THE EFFECTS OF CHOPPING TEMPERATURES ON LOW FAT, HIGH MOISTURE, BEEF FRANKFURTERS

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CHAPTER I

INTRODUCTION

Frankfurters currently marketed in the U.S. contain fat as high as 30% (Forman, 1989). Therefore, they do not fall into the "Okay foods" but rather the "foods to avoid" category in the American Heart Association diet (AHA, 1987) recommendations. As a result, producers are investigating several alternatives in order to meet consumer demands for low fat hot dogs. Although these methods bring about the desired reduction in both calories and fat content, they do not maintain the same taste and texture as their higher fat (30%) counterparts. Therefore, it has become necessary to find ways in which to produce low fat frankfurters at the same quality level as the traditional frankfurters marketed today.

The most common method used to reduce the percentage of fat is by the addition of non-meat ingredients. Producers use protein and carbohydrate based additives to retain moisture, mimic mouthfeel and texture and to act as an extender (Sofos and Allen, 1977, Wallingford and Labuza, 1983, Miller et al., 1986). However, taste panels have recorded lower firmness and cohesiveness scores for frankfurters made with 3.5% wheat starch when compared to a 30% fat control (Claus and Hunt, 1991). Research into adding high levels of soy protein to low fat frankfurters has shown that emulsion break down increases as the amount of soy added increases (Sofos and Allen, 1977). Although adding non-meat ingredients is the most common method used currently to reduce the fat in low fat frankfurters, it still does not produce frankfurters with the same quality as a high fat hot dog.

Another alternative for diluting the percent fat is by adding water . This is now a more economical and practical option available to producers due to a USDA rule change in 1988. The USDA "40% Rule" allows cooked sausages to contain added water and fat, in combination, that does not exceed 40% of the product composition while fat can not be in excess of 30% (Federal Register, 1988). Writh (1988) concluded that acceptable low fat frankfurters could be produced by increasing the amount of added water. Research into the effects of adding water to frankfurter formulations showed lower textural values, greater cook loss and increased purge (Clause et al., 1990, Uram et al,) when compared to high fat, low moisture frankfurters. One possible reason for the occurrence of these negative traits is related to the lack of the meat protein's ability to sufficiently bind water and remain functionally active in protein-protein interaction (Clause et al., 1989) Therefore, existing processing procedures will have to be altered to maximize protein extraction so that sufficient protein-water and protein-protein binding can occur.

Investigation of protein extraction in model systems have suggested that temperature is a variable that can greatly maximize extraction (Gadea De Lopez and Hand, 1993, Gillette et al., 1977). Knowledge that has been gained concerning optimum temperature for protein extraction has been applied to practical production procedures by investigating the effect of chopping temperature on protein extraction in batter type systems (Helmer and Saffle, 1963, Towensend et al., 1971). However, all of the previous work that concerned chopping temperature was done on high fat systems where protein-fat binding was the most important factor, whereas under today's high moisture systems protein-water binding is the key for production (Rust and Olson, 1988). It is the purpose of this research to evaluate the effect of initial and endpoint chopping temperature on low fat, high moisture beef frankfurters.

CHAPTER II

REVIEW OF LITERATURE

The information on the effect of chopping temperature on low fat, high moisture, beef frankfurters is centered around several areas. First, a review and evaluation of current practices utilized to reduce fat in frankfurters must be made to determine where previous research has led the industry. Next, examination of the methods used to evaluate the texture of frankfurters needs to be reviewed so that textural characteristics can be understood. Lastly, past research into the effects of varying chopping temperatures must be made in order to understand the role of chopping temperature in the production of frankfurters.

Fat Reduction Practices

Meat processors are continuously trying to produce no-fat and reduced fat products in order to obtain a share of the estimated 33 billion dollar market (Helm, 1991). In order to develop acceptable low fat products, the texture, flavor, and appearance of product will have to be like its high-fat counterpart. In addition, producers are challenged with delivering low fat foods at the same value to consumers (Best, 1991). Several methods have been used in an attempt to accomplish these tasks. The most common means of fat reduction are; utilizing non-meat ingredients, increasing amounts of added water and utilizing leaner formulations.

Non-meat ingredients

Non-meat fat substitutes generally fall into two categories; carbohydrate or protein based. Carbohydrates include- cellulose, maltodextrins, gums, starches, and polydextrose- have been used for some time as thickening agents, stabilizers and gelling agents in meat products (Campano, 1991). Another limited method of fat reduction includes using oils to alter the saturated fat composition of a product.

Wallingford and Labuza (1983) evaluated the water binding properties of carbohydrate based food hydrocolloids in low fat meat emulsions. Their findings showed that when tested by Bauman WBC, (spontaneous capillary apparatus that measures water uptake over time until equilibrium is reached) Xanthan gum bound the greatest amount of added water while methoxy pectin bound the least. This study only evaluated the effect of water uptake and did not evaluate sensory or textural characteristics of the meat products; therefore, further work would have to be conducted in order to determine the feasibility of Xanthan gum in low fat meat systems.

Evaluation of the sensory and textural characteristics of bologna made with carbohydrate based, texture-modifying ingredients was performed by Clause and Hunt (1991). The study focused on the addition of oat fiber, pea fiber, wheat starch and commercial blends of starches. Sensory evaluation, made by an experienced, seven-member sensory panel, noted significantly lower values for firmness and cohesiveness when treatments with carbohydrates were compared to high fat-all meat control. Moreover, Instron texture profile analysis showed significantly lower values for hardness and fracturability when contrasting carbohydrate based formulations to the high fat control.

Soy proteins have traditionally been the most commonly used extender in formed meats (Keeton, 1991). Soy assists in production by adding a lower priced protein, aiding textural qualities and binding water. The addition of high levels of soy has been shown by Sofos and Allen (1977) not to adversely affect emulsion stability for high fat franks. However, for franks containing 10% fat, the results were not as favorable due to an increased shrink loss. In another study, sensory values from a 10-member experienced sensory panel showed that restructured beef steaks made by replacing 13% of the raw meat with isolated soy protein possessed the highest off-flavor score (Hand et al., 1981) when compared to meat only restructured steaks.

Wheat gluten has been used extensively in the meat industry for its ability to offer many cost advantages to producers. Miller et al. (1986) studied the effect of adding wheat gluten to finely ground restructured steaks. Analysis of visual scores for raw lean color and color desirability, determined by a five member trained visual panel, showed that restructured steaks made with 20% wheat gluten possessed lower values for both the raw lean color and color desirability traits than the control. Moreover, the 20% wheat gluten treatment had a higher cook loss. Hand et al. (1983) showed that the addition of 12.4% wheat gluten to Mortadella sausage caused lower perceived values for visual color when evaluated by an eight member panel.

Oil based substitutes have been used to a limited extent to alter the amount of saturated and monosaturated fats in frankfurters. Park et al. (1990) incorporated varying levels of oleic acid and significantly reduced the amount of saturated fat while increasing the amount of monounsaturated fat. Another study evaluated the effect of Omega-3 polyunsaturated oil in frankfurters (Park et al., 1989). The desired reduction in saturated fat was achieved; however, sensory results were very low.

Using non-meat ingredients in low fat meat products can increase water binding, aid in texture and act as an extender; however, low sensory values are commonly the result.

Added Water

Elevating levels of added water in traditional formulations is currently been utilized as a cost effective way to produce low fat emulsion sausages since a change in the U.S.D.A. regulation (Federal Register, 1988). This change allows for fat and added water to be in an any combination that does not exceed 40% (fat level not to be in excess of 30%). However, increasing the amount of added water in a system brings about both textural and sensory changes. Moreover, the dilution effect of adding water is only valid if the added water is not lost prior to consumption. It has been concluded that of all the components in an emulsion, the added water level is by far the most critical in maintaining emulsion stability (Morrison et al., 1971).

Morrison et al. (1971) studied the relationship between composition and stability of sausage-type emulsions by altering the level of lipid, water and protein in batter formulations. The researchers saw the most definitive results by evaluating total cook stability. Results showed that as added water levels increased above 20% the percent cookout increased significantly. This trend held constant even when the percent lipid an protein was varied. Therefore, the authors concluded that of all the components in an emulsion, the added water level is by far the most critical in maintaining emulsion stability

Claus et al. (1989) evaluated the effects of several added water levels (10, 15, 20, 25, 30 and 35%) on the sensory and textural qualities of bologna. The results showed that cook loss increased as the percent added water increases and that purge loss followed the same trend. Instron texture profile analysis indicated that the treatment with 35% added water had the lowest value for peak force, break force, and total energy as well as the greatest fracturability. Sensory evaluation for juiciness showed that the treatment with 35% added water was perceived by a seven member panel to be significantly more juicy.

