PROCESSING TEMPERATURE EFFECTS ON LOW FAT, HIGH MOISTURE, BEEF FRANKFURTERS

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CHAPTER I

INTRODUCTION

Dietary recommendations issued by the major health organizations in the United States acknowledge the importance of eating a varied diet; achieving and maintaining ideal body weight; and limiting intake of total fat, saturated fatty acids, polyunsaturated fatty acids and cholesterol as positive health measures for optimal nutritional status (National Research Council, 1988).

Animal products provide more than a third of the iron, vitamin A, thiamine and magnesium content; half of the niacin, riboflavin, and vitamin B_6 content; and more than 70% of zinc, calcium and vitamin B_{12}. However, in doing so, they provide 36 percent of the caloric content of the food supply (National Research Council, 1988). Because of this fact and the trend for consumers to purchase low fat products, all realms of the meat industry from the producer to the processor are attempting to produce leaner, lower fat products.

There are numerous products on the market today with reduced fat claims. However, low fat red meat frankfurters are not currently a large seller in the 1.2 billion dollar frankfurter market (Nielsen Scantrack Service, 1988).

Lowering the fat in these products is easily accomplished through formulation with lean raw materials. However, if nothing is added to replace the fat, a tough, rubbery texture usually persists.

In 1988, the USDA made it possible to replace fat in cooked sausages, such as bologna and frankfurters, with water. These changes allow the total added moisture and fat content to not exceed 40%, instead of the traditional 30% fat and 10% added water (Federal Register, 1988).

Increasing the water level beyond traditional levels tends to put increased pressure on the meat system. This is usually accompanied by excess purge in the package, low cooking yields and a soft texture. These characteristics are unacceptable to consumers.

The myofibrillar proteins play a major role in holding the excess water in high moisture formulations. Many factors effect the ability of these proteins to function in a manner that is beneficial to processors. One of these factors is endpoint chopping temperatures (Jones and Mandigo, 1982). However, this factor has not been studied extensively in low fat, high moisture products.

This study investigates the effect of chopping temperatures on low fat, high moisture frankfurters using all beef formulations.

CHAPTER II

REVIEW OF LITERATURE

Development of Low-fat products

Improvements in economic status, along with the enrichment and fortification of a variety of foods, as well as improvements in product quality and distribution have reduced the occurrence of nutritional deficiencies in the United States to a fraction of what was commonplace 90 years ago (National Research Council, 1988). However, despite these improvements, additional nutritional problems have arisen. It is estimated that 34 million adults in the United States are overweight and nearly 1 million adults die each year of cardiovascular disease. This may be directly related to the consumption of red meat, which makes up the largest portion of total calories consumed (National Research Council, 1988). Therefore, it is the responsibility of the red meat industry to produce high quality, reduced calorie meat products.

Even with these staggering statistics, it is estimated that only 30 percent of U.S. citizens have modified their eating habits as a precaution against coronary heart disease (Bischoff, 1990). Therefore, the meat industry has placed the burden on its' own shoulders, rather than relying on the consumer to lower their fat intake, by developing low-fat products that are healthy as well as palatable. Ten percent of 1990's 10,301 new product introductions were flagged with "reduced fat" claims, which forces processors to compete on the basis of lowest fat formulation (Best, 1991).

The red meat industry, in particular, is responding in one of two basic approaches; 1) using leaner meats, which increases formulation costs, or by 2) reducing the fat and caloric density by the "dilution effect", from substances such as water and other non-meat ingredients (plant proteins, starches, gums) (Claus et al., 1990).

The replacement of fat with water was made possible by the USDA cooked sausage labeling change which allows the combined fat and added moisture levels to reach 40%, with a finished product fat content of no more than 30 percent (Federal Register, 1988). This deviates from the former rule, which stated no more than 30% fat and 10% added water in cooked sausages. Rust and Olson (1988) reported that with the advent of the 40 percent rule, the product's water binding capacity will now replace its fat binding capacity as the critical issue in production of low fat sausages. Although the fat may be replaced with water, it is possible that purge and textural problems will arise (Rust and Olson, 1988).

Many researchers have examined the possibility of using non-meat ingredients such as plant proteins, plant oils and gums as replacements for animal fat in low fat products. Park et al. (1989) evaluated the use of monounsaturated and omega-3 polyunsaturated oils for use in low fat frankfurters. In this study, fish oil was used as the source of polyunsaturated fatty acids and sunflower oil was used for the monounsaturated fatty acids. The frankfurters had problems with increased firmness and decreased juiciness. The replacement of animal fat with soy proteins has also been studied (Sofos and Allen, 1977). It was noted that textured soy protein used in combination with soy protein isolate could be used to produce an acceptable wiener type product. However, when used with a formulation that contained low fat (10%), the product became firmer and a lower binding meat (pork) had to be used to alleviate the texture problem. Foegeding and Ramsey (1986) attempted to use various gums to replace the animal fat in low fat meat batters. They found that batter containing the gums was similar in sensory evaluation acceptability when compared to the control batter (25% fat)

Water Holding Capacity

Since water binding is of critical importance in low fat products, it is essential to understand the mechanisms behind it. Obviously, water holding capacity (WHC) is of economic importance since weight losses during storage, freezing, thawing and cooking are all directly related to the quality and juiciness of the product. Likewise, added water can greatly reduce finished product cost. Water holding capacity and water binding capacity in reference to cooked meat products may be used interchangeably (Puolanne and Terrell, 1983; Trout and Schmidt, 1983; Regenstein, 1984). Jauregui et al. (1981) proposed the use of three terms to alleviate the confusion caused by improper use of the term water-holding capacity. The terms: (1) water-binding potential, the ability of a protein system to hold water present in excess and under the influence of an external force, (2) expressible moisture, the amount of liquid squeezed from a protein system by the application of force, and (3) free drip, which refers to the amount of liquid lost by a protein system without application of external force other than gravity. In this investigation water-holding capacity will be used in reference to all of the terms collectively.

Many factors can influence the WHC of meat, including pH, salt content, temperature, age of the meat, presence of phosphate and fat content. Hamm (1960) investigated all of these factors extensively.

The influence of pH is of practical importance because storage and the processing of meat is usually coupled to changes in pH (Hamm, 1960). The effect of pH on WHC was shown in studies by Bouton et al. (1971) in which cooking losses decreased linearly as pH increased in mutton. These results are in agreement with Hamm and Deatherage (1960), who found that within the range of pH 3.0 to 8.0 the pH has a large effect on WHC not only before but after cooking. They found that meats heated with higher pH values produced cooked meats with a higher WHC. Hamm (1960) explains in great detail the specific effects of pH on WHC. He found that the pH at which the WHC is at a minimum corresponds to the isoelectric point of actomyosin. The increasing or decreasing of WHC due to pH is explained by the amount of interfilament spacings for the water to bind to the proteins, as pH increases interfilament spacings increase (Offer and Trinick, 1983).

The effect of salt on WHC is well known (Hamm, 1960). The mode of action in which salt affects WHC is explained by Hamm (1986), in which the association of Cl^- ions with positively charged groups results in a shift of the isoelectric point (IP) to a lower pH. This shifting to a lower pH causes a weakening of the interaction between oppositely charged groups at pH > IP, and therefore an increase in WHC. Furthermore, the addition of NaCl causes a weakening of intermolecular repulsive forces at pH < IP, which results in a decrease of WHC.

With 23% of U.S. households trying to reduce salt intake, salt as a way of increasing WHC may be a thing of the past. A decrease in salt in processed meat formulations is accompanied by questions regarding microbiological safety, economic issues revolving around profitable yields as well as consumers accepting low salt products. Vasgen and Martin (1990) reported that any attempt to manufacture sodium reduced sausage by conventional methods of processing has always failed to produce a high quality end product. They stated that the shortage of sodium ions, which are carriers for water molecules are unavailable, therefore the processing method has to be modified to ensure working of the lean meat and for fat emulsifying. The effects of reduced salt levels in processed meats have been extensively investigated (Hand et al., 1982; Lusby and Olson, 1982; Puolanne and Terrell, 1983).

The effect of temperature on WHC was reported by Wierbicki and Deatherage (1958) in which they found that the WHC of meat decreases with increasing temperatures in the range of 0-25^{o}C. According to Hamm and Deatherage (1960), heating beef from 20^{o}C to 30^{o}C resulted in no changes in muscle proteins and consequently no change in WHC. Between 30^{o} to 40^{o}C a mild denaturation occurred and the WHC increased in the acidic range and decreased in the range of the IP. A much stronger denaturation starts at 40^{o}C and continues to 50^{o}C. WHC decreased from 50^{o} to 80^{o}, but not as markedly as from 40^{o} to 50^{o}C.

Phosphates are used extensively in the meat industry for a variety of reasons. Approximately 400 publications exist on the effect and application of phosphates for meat products (Hamm, 1986). The use of phosphates in cured meat to control the loss of natural juices is a widely accepted practice (Dziezak, 1990). Phosphates, through their interaction with the various meat components, have the ability to influence WHC, texture, color, emulsification and retard development of off flavors (Schults et al., 1972). As far as WHC is concerned, the increase due to phosphate may be attributed to shifting of the pH from its isoelectric range, increasing the ionic strength and disassociating actomyosin to some extent (Sofos, 1986).

The synergistic effect of phosphate in conjunction with sodium chloride has been investigated extensively (Schults et al., 1972; Poulanne and Terrell, 1983; Trout and Schmidt, 1986). These studies suggest that when phosphate is used in conjunction with NaCl the protein extractability of NaCl increases and low salt meat products can be manufactured, while still maintaining their desired properties. Sodium tripolyphosphate is the most common and accounts for approximately 80% of the phosphates used (Barbut et al., 1988).

