Sensory Characteristics of Frankfurters as Affected by Fat, Salt, and pH

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ABSTRACT

Acceptable processing and flavor profile characteristics of frankfurters were achieved near a pH of 6.0. As salt increased, hardness, juiciness, saltiness, and flavor intensity scores increased. As fat increased, juiciness scores decreased (at salt levels > 1.3%) due to substitution of water for fat. In addition, increased fat resulted in decreased off-flavor. Model predictions suggested that acceptable frankfurters could be manufactured with a minimum of 11.25% fat and 1.3% salt at pH 6.0.

Key Words: frankfurters, beef, fat, salt, acidity

INTRODUCTION

Over 2.18 billion kg of sausage products are produced in the U.S. annually, including over 60 million kg of frankfurters and 282 million kg of bologna (AM, 1989). These emulsified sausage products contain up to 30% fat and > 2% salt. To make such products more acceptable to health-conscious consumers, the fat and salt content should be reduced while minimizing changes in product palatability. Dietary guidelines for Americans (USDA and USDHHS, 1985) suggested reducing sodium, fat, and cholesterol in diets. The American Health Association suggested limiting fat consumption to < 30% of calories, to consume < 300 mg cholesterol, and <3g sodium/day (NRC, 1989). Fresh cuts of beef and pork have low sodium ~ 70 mg/100g, cooked basis; however, one frankfurter can contribute more than 14 times that amount of sodium (Maurer, 1983).

Commercially available emulsion products typically contain 30% fat and 12% protein. Keeton (1983) investigated effects of varying fat levels (from 20% to 30%) on physical and sensory characteristics of pork patties. Juiciness was the only sensory attribute to differ and reduced compression energy for the 30% fat patties was the only change observed using texture profile analysis.

The amount of sodium chloride that can be replaced in meat products is limited (Hand et al., 1982). However, it may be reduced, provided changes in physical and sensory properties of the products are minimized. Trout and Schmidl (1987) reported that as salt content of an emulsified product decreased from 2.93% to 2.13% and 1.33%, a decrease occurred in temperature to which the product could be heated before water-binding ability was affected (from 86°C to 63°C to 57°C, respectively). Whiting (1984) reported that raw emulsions made with reduced salt levels (below 2.0%) had a sharp increase in water released by the batter. Gel strength gradually decreased with salt reductions from 3.5% to 1.0%, and fat was released in emulsions containing < 1.0% salt. Seman et al. (1980) evaluated physical properties of bologna made with 2.5% salt vs a similar product made with 1.25% salt. The lower ionic strength product showed increases in fat released, gel liquid released, and total cookout in emulsion stability tests. Instrumental evaluation of textural characteristics indicated that salt reduction resulted in lower hardness, compressed peak force, gumminess scores, and increased elasticity.

Poulanne and Terrell (1983a,b) investigated effects of salt preblending prior to processing. They reported that salt reduction from 2.5% to 1.5% resulted in minimal physical and chemical changes, but the products tasted less "salty." Salt reduction to 1.0% resulted in decreased water-binding capacity despite preblending treatments.

Production of reduced fat and salt frankfurters should have widespread appeal to health-conscious consumers. However, fat and salt contribute to many sensory properties characteristic of frankfurters. According to USDA (1988) guidelines, water may replace fat in the formulation on an equal weight basis. Increased water may affect texture and juiciness. Reducing salt content decreases protein extraction and water binding in addition to altering palatability attributes. Some water-binding properties that could be lost by reducing salt content may be partially compensated by altering pH of the raw meat batter.

Matulis et al. (1994) reported that commercial frankfurters had a wide range of textural and sensory characteristics. Inclusion of the mean ± one standard deviation for each characteristic included about 66% of the products assessed. Because those products have been commercially successful, they presumed they were acceptable.

Our objective was to evaluate effects of fat, salt, and pH on sensory characteristics of frankfurters. From such information, the ranges of fat and salt levels that could produce acceptable frankfurters could be delineated.

MATERIALS & METHODS

Experimental design

Continuous variables of salt, fat, and pH, were evaluated simultaneously to formulate low salt/low fat frankfurters with acceptable palatability attributes. A central composite design (CCD) (Table 1) was used to evaluate results using response surface methods (Box et al., 1978). The CCD consists of a 2 factorial design, 2k star points, and several center points. The star points of a rotatable CCD for k = 3 are ± 1.732(V³). The star points (± 1.67 for fat and salt, ± 1.5 for pH) were chosen based on the range of values within practical constraints of the experiment. The target fat, salt, and pH values are shown in Table 1. The amounts of fat and salt used are shown in Table 2.

Eight batches of frankfurters were manufactured initially in a 2 × 2 × 2 factorial design (pH = 5 or 7; salt = 1.0% or 2.5%; and fat = 10% or 25%). Following initial analyses, the remaining nine batches of frankfurters were manufactured to complete the CCD.