In another study, Claus et al. (1990) evaluated the effectiveness of massaging, preblending and time of addition of water and fat on the characteristics of frankfurters. The study consisted of high fat-low added water and low fat-high added water treatments. Those frankfurters with 30% added water and 10% fat had significantly lower values for energy, cohesiveness, springiness, fracturability and hardness than did a 30% fat and 10% added water frankfurter. The high added water franks also possessed greater cook loss and greater purge.

Uram et al. (1984) evaluated the effect of particle size on smoked sausages with 0, 10 and 20% added water. Sensory evaluation was made by a ten member, trained sensory panel. Analysis of results showed that as the percent added water increased, tenderness, juiciness, and overall acceptability tended to increase. Both shrinkage after processing and total shrinkage increased as the level of added water increased.

Sensory evaluation of high moisture frankfurters with elevated levels of oleic sunflower oil was investigated by Park et al. (1990). The results showed that there was no significant difference for aroma, flavor juiciness and overall acceptability versus franks with high levels of fat. Texture profile analysis indicated that the low fat, high level oleic acid frankfurters had significantly higher gumminess, fracturability, first bite hardness and second bite hardness as compared to the high fat control.

These studies show that low fat, high moisture frankfurters can be produced with acceptable sensory traits but textural characteristics, purge and cooking loss traits would be compromised.

Leaner Formulations

One method used to reduce the fat content of frankfurters is simply to use leaner cuts of meat. However, this method greatly increases the cost of production. Consumer panel evaluation indicated lean formulations in ground beef resulted in products which had decreased palatability and flavor intensity (Huffman and Egbert, 1991).

The effect of reducing fat on frankfurter characteristics was studied by Hand et al. (1987). The study evaluated frankfurter produced with 17% and 25% fat. Sensory analysis was conducted by serving eight panelists warm 2.5 cm pieces of each sample and all treatment combinations and allowing them to evaluate exterior texture, interior texture, juiciness and saltiness. Results indicated that low fat frankfurters possessed lower values for juiciness, perceived saltiness and higher values for both interior and exterior texture. The texture measurements were reinforced by Kramer peak force measurements which indicated higher values for the low fat treatments.

Although utilizing leaner formulations does bring about the desired reduction in total fat it does not provide a viable option due to its high cost, increased textural values and decreased sensory scores.

Textural Analysis

Texture is one of the three major components of food acceptability (Bourne, 1978). Knowledge of the textural characteristics of emulsion sausages can be gained by using objective mechanical evaluation. Mechanical evaluation reduces the time, cost and overall variability as compared to human sensory evaluation. Investigation into the correlation between objective texture measurements and human sensory evaluation has revealed that there is no objective test that can exactly reproduce human evaluation. This has been partially explained by Daget and Collyer (1984) who concluded that sensory panelists used wide and loose interpretations of characteristic definitions. In a comparative study between descriptive analysis and physical measurements of gels, Daget and Collyer (1984) concluded that the residuals were found to be about twenty times larger for the sensory panel than the instrumental testing. Although objective evaluation does differ from human sensory analysis in many cases objective testing is preferable (Rizvi, 1981).

Kramer Shear

The Kramer shear (KS) has been used to evaluate the force required to shear a food product. Traditionally, the Kramer shear consists of a stationary metal box with a slotted bottom. Blades are driven through the box containing the sample and into the bottom slots. As the blades are forced through a sample the resistance is recorded, showing the peak force and the energy required to shear.

The KS has been used to evaluate frankfurters; however, some questions have arisen about its effectiveness to determine the absolute shear force. Szczesniak (1968) found that Kramer shear values did not always correlate to sensory evaluation. The lack of correlation was partially explained by Voisey (1977) in a study of objective texture measurement tests for wiener texture. By using a Kramer shear cell with the front wall replaced with clear plastic, he was able to observe the behavior of wieners under the stress of a Kramer shear. Voisey proposed that franks began to deform at 65% of their original volume and continued to rupture progressively. This, he explained, was an applied complex stress and not a shear. Although faults have been found with the Kramer shear test, researchers have continued to use it for testing shear values of frankfurters because it still provides a standard base for comparison.

Cyclic Compression

The compression test utilizes the simplest apparatus to arrange and duplicate; therefore, it is one of the most commonly used tools to analyze textural parameters of frankfurters (Voisey, 1975). All that is required are flat parallel surfaces moving towards each other at a constant speed. Cyclic compression is performed by compressing a sample to a point of deformation and then compressing a second time in order to evaluate the viscoelastic properties. The peak force of the first compression is noted as hardness and corresponds to a human first bite. The peak force of the second stroke divided by the peak force of the first stroke is termed cohesiveness. Cohesiveness represents a ratio of the degree of recovery the frankfurter was able to maintain due to its viscoelastic properties and thus relates to "chewing" of a human (Friedman et al., 1963).

Voisey (1975) stated that textural characteristics can be predicted by a combination of compression test: First to compress the sample non-destructively to record resilience and then a second compression cycle to compress the sample to rupture to establish firmness and chewiness. Other parameters that have been associated with cyclic compression are fracturability (force at the first significant break in the curve) and the trait of elasticity (rate at which a deformed material goes back to its undeformed condition). Both of these parameters have been evaluated extensively in frankfurter research (Townsend et al., 1971, Clause et al., 1989).

The percent of deformation (total compression) used to evaluate frankfurters has varied among researchers. The percent deformation used on meat products has varied from 20% (Heldman et al., 1973) to 80% (Bouton et al., 1972). In a review, Breene (1975) noted that several researchers used the first point of deformation as the basis for percentage compression. However, no distinct reference is available for the optimum percent compression required to evaluate frankfurter texture.

Extrusion

Extrusion testing is used to measure the energy and force required to force batter through an extrusion cell. Voisey and Larmond (1971) used a 6.2 X 12.6 cm high cell with 33 holes, 8 mm in diameter to evaluate peak force and energy required to force baked beans through the apparatus. They discovered that plate extrusion cells produced results that took place under steady state conditions. The sample was only compressed the amount required to produce the pressure needed for shearing at the plate. Thus, the area of the curve corresponds to the elastic phase which in turn relates to hardness. This allowed a more precise measure of the cohesiveness of the beans. Daget and Collyer (1984) used a similar device to evaluate the work required to extrude gels. Other workers (Hand et al., 1987) have used a modification of Voisey and Larmond's model to determine the peak force, yield force and energy to evaluate meat batters.

Effects of Chopping

Understanding the functional properties of meat protein is required in order to develop new stable meat emulsions (Smith, 1988). One aspect of producing stable emulsions is the relationship between chopping and protein extraction. During comminution, muscle fibrils are cut and the sarcolemma is disrupted, thus allowing the myofibrillar proteins to be exposed (Hamm, 1973). These myofibrillar proteins are what give processed meats their principal functional and structural components.

Smith (1988) defined protein functionality as "an expression of the physicochemical properties of protein, as related to changing environmental conditions." Functional properties in raw sausage batter include factors of water, fat and protein binding. Traditional high fat emulsion systems focused on fat binding (Townsend et al., 1971); however, in today's low fat-emulsion sausages water binding is the critical issue in production (Rust and Olson, 1988). In order to maximize water binding, molecular properties of the myofibrillar proteins must be altered by extrinsic factors. One of the most common ways in which to alter the molecular properties of proteins is by changing the temperature or amount of shear (time) under which the batter is processed (Smith, 1988). Therefore, due to the strong relationship between time and temperature on protein functionality this review will be further divided as to the effects of temperature and the effects of time.

Temperature

The effect of temperature on protein functionality has been studied in several model systems. Deng et al. (1976) concluded that it was crucial to maintain temperatures below 10°C prior to cooking to maximize fat and water binding in a model system of actomyosin solutions. The authors suggested that the combination of temperature and other factors could be responsible for the reported changes in functional properties of meat proteins. Unfolding and aggregation of proteins allow them to lose their structural configuration, which is necessary for water and fat binding. Higher temperatures allowed for higher extent of aggregation and thus allowed more water to be released. This conclusion was supported by Johnson et al. (1977), who found that the temperature at which materials were held during preblending greatly altered the amount of total protein that was solubilized in batter processed through a model emulsitator. Gillette et al. (1977) noted that maximum protein extraction occurred at 7.2°C and decreased at higher temperatures for ground meat samples which were blended in a commercial blender. Soluble proteins were stated to be the best prediction of meat batter stability, as there was a high correlation between soluble protein and emulsifying ability of meat batters. Temperature effect on myofibrillar protein extractibility in finely ground meat was shown by Gadea de Lopez and Hand (1993) to be the greatest at temperatures between 10 and 12°C. This directly corresponds to the findings of Deng et al. (1976) and Gillette et al. (1977). The findings of researchers in model systems provide valuable information on optimum temperatures for protein extraction. However, because these temperatures and protein functionality relationships were conducted using model systems, further research is required to evaluate the temperature effects on practical production situations. Research on the effect of chopping temperature consists of many studies and the results can be divided into three temperature ranges; <15°C, 15-23°C and >23°C.