The influence of fat on WHC has been investigated by Swift et al. (1954) in which they found that up to a fat : protein ratio of 2.8:1 (added water 13.5%) the WHC in sausages increased with an increase in fat content. However, after this point the ability to hold water decreased. Hamm (1960) proposed that the relationship between fat and WHC was due to an effect of other factors that directly influenced WHC, since fat itself had little tendency to hold water.

Meat Protein Functionality

Protein functionality denotes different things to different researchers but broadly it means, any physiochemical property that affects the processing and behavior of protein in food systems as seen in the quality of the final product (Kinsella, 1976). The myofibrillar proteins are of primary concern regarding protein functionality in a comminuted meat product (Acton et al., 1983).

Functional properties of meat constituents are of importance from the raw material stage, completely through to the end processed meat product. The major functional properties are; 1) water binding ability, 2) fat stabilization or emulsification, 3) particle to particle binding and 4) the development of desirable color properties (Acton and Dick, 1984). Zayas and Lin (1988) indicated that proteins of either animal or plant origin are recognized as performing three basic functions in comminuted meats; those being fat emulsification, water retention and the formation of structure. Hermansson et al. (1986) reported that proteins are the principal functional and structural components of processed meats and determine the characteristic handling, texture and appearance of products. Muscle proteins can be viewed as participating in three classes of interactions; protein-water, protein-lipid and protein-protein (Acton and Dick, 1984). These interactions are characterized by the basic functional properties of water binding, fat binding and gelation (Smith, 1988).

The solubility of protein as an important property governing the functional behavior of proteins and their potential application to food processing has been pointed out by Nakai (1983). Wilding et al. (1984) stated that solubility is probably the most important of protein functional properties, which agrees with Trautman (1966). Trautman (1966) also reported that the protein portion of a typical frankfurter contains approximately 30% water soluble protein, 30% salt soluble protein, 30% connective tissue and 10% nonprotein nitrogen. It is readily apparent that the soluble muscle proteins are largely responsible for the distinctive characteristics of franks and many other meat products.

The myofibrillar proteins, myosin in pre-rigor and actomyosin in post rigor muscle, are considered to contribute the most functionality in meat products

(Samejima et al., 1981). The protein of primary importance in relation to solubility is that of myosin. Fukazawa et al. (1961) suggested that myosin was indispensable to the binding properties as well as the water holding capacity of meat and meat products. Samejima et al. (1969) reported that only myosin has the ability to influence heat-induced gelation in model systems and that the entire myosin molecule is necessary to develop desirable gel strength. Extrinsic factors such as environmental and processing conditions influence myosin functionality by altering molecular properties (Smith, 1988). Dudziak and Foegeding (1988) indicated that in an attempt to isolate actomyosin and myosin from post-rigor turkey that myosin not associated with actin was the predominant protein. This could be interpreted as being in disagreement to some extent with Whiting (1988) who reported that actomyosin was the protein responsible for most of the textural properties of meat products. It can easily be recognized that some way of manipulating soluble myofibrillar proteins is essential in binding more water for low fat products.

Processing Techniques for Meat Batters

When frankfurters are manufactured, the meats are extensively comminuted to produce small particles. One key element in manufacturing these products is stabilizing the fat and moisture to prevent excessive losses or product failure. The meat proteins stabilize the fat; therefore meat batters have historically been defined as an emulsion. This two phase dispersion of immiscible liquids is a good representation of the raw meat batter (Foegeding, 1988). Although there is considerable conflict in whether meat batters should be referred to as emulsions, in this investigation the terms will be used interchangeably.

Many processing techniques have been investigated in the last three decades, and more recently low fat processing techniques have gained attention from the meat industry. Acceptable frankfurter type sausages with a minimum of 10% fat can be manufactured with available technology, provided the reduction of fat is accompanied by an increase in either water or collagen (Wirth, 1988).

Claus et al. (1989) investigated substituting varying water levels for fat and found that as fat content was reduced and added water increased, the products became softer, more juicy, darker in color, and exhibited greater problems with purge. They found that the firmness associated with low fat products could be overcome by adding water, however this added water was responsible for the increased purge. They concluded that unless new or improved technology is developed to further optimize the ability of the meat protein to sufficiently bind water and yet remain functionally active, other non-meat ingredients besides water will have to be used to increase protein-water interactions.

In a similar study, Claus et al. (1990) examined the effects of massaging, preblending and time of addition of water and fat on physical and sensory characteristics of low fat, high water bologna. In this study, only two fat and added water combinations were used. They found that the benefits associated with massaging in the cured pork industry were not as apparent when applied to a batter type product. It was noted that the lower water binding in the low fat treatment, could be due to the lower ionic strength of solution as compared to control. In addition, it was pointed out that in traditional massaging, there is no physical disruption, as was done by mincing in this experiment, which may have broken water-protein bonds.

Hand et al. (1987) investigated the use of preblends for low salt and low fat frankfurters. The results indicated that preblending had little effect on the color and texture of the franks. The low fat franks were darker, drier and more resistant to shear than the higher fat franks. It must be noted that nothing was added to replace the fat as was done in the earlier mentioned articles. They concluded that the production of low fat, low salt frankfurters was possible with a modification in the formulation.

These studies all point to the fact that low fat cooked sausage can be manufactured, provided there are modifications in processing techniques or formulations are made. One of the major problems with the low fat, high water products is the excess amount of purge, the soft texture and lower cooking yields. It appears from these studies that water binding has taken the place of fat binding as the critical control point in high moisture, low fat cooked sausage products. It must be pointed out that these experiments used beef and pork formulations rather than all beef as was used in this experiment.

Chopping Temperatures

Endpoint chopping temperatures have been established as critical control points for batter products in relation to maximum protein extraction, fat binding and water binding (Helmer and Saffle, 1963; Brown and Toledo, 1975; Jones and Mandigo, 1982). Whiting (1988) has stated that temperatures between 5° and 7°C are optimum for protein extraction and dry ice can be added to prolong chopping time.

More recently Vasgen and Martin (1990) studied the properties of low-sodium frankfurter sausages after processing in the chopper with varying temperatures while cooling with liquid nitrogen. They found that addition of liquid nitrogen in chopping can ensure the correct cutter processing time to achieve the required fineness of the mixture and final temperature. In their experiments, chopping to temperatures higher than 10°C was a disadvantage in formulations with a full salt content (18g/kg) whether the temperature was intermediate or final. However, with reduced sodium formulations a mixture that had not been chopped to at least 10°C was more watery and spongy than one chopped to 12°C. Vasgen and Martin (1990) also found that dry processing the meat in the cutter with liquid nitrogen before adding water, caused thorough weakening of the meat, which enabled the protein breakdown to be better suited for water binding.

In a similar investigation, Reichert et al. (1988) found that chopping at a constant 0°C resulted in an improved product stability when citrates or phosphates were not added. However, when phosphates were added, the optimum temperature was 10°C; although, only small differences in product stability were noticed. They attributed the difference in phosphate and non-phosphate temperatures to the fact that the positive effect of phosphate is due to the binding of metal ions. This effect has a stronger influence on the product stability than does lower chopping temperatures (Reichert et al., 1988).

Wirth (1987) reported that the optimum degree of comminution should be reached at the same time the optimum temperature is reached. He stated that processing in the cutter should not be adjusted merely to final temperature, as is often the case, but the degree of comminution should also be evaluated. His conclusion was that both of these factors are equally important in achieving stable water and fat binding in a frankfurter.

Jones and Mandigo (1982) evaluated the effects of four endpoint chopping temperatures (10, 16, 22, 28^{O}C) on the ultrastructure of meat emulsions. They found that emulsion stability is influenced by two 2 different factors. The first is the interfacial protein film thickness and the second is the integrity and density of the surrounding emulsion matrix. They concluded that it was these two functions that are directly related to the fat holding and water binding abilities of the emulsion. In their investigation, they found that chopping to 28^{O}C resulted in lower smokehouse yields compared to the lower chopping temperatures. As temperature increased, they reported that total cookout losses also increased.

Brown and Toledo (1975) studied the relationship between chopping temperatures and fat and water binding in meat batters. In their experiment they found that as temperature increased to 24^{O}C the fat and water binding increased. After 24^{O}C, the results showed a steep increase of fat and water released. They found that batters lose their binding capacity for water earlier than for fat. Therefore, it appeared that fat and water binding have an inverse relationship. As fat binding increases the water binding decreases.

As has been pointed out by the previous researchers, chopping temperatures are of critical importance in the production of batter type products. Differences in product formulations may determine the appropriate chopping temperature and time. Not closely monitoring chopping temperatures could result in product failure, especially in lower fat and higher added moisture systems.

<u>Protein Extraction Temperatures</u>

In response to Hamm (1960) who reported that no changes occur in solubilities and ion binding of muscle proteins at temperatures below 30^{o}C. Deng et al. (1976) investigated temperatures below these used in cooking such as in chopping. They proposed that these subtle changes in protein at low temperatures could effect fat and water binding and the ability of the proteins to impart the desired textural characteristics to the finished product. They concluded that maintaining temperatures below 10^{o}C prior to cooking would maximize fat and water binding.

These results are consistent with Gillette et al. (1977) in which they reported the maximum amount of protein was extracted at 7.2^{o}C and declined after that temperature increased. However, in this experiment a higher salt solution was used than would be in a commercial processing plant. These results are in disagreement with Jones and Mandigo (1982) who found as temperatures rose from 10°C to 16°C the surface of the fat globules were surrounded by a thicker protein coating which could be explained by a greater solubilization of proteins at higher temperatures.

