcasses, placed on ice, and transported to the laboratory. Breast fillets were removed from each carcass and assigned to a marination treatment. Ten fillets per treatment were used for each of 4 replicates conducted on 4 separate days. The fillets from a treatment were weighed together for batch weight and then placed in a vacuum tumbler. A marination solution (10% of the batch weight) was added to the batch. Vacuum tumbling was accomplished at 15 mmHg for 20 min in a 2°C cold room.

Formulas used for marinade solutions are presented in Table 1. A 6% NaCl (6S) base solution was used as a control. Variations to this solution included 2% sodium tripolyphosphate (2P); 2% acetic acid (2A), 2% citric acid (2C), 1% sodium tripolyphosphate plus 1% acetic acid (1A) or 1% sodium tripolyphosphate plus 1% citric acid (1C). After being tumbled, each fillet was drained 2 min, weighed, placed in individual heat-seal bags, and heat sealed with a slight vacuum. Samples were removed from the oven and tempered 5 min in the pan before weighing each individual piece.

Samples were prepared for sensory analysis by cutting a 1.9 cm wide strip parallel to fibers. This strip was then cut into 2 to 3 cubes of 1.9 cm. Occasionally the bottom of a strip was trimmed to assure uniform sample cubes for the panel. Samples were placed in prewarmed 178-mL (6-oz) glass custard dishes that were nested in coded styrofoam cups to maintain serving temperature (55°C). Sample containers were coded with 3-digit numbers and presented to panelists (n = 9) in individual sensory workstations equipped with computers for data collection using the CompusenseFive Sensory Analysis System. Panelists used one cube for flavor and one cube for texture to evaluate the intensity of the sample attributes and mark the responses on 15-point line scales, from low (1) to high (15).

**Sensory Evaluation**

A trained descriptive analysis panel (n = 9) was used in this study. Panelists had from 1 to 10 yr experience working in descriptive sensory analysis. Sensory attributes (n = 26) and definitions used by the descriptive panel to evaluate cooked breast meat are detailed in Table 2. Flavor, basic tastes, texture, and afterfeel/aftertaste terms represented different phases of evaluation. The lexicon of flavor and texture terms was developed by the trained descriptive sensory panel during previous studies (Lyon, 1987; Lyon et al., 2001; Lyon and Lyon, 2000). During orientation sessions for this study, the lexicon and panel performance were validated through sampling, discussions, and reference materials. The sample cooking and presentation to panelists followed a monadic sequence at 20-min intervals to allow for fatigue recovery between samples. Sensory evaluations were replicated 4 times. Sample order presentations to panelists were randomized across sessions.

**Statistical Analysis**

Data were analyzed using generalized Procrustes analysis (GPA) for sensory data. This multivariate analysis procedure is used in sensory profiling to analyze treatment effects, panelist effects, and attribute performance. Treatment means are subsequently plotted in a 2-dimensional space to visualize their relationships according to a reduced set of factors derived from the attributes. In addition, the individual attributes were analyzed for treatment effects by GLM procedures (SAS Institute, 1998), and mean values were obtained.
# SENSORY ANALYSIS OF MARINATED FILLETS

## RESULTS AND DISCUSSION

The sensory attributes represented flavor, texture and aftertaste/afterfeel properties that were detected in preliminary training samples. Of the 15 flavor and aftertaste/afterfeel attributes, significant differences ($P \leq 0.05$) were found only for brothy, vinegar, and sour (Table 3). All intensity values for aroma and flavor of the samples were very low on the 1-to-15 universal scale. The 2P samples were scored the highest intensity for broth, and 2A samples were scored the lowest intensity. Vinegar flavor note was significantly higher in samples marinated in 2A, whereas the intensity of vinegar flavor/aroma in 1A was similar to all other samples. Sour was significantly differ-