<15°C

Investigation of chopping temperatures below 15°C shows that acceptable products can be made at low temperatures. Reichert et al. (1986) concluded that frankfurters chopped to 0°C had the least total gel and fat deposition of treatments chopped at -2°C through +15°C. Moreover, results indicated that breaking strength, hardness, and elasticity all increased with decreasing chopping temperatures.

Jones and Mandigo (1982) studied scanning electron microscope micrographs for frankfurter batters formulated to 25% fat and chopped at temperatures of 10, 16, 22, and 28°C. They discovered that a 10°C endpoint chopping temperature exhibited larger protein encapsulated fat globules than treatments chopped at 16, 22 or 28°C. The 10°C treatment also had significantly the same yield and emulsion stability as the 16°C treatment which was declared the optimum endpoint temperature.

In studying the effect of final chopping temperature on batters formulated to traditional fat levels Puolanne et al. (1985) stated that maximum water binding capacity was achieved at a final cutter temperature of 14 to 16°C. However, the optimum temperature range for batters that used phosphates was considerably wider at 12-23°C. The possible explanation for the advantages of chopping at low temperatures was given by Klettner (1987). He stated that chopping at low temperatures allows muscle protein to solubilize better than at high temperatures. However, caution was suggested not to excessively chop the fat portion due to massive destruction of the fat cells at low temperatures.

Although positive results have been shown for emulsions chopped from 0-15°C, some negative factors have been found for temperatures below 0°C. Harbitz and Ebelandsdal (1983) noted textural disadvantages, poorer fat binding, higher jelly deposits as well as lower sensory values for meat batters chopped below 0°C.

15-23°C

The greatest emulsion stability has been noted, by several researchers, in a range from 15-23°C. Helmer and Saffle (1963) reported that 15.6°C was the temperature that showed no emulsion breakdown for frankfurter batters chopped to a peak temperature of 15.6, 21.0, 26.6, or 32.2°C. Maximum fat and water binding occurred in a range from 15-22°C for frankfurters produced in a study by Brown and Toledo (1975). This was true, however, only the first time a batter achieved those temperatures. Batters chopped to 25°C and then cooled by the addition of dry ice to 16°C did not have the same binding ability as batter only chopped to 16°C. Utilizing a scanning electron microscope Jones and Mandigo (1982) evaluated batters chopped at 10, 16, 22 and 28 °C. The batters chopped to 16°C had the greatest density of the protein matrix and the 22°C treatment showed large protein encapsulated fat globules that were well bound to the emulsion.

There was also no difference between the yield percentages and fat released in emulsion stability testing between the 16 and 22°C treatments.

Brown and Ledward (1987) determined that treatments chopped at 15 and 19°C were significantly more stable for percent cooking loss than treatments chopped at higher temperatures. They also observed weight loss after 9 weeks of storage was lowest for the 15°C treatment.

Not only does the optimum range exist from 15-23°C for emulsion stability but for textural quality as well. Webb et al. (1975) found that physical property scores as determined by a sensory panel, were the highest for treatments chopped to 23°C. Kramer shear values of hot English sausages decreased rapidly for treatments chopped above 21°C in a study by Brown and Ledward (1987). Moreover, sensory panelists noted a significant difference in texture between sausages chopped to 15°C and those chopped to 33°C.

Although, due to differences in brine percentage, storage history, and other characteristics that affect protein extraction, no single temperature is repeatedly reported in research articles. However, significant evidence exists to support findings of optimum emulsion stability and textural quality at temperatures in the range of 15-23°C.

>23°C

Steep decreases in emulsion stability were noted for frankfurter batters chopped above 23°C in a study done by Brown and Toledo (1975). Moreover, Helmer and Saffle (1963) noted complete emulsion breakdown for batters chopped at temperatures above 28°C. This was supported by Townsend et al. (1971) who found a significant increase in the formation of fat caps when batters were chopped above 28.3°C. Jones and Mandigo (1982) described frankfurter batters chopped to 28°C as having rupture holes that greatly contributed to severe emulsion breakdown after viewing scanning electron microscope micrographs.

Although most researchers have found complete emulsion breakdown at chopping temperatures above 23°C, Brown and Ledward argued that successful production of comminuted meat products could be made at high chopping temperatures. However, meat products produced at high chopping temperatures have economic disadvantages. As 24.11 percent cook loss was observed for a treatment chopped at 33°C. Moreover, percent weight loss after 9 weeks showed a sharp increase for treatments chopped above 25°C Textural quality of treatments chopped above 23°C were also shown to decline as temperature rose.

Webb et al. (1975) showed significant difference of physical properties between treatments chopped at 20.6 as compared to those chopped at 24.4 and 27.8°C. They concluded that high chopping temperatures are not only related to emulsion stability but to final textural quality as well. Elasticity of frankfurters decreased as chopping temperature increased for frankfurters made with either pork fat, beef fat or cottonseed oil (Townsend et al., 1971).

Based on the literature, intense consideration must be given to the temperature at which the meat is comminuted in the production of emulsion type sausages. Temperature can greatly effect the fat and water binding as well as textural quality of a system. Optimum temperature range is usually considered between 15-23°C, while detrimental effects occur at temperatures above 23°C. Low temperatures can be utilized to process high quality sausages, however maximum water binding values and textural scores are seen at the higher range of 15-23°C.

Effect of chopping time

Research into the effect of chopping time on emulsion stability and textural quality becomes extremely complicated due to the differences in processing machinery. Chopper blade numbers, sharpness and revolutions per minute (rpm) greatly affect results.

Therefore, it is only possible to review chopping time in relation to each experiment performed.

Deng et al. (1981) performed an extensive study on protein-protein interaction as compared to fat and water binding. Meat was comminuted in a silent cutter which was modified to allow the use of six blades. Samples were taken throughout the process and analyzed for emulsion stability. The authors concluded that at five minutes of chopping, water separation was at a minimum as determined on raw batter. Upon continuation of chopping, water separation increased until leveling off after 20-25 minutes. However, the amount of separated water was still considered acceptable by the authors after 30 minutes of chopping. Chopping for 52 minutes resulted in the highest extent of water separation.

A maximum water binding value was seen at 4.5 minutes in a study done by Puolanne et al. (1985). The values began to decrease after that time. Deterioration of binding values was thought to be due to changes in the fat fraction of the formulation rather than the lean portion. Increases in jelly deposition in all treatments was the result of chopping longer than five minutes in frankfurters chopped at +4, -1 and -3 °C (Klettner, 1987).

Townsend et al. (1971) considered the effect of revolutions per minute (rpm) and time on emulsion stability as well as textural characteristics. Shrinkage, texture characteristics or number of fat caps was affected by rpm's. However, the practical importance of changes in rpm's was discovered to be the time required to achieve a desired temperature.

Brown and Ledward (1987) started treatments at different temperatures (15, 19, 21, 23, 25, 30, 33) so that time of chopping would remain constant. Results indicated that temperature impacted parameters more than time.

Overchopping

Overchopping is produced by chopping emulsions for long periods of time at high temperatures (Townsend et al., 1971). Control of overchopping has been studied by chopping to high temperatures followed by the addition of dry ice to quickly reduce the temperature to optimum range. Brown and Toledo (1975) showed that batters chopped to 25°C and then cooled to 12.7°C were less stable than treatments chopped only to 12.3°C or 13.3°C. These results were not supported by Helmer and Saffle (1963) who stated that no emulsion breakdown was noted for frankfurters chopped to 32°C and cooled to 15.5°C. Helmer and Saffle (1963) concluded that emulsion breakdown does not occur at any one temperature but happened at a wide range of temperatures. Puollane et al. (1985) stated that lean meat can stand longer chopping times (17 minutes) as long as the temperatures are low. Brown and Ledward produced acceptable products by equilibrating ingredients to 33°C prior to production and then chopped for a short period of time (6.5). Therefore, this leads to the conclusion that overchopping of emulsions is more involved than the simple effect of time or temperature but rather their relationship to one another.