Helmer and Saffle (1963) found that emulsions were stable at chopping temperatures of 15.5°C but emulsion breakdown occurred at 32.2°C. They reported that emulsion breakdown did not occur at one specific temperature but over a wide range of temperatures. The exact temperature may be affected by processing conditions and type of meats used.

Fat and Chopping Temperature Relationships

Swift (1965) proposed how temperatures influenced emulsifying capacity in that 1) warm more limpid fat can be more highly dispersed and thus will require more protein to coat the surface; 2) the protein may become partially denatured and thus less effective as temperature increases; 3) membrane formation may somehow differ at higher temperatures.

Townsend et al. (1968) suggested that the melting characteristics of meat fats could be the basis for differences in the maximum temperature at which meat formulas should be emulsified. This was in agreement with Swift et al. (1968) who reported that emulsion stability was influenced not only by melting characteristics of fats but also the rate and extent of temperature rise as well as rates of dispersion. However, it is pointed out by Jones (1984) that chopping temperatures seldom exceed 18°C, which is well below the liquefaction point of animal and poultry fats. He suggests that even though the fat particles are still in a solid state that a thin layer of liquid fat likely surrounds each fat particle as a result of tissue disruption and frictional heat during chopping.

Townsend et al. (1971) used two different fat levels (25%, 35%), varying temperature levels from 7.2 to as high as 29.4°C, as well as three different bowl speeds to study their effects on frankfurters. They found as temperature increased the viscosities decreased. This was explained by the effect of fat emulsification was masked by the viscosity of lean portions swollen and viscous after the actions of curing agents and water as well as the continued mincing of the lean portion. They stated that viscosity values are not closely related to emulsion stability and that a combination of time and temperature affected the melting of fat and its dispersion. Their results also indicated that overchopping was produced by long periods and high temperatures in formulas that contained beef fat but not those containing pork fat or cottonseed oil. These results are somewhat in disagreement with Whiting (1988) who reported that the completion of comminution is dependent on temperature rather than time. He indicated that all beef franks should be chopped to 18^{o}C, pork fat to 15.5^{o}C and poultry franks to 11 to 12^{o}C.

Wirth (1987) reported that a mixture was overprocessed if connective tissue and fatty tissue were comminuted too much and if too little structure creating protein was available, as well as too high of temperature in the cutting area around the knives changed the binding properties of the proteins.

It should be pointed out that the experiments involving chopping temperatures did not involve low fat, high moisture formulations. It should also be noted that the chopping temperatures deal mostly with endpoint chopping temperatures rather than chopping at a constant temperature as was done in this experiment.

Effect of Vacuum Processing

The use of vacuum during processing is a common practice in the meat industry. When batter type products are comminuted in a silent cutter, a large amount of air is incorporated into the product unless a vacuum is utilized. Undesirable chemical and physical reactions can result as a result of the interaction between air and ingredients in the sausage (Wirth, 1987). These undesirable reactions cause color, flavor as well as consistency problems. He reported that comminuting under vacuum can stabilize fat binding by making available more protein available to cover fat particles. He also reported that comminution under vacuum does not have an effect on WHC. Wirth (1973) pointed out that meat material that binds poorly or formulas with large amount of added water require as high as vacuum as possible.

This was in disagreement with Mawson et al. (1983) who reported that chopping under vacuum caused significantly greater cooking loss. They explained this phenomena was a result of the expelled liquid becoming entrapped within the air foam. These results were in agreement with Wiebe and Schmidt (1982) in a study that evaluated the effects of vacuum mixing and precooking on restructured steaks. No significant differences were present as far as cook yield, moisture or fat content were concerned but there was significantly greater binding strength when mixed under vacuum. Their explanation was that either increased protein extraction due to vacuum mixing or the absence of air voids at the junction of the meat particles was responsible for the greater binding strength. They found that when the meat was mixed in air for three minutes then vacuumed for one minute that it had greater binding strength than when either vacuumed for four minutes or not vacuumed at all. They speculated that mixing in air for the first 3 minutes increased the availability of muscle cells to be swelled when vacuum was applied.

Solomon and Schmidt (1980) reported that vacuum processing increases protein extraction in both pre and post rigor beef. These findings are in conflict with Booren et al. (1981) who found little difference in protein extraction when using a vacuum. They also found that vacuum processing did not decrease rancidity or alter flavor or juiciness. It must be recognized that these two experiments involved vacuum mixing, not vacuum comminution, as was done in the frankfurters for this investigation. Tantikarnjathep et al. (1983) found that comminuting under vacuum improved the functional properties, product stability and decreased shrinkage on frankfurter systems. They found that comminuting under vacuum was only effective if used throughout the entire chopping procedure.

It is obvious from the previously mentioned research that there is a need for improved technology and utilization of the protein that a meat system contains in order to produce a high quality, low fat product, especially in light of the lack of research with high added moisture levels. These factors as related to processing temperatures will be examined in the following chapters.

CHAPTER III

PROCESSING TEMPERATURE EFFECTS ON LOW FAT, HIGH MOISTURE, BEEF FRANKFURTERS

Abstract

Beef frankfurters were manufactured using four different fat and added moisture formulations and processed at three chopping temperatures. Hardness texture values increased and smokehouse yields decreased as chopping temperature increased ($P<0.05$) for the higher fat, lower added moisture formulations, but temperature did not influence these traits for the other formulations. Purge loss was highest for the lowest fat, highest added moisture formulation. Purge loss continued to increase as storage time increased in all formulations. In most cases, chopping temperature did not influence purge. In conclusion, the effects of chopping temperature on texture, yield and purge are heavily dependent on the formulation of fat and added moisture.

Introduction

With consumers' increased demand for low fat products, the red meat industry is faced with a tremendous challenge.

Although it is relatively easy to reduce the fat content in processed meat products through formulation with leaner meats, this practice increases the cost to produce the product and subsequently the price consumers will have to pay. Recent USDA labeling changes have given the red meat industry the opportunity to produce cooked sausage products, primarily frankfurters and bologna, that are low in fat yet still affordable. These changes allow the combined total fat and added water content to not exceed 40%, whereas the traditional level was 30% fat and 10% added water. Increasing the water level beyond traditional levels tends to put increased pressure on the meat system. This pressure can partially explain the excess purge, high cooking loss and soft texture normally associated with low fat beef products, where water has replaced fat. Water binding now has become as important as fat binding in frankfurter systems (Rust and Olson, 1988). Water binding is affected by many variables, one of those being endpoint chopping temperatures.

Endpoint chopping temperatures have been established as critical control points in frankfurter manufacture in relationship to maximum protein extraction (Jones and Mandigo, 1982). However, these temperatures were not related to low fat, high moisture systems. Optimum temperatures for maximum solubility have been reported between 10°C and 12°C (Gadea, 1990). Therefore the objective of this study is to evaluate low fat, high moisture beef franks using different chopping temperatures to maximize product yield and quality.

Materials and Methods

U.S. Choice beef shoulder clods and 50% beef trim, obtained locally, were individually ground (Grinder, Biro Mfg. Marblehead, OH) through a 1.27 cm grinder plate. Samples taken from each were then reground through a 0.32 cm plate and analyzed for fat, moisture and protein (AOAC, 1984) for formulation purposes. Appropriate lean, fat and water combinations for four different fat and added moisture levels were determined using a least cost formulation program (Least Cost Formulator, Ltd., Virginia Beach, VA). Treatments were formulated for fat and added moisture combinations of 10% fat, 30% added moisture (Trtmt 3.1); 15% fat, 25% added moisture (Trtmt 2); 20% fat, 20% added moisture (Trtmt 3); and 30% fat, 10% added moisture (Trtmt 4). However, when final product proximate analysis was performed actual fat/added moisture combinations differed from the targets (Table 1). This may be attributed to poor sampling technique for proximate analysis. Batch size for each treatment was 11.33 kg.

The percentage of added moisture for initial mixing (26%) was held constant among all treatments. This percentage was calculated by dividing the entire amount of added water by the amount of lean formulated for Trtmt 4. The appropriate amount of water was mixed with the lean portion. 2% salt, .005% sodium tripolyphosphate and 163g of spices (A.C. Legg, Birmingham, AL) in a six blade, vacuum, bowl chopper (K64 Seydelmann, Robert Reiser, Canton, MA) for 30 seconds on low speed without vacuum. The fat portion and remaining water was then added. This mixture was then chopped for four minutes on high speed with the last 30 seconds under vacuum. Chopping times used were a result of a preliminary batch in which the batter was chopped to the optimum temperatures indicated by Jones and Mandigo (1982). Chopping time remained constant among all treatments.

All formulations were chopped to and held at three different chopping temperatures (9^{o}, 12^{o} ,$15^{o}C$). Upon reaching the appropriate temperature, crushed carbon dioxide (CO_2) was added to maintain that temperature within +/- $1^{o}C$. All formulation and temperature combinations were replicated twice.

Thermal emulsion stability was determined using the method described by Townsend et al. (1968). Raw batter (34g) was placed into a plastic conical cylinder, covered with plastic film (Parafilm®, American National Can, Greenwich Ct.) and heated in a $48.8^{o}C$ water bath (Model BKS-350, Gallencamp and Co., Sussex, England) with the temperature raised intermittently after 30 minutes until internal temperature of the batter reached 68.8°C. One tube in each batch cooked was equipped with a thermometer to record temperature during cooking. Liquid released was decanted into 15mL graduated centrifuge tubes and centrifuged (Model J-6M, Beckman Instruments, Palo Alto, CA) for 1 minute at 2.68 x G. After chilling at 4.4°C for approximately 12 hours, volume of liquid, fat gelatinous water and proteinaceous solids were recorded.