## Table 3. Mean values ($\pm$SD) of flavor attributes for broiler breast fillets subjected to six marination treatments

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Treatment²</th>
<th>1A</th>
<th>1C</th>
<th>2A</th>
<th>2C</th>
<th>6S</th>
<th>2P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aromatics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Brothy</td>
<td></td>
<td>3.67 ± 0.75abc</td>
<td>3.91 ± 0.82ab</td>
<td>3.47 ± 0.84³</td>
<td>3.57 ± 0.86bc</td>
<td>4.05 ± 0.72a</td>
<td>3.83 ± 0.89abc</td>
</tr>
<tr>
<td>2. Chickeny/meaty</td>
<td></td>
<td>4.28 ± 0.47</td>
<td>4.23 ± 0.56</td>
<td>4.18 ± 0.48</td>
<td>4.12 ± 0.48</td>
<td>4.31 ± 0.50</td>
<td>4.18 ± 0.48</td>
</tr>
<tr>
<td>3. Cardboard</td>
<td></td>
<td>2.65 ± 0.78</td>
<td>2.46 ± 0.89</td>
<td>2.69 ± 0.87</td>
<td>2.69 ± 0.74</td>
<td>2.51 ± 0.97</td>
<td>2.68 ± 0.91</td>
</tr>
<tr>
<td>4. Wet feathers</td>
<td></td>
<td>2.84 ± 0.85</td>
<td>2.41 ± 0.87</td>
<td>2.66 ± 0.79</td>
<td>2.62 ± 0.82</td>
<td>2.54 ± 1.03</td>
<td>2.51 ± 0.91</td>
</tr>
<tr>
<td>5. Barnyard</td>
<td></td>
<td>2.63 ± 1.01</td>
<td>2.50 ± 0.91</td>
<td>2.60 ± 0.92</td>
<td>2.56 ± 1.02</td>
<td>2.62 ± 1.11</td>
<td>2.53 ± 1.10</td>
</tr>
<tr>
<td>6. Bloody/serumy</td>
<td></td>
<td>2.90 ± 0.90</td>
<td>2.89 ± 0.92</td>
<td>2.89 ± 0.99</td>
<td>2.75 ± 0.89</td>
<td>2.81 ± 0.95</td>
<td>2.87 ± 0.82</td>
</tr>
<tr>
<td>7. Metallic</td>
<td></td>
<td>2.98 ± 0.87</td>
<td>2.95 ± 0.94</td>
<td>3.26 ± 0.94</td>
<td>3.20 ± 0.95</td>
<td>3.00 ± 1.03</td>
<td>2.77 ± 1.04</td>
</tr>
<tr>
<td>8. Vinegar/acetic acid</td>
<td>1.93 ± 1.38b</td>
<td>1.89 ± 1.29b</td>
<td>2.95 ± 1.49³</td>
<td>1.86 ± 1.34b</td>
<td>1.74 ± 1.20b</td>
<td>1.95 ± 1.23ab</td>
<td></td>
</tr>
<tr>
<td><strong>Basic flavor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Sweet</td>
<td></td>
<td>2.63 ± 0.74</td>
<td>2.65 ± 0.58</td>
<td>2.54 ± 0.74</td>
<td>2.60 ± 0.59</td>
<td>2.69 ± 0.67</td>
<td>2.70 ± 0.79</td>
</tr>
<tr>
<td>10. Salty</td>
<td></td>
<td>2.81 ± 0.81</td>
<td>2.91 ± 0.81</td>
<td>2.96 ± 0.86</td>
<td>3.06 ± 0.88</td>
<td>2.95 ± 1.03</td>
<td>2.98 ± 0.79</td>
</tr>
<tr>
<td>11. Sour</td>
<td></td>
<td>2.96 ± 0.88b</td>
<td>2.89 ± 0.87³</td>
<td>3.40 ± 0.84³</td>
<td>3.14 ± 0.84³</td>
<td>2.89 ± 0.85³</td>
<td>3.20 ± 0.75³</td>
</tr>
<tr>
<td>12. Bitter</td>
<td></td>
<td>1.76 ± 1.09</td>
<td>1.82 ± 0.94</td>
<td>2.11 ± 0.98</td>
<td>1.91 ± 0.98</td>
<td>1.86 ± 0.94</td>
<td>1.98 ± 1.02</td>
</tr>
</tbody>
</table>

²Sensory attribute intensities were scored on a scale where 1 = low to 15 = high, based on the universal scale anchors (Meilgaard et al., 1999).

³Values are means of 36 observations (9 panelists x 4 replications) for each sample.

⁴Code abbreviations for marination treatments are 1A = 1% acetic acid + 1% phosphate + 6% salt; 1C = 1% citric acid + 1% phosphate + 6% salt; 2A = 2% acetic acid + 2% phosphate + 6% salt; 2C = 2% citric acid + 2% phosphate + 6% salt; 2P= 2% phosphate + 6% salt; 6S = 6% salt.
ent for 2A samples. However, the other 3 samples with acids (1A, 1C, and 2C) were not rated significantly (P ≤ 0.05) more sour than samples without acid (i.e., 2P and 6S). The level of acid or the presence of salt and/or phosphate with lower levels of acid diminished the sour taste. The acid samples without phosphates had detectable metallic tastes. Sour is the predominant flavor note of organic acids. However, acids may also impart bitter and astringent characteristics as in 1A and 1C, may ameliorate some of the sensory differences in the samples due to marinade ingredients (Table 4). However, the differences associated with the marinade ingredients had the most effect at the early stages of texture evaluation. As the samples were chewed to the point of swallow, the differences in the samples due to marinade ingredients narrowed or became nonexistent. At final evaluation, there were differences in the samples due to residual particles left in the mouth after swallow. The 2A and 2C samples were scored the highest for residual particles. This finding would indicate that phosphates in the presence of acids, as in 1A and 1C, may ameliorate some attributes that could be construed as negative, such as increased quantity of residual particles. Another explanation could be that the sensory differences are due to the level of acid (1 vs. 2%).