Conclusions

Although the addition of non-meat ingredients is currently the most common method used to reduce the fat content of frankfurters, negative sensory and textural characteristics may sacrifice product quality. By utilizing formulations with high levels of added water, researchers have been able to produce frankfurters that are more juicy, tender and posses higher overall acceptability ratings; however, this comes at the cost of higher purge loss, yield loss, and frankfurters which have lower values for cohesiveness, springiness, and hardness. If protein extraction can be manipulated, increasing amounts of added water will greatly enhance low fat, frankfurters. The easiest way in which past research has shown to increase protein extraction is by maintaining optimum chopping temperatures in the range of 15-23°C.

While chopping above this range causes emulsion breakdown, chopping to temperatures below the range can produce frankfurters with diminished textural and water binding qualities. Even though past research has shown that chopping temperature greatly affects protein extraction in traditional high fat, low added water systems current research is not available on the effect of chopping temperature of low fat, high added water meat emulsions.

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CHAPTER III

The effect of chopping Temperature on Low Fat, High Moisture Frankfurters

Abstract

Beef frankfurters were manufactured using six different initial and endpoint chopping temperatures (0-0, 0-15, 0-30, 0-45-15, 15-15, and 30-30) to evaluate the effect of initial and endpoint chopping temperature on low fat, high moisture beef frankfurters. There was no difference for emulsion stability and Kramer shear-energy for those treatments where the endpoint chopping temperature was below 15°C. Purge loss was the highest ($P<.05$) for the treatment with the highest initial starting temperature. The treatment chopped to the highest peak chopping temperature had the lowest values for emulsion extrusion, Kramer shear-energy and possessed the least stable emulsion. In most cases, initial temperature did not affect parameters. In conclusion, chopping above 15°C is detrimental to the production of low fat, high moisture beef frankfurters.

Introduction

Consumers are increasing their demand for low fat food products, and in response researchers are utilizing changes in USDA regulations to develop low fat technology. The USDA's 40% rule (Federal Register, 1988) allows cooked sausages to contain added water and fat, in combination, that does not exceed 40% of the product composition (fat may not to be in excess of 30%). This change has opened an avenue to develop low fat products by reducing the percent fat and thus reducing the caloric density. However, increasing the amount of added water beyond traditional levels tends to put increased pressure on the meat system. The inability of meat proteins to bind increased amounts of water can explain some of the excess purge, high yield loss and decreased textural qualities of high moisture emulsion type sausages (Claus et al., 1990). In order to counteract these negative attributes, water-binding capacity is now the critical issue in production (Rust and Olson, 1988). Therefore, it has become increasingly important to research ways in which maximum protein-water binding can be achieved. One method investigated by researchers in traditional, low added water meat systems to increase water binding was the relationship between temperature of chopping and binding ability of proteins (Helmer and Saffle, 1963, Puolanne et al., 1985). Past research has defined the optimum endpoint chopping temperature to range from 15-23°C (Jones and Mandigo, 1982; Brown and Toledo, 1975), but there has been very limited research on the effect of initial chopping temperature (Brown and Ledward, 1987). However, researchers defined these optimum temperatures for batters with fat content as high as 30% and added water levels below 10%, where today's low fat, high moisture formulations contain much less fat and significantly greater amounts of added water. The findings established by past research need to be evaluated under the higher moisture conditions of today's meat system. Therefore, the objective of this research is to determine the effect of initial and endpoint chopping temperature on low fat, high moisture frankfurters.

Materials and Methods

Two replications of low fat beef frankfurters were manufactured. Fresh (96 hrs postmortem, 4.4°C) lean cow trimmings and fat beef trim were ground through a 1.27 cm plate (Grinder, Biro Mfg, Marblehead, OH) and mixed (Leland ribbon-paddle mixer) for

(1 min.) for homogeneity. Samples were taken for determination of fat, moisture, and protein (AOAC, 1985). Appropriate lean trim, fat trim and water combinations were determined for a 15% fat, 25% added water formulation using least cost formulation (Least Cost Formulator, Virginia Beach, VA). The trimmings were vacuum packed (M855, Multivac, Kansas City, MO), and frozen (-28.8°C) for approximately 1 week prior to production. Raw materials were allowed to thaw at 4.4°C for 36 hours before production. The appropriate amount of lean trimmings and fat trimmings, added water, 2.25% salt, .005% sodium tripolyphosphate, 156 ppm sodium nitrite, and 228.6g of spices (A.C. Legg, Birmingham, AL) were weighed and kept separate in sealed bags. Batch size for each treatment was 15.9 kg.

Six treatment combinations were examined to determine effects of different initial and end point chopping temperatures. For the three treatments 0-0, 15-15 and 30-30, the product was chopped (K64 Seydelmann, Robert Reiser, Canton, MA.). for a constant time (8 min.) and the initial temperature (0, 15, or 30°C) was maintained with the addition of CO_2 snow. For the treatments 0-15 and 0-30, the product was chopped from an initial temperature (0°C) until reaching the desired endpoint temperature (15 or 30°C). The final treatment (0-45-15) was chopped from an initial temperature (0°) until reaching 45°C and then immediately chilled with the addition of CO_2 snow on the low mix setting to an endpoint temperature of 15°C. This was added to duplicate the Helmer and Saffles (1963) treatments. Prior to manufacturing, all materials (meat, spices, water) were equilibrated to the appropriate temperature in either a freezer (0°C), drying chamber, 15°C (1 truck drying chamber, Alkar, Lodi, WI.), or smokehouse, 30°C (1 truck smokehouse, Alkar, Lodi, WI.)

The lean trim, salt and sufficient water for an ionic strength solution of 0.46 was chopped on low speed (30 seconds) and 2.5 minutes on high speed. The ionic strength was determined from the first replication in which 1/3 of the required water, the lean fraction and salt were added first. The dry ingredients, remaining water, and fat trim was added and chopped on high until the desired endpoint temperature was reached or, for those treatments with a constant temperature, an additional 5 minutes. The last 30 seconds of all treatments were chopped under vacuum.

Each treatment was stuffed into 32 mm casings (Nojax, Viskase, Chicago, IL) and heat processed (1 truck smokehouse, Alkar, Lodi, WI). The smokehouse schedule is listed in Table 3.1. Cooked weights were recorded after the frankfurters had been hand showered with cold tap water to an internal temperature of 100°C. Yields were then determined by dividing the cooked weight by the raw-stuffed weight and multiplying by 100. Frankfurters were allowed to cool for 12 hours in a 4.4°C cooler before being peeled (Ranger Appalo, Townsend Engineering, Des Moines IA). Links were vacuum packaged (M855, Multivac, Kansas City, MO), 5 links per package and stored at 4.4°C for purge analysis.

Batter Properties

Thermal emulsion stability was determined using the method described by Townsend et al. (1968). Raw batter (34g) was placed into a plastic tube, covered with plastic film (Parafilm, American National Can, Greenwich, CT) and heated in a 48.8°C water bath (Model BKS-350, Gallencamp and Co., Sussex, England). The temperature raised intermittently after 30 minutes until the internal temperature of the batter reached 68.8°C. One tube in each batch contained a thermometer to monitor temperature during cooking. Liquids released were decanted into 15ml, graduated centrifuge tubes and centrifuged (Model J-6M, Beckman Instrument, Palo Alto, CA) for 1 minute at 2.68 x G. After chilling (4.4°C, 12 hours), the total volume of liquid released, was recorded and expressed as a percentage Of the sample weight.

the testing would be done at the stuffed temperature according to a modification of the Voisey and Larmond (1971) method. Values were determined by packing a cell attached to an Instron Universal Testing Machine (Model 4500, Instron Corp. MA), with 300g of batter and compressing at a cross head speed of 100 mm/min. to a distance of 0.5 cm from the base. A 10 kN load cell was used. Peak force and total energy were used to determine extrusion values. All cooked frankfurter textural measurements were made on samples that had been packaged and refrigerated (4.4°C) for one week prior to testing. Compression values (quadruplicate) were determined by axially compressing 65% of the height (Voisey, 1977) of a 3 cm sample for two cycles between plates attached to an Instron Universal Testing Machine. The machine was set at a crosshead speed of 500 mm/minute and a 1 kN load cell. Values obtained were hardness and cohesiveness (Singh et al., 1985).

Kramer shear values (quadruplicate) were obtained by shearing a 4 cm frankfurter sample placed perpendicular to the blades, using a Kramer shear attachment for the Instron with a cross head speed of 100 mm/minute and a load cell of 10 kN. Peak force and area under the curve (energy) was used to determine shear measurements (Singh et al., 1985).