The batter from the chopper was stuffed into 32 mm cellulose casings (Nojax®, Viskase, Chicago, IL) and heat processed (1 truck smokehouse, Alkar, Lodi, WI). Franks were allowed to cool for 18 hours at 4°C before cooking yields were obtained by weighing the cooked franks and dividing by the weight of the stuffed raw batter.

Frankfurters were then peeled and vacuum packaged (M855, Multivac, Kansas City, MO) 5 links per package. Samples from each treatment were frozen at -23°C until proximate analysis and texture data could be obtained. The remaining packages were stored at 4°C for purge analysis.

Purge was measured once a week for 8 weeks, with week 1 being the first week after production. Purge loss was measured on 2 packages for each sampling time. Each package was opened and the purge present was poured through a funnel into a 15mL graduated centrifuge tube. The franks were then placed in the funnel to drain purge that was present on the surface of the franks. Weights of the franks were then recorded. The vacuum packages were dried in the smokehouse to insure residual purge in the corners of the package was removed, then package weights were recorded. Purge loss was reported as a percentage of content weight.

Compression values (quadruplicate) were determined by axially compressing 62.5% of the height of a 3 cm sample for two cycles with an apparatus attached to an Instron Universal Testing Machine (Model 4500, Instron Corp. MA). 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 sample using the Kramer shear attachment for the Instron with a crosshead speed of 100 mm/minute and a load cell of 10 kN. Area under the curve (energy) was used to determine shear measurements (Singh et al., 1985).

Statistical analysis

The experimental design utilized in this study was a 3 X 4 factorial arrangement of treatments with 2 replications. Treatment means and standard errors were calculated using the Statistical Analysis System (SAS Institute, 1985) The data were analyzed using analysis of variance to determine significant interactions and main effects. Error terms were pooled for nonsignificant interactions.

Significant interactions ($P<0.05$) between formulation and temperature and temperature and days of storage on purge as well as emulsion stability by formulation and temperature were analyzed using analysis of variance and regression techniques (Steel and Torrie, 1980). Differences in final product proximate analysis as well as significant differences in purge by the interaction of formulation level and temperature were analyzed using least square means procedures (Steel and Torrie, 1980).

Results and Discussion

Figure 3.1 shows the effect of chopping temperature and formulation on emulsion stability total loss. Trtmt 2 showed the greatest total loss which increased until 12^{o}C and then dropped dramatically. This high percentage of total loss may not actually reflect the actual characteristics of Trtmt 2 as it was exceptionally high as compared to the rest of the treatments. All emulsion stability measurements followed the same trend as Trtmt 2, as being very high in percentage loss (Figure 3.2-3.4).

Fat loss was the lowest for Trtmt 1 (Figure 3.2), as would be expected, since it contained the highest amount of added moisture and lowest fat level. Water loss for emulsion stability was highest for Trtmt 1 except for when

Trtmt 2 was between 10 and 14°C, which would be expected since Trtmt 1 had the greatest amount of added moisture (Figure 3.3). This was in agreement with Claus et al. (1989) in which treatments containing greater than 25% added moisture had the greatest amount of purge loss. Emulsion stability yield is shown in Figure 3.5. As expected, Trtmt 4 had the highest yield due to the lowest amount of water. Yields decreased as fat level decreased except for Trtmt 2 which did not follow a similar trend to that noted in the other treatments. Formulation may have a greater effect on emulsion stability traits than temperature.

Figure 3.6 illustrates frankfurter hardness values as influenced by formulation and chopping temperature. Hardness is the force required to break the protein bonds of the product. This can be associated with the amount of force required to compress a sample between molar teeth (Brady and Hunecke, 1985). Eating qualities are of critical importance in the marketability of franks, therefore it is essential to examine the hardness associated with varying fat and added moisture combinations. Trtmt 4, the highest fat and lowest added moisture treatment, had greater hardness values than did those of the other treatments. A higher peak force value was noticed at 15°C for both treatments 3 and 4. This may be explained by greater protein extraction and the higher temperature, which is in agreement with Jones and Mandigo (1982), where as temperatures rose from 10^{o} to $16^{o}C$ protein extraction increased. However, the lower fat, higher added moisture frankfurters (Trtmts 1 and 2) were not affected by chopping temperature. ($P>0.05$). In these lower fat, higher added moisture treatments, the amount of water in the product may mask any effect due to temperature. The combination of higher added moisture and lower fat resulted in a much softer product. This may result in a detrimental consumer acceptance of low fat beef franks. There were no significant effects ($P>0.05$) of temperature or formulation on cohesiveness (mean=.48 SE=.17). Kramer shear force values (mean=.80kN SE=.06) were not different for effects of formulation or temperature ($P>0.05$). This can be related to the fact that hardness measures the number of protein bonds whereas cohesiveness measures the quality of those bonds. In this case the higher fat, lower added moisture treatments had more protein bonds than did those of the lower fat, higher added water treatments.

Figure 3.7 illustrates the smokehouse yields as influenced by formulation and chopping temperature. In the two higher fat and lower added moisture formulations (Trtmt3 and Trtmt 4), as temperature increased the yield decreased ($P<0.05$). This may be due to the findings of Gadea (1990) in which the optimum temperature for water holding capacity was $6^{o}C$, which is lower than those examined in this experiment. Yields for the lower fat and higher added moisture formulations were not affected ($P>0.05$) by temperature and their average yields were lower than treatments 3 and 4. This can be directly related to the increased added water content. Yields are of great importance to processors in their attempt to manufacture low fat products. A premium price for low fat, high moisture franks may have to be paid in order to compensate for the low yields associated with these type of products. The smokehouse yields did not follow the same trends as the emulsion stability yields, which can usually be used as an indicator of smokehouse yield. Temperature linearly decreased smokehouse yield in two treatments (3 and 4), while Trtmt 2 showed a curvilinear effect due to temperature in emulsion stability yield analysis.

The effect of chopping temperature and formulation on frankfurter purge percentage is shown in Table 3.2. As the level of fat was lowered and added moisture was increased from treatment 4 to treatment 1, the percentage purge increased. As was expected, the treatment with the highest fat level and lowest added moisture level showed the lowest percentage purge, which is agreement with Claus et al. (1989). Temperature had little effect on purge within fat level except in Trtmt 3 where 9^{o}C exhibited a higher percentage purge than 15^{o}C ($P<0.05$). Many processors chop to endpoint chopping temperatures which typically range from 16-18^{o}C. It is believed that it is necessary to chop to these high temperatures in order to fully comminute the product and more specifically the fat portion. However, it is possible in some instances to have the product fully comminuted while still maintaining a low temperature, especially with the speed of modern day machinery and the use of carbon dioxide or liquid nitrogen.

Frankfurter purge as influenced by formulation and storage time is shown in Figure 3.8. As expected, the percentage purge increased as the number of days increased ($P<0.05$). However, Trtmt 1 increased in percentage purge at a faster rate than did those of higher fat levels ($P<0.05$). This is due to the fact that more water was available in the product from the higher added moisture, which is in agreement with Claus et al. (1989).

Manipulation of the available meat proteins to function in a beneficial manner for holding high levels of added water is more complex than differences in chopping temperatures. In conclusion, the effects of chopping temperature on emulsion stability, texture, yield and purge are heavily dependent on the formulation of fat and added moisture. Additional research is needed to fully understand the interaction of chopping temperature and formulation, especially a fat levels below 14% and added moisture levels above 16%. In order for low fat, high moisture frankfurters to penetrate the highly competitive market, more research is needed to collectively study all the factors (smokehouse schedule, time and amount of water addition, salt concentration, vacuum cutting and amount package vacuum) associated in the production of the franks.

TABLE 3.1

FRANKFURTER TARGET AND ACTUAL FAT/ADDED WATER COMBINATIONS

	TARGET		ACTUAL	
TRTMT	FAT	AW[a]	FAT	AW[a]
1	10	30	6	32
2	15	25	11	22
3	20	20	14	16
4	30	10	23	-2

[a]Added moisture = Chemical Moisture - 4(Chemical Protein)

Figure 3.1. Effect of Chopping Temperature and Formulation on Emulsion Stability Total Loss.