The results of the GPA are given in Figure 1. GPA maximizes the agreement among panelists with respect to scoring of individual samples. A consensus configuration of the samples, graphically represented in Figure 1, illustrates intersample distances. Samples were plotted by their coordinates of dimensions 1 and 2, which explain 33% variation in the data, was defined by positive loadings for bitter (bit), wetness (wet), particle size (psz), and astringent (astr). Attributes loading negatively for dimension 1 were brothy (bro), salty (sli), and residual particles (resd). Dimension 2, explaining 33% variation in the data, was defined by positive loadings for metallic (met) and cohesiveness of mass (cohm) and by negative loadings for chickeny (chk), moisture release (mrel), and metallic aftertaste (amet).

FIGURE 1. Consensus product map from generalized Procrustes analyses (GPA) of broiler breast fillets marinated in phosphates, salt, and acids. Sample abbreviations for products: 1% acetic acid + 1% phosphate + 6% salt; 1C = 1% citric acid + 1% phosphate + 6% salt; 2A = 2% acetic acid + 2% phosphate + 6% salt; 2C = 2% citric acid + 2% phosphate + 6% salt; 2P = 2% phosphate + 6% salt; 6S = 6% salt.

TABLE 4. Mean values (±SD) of texture and aftertaste/afterfeel attributes for evaluation of marination effects on broiler breast fillets

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1A</th>
<th>1C</th>
<th>2A</th>
<th>2C</th>
<th>2P</th>
<th>6S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Springiness</td>
<td>3.51 ± 0.90</td>
<td>3.62 ± 0.84</td>
<td>3.71 ± 0.82</td>
<td>3.51 ± 0.90</td>
<td>3.46 ± 0.75</td>
<td>3.44 ± 0.86</td>
</tr>
<tr>
<td>14. Cohesiveness</td>
<td>4.06 ± 1.17</td>
<td>4.18 ± 0.83</td>
<td>4.07 ± 0.94</td>
<td>3.89 ± 1.02</td>
<td>3.83 ± 0.90</td>
<td>3.75 ± 1.06</td>
</tr>
<tr>
<td>15. Hardness</td>
<td>3.90 ± 0.96</td>
<td>3.96 ± 0.89</td>
<td>4.03 ± 0.91</td>
<td>3.98 ± 0.85</td>
<td>3.63 ± 0.74</td>
<td>3.74 ± 0.82</td>
</tr>
<tr>
<td>16. Moisture release</td>
<td>3.17 ± 0.58</td>
<td>3.42 ± 0.71</td>
<td>3.08 ± 0.61</td>
<td>3.21 ± 0.58</td>
<td>3.43 ± 0.60</td>
<td>3.34 ± 0.75</td>
</tr>
</tbody>
</table>

1 Codes for marination treatments are 1A = 1% acetic acid + 1% phosphate + 6% salt; 1C = 1% citric acid + 1% phosphate + 6% salt; 2A = 2% acetic acid + 2% phosphate + 6% salt; 2C = 2% citric acid + 2% phosphate + 6% salt; 2P = 2% phosphate + 6% salt; 6S = 6% salt.

2 Mean values are means of 36 observations (9 panelists × 4 replications) for each sample.

3 Treatment means within the same row not followed by common superscript letters are significantly different (P = 0.05).
plained 33 and 24% variation in the data, respectively, for a cumulative total variation explained of 57%. Attributes are plotted to show their position in the product space. The meaning of the dimensions can be subjectively interpreted by observing the loadings (correlations) for the individual attributes for each dimension. Bitter, wetness, particle size, and astringency loaded positively on dimension 1 and brothy, salty, and residual particles loaded negatively. For dimension 2, metallic and cohesiveness of mass loaded positively and chickeny, moisture release, and metallic aftertaste/afterfeel loaded negatively. Sample 2P was plotted further from the origin of dimensions 1 and 2, being perceived as more metallic, higher cohesiveness of mass, more bitter, more wet, more astringent, and having larger particle sizes. The 6S sample was positive on dimension 1 (bitter, wet, particle size, astringent) but negatively loaded on chickeny, moisture release, and metallic. Samples 1C and 1A were both plotted in the negative quadrants of dimensions 1 and 2, indicating the perception as less chickeny, less moisture released, less metallic, less brothy, less salty, and with fewer residual particles. Sample 2A would be considered fairly neutral on either dimension, whereas 2C was plotted as less brothy, less salty, and with fewer residual particles but more metallic and higher cohesiveness of mass.

The samples in this study were fully aged. Therefore, the addition of acid to adjust the pH may not be as beneficial in marinade solutions of fully aged product as would the addition for samples in a pre-or peri-rigor state. The effects of acid in solutions to marinate samples in the pre- or peri-rigor state should be investigated. Consumer tests are needed to complement the descriptive studies.

REFERENCES