Compositional Analysis

Raw trimmings and final product proximate composition (moisture, fat and protein) were analyzed according to AOAC (1985) procedures (drying oven, ether extract, and nitrogen by Kjeldhal).

Purge Analysis

Packages were stored at 4.4°C for purge analysis. Purge was measured once a week for 8 weeks, starting 1 week after production. Two random packages from each treatment were weighed, opened and drained of purge (5 min.) and reweighed. The package was dried at 100°C for 2 hours so that residual purge in the corners of the packaged was removed, then package weights were recorded. Purge loss was reported as a percentage of total frankfurter weight after draining divided by the initial packaged weight.

Statistical Analysis

Statistical analysis was performed using the Statistical Analysis System (SAS Institute, 1985). The main treatments (six) with two replications, from this randomized complete block design were analyzed by one-way analysis of variance. Treatment means were separated using least significant means procedure (Steel and Torrie, 1980).

Results and Discussion

Proximate Composition

Chemical composition data for the frankfurters is displayed in Table 3.2 The percent protein for all treatments was not different ($P>0.05$). Treatments 0-0, 0-15 0-30 and 30-30 had the highest ($P<0.05$) percentage of moisture and conversely the lowest percentage of fat. The 0-45-15 treatment was significantly higher ($P<0.05$) in fat and lower in percent moisture than all other treatments. Claus et al. (1990), in a study of low-fat, high added water bologna, had similar composition diffrences. Analysis indicated that the formulations were below targeted goals for added water. This may be due to the loss of moisture during chilling as samples for proximate composition were not taken until after the frankfurters were chilled (4.4°C, 18 hrs). However, the differences found in composition are not due to formulation as all treatments were formulated equally.

Therefore, the compositional differences are due to the effects on protein-water binding by the treatments.

Smokehouse Yield

Smokehouse yields (Table 3.2) were not different ($P>0.05$) for all treatments. This is in contrast to the results of Jones and Mandigo (1982) who determined cook yield for frankfurters chopped at 10, 16, 22, and 28°C and noted that the 28°C treatment yield was significantly lower than all other treatments.

Thermal Emulsion Stability

The thermal emulsion stability (Figure 3.1) data indicated that the treatment with the greatest peak temperature (0-45-15) had more total percentage loss than all other treatments. Helmer and Saffle (1963) also saw complete emulsion breakdown for a treatment chopped above 28°C. The two treatments that had endpoint chopping temperatures of 30°C (0-30 and 30-30) possessed similar ($P> 0.05$) total percentage loss, but were higher ($P<0.05$) than treatments 0-0, 0-15 or 15-15. Jones and Mandigo (1982) also noted the trend for high fat treatments chopped above 22°C to have higher total emulsion loss than treatments chopped to a peak temperature of 16°C. Treatments 0-0, 0-15 and 15-15 were not different ($P>0.05$) for total percentage loss and possessed the lowest ($P<0.05$) percentages of all treatments. Similar results were also reported by Puolanne et al. (1985) in which water binding values remained constant in the range between 12 to 20°C and then decreased above that point.

Raw Frankfurter Batter Extrusion

Raw frankfurter batter extrusion peak force and total energy can be found in Figures 3.2. and 3.3, respectively. The treatment 0-0 possessed the highest ($P<0.05$) values for both peak force and energy. The 0-15 and 15-15 treatments were not different ($P>0.05$) from each other and were significantly higher than those treatments chopped to a peak temperatures higher than 15°C (0-30, 30-30, and 0-45-15). The 0-45-15 treatment possessed the lowest value for both peak force and energy. These raw batter parameters correspond to the thermal emulsion stability data, in which the 0-0, 0-15, and 15-15 treatments were not different (P>0.05) from each other and were superior (P<0.05) than treatments chopped above 15°C.

Textural Properties

Kramer energy shear data, shown in figure 3.4, indicated that treatments chopped to peak chopping temperatures above 15°C (0-30, 30-30 and 0-45-15) required less (P<0.05) energy to shear than those treatments chopped to peak temperatures 15°C or below. Treatments with endpoint chopping temperature of 30°C (0-30 and 30-30) were not different (P>0.05) from each other and required more energy than the 0-45-15 treatment. In addition, 0-0, 0-15 and 15-15 were not different (P<0.05) from each other. As expected from the previous raw batter extrusion analysis, the 0-45-15 treatment was the softest. This trend for reduction in shear force required as peak chopping temperature increased was also seen by Brown and Ledward (1987) in a study on the effect of temperature of comminution on the stability and eating quality of 'English' sausages. Brown and Ledward's study showed that the toughness of sausages deceased significantly (P<.001) with increased temperature of comminution.

Numeric values for Kramer shear peak load (Figure 3.5), tended to decrease as endpoint chopping temperature increased. The 0-15 treatment possessed the highest value (P<0.05, .44 kN) while the treatment 0-45-15 had the lowest value (P<0.01, .20 kN). This loss of bind for the 0-45-15 treatment could be related the prolonged and excessive mechanical action sustained by this treatment. Webb et al. (1975) stated that a great degree of protein denaturation occurs under these conditions, therefore resulting in less protein-water binding.

Compression measurements were used to determine cohesiveness and hardness. Treatments were not different (P>0.05) for cohesiveness values (mean=1.00). Claus et al. (1990) also noted similar results for low fat, high moisture bologna. Analysis of hardness (Figure 3.6) showed that the 0-45-15 treatment required the greatest amount of force to compress the sample to 65% of its original height. All other treatments were not different (P>0.05) from each other.

Purge

Figure 3.7 shows the total purge percentage for the 8 week period. Total purge was the greatest for the treatment 0-0 and 30-30. These findings are supported by Harbitz and Ebelandsdal (1983) who found reduced binding ability for frankfurter batters chopped below 0°C and Helmer and Saffle (1963) which noted complete emulsion breakdown of sausage emulsions chopped above 28°C. The 0-30 treatment tended to also be higher than those treatments chopped only to endpoint temperatures of 15°C, although no significant relationship existed. The treatment which lost the least total purge was the 0-45-15 treatment; however, this treatment also contained significantly less proximate moisture than all other treatments

Conclusion

Analysis of the raw frankfurter batters indicated the 0-45-15 treatment was less (P<0.05) stable and possessed lower (P<0.05) extrusion values than all other treatments. This was further indicated in cooked frankfurter textural analysis in which the 0-45-15 treatment required the least (P<0.05) amount of force and energy to shear. Treatments 0-15 and 15-15, which possessed different initial temperatures and the same endpoint temperatures, were not different for total percentage loss, emulsion extrusion energy and peak load, energy required to shear, hardness, and percentage purge after 8 weeks of storage. The other treatments with different initial temperatures and the same endpoint temperature, 0-30 and 30-30, were not different (P>0.05) for total percentage loss, peak force required to extrude, energy to shear, and hardness. The 0-0, 0-15 and 15-15 treatments were not different (P>0.05) for hardness, total percentage loss, and Kramer shear energy.

In general, the results showed that as peak chopping temperature increased frankfurters were less stable and softer. Moreover, achieved added water decreased as chopping temperature rose. In most cases, intitial temperature did not affect parameters. Treatments with peak temperatures of 15°C and below (0-0, 0-15 and 15-15) were more stable, had more indication of raw bind and were firmer than the 0-30, 30-30, and 0-45-15. Treatments 0-15 was not different than 15-15 nor was 0-30 different from 30-30 for total percent loss, peak force required to extrude and Kramer shear energy. Consequently, initial temperature does not influence results to the same magnitude as endpoint temperature. Therefore, chopping above 15°C is detrimental to production of quality, low fat high moisture beef frankfurter, yet initial chopping temperature is not as critical for production parameters.