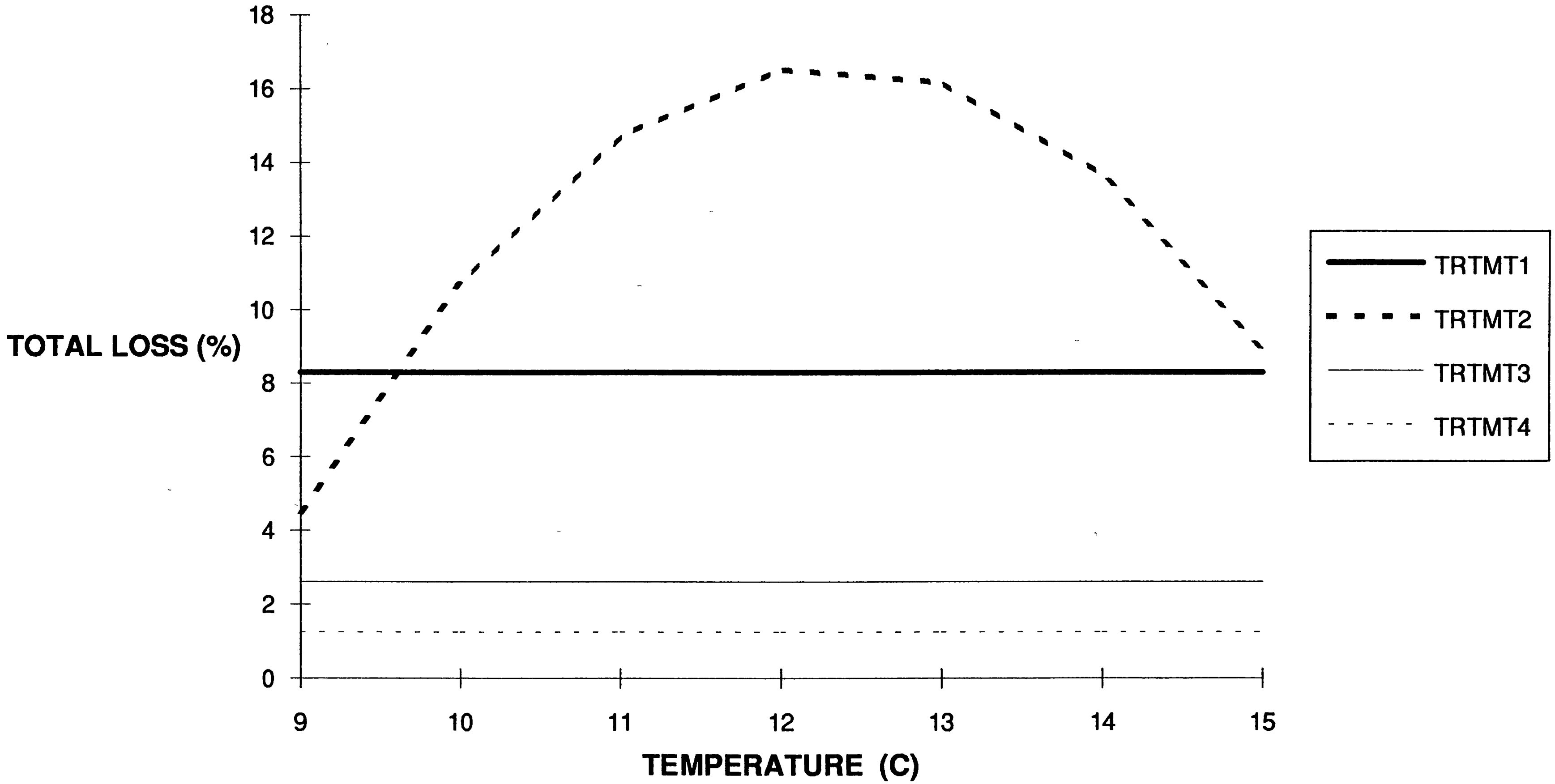


Figure 3.2. Effect of ChoppingTemperature and Formulation on Emulsion Stability Fat Loss.

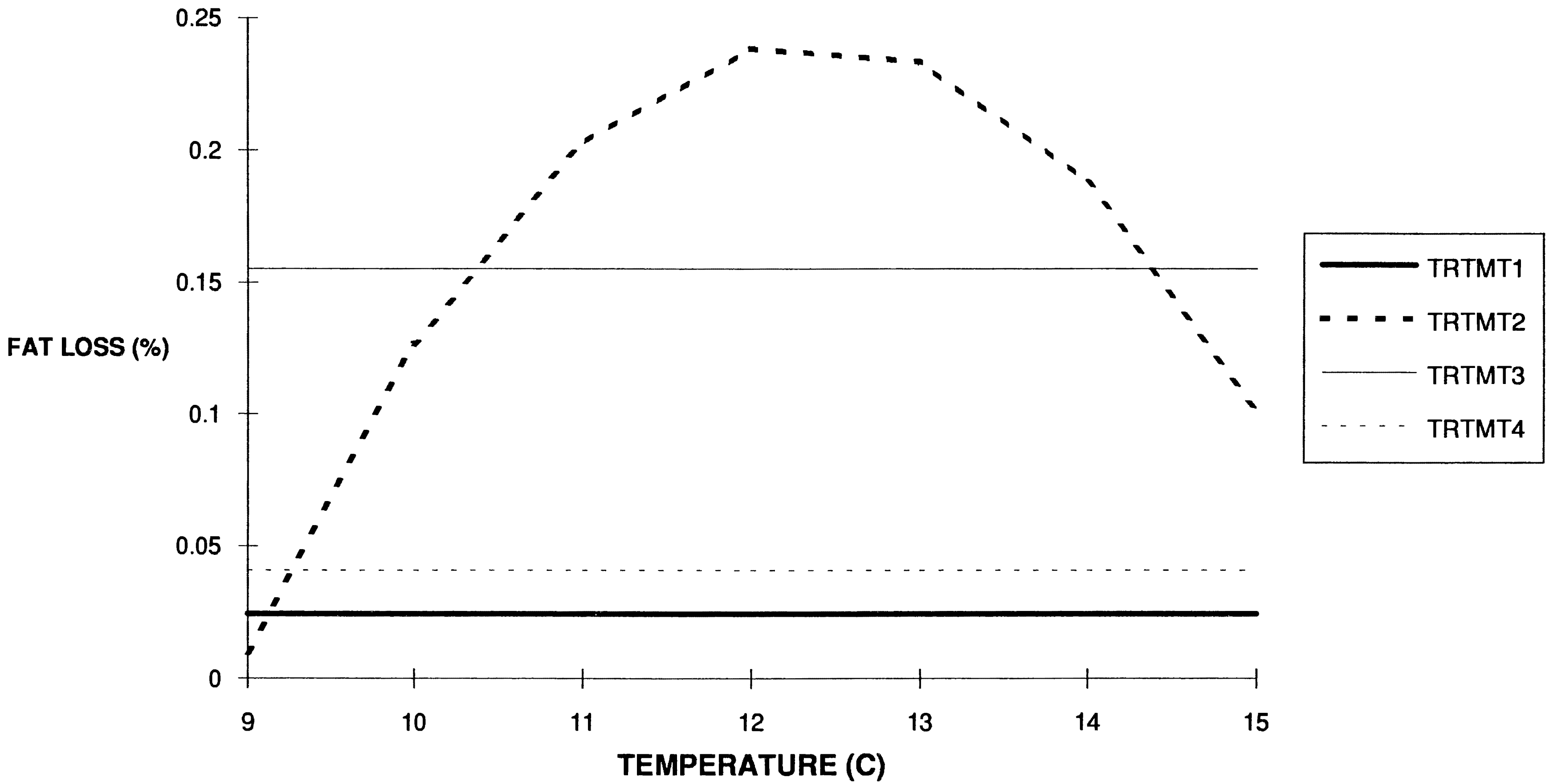


Figure 3.3. Effect of Chopping Temperature and Formulation on Emulsion Stability Water Loss.

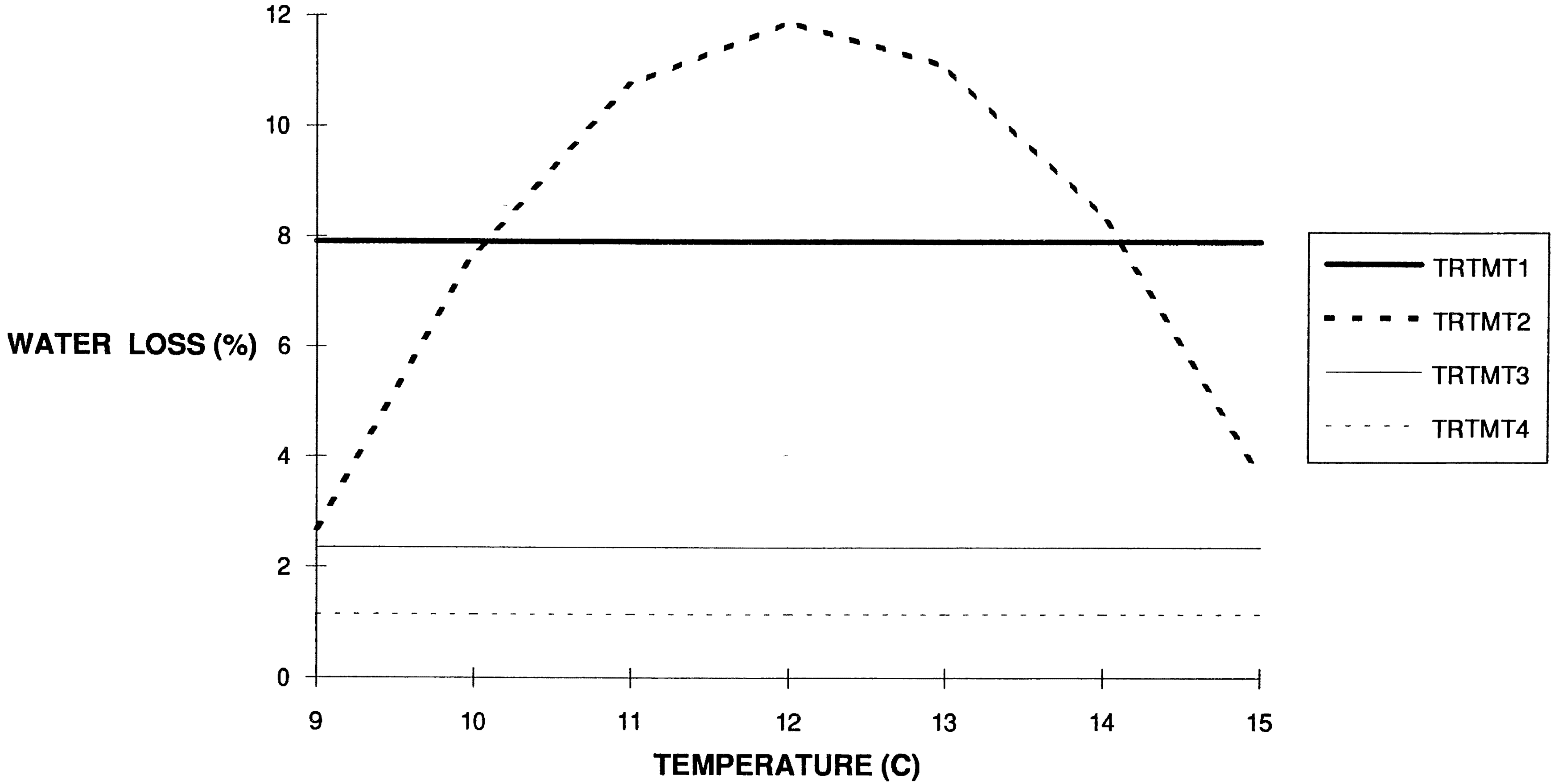


Figure 3.4. Effect of Chopping Temperature and Formulation on Emulsion Stability Protein Loss.