Frankfurter production

Two masterblocks of lean beef trim (5% fat) and beef fat (90% fat) were used to formulate frankfurters to the desired fat level. Lean trim was obtained from boneless rounds trimmed of subcutaneous and intermuscular fat. Beef fat (subcutaneous and intermuscular deposits) was obtained from USDA Choice wholesale beef cuts. Raw materials were ground through a 2.5-cm plate, mixed thoroughly, vacuum-packaged (B540 bags, CryoVac, W.R. Grace, Simpsonville, SC), evacuated at 1 kpa/cm², and frozen (~30°C) for subsequent use. Lean and fat trim were allowed to temper (4°C) 48 hr prior to formulation and processing.

All frankfurters were formulated to result in a final product with 40% added water plus fat in compliance with USDA standards for frankfurter production (USDA, 1988). Additional water was included in the for...
Table 1—Experimental design for response surface model for characteristics of frankfurters with varied pH, fat, and salt

<table>
<thead>
<tr>
<th>Run</th>
<th>X1 (% fat)</th>
<th>X2 (% salt)</th>
<th>X3 (pH)</th>
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<tbody>
<tr>
<td>1</td>
<td>+1</td>
<td>+1</td>
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<td>+1</td>
<td>-1</td>
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<td>+1</td>
<td>-1</td>
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<tr>
<td>17</td>
<td>+1.67</td>
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</tr>
</tbody>
</table>

Coded matrix variables: Treatment: -1.67, -1.5, -1, 0, +1, +1.5, +1.67

Table 2—Sensory characteristics of frankfurters with varied pH, fat, and salt

<table>
<thead>
<tr>
<th>Treatment</th>
<th>X1 (% fat)</th>
<th>X2 (% salt)</th>
<th>X3 (pH)</th>
</tr>
</thead>
<tbody>
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<td>10.0</td>
<td>17.5</td>
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<tr>
<td></td>
<td>-4.5</td>
<td>5.0</td>
<td>6.0</td>
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Statistical analysis

Bartlett’s test for homogeneity of variance (Bartlett, 1947) was conducted to determine if variance was the same for all six panelists × 17 tests (102 panelist/test combinations [two trials/combination/panelist]). If the hypothesis of a constant variance was rejected, then the replicate measurements that differed by more than 7.5 cm out of 15 cm were discarded. By sensory characteristic, the number of data points discarded was hardness—4, cohesiveness—4, juiciness—3, saltiness—2, flavor intensity—2, and off-flavor intensity—1.

All equations and response surface plots were generated using a Response Surface Methodology program (Anonymous, 1989). The response surface was characterized using the model shown in Table 3.

RESULTS & DISCUSSION

The influences of salt, fat, and pH on sensory characteristics of frankfurters were expressed as contour plots. These were two-dimensional plots with two continuous variables on the X and Y axes, while the third was held constant. The test for homogeneity of variance (Table 4) indicated that panelists tended to be inconsistent when evaluating sample replicates for all responses except saltiness and flavor intensity. The inconsistency of some attributes may indicate that some panelists needed more training. Regression equations developed to predict sensory characteristics from fat and salt content and pH are presented in Table 3.

The effect of salt and pH on sensory hardness with fat constant at 15% were compared (Fig. 1). Maximum hardness was achieved at ~ pH 6.0 for all salt levels. As salt concentration increased, frankfurter hardness increased. These results agreed with those of Seman et al. (1980), who reported that salt reduction (from 2.5% to 1.25%) resulted in decreased hardness and Instron peak force in bologna. The salt concentration to achieve hardness scores of ~ 6 (previously determined acceptable, Matulis et al., 1994) may be minimized at pH values between 5.8 and 6.3. As pH is reduced and approaches the isoelectric point of muscle proteins (pH 5.0), protein dissociation prior to matrix formation is minimized. If pH were reduced below the isoelectric point, more protein would be extracted producing a firmer frankfurter. However, at very low pH values some proteins may be denatured, becoming ineffective in emulsion formation (Hamm, 1986).

Hardness decreased as pH increased above 6.3. At higher pH, more water is bound and retained. Such increased moisture levels may result in softer texture. Hamm (1986) suggested that as beef muscle homogenate pH increased from the isoelectric point (~ 5.0) to 10.0, water-holding capacity increased; as pH increased, repulsion of protein chains increased enabling them to attract water molecules.
When salt concentration was constant at 2.0%, the firmest frankfurters were produced at \( \approx \) pH 6.0 (Fig. 2). The salt-pH relationship was similar to that for hardness (Fig. 1). From pH values \( \approx 5.2 \) through 6.9, hardness increased as fat content increased. This may be due to substitution of water for fat. Increased water decreased the force required to bite through the frankfurter. Claus et al. (1989) found that bologna firmness decreased as added water increased. They suggested that as added water increased, more hydrophilic regions of proteins associated with water instead of forming intermolecular protein-to-protein cross bridges.

Fat content had limited effects on sensory hardness at pH < 5.2. At pH near the isoelectric point, skeletal proteins (especially myosin) have few charged groups free to interact in network formation to trap water and fat in the batter. With reduced protein-protein interactions for matrix formation, frankfurters become softer.