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TABLE 3.1. SMOKEHOUSE SCHEDULE FOR ALL TREATMENTS

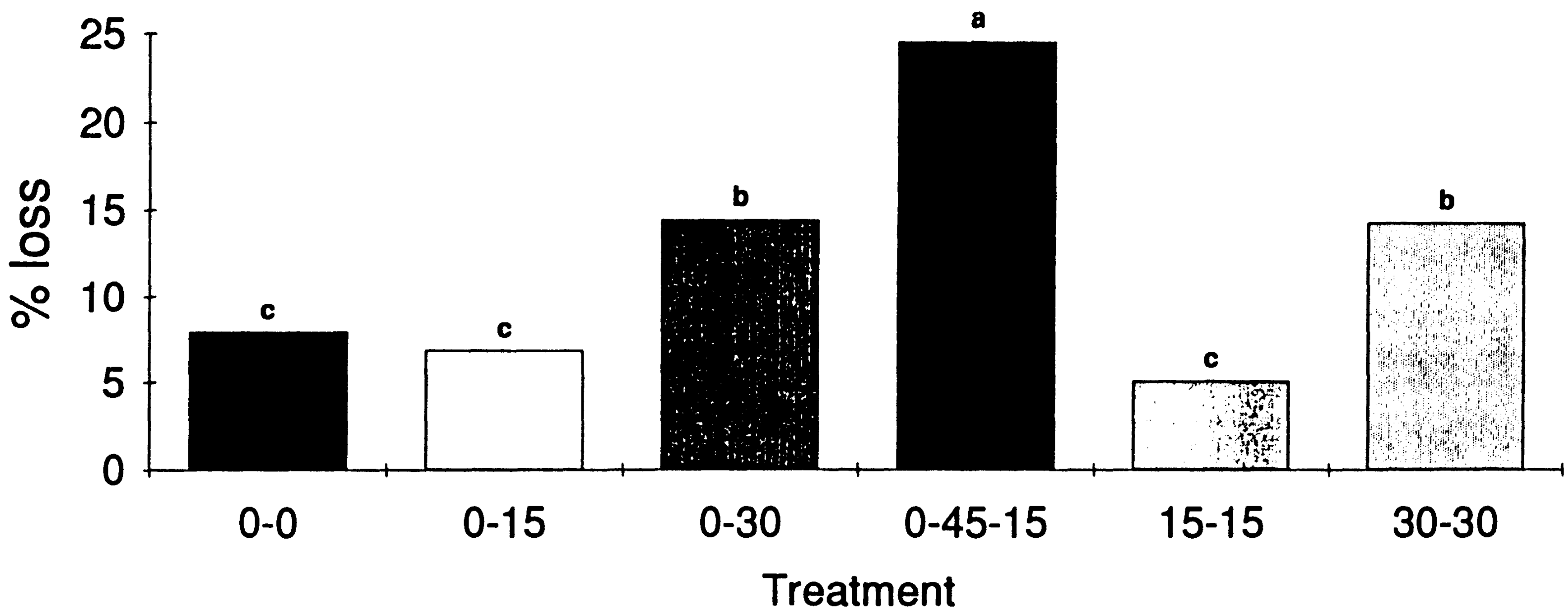
METHOD	DRY BULB (°C)	WET BULB (°C)	TIME (min)
Cook	62.8	-	20
Smoke and Cook	68.3	-	30
Smoke and Cook	73.8	56.7	35
Smoke and Cook	85	68.8	-
Cold Shower	-	-	10

TABLE 3.2 PROXIMATE COMPOSITION AND YIELD OF LOW FAT, HIGH MOISTURE BEEF FRANKFURTERS

Treatment[a]	Protein	Moisture	Fat	AW[b] (calculated)	Yield[c]
0-0	13.0[d]	69.6[de]	13.5[g]	17.6[d]	88.4[d]
0-15	13.1[d]	69.0[ef]	14.1[f]	16.6[de]	87.2[d]
0-30	13.4[d]	69.2[def]	14.8[e]	15.6[de]	87.6[d]
0-45-15	13.9[d]	64.4	17.0[d]	8.8[f]	86.7[d]
15-15	13.5[d]	68.7[f]	14.1[fg]	14.8[e]	85.7[d]
30-30	13.3[d]	69.8[d]	13.6[fg]	15.3[de]	88.2[d]

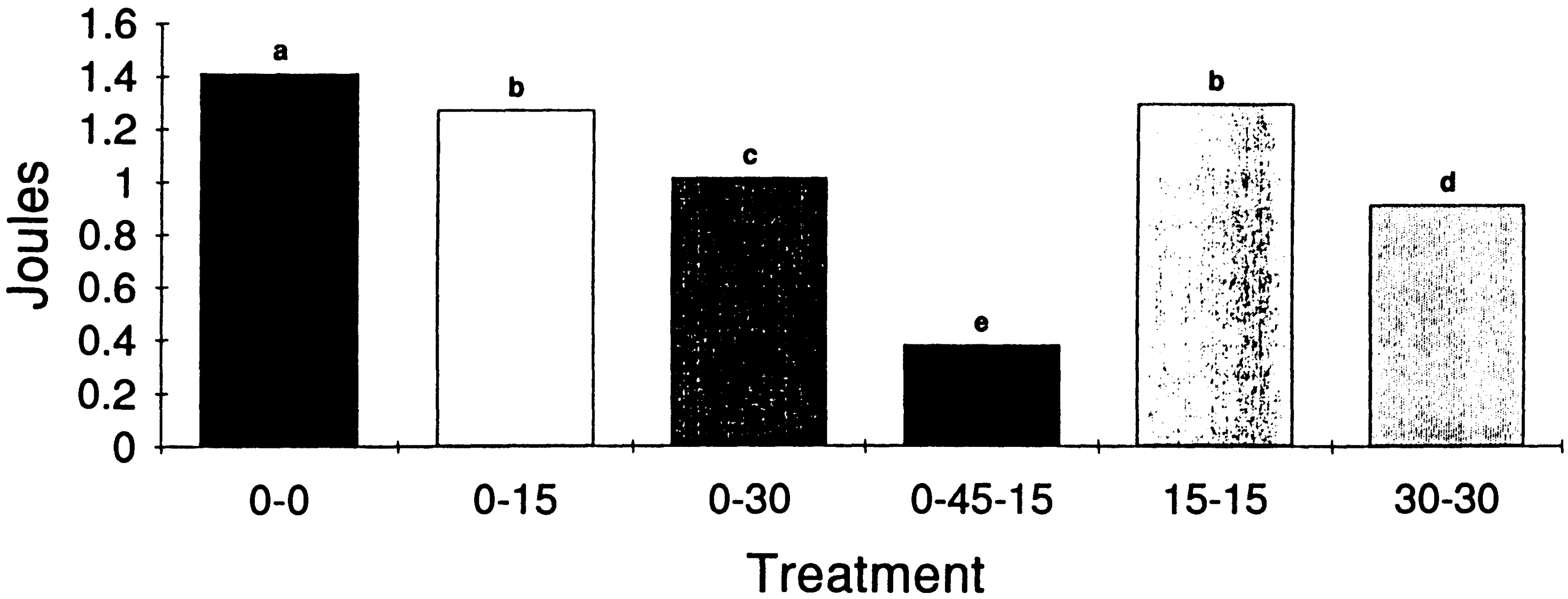
[a] Treatment: Initial-endpoint temperatures in degrees C
[b] Added water=%Moisture -(4 * % Protein)
[c] Yield=raw weight divided by cooked weight and multiplied by 100
[d-g] Means within the same column that have unlike superscript letters are different (P<0.05)

FIGURE 3.1. TOTAL LOSS PERCENTAGES FOR RAW FRANKFURTER BATTER THERMAL EMULSION STABILITY



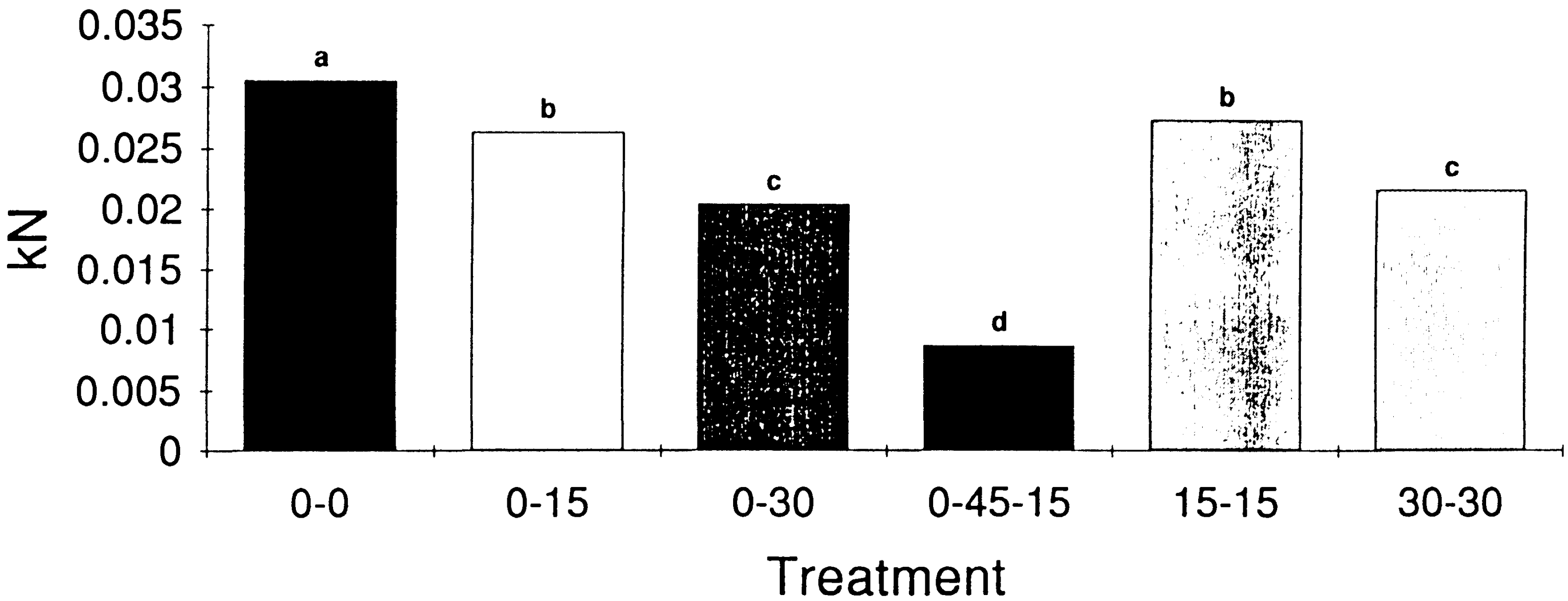
abc Columns which have unlike superscripts letters are different (P<0.05)