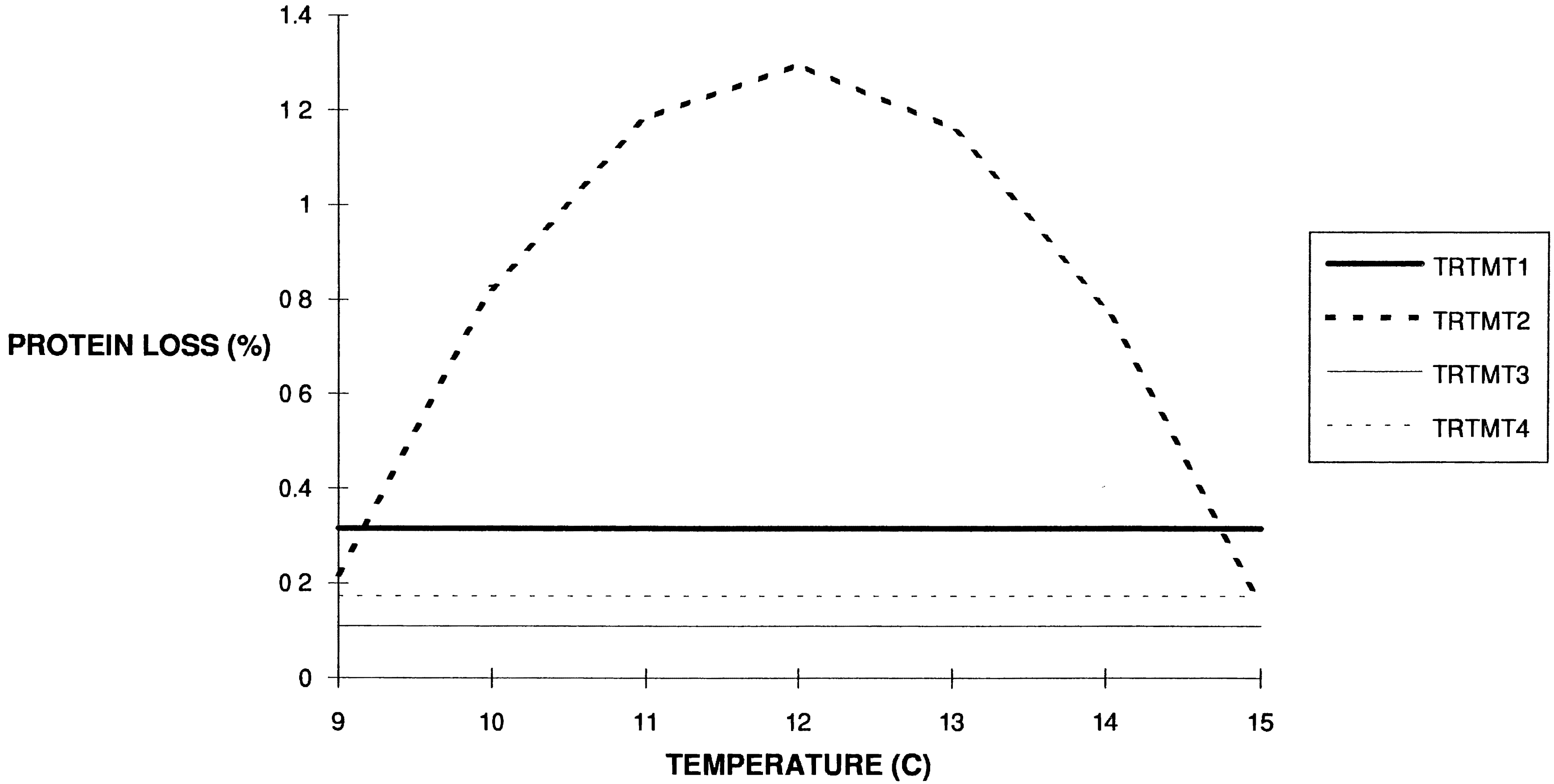


Figure 3.5. Effect of Chopping Temperature and Formulation on Emulsion Stability Yield.

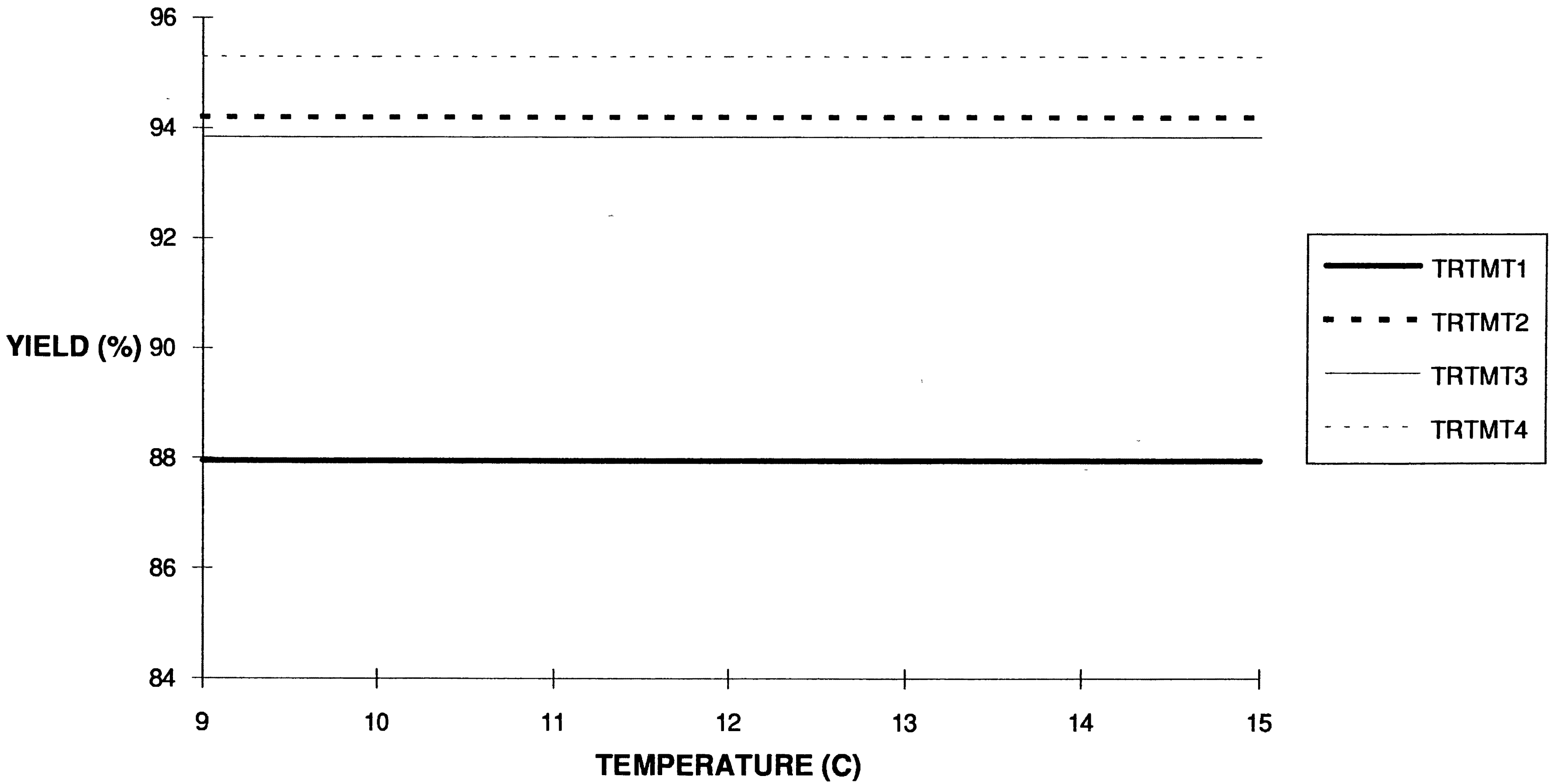


Figure 3.6. Frankfurter Hardness Values as Influenced by Formulation and Chopping Temperature.