At pH \( \approx 6.0 \), relatively high hardness was achieved in reduced fat frankfurters. Altering the pH from this point would require addition of acidic or basic buffers that could cause flavor changes. The remaining experiments were conducted holding pH constant at 6.0 to avoid addition of such flavor-modifying components.

When pH was constant at 6.0, low salt concentrations (0.5% to 1.5% salt) had a greater emulsifying and stabilizing influence on hardness than did changes in fat concentration (Fig. 3). Salt assists in extraction of myofibrillar proteins that emulsify and stabilize bater. Poulann and Terrell (1983a,b) found that salt levels could be reduced to 1.5% with minimal changes in physical properties of frankfurters. However, when salt was reduced to 1.0%, water-binding capacity was adversely affected.

At salt concentrations > 1.5%, modification in fat and salt content had similar effects on sensory hardness. Results suggested that a minimal amount of salt (\( \approx 1.5% \)) is required to
extract protein and form a stable matrix. Trout and Schmidt (1987), studying the role of ionic strength on beef muscle homogenates, found that tensile strength of the homogenate was greatest between 1.29% and 1.87% salt.

The effects of salt and fat on Warner-Bratzler shear forces were similar to those for sensory hardness (Fig. 4). Increased fat and salt concentrations increased shear force values. Differences between shear force and sensory hardness may be attributed to differences between instrumental and sensory evaluation.

No significant correlation was found between sensory hardness and shear force (Instron) of cold commercial frankfurters (Matsulis et al., 1994).

The effects of fat and salt content on sensory cohesiveness were compared (Fig. 5). Cohesiveness was the least consistent sensory attribute among panelists. The panelists were trained to evaluate cohesiveness in frankfurters. However, the range of cohesiveness of these frankfurters may have been too low for panelists to make consistent judgments. As salt increased, frankfurter cohesiveness increased. This may be due to increased pro-
tein extraction resulting in more protein-protein interaction at higher salt levels. The most cohesive frankfurters resulted from reducing fat and increasing salt.

As salt concentration increased, juiciness increased (Fig. 6). Sodium chloride extracts myofibrillar proteins allowing formation of a water-binding protein matrix. Terrell et al. (1981) reported decreased moisture loss (from 46.7% to 30.7%) during cooking of beef clot muscle with addition of 2.5% salt. Whiting (1984) found that salt reduction (from 2.5% to 1.5%) resulted in increased water release from frankfurters.

The effects of fat concentration on juiciness could be separated into two distinct phases: above and below 1.3% salt. Reducing salt < 1.3% resulted in incomplete protein extraction and water was released during packaging and cooking. This condition increased the importance of fat as a contributor to juiciness. Increasing fat content at salt > 1.3% decreased juiciness scores. As fat content decreased, water was added to the formulation. It appeared that panelists related moisture content to juiciness. Fat concentration may contribute to juiciness only when moisture content is lower.
Most of the variation in frankfurter saltiness was attributed to changes in salt concentration (Fig. 7). Matlock (1983) reported that saltiness of pork sausage patties decreased with levels of salt from 1.5% to 0% salt. Fat and moisture concentrations appear to have limited effects on perceived saltiness.

Flavor intensity of frankfurters was influenced by salt concentration (Fig. 8). As salt increased, flavor intensity increased. These results may be related to flavor enhancement (Gillette, 1985). Fat level had a limited effect on flavor intensity. Fat is a component of meat flavor; however, at fat levels above 5% its influence on flavor intensity appeared to be minimal. Flavor intensity of cured/smoked meat includes salty flavor; the contribution of cooked lean and fat may contribute less to overall flavor intensity because of the high contribution of saltiness. Fat content had more influence than salt concentration on off-flavor intensity (Fig. 9). As fat increased, less off-flavor was perceived at constant salt levels.

At pH 6.0, pH-altering additives (sodium bicarbonate and lactic acid) were not included and no off-flavors were observed. When these additives were included, they produced off-flavors that were not characteristic of commercial frankfurters (data not shown). Bechtel et al. (1989), investigated physical and sensory characteristics of frankfurters produced with various levels of potassium and sodium bicarbonate. They found that adding 0.25% sodium bicarbonate increased off-flavor intensity. The level of sodium bicarbonate to increase pH from 6.0 to 7.0 in our study was 0.4%.

A composite of effects of salt and fat levels on hardness, juiciness, and off-flavor intensity was developed (Fig. 10). For reference, acceptable frankfurters were defined as those products within one standard deviation of the mean for each sensory characteristic of commercial frankfurters. The area within the contours for each sensory characteristic represents the limits of fat and salt combinations at which acceptable frankfurters could be manufactured (Matulis et al., 1994). An acceptable frankfurter (hardness, juiciness, and off-flavor intensity) should be produced with 11.25% fat and 1.5% salt (Fig. 7). These levels represent a 62.5% reduction in fat and a 46.8% reduction in salt content compared to commercial frankfurters (30% fat and 2.5% salt).

REFERENCES

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