FIGURE 3.2. ENERGY REQUIRED TO EXTRUDE RAW FRANKFURTER BATTER



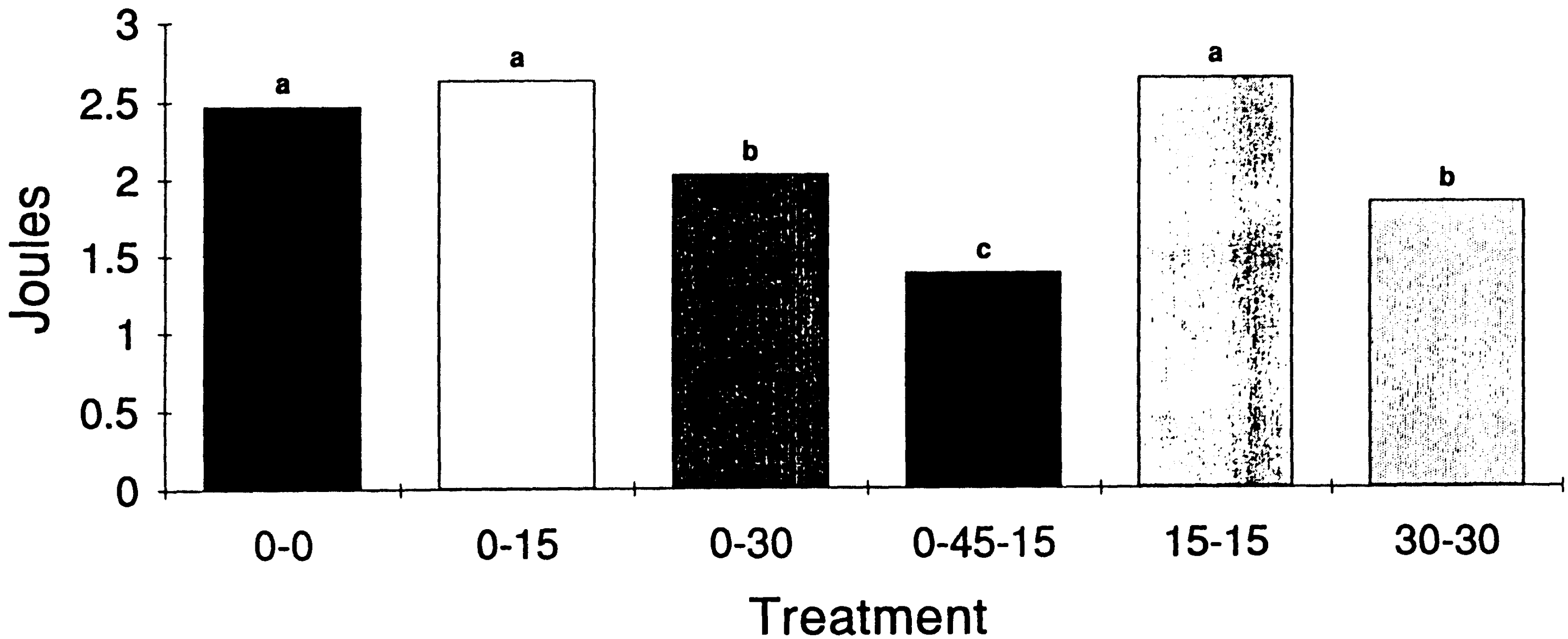
abcde Columns which have unlike superscripts letters are different ($P<0.05$)

FIGURE 3.3. PEAK FORCE REQUIRED TO EXTRUDE RAW FRANKFURTER BATTER



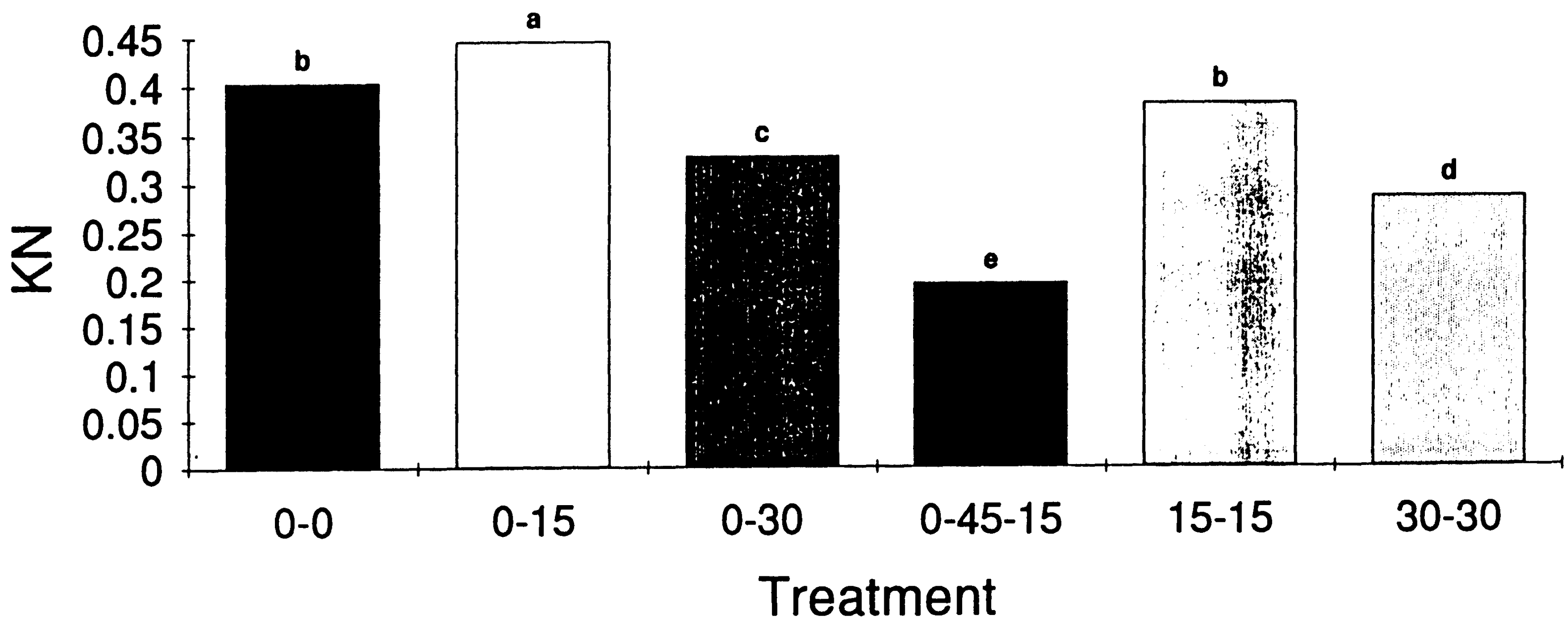
[abcd] Columns which have unlike superscripts letters are different ($P<0.05$)