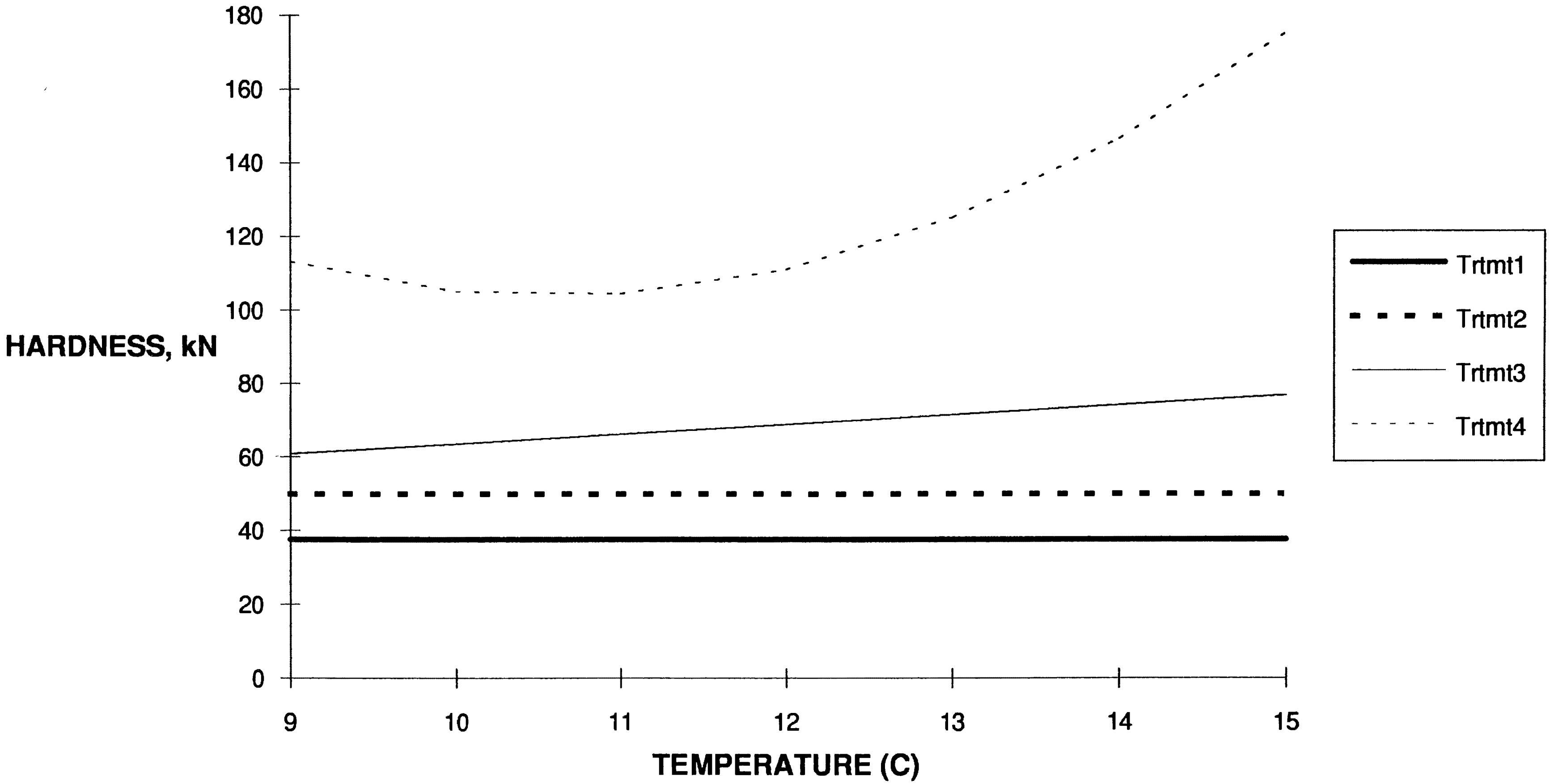


Figure 3.7. Smokehouse Yields as Influenced by Formulation and Chopping Temperature.

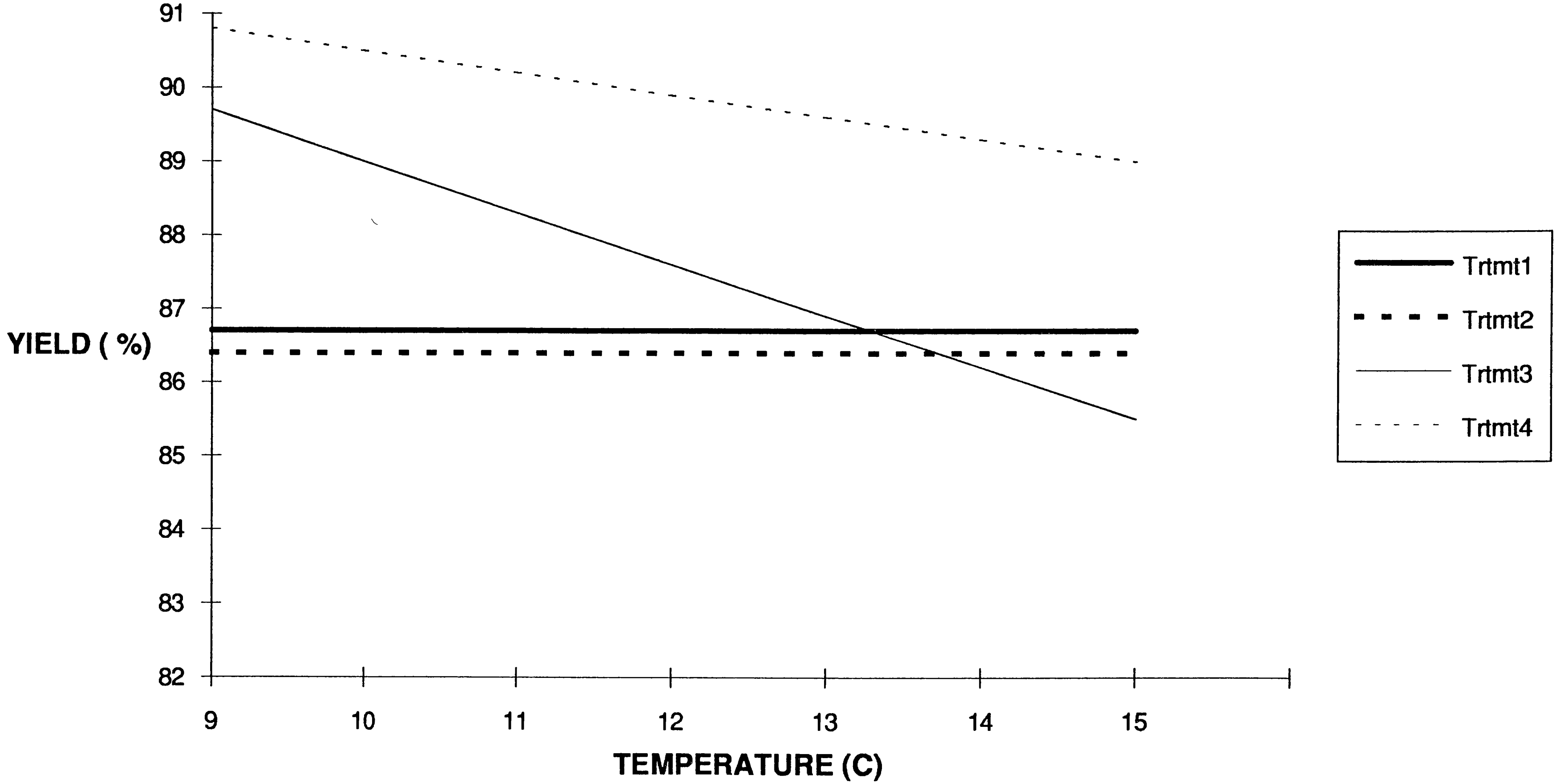


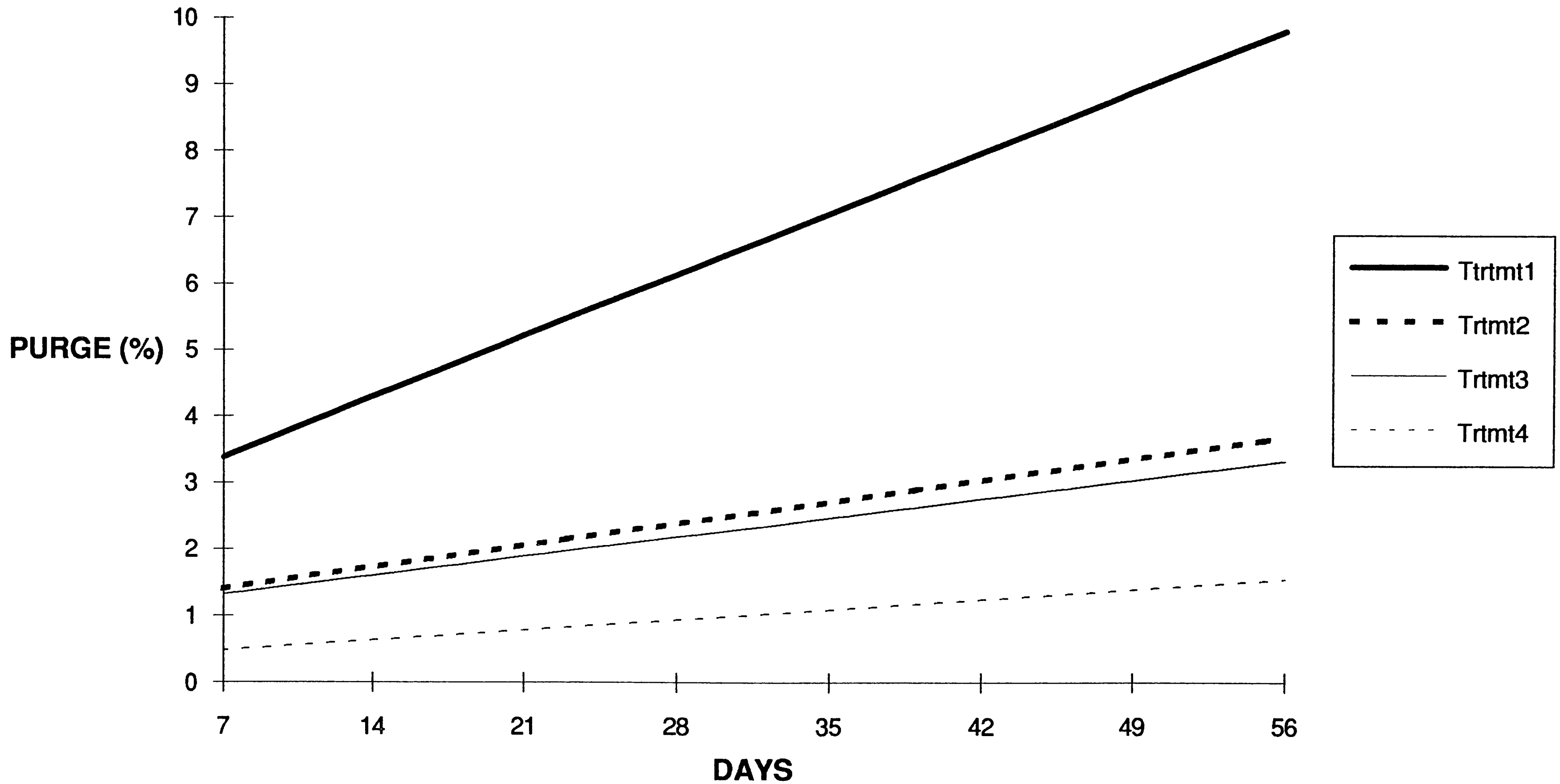
TABLE 3.2

THE EFFECT OF CHOPPING TEMPERATURE AND FORMULATION ON FRANKFURTER PURGE PERCENTAGE

	TREATMENT 1		2		3		4	
TEMP °C	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
9	6.69[a]	.46	2.06[cd]	.21	3.05[b]	.33	.55[e]	.09
12	6.58[a]	.45	2.74[bc]	.31	2.25[bcd]	.17	.72[e]	.04
15	6.14[a]	.61	2.67[bc]	.33	1.32[de]	.22	.57[e]	.03