FIGURE 3.4. ENERGY REQUIRED TO SHEAR COOKED FRANKFURTERS



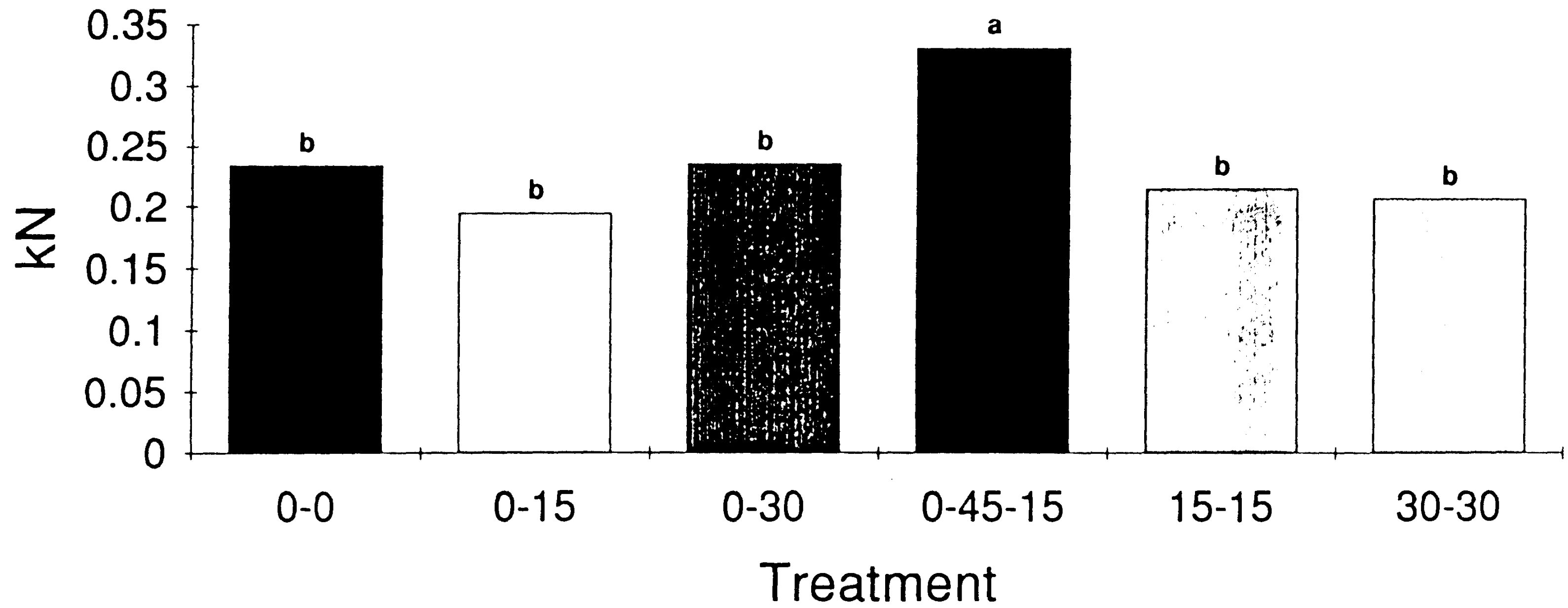
abc Columns which have unlike superscripts letters are different ($P<0.05$)

FIGURE 3.5. PEAK FORCE REQUIRED TO SHEAR COOKED FRANKFURTERS



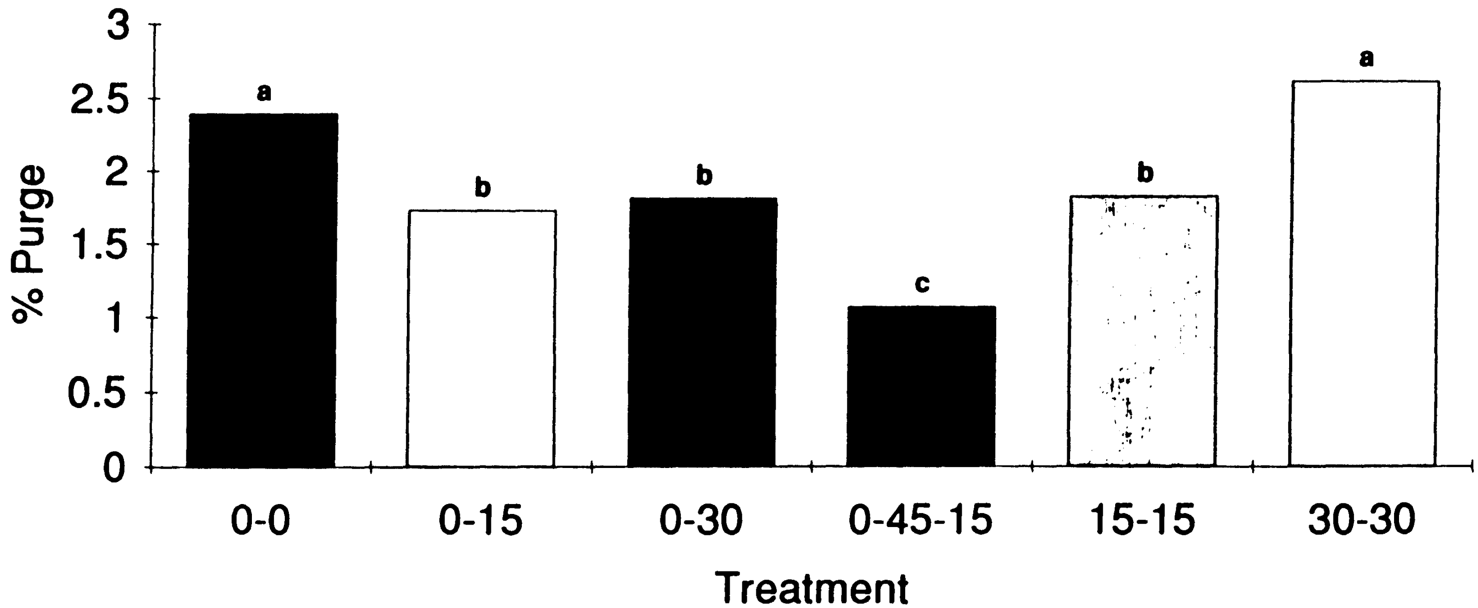
abcde Columns which have unlike superscripts letters are different ($P<0.05$)

FIGURE 3.6. HARDNESS FOR CYCLIC COMPRESSION TEST ON COOKED FRANKFURTERS



ab Columns which have unlike superscripts letters are different (P<0.05)

FIGURE 3.7. PERCENTAGE PURGE OF FRANKFURTERS AFTER 8 WEEKS OF STORAGE



abc Columns which have unlike superscripts letters are different (P<0.05)

APPENDIXES

APPENDIX A

TEXTURAL CHARACTERISTICS

Textural Characteristics

Treatment	Emulsion Extrusion Energy (J)	Emulsion Extrusion Force (kN)	Compression Hardness (kN)	Kramer Shear Energy (J)	Kramer Shear Force (J)
0-0	1.41[a]	0.031[a]	0.23[b]	2.47[a]	0.40[b]
	(0.28)	(0.006)	(0.05)	(0.92)	(0.17)
0-15	1.27[b]	0.026[b]	0.20[b]	2.63[a]	0.45[a]
	(0.17)	(0.004)	(0.03)	(0.74)	(0.13)
0-30	1.02[c]	0.020[c]	0.24[b]	2.03[b]	0.33[c]
	(0.17)	(0.002)	(0.06)	(0.84)	(0.15)
0-45-15	0.38[e]	0.009[d]	0.33[a]	1.38[c]	0.20[e]
	(0.25)	(0.004)	(0.07)	(0.32	(0.05)
15-15	1.30[b]	0.027[b]	0.22[b]	2.64[a]	0.38[b]
	(0.12)	(0.002)	(0.09)	(1.08)	(0.16)
30-30	0.91[d]	0.022[c]	0.21[b]	1.84[b]	0.29[d]
	(0.19)	(0.005)	(.04)	(0.36)	(0.08)

[abcde] Column values with unlike superscrip letters are different (P<0.05)

APPENDIX B

STABILITY CHARACTERISTICS

Stability Characteristics

Treatment	Emulsion Stability Total % Lost	8 Week Purge % Purge
0-0	2.70[c] (1.15)	2.63[a] (0.79)
0-15	2.32[c] (1.03)	2.02[b] (0.22)
0-30	4.93[b] (3,06)	1.73[b] (0.75)
0-45-15	8.36[a] (0.58)	1.31[c] (0.26)
15-15	1.73[c] (1.47)	1.84[b] (0.29)
30-30	4.86b (1.65)	3.50[a] (0.18)

[abc] column values with unlike superscript letters are different ($P<0.05$)

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