[abcde]Means followed by different superscripts are significantly different ($P<0.05$).

Figure 3.8. Frankfurter Purge as Influenced by Formulation and Storage Time.



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APPENDIXES

APPENDIX A

SUPPLEMENTAL DATA

TABLE A.1

EMULSION STABILITY TOTAL LOSS (%) REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.690	.083[a]	.048
2	.042	INTCPT-50.66 TEMP 9.13 $TEMP^2$ -0.37	.344
3	.292	.026[a]	.152
4	.298	.0125[a]	.148

[a]Nonsignificant regression equations reported as means.

TABLE A.2

MEANS AND STANDARD ERRORS OF EMULSION STABILITY TOTAL LOSS (mL)[a]

FAT LEVEL	TEMP °C	MEAN	SE
6	9	2.77	.545
6	12	3.14	.548
6	15	2.55	.325
11	9	0.93	.033
11	12	4.51	1.48
11	15	1.29	.213
14	9	1.11	.168
14	12	0.71	.124
14	15	0.83	.226
23	9	0.36	.095
23	12	0.30	.077
23	15	0.60	.198

[a]Reported in text and graphs as mL/34.

TABLE A.3

EMULSION STABILITY FAT LOSS (mL) REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.561	.008[a]	.074
2	.039	INTCPT -.975 TEMP .170 $TEMP^2$ -0.006	.350
3	.635	.052[a]	.058
4	.440	.013[a]	.102

[a]Nonsignificant regression equations reported as means.

TABLE A.4

MEANS AND STANDARD ERRORS OF EMULSION STABILITY FAT LOSS (mL)[a]

FAT LEVEL	TEMP °C	MEAN	SE
6	9	.016	.016
6	12	.008	.008
6	15	0	0
11	9	0	0
11	12	.075	.030
11	15	.025	.011
14	9	.091	.082
14	12	.033	.016
14	15	.033	.016
23	9	.025	.017
23	12	0	0
23	15	.016	.016

[a]Reported in text and graphs as mL/34.

TABLE A.5

EMULSION STABILITY WATER LOSS (mL) REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.727	2.69[a]	.041
2	.043	INTCPT -43.87 TEMP 7.92 $TEMP^2$ -0.32	.341
3	.353	.800[a]	.129
4	.346	.391[a]	.131

[a]Nonsignificant regression equations reported as means.

TABLE A.6

MEANS AND STANDARD ERRORS OF EMULSION STABILITY WATER LOSS (mL)[a]

FAT LEVEL	TEMP °C	MEAN	SE
6	9	2.63	.512
6	12	2.98	.553
6	15	2.45	.325
11	9	.896	.036
11	12	4.008	1.48
11	15	1.213	.201
14	9	.988	.160
14	12	.646	.112
14	15	.765	.206
23	9	.330	.090
23	12	.305	.077
23	15	.538	.170

[a]Reported in text and graphs as mL/34.

TABLE A.7

EMULSION STABILITY PROTEIN LOSS (mL) REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.542	.107[a]	.078
2	.050	INTCPT -5.54 TEMP 1.00 $TEMP^2$ -0.04	.328
3	.980	.037[a]	.002
4	.240	.058[a]	.170

[a]Nonsignificant regression equations reported as means.

TABLE A.8

MEANS AND STANDARD ERRORS OF EMULSION STABILITY PROTEIN LOSS (mL)[a]

FAT LEVEL	TEMP °C	MEAN	SE
6	9	.121	.027
6	12	.100	0
6	15	.100	0
11	9	.075	.038
11	12	.441	.192
11	15	.055	.016
14	9	.038	.015
14	12	.038	.015
14	15	.035	.009
23	9	.013	.008
23	12	.005	.004
23	15	.158	.12

[a]Reported in text and graphs as mL/34.

TABLE A.9

EMULSION STABILITY YIELD (%) REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.612	.879[a]	.016
2	.033	INTCPT 2.645 TEMP -0.301 $TEMP^2$ .012	.365
3	.522	.938[a]	.026
4	.060	.953[a]	.120

[a]Nonsignificant regression equations reported as means.

TABLE A.10

MEANS AND STANDARD ERRORS OF EMULSION STABILITY YIELD (%)

FAT LEVEL	TEMP °C	MEAN	SE
6	9	87	.015
6	12	86	.020
6	15	89	.007
11	9	94	.001
11	12	82	.053
11	15	93	.008
14	9	93	.004
14	12	94	.006
14	15	93	.009
23	9	95	.002
23	12	96	.003
23	15	93	.012

TABLE A.11

COMPRESSION REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.560	37.53[a]	.024
2	.390	49.88[a]	.040
3	.0013	INTCPT -23.62 TEMP 13.18 $TEMP^2$ -.043	.254
4	.0001	INTCPT 517.05 T1 -78.39 T2 3.68	.636

[a]Nonsignificant regression equations reported as means.

TABLE A.12

MEANS AND STANDARD ERRORS OF COMPRESSION VALUES (kN)

FAT LEVEL	TEMP °C	MEAN	SE
6	9	39.25	1.70
6	12	36.61	1.39
6	15	36.78	2.42
11	9	50.80	2.14
11	12	47.33	3.14
11	15	51.51	1.05
14	9	59.53	3.95
14	12	71.47	1.96
14	15	75.52	2.71
23	9	109.94	4.02
23	12	106.88	4.13
23	15	170.15	7.96

TABLE A.13

SMOKEHOUSE YIELD REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.996	.867[a]	.000
2	.270	.864[a]	.080
3	.027	INTCPT .966 TEMP -.007	.323
4	.086	.892[a]	.195

[a]Nonsignificant regression equations reported as means.

TABLE A.14

MEANS AND STANDARD ERRORS OF SMOKEHOUSE YIELDS(%)

FAT LEVEL	TEMP °C	MEAN	SE
6	9	88.2	.006
6	12	84.1	.022
6	15	100	.016
11	9	87.1	.012
11	12	86.7	.007
11	15	85.3	.012
14	9	89.7	.017
14	12	92	.008
14	15	85.5	.007
23	9	89.7	.005
23	12	90.3	.007
23	15	87.6	.008

TABLE A.15

PURGE BY DAY REGRESSION EQUATIONS

TRTMT	F-VALUE	PARAMETER ESTIMATE	R^2
1	.0001	INTCPT 2.463 TEMP .131	.528
2	.0001	INTCPT 1.076 TEMP .046	.200
3	.0001	INTCPT 1.032 TEMP .040	.178
4	.04	INTCPT .330 TEMP .021 $TEMP^2$ -.003	.636

[a]Nonsignificant regression equations reported as means.

APPENDIX B

RAW BATTER EMULSION STABILITY

RAW BATTER EMULSION STABILITY

Townsend, W.E., Witnauer, L.P., Riloff, J.A. and Swift, C.E. 1968. Comminuted meat emulsions: Differential thermal analysis of fat transitions. Food Technol. 22: 319.

1. From stuffing horn stuff raw batter for each treatment into three preweighed, 50 cc graduated conical tubes.

2. Weigh tubes back to 34g of raw batter sample. Cap end with plastic film.

3. Place tubes into 48.8^{O}C water bath.

4. After 30 minutes raise temperature intermittently until product reaches 68.8^{O}C in about 1.5 to 2 hours.

5. Add extra tubes for each batch to record temperature with thermocouple while cooking.

6. Samples of raw emulsion, cooked in triplicate, are removed from water bath and the liquid released during cooking is decanted into 15 mL graduated cetrifuge tubes.

7. Centrifuge tubes at 2.68 X G. for 1 minute.

8. Record total volume of liquid, fat gelatinous-water and proteinaceous solids released during cooking.

9. Cooked sample weight can be weighed for estimates of processing yield.

APPENDIX C

SMOKEHOUSE SCHEDULE

SMOKEHOUSE SCHEDULE

STEP #	STEP TYPE	STEP TIME (min)	DRY BULB (F)	WET BULB (F)	HUMIDITY
1	COOK	00:20	135	0	-
2	SMOKE COOK	00:35	155	115	30
3	SMOKE COOK	00:15	175	135	35
4	EVACUATION	00:03	-	-	-
5	STEAM COOK	00:05	185	-	-
6	COLD SHOWER	00:01	-	-	-

VITA

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